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Environment Agency Anglian Region:

Essex Groundwater Investigation

Project Initiation Document

12 June 2000

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EA-Anglian Water Resources

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Environment Agency Anglian Region:

Essex Groundwater Investigation

Project Initiation Document

12 June 2000

Entec UK Limited

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Executive Summary

Introduction

This document presents the business case and project plan for the Essex Groundwater Investigation. This investigation will provide the technical framework for sustainable management of the water resources in the Essex area.

This project is one of eleven identified within the "Anglian Region Strategy for Groundwater Investigations and Modelling" (the Strategy) which was published during February 1998. The Strategy recommends a staged approach to the groundwater resource investigation projects in order to effectively manage the risks and uncertainties. **As such this document seeks authorisation to proceed with Stage 1 of the Essex Groundwater Investigation while presenting the business case for the project as a whole.**

The project covers the North and South Essex Local Environment Action Plan areas and for data collation (Stage 1) purposes also includes that part of the Thames Region area up to and including the River Ash. The extension of the area so far into the Thames region is to allow the probable eventual Essex model to have a common boundary with the anticipated Thames Lee-Mimram model. All the main Essex rivers (the Stour (including the Brett), the Colne, the Pant-Blackwater, the Chelmer and the Crouch) are included in the investigation.

Rainfall is low throughout the area, with a long term average varying from 550 to 650 mm per year. There is therefore much reliance on groundwater for water supply. Groundwater supports direct abstraction and also provides a high proportion of riverflow. There are nearly 1900 groundwater and surface water abstractions in the study area, including 61 public water supply abstractions and 17 river support boreholes.

Though the existing resource estimates can be challenged, they do nevertheless indicate the severe water resource difficulties facing the region, particularly in light of the planned further increase in housing provision. To help maintain current rates of abstraction, the augmentation of surface flows by means of the Ely Ouse to Essex Transfer Scheme and the Stour Augmentation Groundwater Scheme is required. Despite these provisions, in-area abstraction remains insufficient to meet demand, and large volumes of water are imported into supply from outside the area. Furthermore, Asset Management Plan 3 studies are necessary to investigate low flow problems with respect to three rivers in the area (the River Brett, the upper River Pant and the upper River Colne), where it is perceived that groundwater pumping has depleted riverflows.

The Environment Agency recognises the seriousness of the water supply problems in the area, and in it's 'Water Resources in Anglian: Summary Document' (September 1994) it advocated the development of the small remaining groundwater resources. However, there is only a limited understanding of the groundwater resources that underlie the area. Over the past 25 years groundwater investigations have been restricted to local problems and isolated catchments. The resource estimates for Essex are based on baseflow analysis for the main Essex rivers during the period 1967 to 1974, and the uncertainty associated with these estimates is large and means that resource allocation constraints can be challenged. There are no reports that provide the coherent and defensible technical framework required to sustainably manage the competing demands for water in the area or to forecast the likely impacts of climatic change.

Project Objectives
The overall objective is to develop and deliver information and technical tools to enable and improve the sustainable management and regulation of the groundwater resources of the Essex area. This will include the delivery of the following series of reports, computer models and databases:

- a report detailing, synthesising and analysing all the available meteorological, hydrological, geological, hydrogeological, abstraction/discharge and topographical information available for the area;
- computer databases and GIS information that will result in more efficient license application determination and review;
- computer models capable of forecasting the impact of groundwater pumping, land use and climatic changes on water levels and river flows; and
- a report identifying availability and constraints on the current and future use of groundwater resources within the area.

Identification and Appraisal of Options
The project is structured in five stages. Each stage consists of a number of technical activities and the degree of effort or cost put into these activities was used to define the range of options considered for the project. The options considered are as follows:

i) 'Do Nothing' Option: essentially continued use of the disparate information and ad-hoc methods to manage and regulate the groundwater resources of the area;

ii) 'Low' Option: the least technical effort required to complete the activities in each stage of the project;

iii) 'Intermediate' Option: an intermediate level of effort directed to completing the activities in each stage; and

iv) 'High' Option: involving the greatest effort in completing the activities in each stage.

Adoption of the 'Do Nothing' Option would fail to provide the technical framework and tools necessary to achieve the sustainable management of groundwater resources in the Essex area. The available groundwater resource would be incorrectly estimated, resulting in the formulation of unreliable Abstraction Management Strategies and inefficient and ad-hoc processing of licence applications and reviews that either over or under estimate the extent of impact on the water environment. A situation would arise whereby either too many abstraction licences are being issued with resultant environmental damage, or licence applications and extensions are being incorrectly refused with a resultant increased and unjustifiable expense to applicants and the Environment Agency. In addition, the opportunity to manage the existing river augmentation schemes more efficiently and possibly identify additional water resources would be lost.

On the basis of this discussion it is considered that there is a strong technical case for the whole Essex Groundwater Investigation (adopting the 'Low', 'Intermediate' or 'High' Options) to proceed, but with its business case reviewed in the light of completing key stages. An economic analysis has been undertaken of these three remaining options. Many of the benefits that would result from completion of the various stages of the project cannot be readily quantified in monetary terms and so a weighting and scoring methodology has been applied. The exception is the improved effectiveness of the technical determination of abstraction licence applications that would result in reduced costs to the applicant and to the Environment Agency. This is the basis of the economic benefits of the project options presented in the table below.

Option	Costs	Quantified Benefits	Benefit Cost Ratio	Net Present Value	Unquantifiable Benefits 'Score'	Risk Ranking (1 lowest risk, 4 highest)
Do Nothing	n/a	n/a	n/a	n/a	0	4
Low	641 763	635 938	0.99	-5 795	52	3
Intermediate	770 412	1 557 643	2.02	787 231	66	1
High	1 016 255	1 557 643	1.53	541 388	66	2

Justification of the Preferred Option

Within the table above a comparison between project options is presented. On the basis of these figures the preferred option is the **'Intermediate'** one. This has the most favourable benefit-cost ratio of 2.02 and would deliver all the products identified within the project to the standards established in The Strategy. This option is also robust when applying worst case costs to the uncertainties that exist in the project in it later stages. These still result in a benefit-cost ratio of 1.07.

Project Risks

The adoption of a five staged approach provides a coherent structure for managing the decisions and minimising the risks associated with the complexities of this project. The uncertainties that exist at the end of each stage may be reflected in the range of costs for completing the project. As such it is proposed to review the technical progress and revise the business case for the project towards the end of each stage.

There remain significant risks in producing products that are both to national standards and that will be accepted as the framework for future decision making both within and outside the Environment Agency. To manage these risks it is proposed that the Project Review Group include at least one groundwater specialist appointed from outside the Environment Agency. It is also proposed that the recommendations and actions that result from regular reviews are made widely available to 'stakeholders' and other interested parties.

Who when how etc.

Costs

The potential total cost of the preferred option is identified as £774 982 (non-discounted). This however is for all Stages of the project and there is significant uncertainty in costs beyond Stage 1 (especially within Stage 2). The currently perceived probability of different costs for Stage 2 and beyond have been taken into account.

This PID seeks approval only for Stage 1 of the project: it is intended that the PID will be revised towards the end of Stage 1, when a clear picture of Stage 2 requirements emerges. The estimated cost of Stage 1 is £365 122 (non-discounted), over a period of approximately 18 months, of which the final 3 months is principally used for review of the final report by Environment Agency staff. Environment Agency staff resource requirements have been separately identified, and agreed between the Environment Agency Project Manager and Area Resource Managers.

The project will be funded from the Water Resources Capital programme. In addition negotiations are in progress with Water Companies to try and secure additional funding from the Asset Management Plan 3 investigations within the project area.

Timing
It is proposed to start Stage 1 in September 2000 with delivery of final reports in December 2001 and completion of review scheduled for February 2002. Overall project completion is scheduled for the end of 2004.

Management Structure
Project Executive : David Burgess, Groundwater Manager.

Project Manager : Bill Morgan-Jones.

Budget Manager : Graham Wilson, Regional Water Resources Manager.

Recommendations
The following recommendations are made:

i) Approval is given to adopt the 'Intermediate' Option as the preferred option for this project;

ii) Approval is given to undertaking Stage 1 of this option at an estimated cost of £365 122 (non-discounted); and

iii) The PID for Stage 2 together with the revised business case for the project are submitted for approval towards the middle of 2001.

Contents

Glossary

AEG	Area Environmental Group
AOD	Above Ordnance Datum
AMP	Asset Management Plan
AMS	Abstraction Management Strategy
DETR	Department of the Environment Transport and the Regions
DSA	Data Search Area
EOETS	Ely Ouse to Essex Transfer Scheme
EU	European Union
LEAP	Local Environment Action Plan
NCGCL	National Centre for Groundwater and Contaminated Land
Ml/d	Million litres per day
NPV	Net Present Value
NRA	National Rivers Authority
PAB	project Assessment Board
PID	project Initiation Document
RWRMT	Regional Water Resources Management Team
SAC	Special Area of Conservation
SAGS	Stour Augmentation Groundwater Scheme
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
Tcmd	Thousand cubic metres per day

1. Introduction

1.1 Overview

This document is the Project Initiation Document (PID) for the Essex Groundwater Investigation. The North/South Essex Groundwater Unit is indicated in Figure 1.1. The Essex area was one of the priority areas identified in the Environment Agency (EA) Anglian Region Strategy for Groundwater Investigations and Modelling (The Strategy), and is the third project under the Strategy to be initiated. The project covers the catchments associated with the Rivers Stour (including the Brett), Colne, Pant-Blackwater , Chelmer and Crouch.

Following standard practice for regional groundwater investigations and modelling the Strategy projects are subdivided into five stages. This is partly because the costs of individual stages are dependent on the results of previous stages. In the face of this, the regional Project Assessment Board (PAB) has advised that Strategy projects can be approved on a stage by stage basis (see PAB minutes for July 1998 and August 1998).

This PID therefore seeks approval for Stage 1 of the Essex Groundwater Investigation. The estimated cost of the preferred option for Stage 1 is £365 122.

This PID presents the business case for the full Essex Groundwater Investigation. This business case will be updated as the stages are completed.

The business case for the Essex Groundwater Investigation is presented in part 1 of this PID. Part 2 then presents the Project Plan for Stage 1.

The primary objective of the project is to provide a quantified understanding of groundwater flows within the area. In doing so this will provide a firm technical basis for managing the groundwater resources and regulating groundwater use in the area.

1.2 Strategy for Groundwater Investigations and Modelling

The Water Resources Strategy of the Anglian Region of the predecessor organisation to the EA, the National Rivers Authority, was published in September 1994. It identified the groundwater resources available for abstraction within the main groundwater units across the Anglian Region and identified the amount of resource which it was believed should be allocated to maintain acceptable river flows. However, this assessment of groundwater resources was, like many elsewhere in the country, based on simplistic groundwater balance techniques using average climatic conditions (see Annex 4 of the Water Resources Strategy).

The need for a more rigorous and technically defensible groundwater resource appraisal is driven by the combination of increasing resource usage and increased awareness of the importance of groundwater in environmental conservation. These drivers have led to a series of regulatory and consultative documents which provide (or imply a future) statutory obligation to improve resource assessments and to generate public understanding of these assessments. Specifically the key documents include the following:

- the Water Resources Act (1991) and the Environment Act (1995), which set out the continued duty to manage and regulate groundwater resources in a sustainable way;
- the European Union (EU) Water Framework Directive and its requirement for the preparation of river basin management plans and their review on a six year cycle;
- the Department of the Environment, Transport and Regions (DETR) White Paper, 'Taking Water Responsibly', which recognises the obligations imposed by the Framework Directive;
- the EU Habitats Directive (via the Conservation (Natural Habitats etc) Regulations, 1994) and the obligation to review abstractions with potential impacts on designated conservation sites by March 2004;
- the developing EA Abstraction Management Strategies (AMSs) as a first step to implementation of the Framework Directive and White Paper requirements; and
- the Local Environment Action Plan (LEAP) process and the issues identified in the LEAP reports.

Following the publication of the EA Environmental Strategy and the Water Resources Functional Strategy in 1998, a national initiative for the implementation of the review of groundwater resources was instigated. The review is being led by the National Centre for Groundwater and Contaminated Land (NCGCL).

The Anglian Region 'Strategy for Groundwater Investigations and Modelling' (The Strategy) was accepted by the PAB in February 1998, and forms part of the NCGCL national review. It sets out detailed proposals for the review of the groundwater resources in the Anglian Region, in line with sound science and defensible technical practice. In the process of development of a resource management tool (probably a distributed groundwater model) improved understanding and resource assessments of groundwater systems of aquifers across the Region will be achieved.

The Strategy divides the Anglian Region into the following four main aquifers and eleven groundwater units. Each groundwater unit provides the basis for the series of projects identified within the Strategy. The Essex Groundwater Investigation is the third such strategy project to be proposed. It is centred on the North/South Essex LEAP areas (see Figure 1.1) and its early implementation is a recognition of the water resource difficulties being faced by the area, especially in the light of Government proposed increases in housing provision.

This document presents the PID for the Essex Groundwater Investigation and is arranged such that this Introduction is followed by a Business Case for the overall Essex Groundwater Investigation (Part 1) and a Project Plan for the Stage I activities (Part 2).

1.3 Project Stages and Approvals

This project, as with others in the Strategy, is divided into the following five main stages:

- Stage 1: Development and documentation of conceptual understanding;
- Stage 2: Further investigation/monitoring;

- Stage 3: Development of a method of quantifying and managing groundwater resources;
- Stage 4: Predictive simulations/management runs; and
- Stage 5: Project reporting.

Stage 1 involves collating, analysing and interpreting data. In terms of costing the Stage 1 study, it is important to establish the extent of the data available for the proposed Stage 1 Data Search Area (DSA). For this reason, it has been proposed that Strategy projects are preceded by a Scoping Study as a necessary basis for a business case and PID preparation. This current PID is therefore supported by a Scoping Study Report (Entec, April 2000) which is bound under separate cover.

At this stage, costs beyond Stage 1 (particularly for Stage 2) are difficult to reliably estimate with confidence. Data availability in space and time is addressed in the Scoping Study Report, but data quality and possible gaps cannot be rigorously appraised until Stage 1 is well advanced. Consequently, definition of Stage 2 requirements and costs cannot be made until late in Stage 1. Similarly the detailed scope and nature of Stage 3 activities is dependent on the option of Stages 1 and 2.

This problem was discussed with PAB during July 1998 and it was agreed that Strategy projects should adopt an approach to project approval similar to that for Research and Development projects. This approach requires that approval to proceed to successive stage(s) is sought late in the preceding stage. A flow chart illustrating the proposed approval process for the Strategy projects is shown in Box 1.1.

1.4 The Essex Groundwater Investigation

The location of the Stage 1 DSA is shown on Figure 1.2. The DSA is the area of investigation for Stage 1 of the project, and is deliberately set larger than the main area of interest (the Essex LEAPs).

The northern boundary of the DSA lies just to the north of the River Stour surface water catchment. The eastern and south-eastern boundary is along the North Sea and Thames Estuary coast. The southern boundary is currently situated along the north bank of the River Thames, but may require redefinition following the Stage 1 inspection of hydrogeological data acquired during the Channel Tunnel Rail Link investigations.

The most difficult DSA boundary to currently define is the western boundary. The southern part of this boundary (south of Northing 210) runs along Easting 545 line. The middle part of the western boundary (between Northings 210 and 240) has been chosen to coincide with the eastern boundary of the Thames Region Lee-Mimram DSA (along the line of the River Ash). The northern part of the western boundary (above Northing 240) lies just to the north-west of the surface catchments of the Essex rivers.

The area so defined extends beyond the North Essex and South Essex LEAP areas, which are principally based on the Essex surface water catchments. The larger area has been chosen because the groundwater catchment area (and hence the probable eventual groundwater model) could extend beyond the surface water catchment boundaries. The extension of the area so far into the Thames Region is to allow for particular uncertainties in the position of the boundary of the probable groundwater model in the confined zone of this area. It also leaves open the option for the eventual Essex model to have a common boundary with the planned Thames Region Lee-Mimram model, thereby enabling cross-region aquifer management.

The activities that will be required for the project can be subdivided into a number of stages and sub stages. These are as follows:

	Scoping study and PID preparation
Stage 1:	Collation of data
	Analysis of data
	Interpretation of data and development of conceptual understanding
	Review of conceptual understanding
	Revised business case and benefits appraisal methodology
Stage 2:	Specific focussed investigations
	Asset Management Plan 3 investigations
	Water level monitoring of existing boreholes
	Updating of conceptual understanding
Stage 3:	Construction and calibration of an appropriate resource management tool (if possible, a distributed groundwater model)
Stage 4:	Predictive and management simulations
Stage 5:	Project reporting.

An estimated overall programme for these activities is shown on Figure 1.3. The activities and durations are typical for a project of this scale and possible alternatives are discussed in this PID.

The business case is based on a 18 month completion period (15 months investigation and 3 months review) for Stage 1, with the interpretation and review activities of the final quarter overlapping with the start of Stage 2. This programme anticipates completion of model development by the end of 2003, and model predictive runs by the middle of 2004.

The subdivision of the project into Stages is designed to facilitate effective project management and review. However, the time scales, even for individual Stages, are long and interim subdivision and review is also anticipated (see Part 2). A more detailed introduction to each Stage and the approach to management of uncertainties is presented below.

1.4.1 Scoping Study

The principal objectives of the Scoping Study are as follows:

- Establish the need for the project;
- Identify particular issues by consultation with EA staff and Stakeholders; who?
- Summarise the current understanding and data availability;

- Present and discuss the range of technical options within each stage; and
- Identify a range of potential options of the project as a whole.

There are a number of different ways in which the project can be approached and different quantities of data that can be processed. Each has an impact on cost. As part of the Scoping Study these are rationalised into 'Low, 'Intermediate' and 'High' Options for the project as a whole. On this basis the business case for the whole Essex Groundwater Investigation is presented.

1.4.2 Stage 1

Stage 1 will provide coherent and consistent data bases for the DSA. This data will be analysed and interpreted to provide a conceptual understanding of the groundwater flow regime. The 'first pass' quantitative testing of this understanding will be achieved through water balance calculations.

It is possible that gaps in the data and understanding will be identified which may require further monitoring, field investigation or data acquisition (Stage 2). A preferred course of action for Stage 2 will be identified and in this context the potential options of the project as a whole will be reviewed.

This review will provide a basis for updating and refining the business case and a PID will be prepared seeking approval for Stage 2.

1.4.3 Stages 2 to 5

The duration of the Stage 2 investigations may be about 18 months. In the middle of this period the Stage 1 Report and conceptual understanding are likely to require updating within a Stage 2 Report.

This Stage 2 Report will identify the preferred course of action for Stage 3 and review potential project options. This will permit further updating and refinement of the project option and business case, and enable a further PID to be prepared. This PID will seek approval for Stages 3, 4 and 5, and update the business case for the overall project.

The principal objective of the Essex Groundwater Investigation is to provide a practicable and supportable water resources management tool based on recognised best hydrogeological practice to assist in the sustainable management of the water resources in the area. Present best practice suggests that this tool will be a distributed groundwater model representing variation in both time and space. The definition of this management tool must however be kept under review as management priorities vary, the understanding develops and as scientific 'best practice' evolves.

Box 1.1 Flow Chart Showing Project Stages and Approvals

Form A

↓

SCOPING STUDY
Identify Technical and Managerial Issues
Identify Data and Information Available

Identify Options and Costs for Stage 1
Identify Preferred Course of Action/Plan of Work for Stage 1

Identify Options and Costs for Stages 2-5
Identify Potential Options and Costs for Whole Project

Prepare Business Case for Whole Project
Evaluate Benefits of Whole Project
Prepare Business Case for Whole Project

Prepare PID for Stage 1
Include Business Case for Whole Project
Seek Approval for Stage 1

↓

STAGE 1: DEVELOPMENT AND DOCUMENTATION OF CONCEPTUAL UNDERSTANDING OF GROUNDWATER REGIME
Collect Data
Analyse Data
Interpret Data
Develop and Document Conceptual Understanding
Identify Preferred Course of Action/Plan of Work for Stage 2

Update and Refine Business Case
Review Potential Options and Costs for Whole Project
Review Benefits of Whole Project
Update and Refine Business Case

Prepare PID for Stage 2
Include Business Case
Seek Approval for Stage 2

↓

STAGE 2: FIELD INVESTIGATION/MONITORING (OPTIONAL)
Enhance Existing Monitoring
Set Up New Monitoring Installations
Carry Out Field Investigations
Identify Preferred Course of Action/Plan of Work for Stages 3, 4 and 5

Update and Refine Business Case
Review Potential Options and Costs for Whole Project
Review Benefits of Whole Project
Update and Refine Business Case

Prepare PID for Stages 3, 4 and 5
Insert Business Case
Seek Approval for Stages 3, 4 and 5

↓

STAGE 3: FORMULATE METHOD FOR QUANTIFYING AND MANAGING GROUNDWATER RESOURCES

↓

STAGE 4: PREDICTIVE SIMULATIONS/MANAGEMENT RUNS

↓

STAGE 5: PROJECT REPORTING

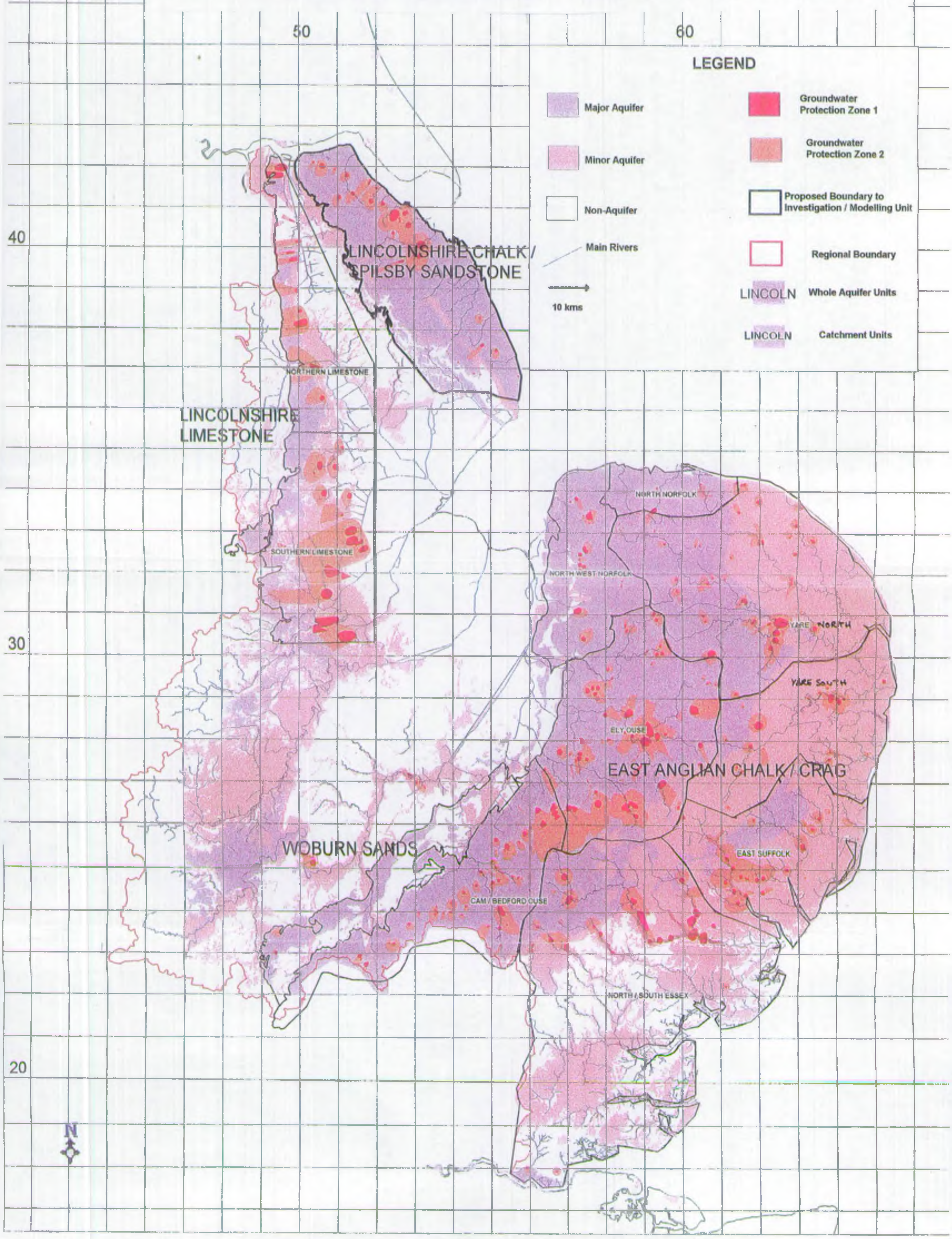
1.5 This Project Initiation Document

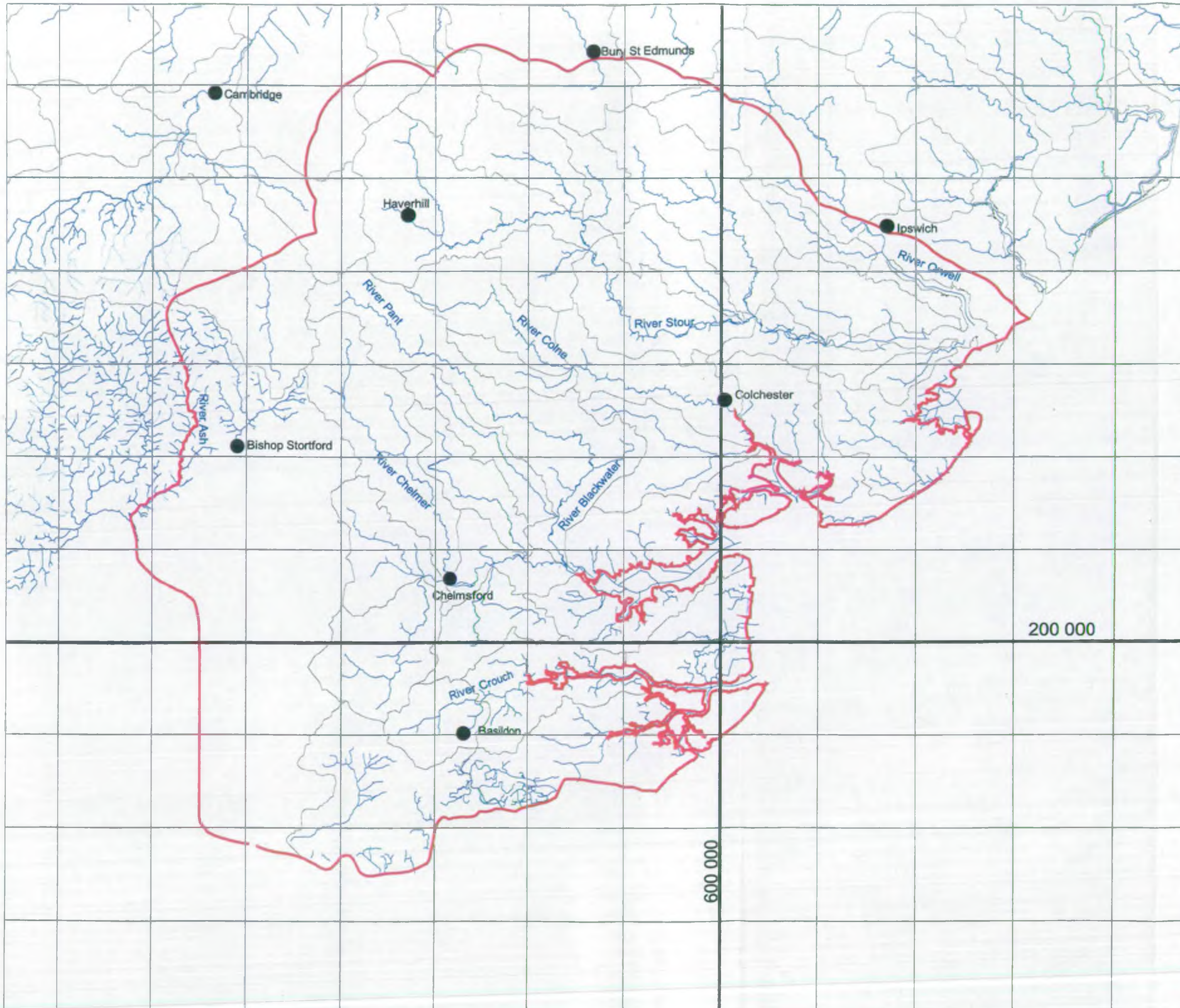
This PID for the Essex Groundwater Investigation has been prepared at the end of the Scoping Study. The Business Case (Part 1) which follows this Introduction is presented for the project as a whole. However the detailed Project Plan (Part 2) only refers to Stage 1 and the PID seeks approval for Stage 1 only.

For the purposes of seeking approval this PID is prepared as a stand alone document. Much of the background detail on which this PID is based is presented in the Scoping Study Report[1]. Reference should be made to this report if more detailed information is required. The Strategy is also an important reference document and integrates the Essex Groundwater Investigation, its options and deliverables into a coherent regional programme.

[1] Review of the Essex Groundwater Investigation Area, Scoping Study Report, Entec Report, April 2000

FIGURE 1.1: PROPOSED INVESTIGATION/MODELLING UNITS ('FROM THE STRATEGY')





Key:

- Essex Stage 1 Data Search Area
- Hydrometric Areas from EA GIS
- Main Rivers
- Major Towns

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FIGURE 1.2
ESSEX STAGE 1 DATA SEARCH AREA

Drawing No: **02894-10.S007**

Scale: **1:400 000**

Date: **JUNE 2000**

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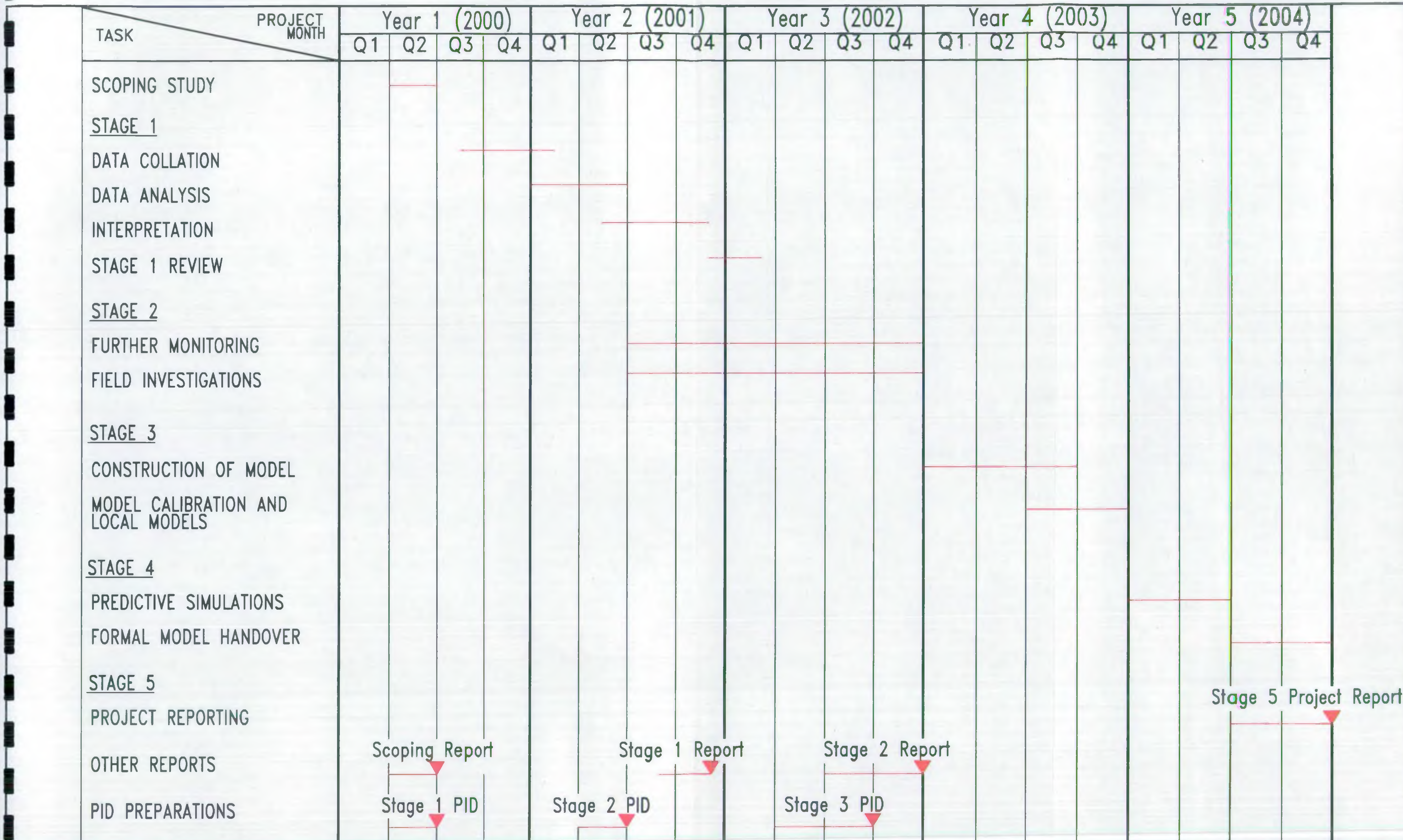

FIGURE 1.3 ESSEX GROUNDWATER INVESTIGATION: ESTIMATED OVERALL TIMESCALE AND ACTIVITIES

Drawing No: 02894_001_3 Date: JUNE 2000 Scale: NTS

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Part 1 - Business Case for the Essex Groundwater Investigation

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2. Background to the Project

2.1 Introduction

This section summarises the background to the Essex Groundwater Investigation and explains why a high priority should be given to this particular project. This section should be considered in conjunction with The Strategy, which gives the general background to all the Strategy projects, and with the Scoping Study Report, which identifies the specific water resources and other related issues which need to be addressed within the Essex area.

2.2 Regulatory and Policy Framework

The proposed Essex Groundwater Investigation needs to be viewed in the context of the regulatory and policy framework in which the EA operates.

The EA is required and guided by Government to use the duties and powers granted to it in the Water Resources Act (1991) and the Environment Act (1995) to help achieve the objective of sustainable development. One definition of sustainable development is 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs' (Brundtland Commission). In September 1997, the EA published 'An Environmental Strategy for the Millennium and Beyond' in which it described how it intends to take forward an integrated and long term approach to the management of the environment. With respect to water resources, the EA pledged itself to achieving 'the proper balance between the country's needs and the environment...basing [its] decisions around sound science and research'.

In support of its environmental strategy the EA produced in 1998 a series of 'Functional Action Plans' for its Environmental Protection and Water Management functions. The Water Resources Action Plan identifies the contribution the Water Resources function makes towards achieving the aims of the EA's environmental strategy.

The principal mechanism for achieving sustainable management and development of water resources is through the EA's regulation of water abstraction. Abstraction licensing requirements were first consolidated nationally under the 1963 Water Resources Act and are currently defined by the 1991 Water Resources Act and the 1995 Environment Act. The 1991 Act also incorporates some of the water quality protection requirements of the 1980 EU Groundwater Directive (80/68/EEC).

This legislative framework has recently been comprehensively reviewed. The results of this review are presented in the March 1999 Government White Paper 'Taking Water Responsibly' which recognises the obligations imposed by the draft EU Water Framework Directive. The White Paper sets out both the steps the Government wishes the EA to take within current legislation and also legislative changes the Government plans to make as soon as Parliamentary time allows.

The EA was asked by Government to develop new strategies for the sustainable management of water resources. In October 1999 the EA therefore published a consultation document entitled 'Sustainable Water Resources for the Future: Values and Challenges', in which opinions of individuals and organisations against thirteen fundamental issues were sought. The main implications of these issues from a regional point of view were discussed in a follow up document entitled 'Sustainable Water Resources for the Future: Values and Challenges, the Anglian Region Perspective'. Response to these two documents will be used to help update and revise the EA national and regional water resource strategies prior to their publication in December 2000.

'Taking Water Responsibly' also identifies proposed legislative changes. These include placing regulatory requirements for more licence or renewal applications to be supported by Environmental Impact Appraisals and for all licences to be time limited. The determination of licence applications will be undertaken in accordance with a published abstraction management strategy (AMS) for each catchment. The AMS will complement the LEAPs by describing the water resources position in each catchment and by setting out a strategy to deal with pressures on water resources. It will be physically separate from the LEAPs so as to present the more detailed information that will underpin the strategy. The AMS will be reviewed every six years with a fifteen year look ahead period.

These developments in the regulatory and policy framework have major relevance for the Anglian Region Strategy for Groundwater Investigations and Modelling in general, and the Essex Groundwater Investigation in particular. To meet its responsibility to help achieve sustainable development, it has been recognised that the EA has to develop new strategies and implement more defensible licensing procedures. The implementation of the Anglian Region Strategy is very much complementary to this new approach, the conceptual understanding and numerical model(s) that result from the Anglian Region Strategy providing the basis for implementation of the pending abstraction management strategies and licence reviews.

The Essex Groundwater Investigation forms part of the implementation of the Anglian Region Strategy, and will provide a means of assessing the sustainability of current and proposed water resource management in an area where water resources are particularly heavily exploited. Integration of the results of the Essex Investigation with those from surrounding areas (e.g. Lee-Mimram, Ely-Ouse) will permit cross-region resource management and impact assessment.

The study also supports the draft Environment Strategy of the EA, in particular the sections entitled 'Using Natural Resources Wisely', 'Improving and Protecting Inland and Coastal Waters', and 'Limiting and Adapting to Climatic Change'.

Furthermore, the study addresses certain of the Anglian Region Priorities for 1999/2000 (June 1999). The Form A justification for the Essex Groundwater Investigation Scoping Study made reference to these priorities and how the Essex Groundwater Investigation would address them.

The Essex Groundwater Investigation is included as Project WR/R/22 in the current Water Management Business Plan.

2.3 Essex Groundwater Investigation Area

The Stage 1 DSA (and the eventually agreed Essex Groundwater Investigation Area) comprises the surface water catchments of five principal river systems, the Stour (including the Brett), the Colne, the Pant-Blackwater, the Chelmer and the Crouch. The first four of these rivers rise in the northern Chalk outcrop area about 100 metres Above Ordnance Datum (AOD) and drain over the London Clay and Superficial Deposits to the North Sea. Flows in the Stour and Pant can be augmented by the water transfers through the Ely-Ouse Essex Transfer Scheme (EOETS) and by inputs from the Stour Augmentation Groundwater Scheme (SAGS).

The geology of the area is illustrated by Figure 2.1, and is described in detail in the British Geological Survey (BGS) Regional Geology Guide (London and the Thames Valley, 1996). Relevant BGS geological maps include the 1:250 000 Thames Estuary map, a series of 1:50 000 scale published maps and associated memoirs and a large number of mineral assessment reports.

The Chalk is the Main Aquifer of the area. It comprises a very fine-grained, pure limestone with flint, and has been folded into a broad, eastward-plunging asymmetrical syncline (the London Basin) with several intersecting minor folds e.g. Purfleet-Grays area. The majority of the Chalk in the Essex area lies on the gently-dipping north-western limb of the syncline, and outcrops in the headwater areas of the Rivers Brett, Stour, Colne and Pant. However, the southern limb of the Chalk syncline occurs within the southern limit of the area beneath drift on the north bank of the River Thames at Tilbury.

Away from the outcrop areas on the two limbs of the syncline, the Chalk is overlain by Lower London Tertiaries (LLT) and the London Clay Formation. The LLT comprise the Thanet Sand Formation and the Lambeth Group, a variable mix of sands, silts and clays up to about 26 metres in thickness. The London Clay Formation is mainly a dark bluish to brownish grey clay, containing variable amounts of fine-grained sand and silt, and is up to 150 metres thick in south Essex.

The project area is extensively covered by Superficial Deposits. Boulder Clay associated with the Anglian Stage glaciation extends over the entire northern Chalk outcrop area and over the London Clay as far south as Colchester and Chelmsford. The Boulder Clay consists of a stiff, unstratified clay with abundant fragments of chalk and flint, and is typically between 35 and 50 metres thick. However, exceptional thicknesses have been identified in the base of 'tunnel valleys' cut into the underlying Chalk e.g. 147 metres at Clare, on the Lower Stour.

Other Superficial Deposits in the area include Glacial Sands and Gravels, most notably those beneath the Boulder Clay in the Chalk tunnel valleys and directly overlying the London Clay south of the Lower Stour, Recent Valley Gravels in the river headwaters and Alluvium along the coastal margins.

2.4 Past Resource Investigations and Current Understanding

The Essex area has been the subject of several previous resource investigations. The findings of the main investigations are presented below:

- *Essex River Authority, the First Survey of Water Resources and Demands (1971).* This was formulated to meet the requirements of the Section 14 of the 1963 Water Resources Act. It quantified available water resources and existing and future demand, but noted the difficulties in undertaking water balance calculations in such low recharge areas;
- *Anglian Water Authority, Groundwater Resources (December 1978).* This presented summary hydrological and hydrogeological data to support a Central

Water Planning Unit study of national water resources. Groundwater contours were used to delimit flow-lines and three groundwater catchments (Stour, Middle Essex and Thameside) that provide the basis for current resource estimate reporting. Other important hydrogeological features identified include the association of high transmissivity and high recharge with river valleys, and high storage in the LLT supporting groundwater abstractions in the underlying Chalk;

- *Anglian Water Authority, Saline Intrusion in South Essex (February 1979).* This updated previous salinity studies in the Thameside Chalk. Saline intrusion in the area seemed to increase up to 1976, particularly west of the Dartford Tunnel, but between 1976 and 1978 it decreased, primarily in response to reduced abstraction;
- *Anglian Water Authority, Chalk Hydrochemistry in Essex (December 1980).* This presented a reinterpretation of the area's chalk hydrochemistry. Five predominant water types were identified, ranging from calcium bicarbonate waters on outcrop to calcium-sodium bicarbonate waters within the majority of the Middle Essex Chalk and to sodium chloride connate waters along the coast. Most importantly, modern recharge waters with relatively high nitrate concentrations were identified along the line of the river valleys on outcrop;
- *Lloyd, Harker and Baxendale, Recharge Mechanisms and Groundwater Flow in the Chalk and Drift Deposits of Southern East Anglia (1981).* Reliance was placed on the earlier hydrochemical interpretation by Thomas (1977) to define chalk water types. Though the resulting interpretation of the regional hydrogeology was similar to that defined by Anglian Water Authority, sampling of drift waters allowed a recharge conceptual model to be formulated. Glacial Sands and Gravels below the Boulder Clay receive recharge from the Boulder Clay and promote horizontal groundwater flow beneath the interfluves towards the valleys; and
- *Anglian Water, Stour Augmentation Groundwater Scheme – Phases 3 and 4 (January 1987).* This identified long term resource options for the area, and advocated the further development of SAGS in four areas – the Upper Stour, the Chelmer, the Roman River and the Brett/Stour tributaries.

Other key references for the area include reports associated with the EA Pant Groundwater Model and the Central Electricity Generating Board's Tilbury Groundwater Model, the BGS Southern East Anglia Hydrogeological Map (two sheets) and the area's Groundwater Vulnerability Map.

The previous work has identified important features of the surface and groundwater flow regime. However, it has not been sufficiently comprehensive to lead to an overall understanding of the flow system.

2.5 Essex Water Resources

Groundwater in the Essex area is heavily utilised for water supply. Groundwater supports direct abstraction and also provides a high proportion of riverflow. A summary of the current water resource assessments and abstractions is provided in Table 2.1. Table 2.1 is based on information from three key documents, the North Essex LEAP consultation report (February 1998), the South Essex draft LEAP report (December 1999) and the EA Groundwater Balance

Review (May 1994). The water volumes are expressed in units of tcmd (thousand cubic metres per day).

There is insufficient understanding of the surface and groundwater flow regime for the resource assessments to be considered reliable. The resource estimates for Essex are based on baseflow analysis for the main Essex rivers during the period 1967 to 1974. The environmental allocation is based on an estimate of the proportion of recharge necessary to sustain riverflow which would, in natural circumstances, be equalled or exceeded for ~95% of the time. The uncertainty in these estimates is large and as such that resource allocation constraints can frequently be challenged. Additionally, this analysis has been carried out for individual sub-catchments only and is probably not sufficiently consistent to permit synthesis for the whole Essex area.

In summary, the current resource estimates are simplistic and considered to be inaccurate. They are also whole catchment totals, and, in the case of the Chalk, the aquifer is probably not subdivided on a reasonable basis.

Table 2.1 Essex Summary Water Statistics (based on LEAPs and EA data)

Groundwater Balances (tcmd)	Gross Resource	Effective Resource	Environmental Allocation	Licensed Abstraction	Balance
Stour Chalk	123	123	36	117	-30
Middle Essex Chalk	37	37	7	40	-10
Thameside Chalk	10	10	0	26	-16
Essex Gravels	46	27	0	28	-1

Abstractions		
Public Water Supply Abstractions	: 61	(44 GW/ 17 Surface)
Agricultural Spray Irrigation	: 1057	(271 GW/ 786 Surface)
Agricultural General	: 654	
Industrial	: 99	
Augmentation	: 17 SAGS	
Discharges		
Sewage Treatment Works	109	
Trade Effluent	135	

Though the resource estimates can be challenged, they do nevertheless indicate the severe water resource difficulties facing the region, particularly in light of the planned further increase in housing provision. The majority of abstraction is undertaken for public water supply to the major towns of the area (in order of population size - Southend, Basildon, Colchester, Chelmsford, Thurrock, Braintree, Rayleigh, Brentwood, Maldon, Benfleet/Hadleigh/Thundersley, Canvey Island, Haverhill and Sudbury).

To help maintain the current rates of abstraction, the augmentation of surface flows by means of EOETS and SAGS is required. Despite these provisions, in-area abstraction remains insufficient to meet demand, and large volumes of water are imported into supply from outside the area, principally via a Thames Water bulk transfer (about 100 tcmd) and an Anglian Water input to Alton Water (about 30 tcmd). Furthermore, Asset Management Plan 3 (AMP3) studies are necessary to investigate low flow problems with respect to three rivers in the area (the River Brett, the upper River Pant and the upper River Colne), where it is perceived that groundwater pumping has depleted riverflows.

The EA recognises the seriousness of the water supply problems in the area. In it's 'Water Resources in Anglian: Summary Document' (September 1994) it advocated the development of the small remaining groundwater resources and investigating the expansion of the EOETS and the development of a new surface reservoir.

Groundwater quality is also an issue in Essex. Groundwater quality within the Essex area (particularly in Thameside) is at risk principally from past and current gravel abstraction and waste disposal activities and from local saline intrusion. Quality may also be impacted by future developments that County Structure Plans anticipate as light industrial and residential.

2.6 Management of Groundwater Resources

The operational control and management of the groundwater resources of the Essex area is the responsibility of the Area Water Resources Manager in the Ipswich Office. This office has the following responsibilities:

- hydrometric data collection;
- administration, control and review of existing abstraction licences;
- consideration of new abstraction licence applications;
- responses to development proposals likely to affect groundwater resources e.g. mineral working;
- waste disposal regulation; and
- operation of SAGS.

Calculations of the availability of groundwater resources and strategic planning of resource allocation are the responsibility of the Regional Water Resources Manager at Peterborough.

The difficulties faced by the EA (at both Area and Regional level) in implementation of these responsibilities are discussed in Section 4. They principally relate to insufficient understanding of the surface and groundwater flow regime to enable anything but the most simplistic resource and licence assessments.

2.7 Statement of Needs

The strategic and tactical management of the groundwater resources of the Essex area is hampered by a lack of understanding of the groundwater flow regime in the area. There is no authoritative technical report summarising the hydrogeology of the area, and there is no one groundwater model that can aid in evaluating and forecasting the impact of pumping on existing users, rivers and the water environment.

The water resources management problems of the Essex area arise from the following four broad groups of issues:

- Strategic water resources management;
- Tactical/operational water resources management;
- AMP3/Habitats Directive and conservation; and
- Protection of groundwater quality.

These issues and the resource management needs to which they give rise are summarised in Box 2.1. Where a need has been previously identified as Anglian Region Priorities for 1999/2000 it's priority class is also provided.

The needs can be summarised as a requirement for a management tool that can achieve the following:

- Provide rigorous and defensible recharge estimation and resource assessment;
- Quantify understanding of groundwater/surface water interaction;
- Is accepted as being based on clear understanding and best practice;
- Is usable on a regular basis by Area office staff;
- Can be used to investigate impact of continued, altered or increased abstractions;
- Can quantify the future impacts of climate or landuse change on the availability of groundwater resources; and
- Can investigate long-term strategic options and predictions.

Current experience suggests that the most appropriate tool is a distributed groundwater model which in its development imposes rigor and discipline on the conceptual understanding and in its use permits iteration around uncertainties and strategic investigation of options. As the understanding of the area develops and hydrogeological methodology evolves the definition of this tool may change. A detailed specification of the most appropriate management tool will form part of the Stage 1 Report and will be reviewed again following Stage 2.

2.8 Local Environment Action Plans

The LEAPs are the EA's integrated management plans for identifying, assessing, prioritising and addressing local environmental issues. The LEAPs and the consultation process have identified a series of issues arising from the operation, regulation and protection of the water resources in the Essex area.

Box 2.2 and Box 2.3 summarise those issues identified in the North and South Essex LEAPs respectively which will be supported by the Essex Groundwater Investigation. Input into LEAPS is a 1C Anglian Region Priority. In some instances the benefits provided by the Essex Groundwater Investigation will not be realised until the development of the distributed groundwater model(s) in Stage 3, but in other cases benefits will be realised much earlier in the investigation.

2.9 AMP3

There is a need to investigate three sub-catchments using the AMP3 funding source. These are the Brett, Upper Colne and Pant valleys. Stage 1 will determine any fieldwork that should be carried out at these sites. Stage 2 fieldwork and Stage 3 modelling of these areas should be complete by the end of 2003, and this means that the Essex Groundwater Investigation will provide the major hydrogeological understanding to underpin the AMP3 solutions of these sites. It is agreed that funding for this part of the project will be sought from the appropriate water companies.

Box 2.1 – Essex Groundwater Investigation: Identification of Need

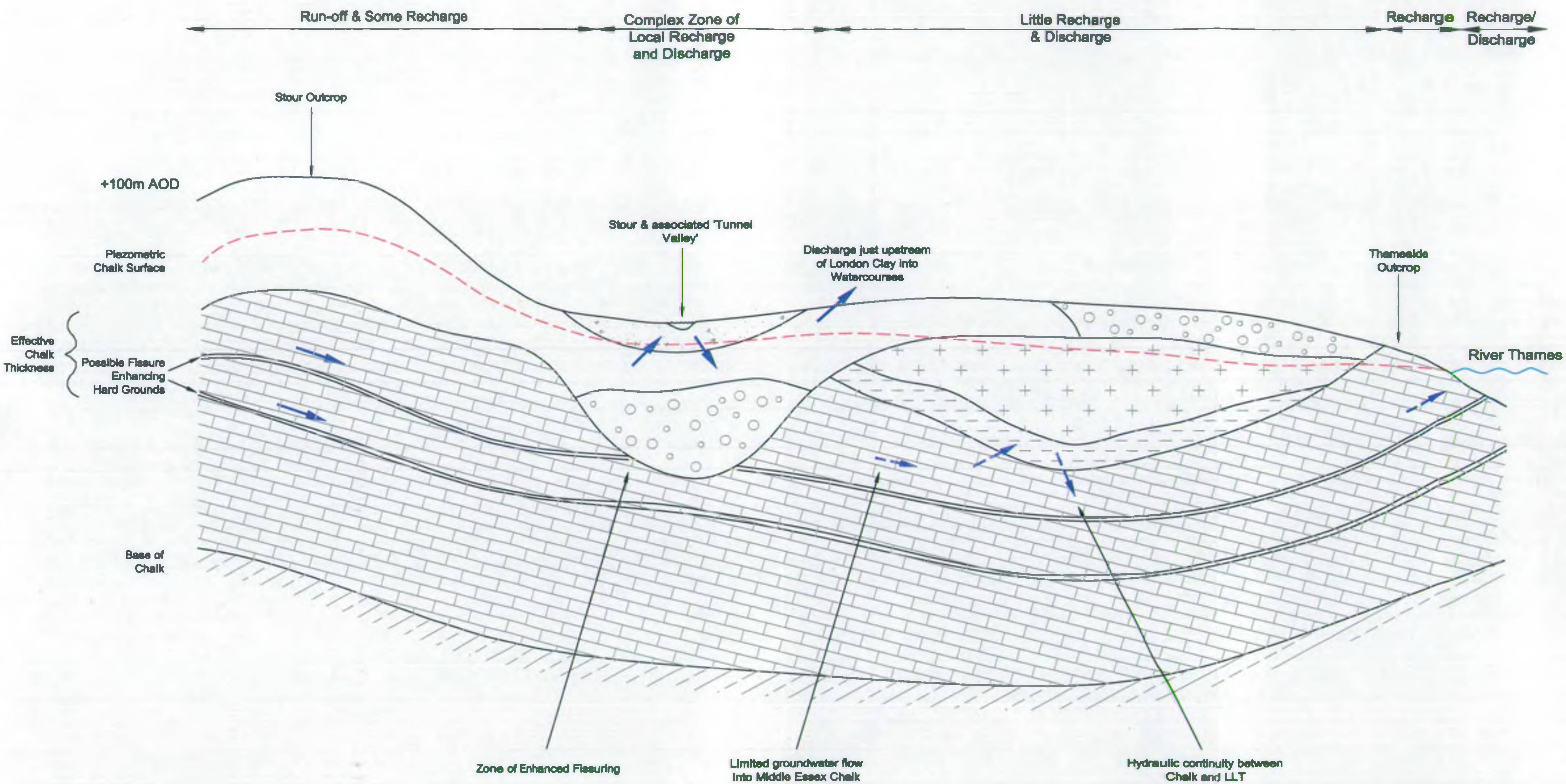
Problem	Need (and Priority Class)
Strategic Water Resources Management	
a) The current assessment of the gross groundwater resource is based on crude and oversimplistic steady state methods.	Need to develop a more objective and defensible approach to recharge estimation and groundwater resources assessment based on established technical practice.
b) The current method of assessing the effective groundwater resource is based on arbitrary factors and does not adequately represent seasonal variations in recharge.	Need to develop a valid, time-variant approach to groundwater resources assessment.
c) The Brett, Colne and Pant rivers have all suffered from low flows during drought periods and are perceived to have been impacted by groundwater pumping.	Need to develop a quantifiable understanding of river aquifer interaction.
d) It is known that abstractions from some aquifers approach or exceed the resource limit but it is not known whether there is any surplus resource which could meet future growth in demands, or whether the pattern of abstraction is optimal.	Need to develop a framework for assessing the impacts of current licensed abstractions on surface watercourses.
e) The current method of assessing the effective resource does not properly take account of the EOETS inflows and SAGS.	Scientific methods are required to provide credible assessment of surface water, shallow groundwater and chalk groundwater interaction (Priority 1A).
f) There is currently no method available which represents the detailed river-aquifer interaction along the Essex rivers, and which can reliably confirm the net gain associated with the EOETS flows and SAGS abstraction.	
g) There is currently no method available which can forecast the impacts of climate change on the Essex aquifers.	
h) There is currently no method available which can forecast the impacts of land use/ land drainage change on Essex aquifers.	Accessible, predictive and defensible management tool required.
i) There is currently no method of linking resource appraisals across regional administrative boundaries, even though import of water to meet demand is important.	
j) There is currently no means of tinking resource appraisals across area and regional administrative boundaries even though Essex relies on water imports from neighbouring areas to meet demand.	
Tactical/Operational Management	
k) An established framework for assessing the impacts of current/new/varied abstraction on rivers within the context of licence determination is not available.	Need to develop a quantitative resource analysis and simulation model which is accepted as representing 'best practice' by a range of conflicting stakeholder interests (Priority 1A).
l) The current method of assessing groundwater resource status and of forecasting abstraction prospects for the coming season is over-simplistic and coarse.	
m) There is currently no method available which can forecast the need for mitigation measures, such as river support pumping, cutbacks in abstraction, etc for the coming season given the prevailing groundwater conditions.	
n) There is currently an insufficient understanding of the groundwater system to allow the design of an optimum hydrological monitoring network	Need for synthesis of regional understanding to prioritise further investigation requirements.
AMP3/Habitats Directive and Conservation	
o) A rigorous framework for assessing the impacts of current licensed abstractions on river headwaters/SACs/SPAs is currently not available.	Detailed representation of boundary conditions in which local models can be established is required (Priority 1A).
Groundwater Quality	
p) There is no clear understanding of regional groundwater flow systems that could provide a valid framework for detailed capture zone, NVZ, pollution or contaminated land investigations.	Need for a regional groundwater model that can be linked to contaminant transport analysis (Priority 2B).

Box 2.2 – North Essex LEAP Issues and Support from the Essex Groundwater Investigation

	LEAP Issue	Support from the Essex Groundwater Investigation
1a	Actual flows are perceived to be inadequate to meet river needs.	The project will deliver a distributed groundwater model which will simulate flows in the major watercourses, and which could be used to determine management strategies to meet minimum residual flow targets and river flow objectives.
1c	There is a need to develop a better understanding of the extent and interaction of the aquifer system.	The project will deliver a better understanding of flow mechanisms and more precise assessment of the groundwater flows within and between aquifers, including the Superficial Deposits. The delivery of a distributed groundwater model will provide more reliable estimates of sustainable abstraction.
1d	Problems of stagnated river flows.	The project will deliver a distributed groundwater model which will simulate flows in the major watercourses, and which could be used to determine if the stagnated flows are due to surface and groundwater abstraction and to contribute to the design of mitigation measures.
1e	Existing available water resources are inadequate to meet future demands.	The project will deliver more precise water balances for the area. This and the delivery of a distributed groundwater model will provide the means of assessing whether proposed future abstraction is sustainable, and of recommending more appropriate abstraction management strategies.
1f	Need to review the operation, efficiency and environmental impact of the SAGS.	The project will deliver a distributed groundwater model that will simulate flows in the major watercourses and in the underlying Chalk. The model could therefore be used to determine the impact of the abstraction and the effectiveness in terms of operational net gain at downstream flow targets, and recommend a more sustainable abstraction regime.
1g	Current groundwater level monitoring is inadequate.	The project will deliver an improved understanding of the groundwater flow regime, from which the adequacy of the monitoring network can be assessed.
2a	The need to better understand the requirements of headwaters in the Plan area.	The project will deliver a distributed groundwater model that will assist in the assessment of groundwater abstraction impacts in headwater areas and guide future abstraction.
5b	Potential impacts on the environment from contamination originating from closed landfill sites.	The project will deliver a distributed groundwater model that could form the basis for later landfill contaminant transport modelling.

Box 2.3 – South Essex LEAP Issues and Support from the Essex Groundwater Investigation

LEAP Issue		Support from the Essex Groundwater Investigation
5	Concern about rising groundwater issues.	The project will deliver a distributed groundwater model which will simulate groundwater levels, and which could be used to identify suitable management techniques to suppress water level rise.
6	Concern over the water availability with regard to future housing requirements.	The project will deliver a more precise assessment of the groundwater and surface water resources available for abstraction within the Essex catchment. This will allow the extent to which future growth in demand can be met by local resources to be better defined. The delivery of a distributed groundwater model will assist in the identification of a sustainable abstraction regime.
7	Water resource availability for spray irrigation of crops.	The project will deliver an improved understanding of the sustainable yield of the Superficial Deposits, and so help determine whether shallow groundwater is a viable alternative to winter storage in coastal areas.



KEY:
- Principal Water Movement
- Subsidiary Water Movement
- Base of Chalk
- Alluvium
- Boulder Clay
- Gravels
- London Clay
- Lower London Tertiaries (LLT)
- Chalk

FIGURE 2.1
CONCEPTUAL CROSS SECTION OF ESSEX AREA HYDROGEOLOGY

Drawing No: 02894_002_1

Scale: NTS

Date: JUNE 2000

Entec

3. Objectives of the Project

3.1 Introduction

The proposed Essex Groundwater Investigation is designed to deliver the objectives of The Strategy. This section presents the objectives of the investigation as a whole. The more detailed objectives and deliverable products of the Stage 1 Study are presented in Part 2 of this document.

3.2 Objectives of the Investigation

3.2.1 General

The general objectives of the investigation are as follows:

- To improve the understanding of the groundwater and surface water system of the Essex Groundwater Investigation Area;
- To provide a credible method of assessing the groundwater resources available within the area;
- To provide a method of evaluating the impact of current and proposed groundwater abstractions on surrounding users, rivers and the water environment;
- To provide a method of simulating changes to groundwater abstraction licences proposed by local consultation under the AMS process;
- To provide a method of assessing the efficiency of the EOETS and SAGS and to provide guidance for SAGS operation; and
- To develop a tool compatible with resource assessment methods under development for adjacent areas and thereby enable the formulation of cross-region abstraction management strategies.

3.2.2 Specific

The specific objectives of the investigation are as follows:

- to collate the available data and information for the DSA;
- to set up new databases as required. These will be a relatively early Stage 1 deliverable which will then be updated near the end of Stage 1;
- to create and set up access to a number of GIS layers for the area, and to provide a series of paper maps showing important hydrological features across the area. These will be provided as deliverables during and on completion of Stage 1;

- to develop an improved understanding of the hydrological and hydrogeological processes, including recharge and groundwater flow mechanisms and surface-groundwater interactions. The final Stage 1 report will present a conceptual model incorporating this understanding;
- to carry out any further monitoring and/or field investigations which would help to improve the understanding of the groundwater and surface water system at a regional scale, and which may be necessary to allow the production of a valid distributed groundwater model. The results of this work will be reported during and at the end of Stage 2;
- to develop a distributed groundwater model (with an accompanying recharge model) capable of representing the groundwater flow and discharge processes at a regional scale, and of representing total flows from the catchments of the Essex area. This model will be delivered from Stage 3;
- to use Stage 1-3 activities in support of AMP3 investigation sites;
- to undertake a series of predictive simulations using the distributed groundwater model aimed at resolving the main groundwater resource issues within the Essex area, and aimed generally at determining the optimum long-term sustainable strategy for managing abstraction across the area. This work and its reporting occurs in Stages 4 and 5 of the Investigation;
- to identify any underexploited parts of the groundwater system with sufficient potential to justify carefully targeted resource investigations;
- to use the improved understanding of the groundwater/surface water system, together with the distributed groundwater model, to assess the impacts of individual existing and proposed abstractions on the water environment. This work and its reporting also occurs in Stages 4 and 5 of the Investigation;
- to transfer all databases and models for use by both Area and Regional EA staff; and
- to provide adequate training to EA staff in the operational and tactical use of all databases and models and thereby enable all the benefits of the project to be fully realised.

A key component in the achievement of these objectives is the timely delivery of appropriate project 'products', their integration into EA resource management and their acceptance by organisations who are stakeholders in the water resources of the area. In the preparation of the PID and supporting Scoping Study Report these stakeholders have been involved through consultation and discussion.

4. Options within Project Stages and Potential Options of the Project

4.1 Introduction

For the Essex Groundwater Investigation there are a number of potential courses of action, both within each stage and for the project as a whole. For the project as a whole, the basic options are to proceed or not to proceed. Within Stage 1, the range of options are identified in the Scoping Study and a preferred course of action can be identified. For Stage 2, a likely range of options for additional investigations can be examined, but the preferred course of action cannot. Probabilities can however be assigned to the different options. For Stages 3, 4 and 5 the range of options available may well change as the project proceeds, for example the preferred management tool in two years time may not be a distributed groundwater model. However, the present range of options and associated costs has been based on experience of model development and usage.

This section is organised to present a brief summary of options (including the 'Do Nothing' option), and then looking at each stage of proposed work individually.

4.2 Summary of Potential Project Options

Within each stage of the proposed Essex Groundwater Investigation a number of potential work options are available. These options have been combined to provide three potential project options identified as 'Low', 'Intermediate' and 'High' with reference to the amounts of work required and ultimately cost. The fourth potential option is 'Do Nothing'.

The **'Low' Option** is based on retaining technical project inputs at a minimum level compatible with national EA standards. In Stage 1 it allows for a minimum number of project meetings, no interim review and limited data collation, though, at Stage 2 in particular, this could still require one or other of the more extensive investigation and monitoring options. This option reduces Stage 1 costs but is regarded as seriously jeopardising the ultimate acceptance of the project products by the 'stakeholders' and their adoption and usage by EA staff. This in turn increases the risk of additional Stage 2 work and delayed project completion.

The **'Intermediate' Option** requires closer co-operation with stakeholder organisations and EA staff throughout. It also assumes more extensive data collation. It is recognised that the scope of the required Stage 2 investigations may vary although a 'most likely' scenario is identified. This option includes the range of options within Stage 3, 4 and 5 which are considered most likely to deliver an improved understanding and 'best practice' resource management tool that are both acceptable to stakeholders and adopted by EA staff.

The **'High' Option** incorporates additional consultation and review processes and maximum data collation and analysis. It is likely to deliver a product of higher quality to the 'Intermediate'. During the early stages of this option extensive field surveying of rivers and shallow geology would be scheduled. This activity introduces a considerable risk of involving unnecessary additional work. This extensive early work also introduces a significant risk of serious programme overruns and failure to deliver improved understanding or 'best practice' resource management tools to schedule.

The **'Do Nothing' Option** effectively implies a continuation of present practice. This is taken to be the continued use of the current methods used to manage groundwater resources and adopted in both the Regional and Area offices. The shortcomings of these methods are as follows:

- Groundwater Resource Availability

  There is insufficient understanding of the surface and groundwater flow regime for the resource assessments to be considered reliable. The resource estimates for Essex are based on baseflow analysis for the main Essex rivers during the period 1967 to 1974. The environmental allocation is based on an estimate of the proportion of recharge necessary to sustain riverflow which would, in natural circumstances, be equalled or exceeded for ~95% of the time. The uncertainty in these estimates is large and is such that resource allocation constraints can frequently be challenged. Additionally, this analysis has been carried out for individual sub-catchments only and is probably not sufficiently consistent to permit synthesis for the whole Essex area.

  In summary, the current resource estimates are simplistic and considered to be inaccurate. They are also whole catchment totals, and, in the case of the Chalk, the aquifer is probably not subdivided on a reasonable basis. The reliance on a mean figure places an over-reliance on groundwater storage sustaining resources and river flows through prolonged droughts. Such crude calculations cannot be adopted to identify additional water resources or to evaluate the effects of land use change, climatic changes or other scenarios. The lack of such tools seriously hampers the resource planning process, and would seriously limit the EA's ability to formulate sound and technically defensible AMSs;

- Control and review of existing groundwater licences

  The individual and collective impact of groundwater pumping on resources and the water environment is poorly understood. This is principally because most licences over 5 years old lack a detailed evaluation of the impact on the surrounding area. This can lead to problems in managing resources, particularly during prolonged drought periods. The future requirement for sound and technically defensible time-limited licences will mean that a fuller and more integrated understanding of the groundwater flow regime is required;

- Determination of new licence applications

  Consideration of new licence applications requires a forecast of the likely impact of the proposed pumping on existing groundwater users and the water environment. For smaller applications this is currently conducted in a piecemeal and ad-hoc fashion, often based on largely subjective opinions of how the aquifer behaves and relying on overly simplistic techniques such as Theis, Jenkins and Micro Lowflows. Larger public water supply applications are generally submitted with some form of environmental impact assessment, but EA staff have little means by which to test the validity of these assessments and often resort to making unduly precautionary judgements. As a result the licensing process is inefficient, sometimes contentious and lacks true impartiality;

- Determining the impact of development proposals (Town and Country Planning Act)

  The impact of development proposals on the surrounding groundwater flows and levels is done on a site by site basis using overly simplistic techniques. The lack of a common and well documented resource assessment means that assessment of proposed developments can be time consuming. There are few crude tools available for forecasting the effects of land use changes or dewatering on the local environment;

- Assessing the performance of the EOETS and SAGS

  These two schemes are employed by the EA to increase flows in the Rivers Stour and Pant and to support downstream public water abstractions. However, despite their high cost of operation there is no authoritative report detailing the performance or impact of the schemes. There is no evaluation of the net gain of the schemes, or how this may vary according to their method of operation, and as a result pumping is likely to be less than optimal; and

- Development and assessment of AMP3 activities

  Current methods and understanding will prevent the EA contributing decisively to the AMP3 investigations.

In the past, a number of groundwater abstraction licence applications, renewals and reviews have been extremely contentious. With the move to time-limited licences and increases in water demand partly due to the additional housing provision, it is probable that the contention arising from resource allocation will grow. Consequently, costs associated with defending resource allocations will also increase.

The water resources problems identified in Boxes 2.1, 2.2 and 2.3 would not be addressed by the 'Do Nothing' option. Little progress would be made towards the development of a regional conceptual understanding or the development of a tool which could be used to determine sustainable AMS or to assist in the operational management of the area's groundwater resources (see Section 3.2). Furthermore, EA staff are themselves aware of the inadequacies of current resource and impact assessment techniques, and have difficulty in justifying or supporting their continued use.

On the basis of this discussion it is considered that there is a strong technical case for the whole Essex Groundwater Investigation (adopting the 'Low', 'Intermediate' or 'High' Options) to proceed, but with its business case reviewed in the light of completing key stages. Within this document permission is sought simply to proceed with Stage 1 of the project. The potential project options are carried forward to the summary presentation of project costs and benefits (Section 5) and economic analysis (Section 6).

4.3 Options Within Stages

For the 'Low', 'Intermediate' and 'High' Options the scope of work has been divided into Stages. A range of options are available within each Stage, and are summarised below. More detailed information can be found in the Scoping Study report.

4.3.1 Options Within Stage 1

The Stage 1 tasks have been grouped into the following four general categories:

- meetings (Task 1) and review (collation, analysis and final reports);
- data collation (Tasks 2 to 7);
- analysis (Tasks 8 to 12); and
- interpretation (Tasks 13 to 18).

Within many tasks there is a range of options that vary the amount of work required and which will control the inputs necessary for task completion. The range of options available within each task and each task grouping are summarised on Figure 4.1. This Figure also shows the preferred option (relating to the 'Intermediate' Option and based on the Section 6 economic analysis) within each task and the estimates of staff week inputs (EA and Consultant combined) that might be required to complete each option. Table 4.1 shows how the range of Stage 1 options identified in Figure 4.1 relate to the previously described Options.

Table 4.1 Summary of Stage 1 Options

Option	Meetings and Review	Collation	Analysis	Interpretation
Low	1C, no interim reviews	2A, 3A, 4A, 5A, 6, 7	7, 8, 9A, 10, 11, 12	13, 14, 15A, 16, 17, 18
Intermediate	1B, all reviews	2B, 3B, 4E, 5A, 6, 7	7, 8, 9A, 10, 11, 12	13, 14, 15A, 16, 17, 18
High	1A, all reviews	2C, 3F, 4E, 5B, 6, 7	7, 8, 9B, 10, 11, 12	13, 14, 15A, 16, 17, 18

There is potentially a wide range of work permutations available from the options identified. However, for the purposes of this PID they can be broadly classified into the six main categories described below.

Meetings (Task 1) and review

The preferred scope of work incorporates monthly meetings of the Project Working Group, quarterly meetings of the Project Review Group (including stakeholders) and two periods of interim review. The preferred scope for this task is considered sufficient to ensure that the Stage 1 deliverables meet the requirements of both the EA and the stakeholders, whilst ensuring that staff time devoted to this task is not excessive. However, options have been presented for increased or decreased consultation and review.

Data assembly (Task 2)

The preferred scope of work allows for assembly of all EA data, including that pertaining to the eastern part of the Ash catchment, and Ordnance Survey topographic data. An option is provided for not including the Ash catchment, but this would eventually result in a small area of Chalk being isolated between the Lee-Mimram and Anglian Essex models, and is therefore hard to justify technically. Funding from the Thames Region to cover this additional work should be discussed. An option is also provided for long and cross-section profiling of all major Essex rivers, but the staff time required is significant and it is considered that the existing Ordnance Survey data supplemented by the findings of a more restricted Stage 2 survey investigation should suffice.

Data appraisal (Tasks 3 and 4)

In identifying a scope of work for the assessment of geology, land use and drainage, it has been necessary to strike a balance between just obtaining readily accessible data within the EA and spending excessive amounts of time locating and digitising all potentially relevant data. The preferred approach allows for supplementing obvious gaps in the EA database with selected BGS and Essex County Council borehole records and satellite and landuse data, together with an assessment of mains and sewer leakage. Reduction of the scope of work below this level will not permit a quantitative evaluation of the potential contribution of other less accessible bodies of data and will significantly increase the risk of emerging with an inadequate understanding of surface processes and surface water groundwater interaction. If additional bodies of information are identified, the collation and interpretation of this information will be incorporated into Stage 2 of the project.

Modelling and literature review (Tasks 5 and 6)

The preferred scope of work allows for a review of the data inputs to each of the seven existing groundwater models within the study area. A more detailed appraisal of the models is an option but is not considered necessary at present.

Pumping test analysis (Task 9)

It is recommended that pumping test records are reviewed rather than reanalysed. The results of pumping tests are open to interpretation, and therefore are of limited value. In many cases the tests will already have been assessed by EA staff or by BGS during compilation of it's Aquifer Properties Manual. It therefore becomes difficult to justify the significant staff time that would be required to reanalyse these tests.

Deferred completion because of data inadequacy (Tasks 15 and 18)

This is not strictly speaking an option, but is included here as an indicator of potential reduction in unproductive time and cost e.g. deferring the Stage 2 PID if the conceptual understanding is demonstrably inadequate.

Estimated time input requirements per task and option are also shown on Figure 4.1. An additional £20 000 to £40 000 cost estimate is made for purchase of data from organisations such as the Ordnance, Soil and Geological Surveys, the Meteorological Office and other consultants.

4.3.2 Options within Stage 2

During or towards the end of Stage 1, sufficient information will become available to provide a detailed description and evaluation of the range of options for further investigations. These investigations will focus on reduction of conceptual uncertainty to a level that minimises the risks associated with proceeding to development of a numerical distributed groundwater model of the Essex Groundwater Investigation area. Reasons for not proceeding with Stage 2 could range from the understanding being sufficiently certain that no further investigations are necessary to the necessary investigations being so large that the time or costs are prohibitive. Both of these scenarios are considered unlikely. The range of potential investigations between these two extremes is illustrated in Figure 4.2.

A key aspect of all these alternatives will be the allowance of sufficient time to process and interpret the results obtained. Mid way through Stage 2 an updated PID for Stage 3 will be required.

Specific focussed studies

It is probable that at least some uncertainties regarding the groundwater flow regime will remain on conclusion of Stage 1 and that they will require specifically targeted field investigations. The priority for these investigations is likely to be groundwater-surface water interaction related to the following:

- Variations in runoff and infiltration in drift covered areas and across the drift/Chalk boundary on valley sides. This may require two to three months small channel and stream gauging at carefully selected locations;
- Surface water /groundwater level relationships. This may require river profiling and the installation of temporary shallow piezometer and gaugeboard installation at selected channel cross-sections and continuous monitoring of the level relationships for a two to three month period. This work may be appropriate at several locations along the main river channels where groundwater abstractions are thought to affect riverflows;
- River profiling. It is understood that no extensive cross-section or long profiling has been undertaken for the Essex rivers. Summary profiling for a selected number of watercourses will be required to facilitate further modelling of surface-aquifer interactions;
- Accretion profiling. There is likely to be a complex pattern of surface water-groundwater interaction along the main watercourses that changes in response to the operation of SAGS and EOETS. Current meter gauging of a number of watercourses at times of low flow and during periods of stable EOETS input may be required;
- Calibration of suspect long term monitoring installations; and
- Local inspection and possibly temporary flow gauging installation on springs along the edge of the coastal gravel terraces and mudflats.

Interpretation of hydrochemical datasets to resolve specific uncertainties may also be appropriate at this stage.

This option represents the probable minimum Stage 2 activity and is included in each of the subsequent options. If there are no other components to Stage 2 this work could continue in parallel with Stage 3 (Model Development).

AMP3/Habitats Directive investigations
The three groundwater-based AMP3 sites are likely to require additional flow and groundwater level monitoring. The timing of monitoring installation for these sites may be such that it will be appropriate to carry out this work under Stage 2 of the Essex Groundwater Investigation.

Water level monitoring of existing boreholes
There is a paucity of groundwater level data in the Superficial Deposits and the confined Chalk. It is possible that this can be resolved by locating and dipping existing boreholes in the area, for a minimum 12 month period.

Additional desk study and borehole drilling
In connection with the geology (Task 3) and land use and drainage (Task 4) components of Stage 1, limits have been imposed on Stage 1 inputs that are thought to represent a judicious balance between cost and understanding. However, it is possible that major uncertainties may remain on conclusion of Stage 1 or that Stage 1 activities will identify valuable additional data sources. Should either of these alternatives identify a need for further substantial synthesis of existing records (say in excess of 5% of the agreed Stage 1 input), it may be appropriate and cost effective to include this work within Stage 2.

Information sources that might require work at this Stage include the following:

- Reanalysis of current (1990-2000) satellite imagery;
- Land use interpretation of additional satellite imagery e.g. late 1970's LANDSAT;
- Investigation of MAFF parish drainage or land use records; and
- Detailed search of local museum and library archives.

Furthermore, the drilling of up to ten additional boreholes into the Superficial Deposits and/or the confined Chalk is allowed for under this option. Should such installations be required, the following two features will have significant programme and cost impacts:

- the time required for access, land acquisition, contractual procurement and completion of the work; and
- the need to ensure that this monitoring is also carried out over a minimum 12-month period to provide data for all stages of the seasonal cycle.

On this basis, total costs of £50 000 per borehole have been assumed in the costing and economic analysis.

Extensive field surveys
This option for Stage 2 is essentially a remote possibility, which if required would cast doubt over the overall project feasibility. For instance, total inability to establish meaningful boundary conditions or recharge distribution for the Essex groundwater regime might give rise to this scenario.

At this stage, Option 3 (Figure 4.2), a combination of specific focussed studies, AMP3 monitoring and water level monitoring of existing boreholes, is considered to represent the most likely Stage 2 activities. Provisional cost estimates are provided in Section 5.

4.3.3 Options within Stages 3, 4 and 5

The ultimate intended deliverables from the Essex Groundwater Investigation are the following:

- a distributed groundwater model installed on EA computers which can be used with confidence as a predictive and management tool; and
- a report detailing the results derived from use of the model in the assessment of an agreed range of future scenarios

The stages after completion of Stage 2 to reach these deliverables are summarised in Figure 4.3.

The risks of failing to achieve these deliverable products are effectively managed by the continuous process of review and reappraisal through Stages 1 and 2 and the contractual flexibility afford by the Framework Agreement to increase, reduce or terminate the work at any stage.

At this stage the positive options on completion of Stage 2 are as follows:

- develop a single distributed groundwater model for the area ('Low' Option);
- develop a distributed groundwater model of the area with detailed local models of areas of specific interest within it e.g. AMP3 sites ('Intermediate' Option);
- develop a single high resolution distributed groundwater model which is itself sufficiently detailed to examine most local issues in all aquifers ('High' Option);
- develop a number of separate distributed groundwater models for the area e.g. one model for the Superficial Deposits and one regional or three sub-unit models for the Chalk/LLT; or
- develop lumped parameter models rather than distributed groundwater models.

This list recognises that data or conceptual model constraints may mean that Stage 3 deliverables could be separate regional models for each aquifer or simple lumped parameter models. However, because these would not meet all the EA objectives for the project these are not currently identified as costed options.

Based on present estimates these modelling options will be assessed at the end of 2002. It would, therefore, be premature to identify a preference at this stage as developments in computer hardware and software may open new options. Based on currently available computer facilities and experience elsewhere it is estimated that the period for the development and calibration of an acceptable groundwater flow model of the area is likely to take about 12 months. Within this period it will be essential that time is allowed for consideration and evaluation of preliminary model output and implications that it may have for modification of aspects of the conceptual understanding. It is also probable that the conceptual model will continue to evolve as model development proceeds and model output is analysed.

In the latter stages of model development it will be extremely important that stakeholder consultation is maintained. Ultimately confidence in model predictions can only be derived from adequate calibration of the model against field observations. Agreement of this reconciliation can only be achieved by consultation.

There is always a risk that satisfactory model calibration will not be achieved. Control and review of Stages 1 and 2 will minimise this risk. The final stage of the Essex Groundwater Investigation will be the agreement of the future management and natural scenarios that the model should address. An initial scenario identification is shown on Figure 4.3. By 2004 this list may well have been superseded by other issues. The principles of sustainable resource management are, however, unlikely to alter. The ongoing requirement for the development of a practical tool to support the management of the water resources of the Essex area must guide and constrain all stages of the project.

MEETINGS & REVIEW

1. PROJECT MEETINGS
- 1A – Monthly & 9 Review Group (30)
- 1B – Monthly & 6 Review Group (23)
- 1C – Quarterly & 2 Review Group (10)

COLLATION REVIEW
- Complete (2)
- Do Not Complete

ANALYSIS REVIEW
- Complete (2)
- Do Not Complete (0)

FINAL REPORT REVIEW
- Complete (4)

COLLATION

2. DATA ASSEMBLY
- 2A – Agency Data (14)
- 2B – Including Ash (16)
- 2C – River Profiling (50)

3. GEOLOGY
- 3A – Agency Data Only (12)
- 3B – Agency & some BGS & ECC/SCC (18)
- 3C – All Data (28)
- 3D – Selected Thameside (14)
- 3E – All Data & Mapping (120)

4. LAND USE+DRAINAGE
- 4A – 1990/2000 Data Only (4)
- 4B – 1930/1960/1990/2000 Data (12)
- 4C – More Imagery (18)
- 4D – Chalk Outcrop Only (8)
- 4E – Leakage Assessment (16)

5. MODELLING REVIEW
- 5A – Review of Data Inputs (3)
- 5B – Model Appraisal (6)

6. LITERATURE REVIEW
- Complete (8)

7. DATA CATALOGUE
- Complete (4)

ANALYSIS

8. RAINFALL DISTRIBUTION
- Whole Area (4)

9. GROUNDWATER HEAD INTERPRETATION
- 9A – Whole Area (12)
- 9B – Pumping Test Re-analysis (20)

10. HYDROCHEMISTRY
- All Data (8)

11. RIVER FLOW ANALYSIS
- All Area (12)

12. EFFECTIVE RAINFALL CALCULATIONS
- All Areas (8)

INTERPRETATION

13. WATER BALANCES
- All Aquifers (20)

14. CONCEPTUAL MODEL
- All Aquifers (12)

15. SPECIFICATION OF NUMERICAL MODEL
- 15A – Complete (4)
- 15B – Defer (0)

16. FURTHER INVESTIGATION
- Complete (2)

17. STAGE 1 REPORT
- Complete (16)

18. STAGE 2 PID
- Complete (6)
- Defer (0)

KEY:

——— (red line)	Indicates Preferred Option For Task
(6)	Estimated Task Inputs In Staff Weeks

FIGURE 4.1
SUMMARY OF STAGE 1 TASK OPTIONS AND INPUT ESTIMATES

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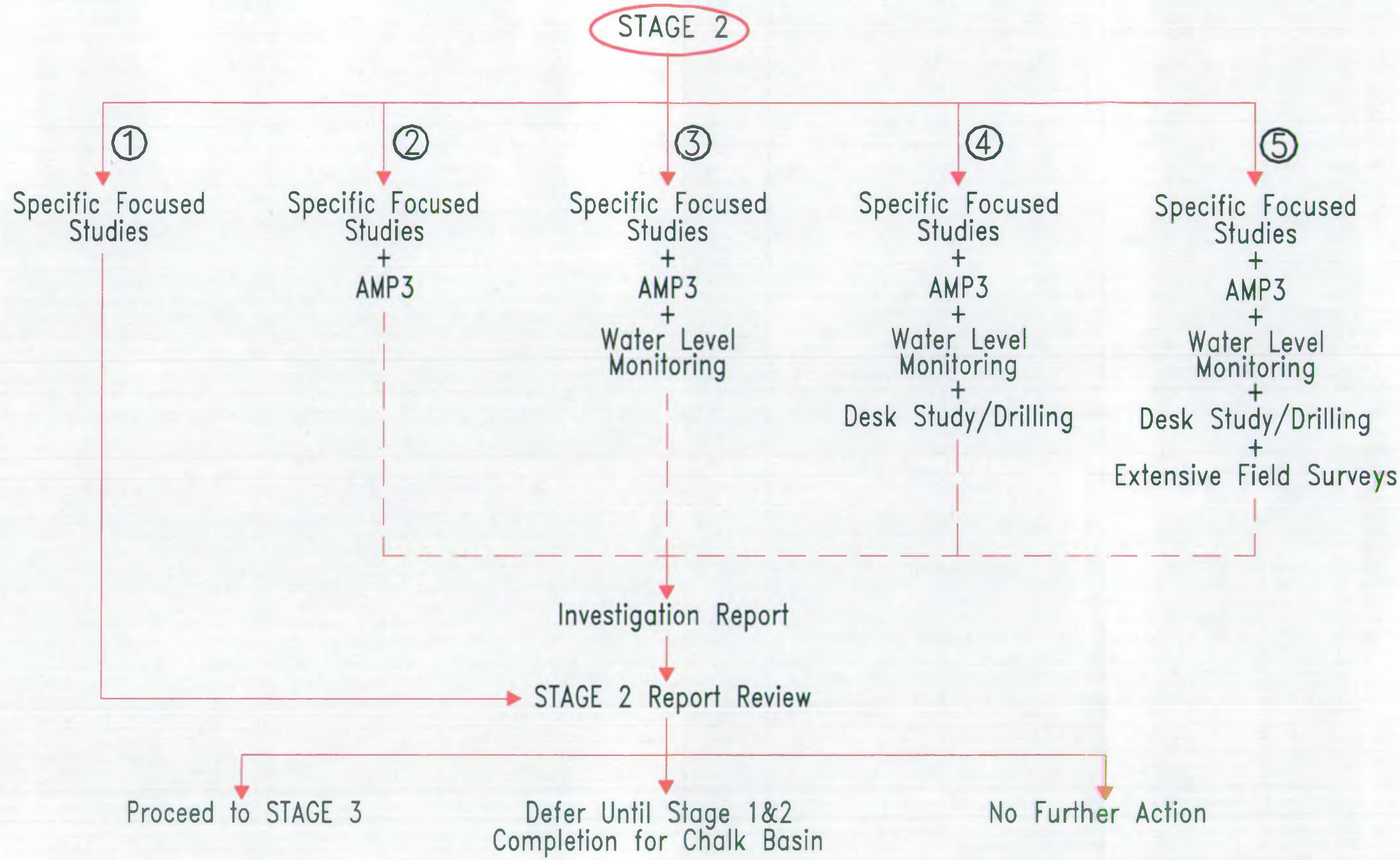

FIGURE 4.2 STAGE 2 OPTIONS

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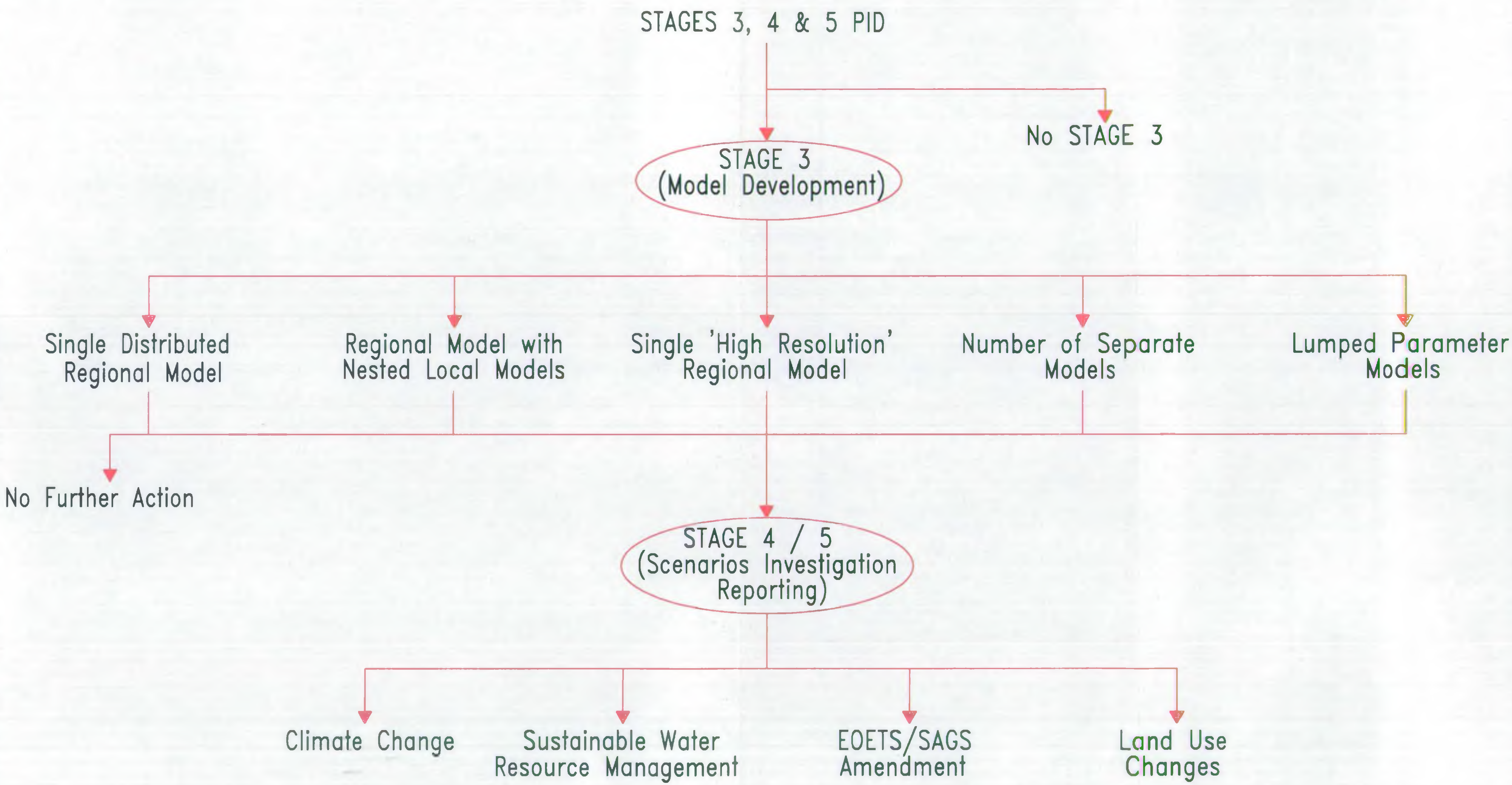

FIGURE 4.3 OPTIONS FOR STAGES 3, 4 AND 5

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5. Project Costs and Benefits

5.1 Introduction

This section identifies the basis for estimating project costs and provides cost estimates for each Stage of the project and three potential options ('Low', 'Intermediate' and 'High') discussed in Section 4. This presentation of direct cost estimates is followed by a summary of potential benefits.

5.2 Basis of Cost Estimates

The estimated costs of the proposed Essex Groundwater Investigation are based on staff costs. These are identified from current EA contracts and EA standard staff costs. These costs include for all expenses, except those related to data purchase.

In accordance with Appendix C of the EA Project Management Manual, appropriate contingencies have been included in these costs. Based on an assessment of the proposed tasks, Entec's previous experience regarding water resource investigations and the performance of the previous two Strategy projects to date, a 10% contingency has been incorporated. The figures should therefore be regarded as reasonable 'upper limit' estimates of the likely resource requirements of the project as it has been described.

Details of the staff costs are presented on a task by task basis for each staff grade in the Stage 1 Project Plan (Part 2). From the detailed Stage 1 costs and assuming similar relative proportions of staff time per grade throughout the project current (2000) daily staff cost estimates are calculated as follows:

Consultant	£329
EA	£334
(Average Stage 1	£330).

Data purchase costs are estimated at approximately:

£10000 (data from other consultants);

£10000 - £20 000 (BGS borehole and map records);

£10000 (Ordnance Survey, Met Office and other data).

These costs would be incurred during Stage 1.

5.3 Stage 1 Cost Estimates

The Stage 1 options are discussed in Section 4 and detailed estimation of required time inputs for the tasks are presented in Part 2 of this PID. Table 5.1 summarises these cost estimates. For further details of the individual tasks and components reference should be made to the Scoping Study Report.

Table 5.1 Summary of Stage 1 Cost Estimates

Option	Staff Days			Staff Costs		Data Costs	Total Costs
	Consultant	EA	Total	Consultant	EA		
Low	720	115	835	237 135	38 608	30 000	305 743
Intermediate	814	186	1000	267 915	62 207	35 000	365 122
High	1524	246	1770	461 940	79 713	40 000	581 653

Notes: The tasks within each option are defined in Table 4.1.

5.4 Stage 2 Cost Estimates

For Stage 2 the potential further investigation work required will be defined during Stage 1. The range of possible tasks is wide and identification of a preferred set of Stage 2 tasks at this stage is premature. It is possible however, to assign a probability to each component. These and associated cost estimates are summarised in Table 5.2. In simplistic terms Stage 2 Option 1 can be regarded as related to the 'Low' Option for the project as a whole, Stage 2 Options 1, 2 and 3 relate to the 'Intermediate' Option, and the additional work required for Stage 2 Options 4 and 5 is added to form part of the 'High' Option. However, in the economic analysis these costs are factored by the assigned probability for each component.

Table 5.2 Summary of Stage 2 Cost Estimates

	Option	Combination Probability	Inputs	Costs
(1)	Specific Focussed Studies	0.1	400 Staff Days	£132 000
(2)	(1) + AMP3 (3 sites)	0.2	(1) + 30 Staff Days	£141 900
(3)	(2) + Water Level Monitoring (1 year monitoring of additional existing boreholes)	0.6	(2) + 50 Staff Days	£158 400
(4)	(3) + Desk Study + New Boreholes	0.05	(3) + 200 Staff Days +£500k Borehole Costs	£724 400
(5)	(4) + Extensive Field Surveys	0.05	(4) + 400 Staff Days	£856 400

Note: Staff day cost estimate based on £330/day average rate.

5.5 Cost Estimates Stages 3, 4 and 5

Stage 3 Construction and Calibration of Distributed Model
In order to best achieve project objectives for Stage 3, the 'Intermediate' Option is most likely to involve the construction of a regional distributed groundwater model of all the principal aquifers, with three 'nested' local models for the AMP3 sites. Likely undiscounted costs for this option are summarised below:

Distributed Regional Model (450 staff days)	=	£148 500
Nested Local Models (3 @ 60 staff days each)	=	£59 400
	Total	£207 900

Based on these costs, approximate undiscounted estimates for the two other options can be derived. The 'Low' Option is the construction of the regional model alone (350 staff days, £148 500). The 'High' Option is the development of a single, high resolution regional model which is itself sufficiently detailed to examine most local issues (say 700 staff days, £231 000).

Two other model variants not currently identified as options but which may require consideration in the Stage 3 PID (due to data and conceptual understanding constraints) are the development of several distributed models (one for each aquifer) or lumped parameter models.

Stages 4/5 Productive Simulations/Management Runs and Reporting
The present 'Intermediate' Option assumes four scenarios at 30 staff days per scenario (including reporting). However, senior staff input may be high so staff cost estimates are increased by 10% to £363 per day, giving a Stage 4/5 'Intermediate' Option cost of £43 560.

A potential 'High' Option might include two additional scenarios (£65 340 total) while the 'Low' Option would reduce the number of scenarios to two (£21 780 total).

5.6 Cost Summary

A summation of these cost estimates for the various options is given in Table 5.3 below.

Table 5.3 Essex Summary Cost Estimate

	Option		
	Low (£)	Intermediate (£)	High (£)
Stage 1	305 743	365 122	581 653
Stage 2	132 000	158 400	856 400
Stage 3	148 500	207 900	231 000
Stage 4/5	21 780	43 560	65 340
Total	608 023	774 982	1 734 393

These are presented graphically on Figure 5.1 which also illustrates the impact of, for example, an 'Intermediate' Stage 1 being followed by a 'Low' or High' Stage 2 etc. Figure 5.1 illustrates a progressive reduction in cost uncertainty as the project proceeds.

These estimates have been derived by purely arithmetic summations of Stage cost estimates at 2000 prices. An economic analysis is presented in Section 6 with supporting information in Appendix A.

5.7 Project Benefits

The potential benefits that could accrue from the execution of the Essex Groundwater Investigation originate from the following four specific project products:

- The improved accessibility, presentation and compatibility of different datasets;
- The enhanced conceptual and quantitative understanding of the water resources of the area;
- The development of accessible, defensible and practical water resource management tools to assist in both strategic and operational management; and
- The promotion of consensus between stakeholders and regulator on the volume and distribution of available resource.

The generic benefits that arise from the application of these project products to the issues relevant to the Essex area are as follows:

- Greater effectiveness and reduced confrontation in AMS and licence determination and review and planning consultation;
- The reduced risk of environmental damage associated with abstraction;
- The delay in capital expenditure which should arise from optimisation of use of the current resource infrastructure, especially with regard to EOETS and SAGS;
- The possible identification of additional water resources to help meet additional housing demand; and
- Reduction of risk of water resource loss through contamination.

Table 5.4 shows which issues (previously identified in Boxes 2.1, 2.2 and 2.3) these products are expected to contribute towards resolution.

Realisation of these benefits requires the development of consensus between stakeholders and the EA and the efficient adoption and use of the project products by EA staff.

The benefits predicted from the products of the Essex project will accrue to the EA and to the stakeholders (principally abstractors, conservation organisations and local authorities) and the environment.

The economic assessment of these benefits (Section 6) is based solely on the anticipated greater effectiveness and reduced confrontation in licence review determination and the planning consultation process. The other potential benefits are treated as 'intangible' (economically unquantified) benefits and assessed by weighting techniques (Section 6.8) as described in the EA's Project Management Manual.

Table 5.4 Summary of Project Products, Benefits and Issues

Product	Benefit	Beneficiary	Problems/Issues	Box 2.1	Box 2.2 (N. LEAP)	Box 2.3 (S. LEAP)
Improved Data Sets	Greater effectiveness in licence determination and review	EA	Operational Management	j and k		
Enhanced Understanding	Greater effectiveness in licence determination and review More reliable AMS Reduced risk of environmental damage Reduced risk of resource loss	EA Environment	Tactical/Operational Management Strategic Management AMP3/Habitats Directive	j to m a to i n	} 1a, 1c, 1d, 1e, 1f, 1g 2a	} 5, 6, 7
Best Practice, Accessible and Defensible Resource Management Tools	Greater effectiveness in licence determination and review More reliable AMS Reduced risk of environmental damage Reduced risk of resource loss Delay in capital expenditure More informed contribution to 'Structure' Plan	EA Environment Stakeholders	Tactical/Operational Management Strategic Management AMP3/Habitats Directive Groundwater Quality Protection	j to m a to i n o	} 1a, 1c, 1d, 1e, 1f, 1g 2a 5b	} 5, 6, 7
Promotion of Consensus	Reduced confrontation	EA Environment Stakeholders	Tactical/Operational Management Strategic Management AMP3/Habitats Directive	j to m a to i n		

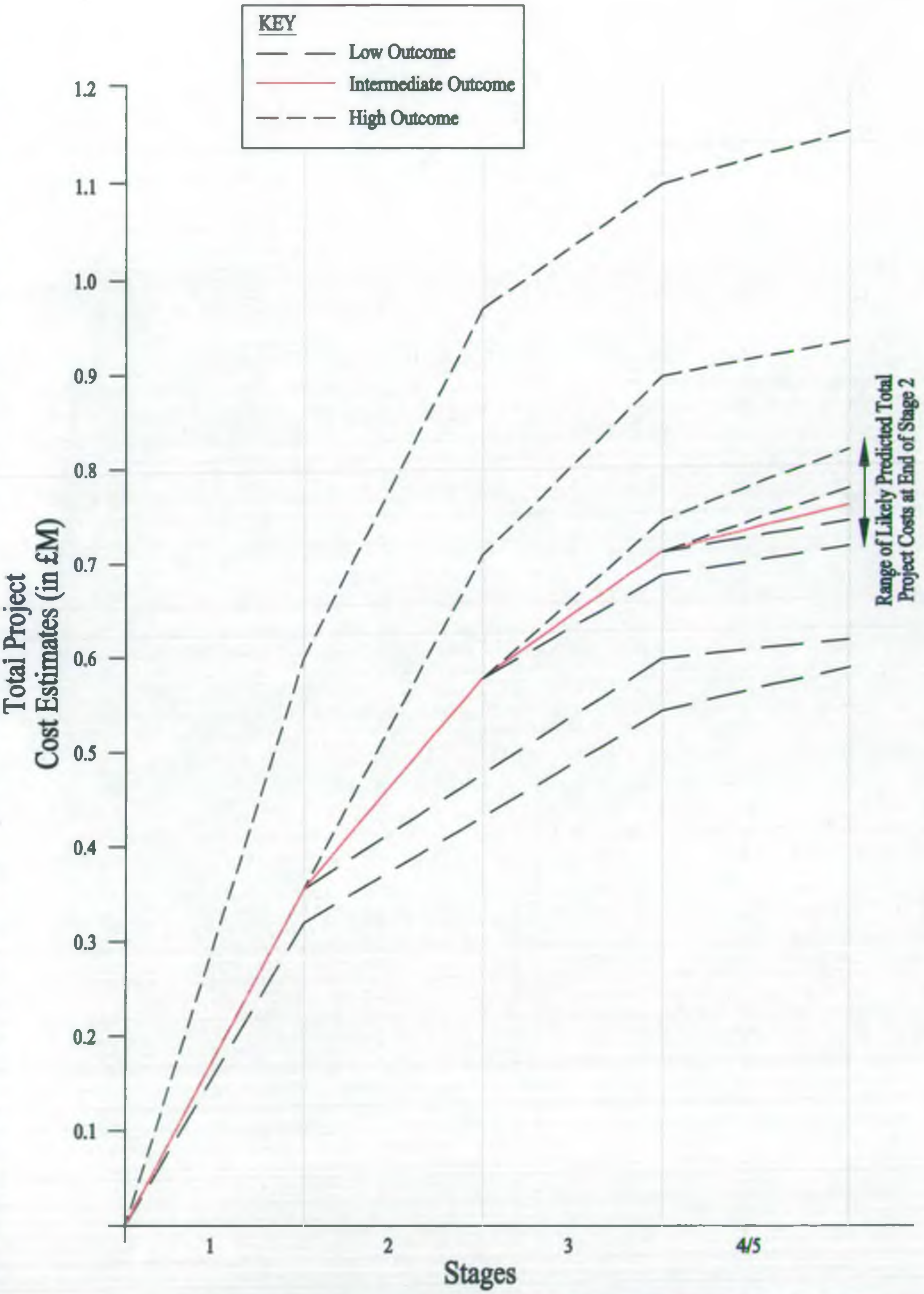

FIGURE 5.1 ESSEX GROUNDWATER INVESTIGATION POTENTIAL SPENDING PROFILES

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6. Economic Appraisal

6.1 Introduction

This economic appraisal presents the assumptions under which the costs and benefits of each potential option for the project discussed in Section 4 are quantified. It then compares the costs and benefits of each option and calculates an associated benefit-cost ratio. The preferred option is finally identified on the basis of a combination of the calculated benefit-cost ratio and a consideration of other costs and benefits that cannot be quantified.

All economic calculations are based on an estimate of Net Present Value (NPV). Timings for NPV calculations are based on the timescales indicated in Figure 1.3. The process of assigning values to costs is illustrated in Table 6.1 and discussed and presented in detailed spreadsheets in Appendix A.

Table 6.1 Assigning Values to Costs

Stage 1	Identify Options (Section 4)	→	Assign Costs (Section 5)	→	Discount (to NPV) assuming even cost distribution over stage duration (Section 6)		
Stage 2	Identify Options (Section 4)	→	Estimate Cost (Sections 5)	→	Discount over stage duration (Section 6 and Appendix A)	→	Weight costs by probabilities (Section 6 and Appendix A)
Stage 3	Identify Options (Section 4)	→	Estimate Cost (Section 5)	→	Discount over stage duration (Section 6 and Appendix A)	→	Weight by probability of overrun (Section 6 and Appendix A)
Stages 4/5	Identify Options (Section 4)	→	Estimate Cost (Section 5)	→	Discount over stage duration (Section 6 and Appendix A)		

6.2 Assigning a Value to the Benefits

The benefits associated with the project and which are quantified in this economic appraisal relate to resource savings that can be made in the abstraction licence application determination and review process. In the Essex area there are 229 groundwater spray irrigation licences (26 in Chalk) and 18 public water supply licences (16 in Chalk). Currently, around 50% of reviews require determination, leading to about six licences for spray irrigation being determined each year, and about three public water supply licences every two years. This tallies quite closely with actual EA experience. From 2005, licences are expected to become time-limited, with a review period of six years (the AMS review period). With the same proportion assumed to be contentious, this will give an average number of determinations per year of 19.08 for groundwater spray irrigation (2.17 in Chalk) and 1.5 (1.33 in Chalk) for public water supply.

Previous discussions with EA staff and with the National Farmers' Union suggested a total cost (Applicant and EA) for each groundwater spray irrigation determination of around £35 000, and research indicates a figure of £100 000 to be a conservative estimate for public water supply determination.

For each option a likelihood of achieving cost savings is assigned. Benefits are derived by using this factor to identify potential cost savings from a baseline, 'Do Nothing', scenario. These benefits assume implementation of licence time limitation and review as recommended by the Department of the Environment, Transport and Regions review. The outline of the process of assigning a value to benefits is outlined in Table 6.2 and discussed and presented in detailed spreadsheets in Appendix A. Two main benefits are identified – savings in licence processing times and an increased review period.

The costs and benefits for each option are assessed *relative* to the baseline, 'Do Nothing' Option, rather than calculating them in absolute terms for each option and for the baseline. This approach has the advantage that it makes the identification of the effects of each option simpler and clearer, as well as facilitating the calculation of a benefit-cost ratio.

6.3 'Do Nothing' Costs

Combining the estimates of costs for, and numbers of, licence applications gives a total present value of the cost of determinations of just over £7.79 million over a 20 year period assuming 50% are contentious (Table 6.3). This is made up of £1.25 million over the next four years before time-limited licences are introduced, and £6.55 million after 2005 when licences are reviewed every six years. By type of licence, the split is £6.07 million for groundwater spray irrigation licences, and £1.72 million for public water supply.

6.4 Appraisal of the Project Options

Three options for the project overall have been identified that require economic analysis. This section will briefly summarise the costs and benefits of each option, and present estimates of the quantified costs and benefits, together with an explanation of the assumptions underlying those estimates.

6.4.1 'Low' Option

Costs

This option involves the minimum Stage 1 tasks necessary to achieve the objectives of the project as a whole. The cost estimates for undertaking these tasks have been outlined in Section 5. A total of 835 staff-days are required, at a total cost of £275 743, plus data purchase costs of £30 000. These costs would be incurred over an 18-month period. Assuming they are equally distributed over the 18 months is equivalent to assuming that all costs are incurred in month 9 (since for each item of cost incurred at time x before month 18, there is an equal amount incurred at time x *after* month 18). This gives a present value cost of £292 669 (discounted at six per cent).

Table 6.2 Assigning Values to Benefits

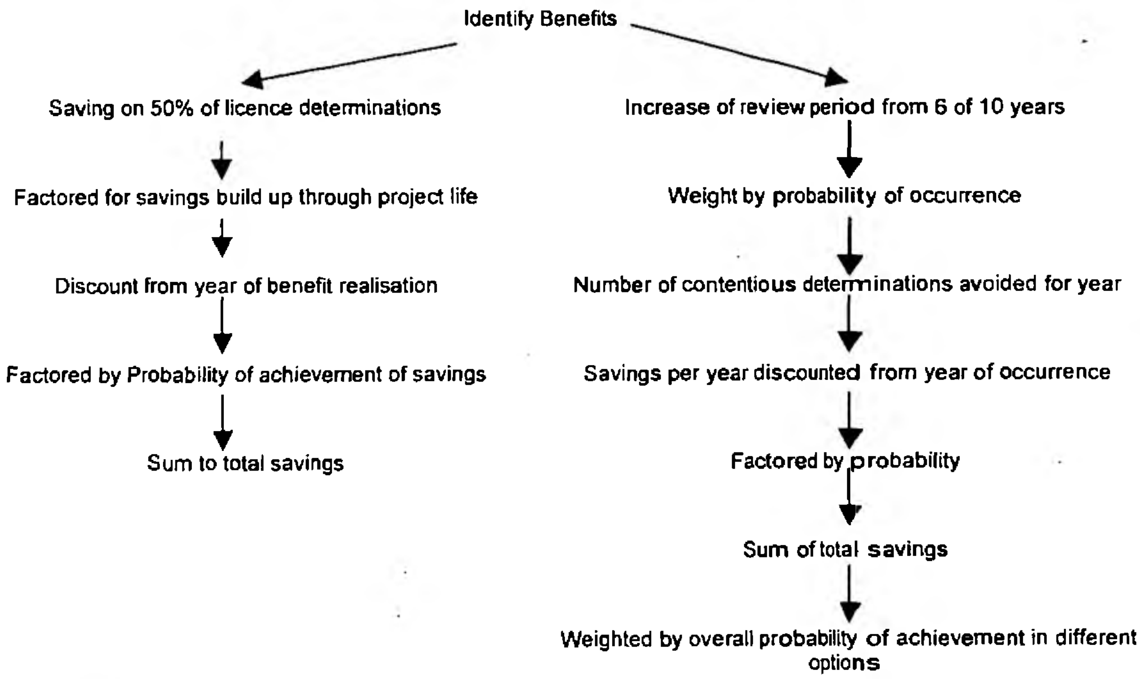

Table 6.3 Costs Associated with the 'Do Nothing' Option

Type of Licence		Groundwater spray irrigation	Public water supply
Number		229	18
Contentious		50%	50%
Determinations per year			
	to 2004	6	1.5
	from 2005	19.08	1.5
Unit Cost		35 000	100 000
Annual Cost			
	to 2004	420 000	150 000
	from 2005	667 800	150 000
Present value			
	to 2004	727 672	519 766
	from 2005	5 346 550	1 200 722
Total present value (20 years)		6 074 223	1 720 488

The tasks required in Stage 2 of the project are uncertain, and will depend on the level of data availability encountered in the course of Stage 1. A number of possible combinations have been identified and assigned probabilities. These are listed in Table 6.4. The undiscounted cost estimates for each combination and component task are given. Table 6.4 also gives the implied probability of each of the individual tasks occurring. These probabilities have been used to calculate the expected value of the costs of each task. The expected present value has been calculated by discounting by the number of months after the commencement of the project at which the timing midpoint of the task is reached (month 20). The total expected value of the costs of Stage 2 can then be calculated. For the 'Low' Option, this is equal to £195 701.

Table 6.4 Probability and Timing of Stage 2 Tasks

Task Combination	Combination Probability	Task	Task Probability	Timing Mid-Point (month after start)	Estimated Costs (£)
1. Specific focussed studies	0.1	Specific focussed studies	1	20	132 000
2. Combination 1 plus AMP3	0.2	AMP 3 monitoring	0.9	20	141 900
3. Combination 2 plus water level monitoring	0.6	Water level monitoring of additional existing boreholes	0.7	20	158 400
4. Combination 3 plus desk study and drilling	0.05	Desk study and drilling of new boreholes	0.1	20	724 400
5. Combination 4 plus extensive field surveys	0.05	Extensive field surveys	0.05	20	856 400

As discussed in Section 5, the Stage 3 undiscounted costs for the 'Low' Option involve the construction of the regional model alone (£148 500). In addition, it is suggested that, because of its expected complexity, there is a chance that extra labour input might be required to construct the regional model, and that this could increase the costs of this model by 40 per cent. The probability that this extra input would be required is estimated at 0.2. The expected midpoint date for Stage 3 is 34 months after the project start date. Discounting the costs accordingly gives an expected present value of the costs for Stage 3 under this option of £135 972.

Finally, Stages 4 and 5 cover scenario analysis and reporting. For the 'Low' Option, it has been assumed that two scenarios would be undertaken at an undiscounted cost of £21 780. This task would take up to 12 months to complete, with an expected timing midpoint of month 46. The resulting expected present value of the costs of this Stage is then £17 420.

The total expected present value of the costs of the 'Low' Option is therefore equal to £641 763.

Benefits
The quantified benefits of the 'Low' Option are based on two sources of savings: the reduction in costs required to undertake an abstraction licence review; and the increase in the length of time permitted between abstraction licence reviews.

In the case of reduction in costs related to abstraction licence reviews, we assume that, on average, 1.5 public water supply reviews are currently required per year in the Essex region, and 6 reviews per year of groundwater spray irrigation licences. After 2005, we assume 1.5 and 19.08 are required respectively each year. These are assumed to cost £100 000 and £35 000 each respectively (see Table 6.3). We assume that use of the groundwater model could reduce these costs by 25 per cent. However, the full benefit of these savings will only be achieved in year 5 of the project. In year 1, we assume 25 per cent of the savings will be achievable, 50 per cent in years 2 and 3 and 75% in year 4. In addition, we assume a probability that the model will achieve these savings of 0.4. This figure reflects the uncertainty over whether the model will be adopted. This figure is lower for the 'Low' Option than for the other options as a result of the reduced consultation undertaken in Stage 1, which is expected to lead to greater risk of rejection by the EA and stakeholders. With a 20-year life for the model, the resulting expected present value of these benefits is equal to £571 413.

For an increase in the period between licence reviews, we assume that from year 6 (2005) onwards, greater certainty about the groundwater resource position will enable the review period for abstraction licences to be extended from six to ten years. We assume that this will be possible for 25 per cent of abstraction licences with a probability 0.75, for 50 per cent of licences with a probability of 0.15 and for 100 per cent of licences with a probability 0.1. These numbers were chosen to be conservative. They result in estimated savings over a 20-year period of £516 439, as shown in Table 6.5. In addition, we generally assume that the probability that these savings can be achieved is equal to 0.25. This low probability reflects the uncertainty that surrounds the future setting of abstraction licence review periods. For the 'low' option case, we further reduce this by 50 per cent to reflect the lower chance of model acceptance with this option due to the reduced level of consultation in Stage 1. With a 20-year life for the model, the resulting expected present value of these benefits is equal to £64 555. This gives a total expected present value of the benefits of the 'Low' Option of £635 938.

Benefit-cost Ratio
The total expected present value of the costs of the project under the 'Low' Option is equal to £641 763. The total expected present value of the benefits is equal to £635 938. This gives a benefit-cost ratio of 0.99, and an expected net present value of - £5 795 (Table 6.6).

Table 6.5 Benefits of Extending the Licence Review Period

	Percentage of licences affected	New review period	New number per year	Number avoided	Savings per year	Probability	Expected present value
Groundwater spray	25	10	17.175	1.91	40 075	0.75	218 135
PWS	25	10	1.35	0.15	9 000	0.75	48 989
Groundwater spray	50	10	15.27	3.82	80 150	0.15	87 254
PWS	50	10	1.2	0.3	18 000	0.15	19 595
Groundwater spray	100	10	11.45	7.63	160 300	0.1	116 339
PWS	100	10	0.9	0.6	36 000	0.1	26 127
TOTAL							£516 439

6.4.2 'Intermediate' Option

Costs

The evaluation of the 'Intermediate' Option proceeds in the same way as that of the Low, although some duplication of information allows some short cuts in the presentation of its case. The 'Intermediate' Option involves a number of extra tasks for Stage 1 which are considered feasible and desirable to achieve the overall objectives of the project. The costs of undertaking these tasks have been outlined in Section 5. A total of 1000 staff-days are required, at a total undiscounted cost of £330 122, plus data purchase costs of £35 000. These costs would be incurred over an 18 month period. Assuming they are equally distributed over the 18 months, this gives a present value cost of £349 509.

The expected tasks required and related probabilities for Stage 2 in the 'Intermediate' Option are the same as for the Low (Table 6.4), with the same expected present value cost, equal to £195 701. In Stage 3, we assume that three nested local models will be combined with the regional model, giving a total expected present value cost of £190 361 (Section 5.5). Finally, Stage 4/5 is assumed to involve four modelling scenarios at a total cost of £43 560, or £34 840 in present value terms. This gives a figure for the total expected present value of the cost of the project under the 'Intermediate' Option of £770 412 (Table 6.6).

Benefits

The expected benefits of the project under the 'Intermediate' Option are calculated in exactly the same way as for the 'Low', with one exception. This is that we relax the assumptions about the reduced probability that the benefits will be achieved due to the limited consultation assumed with the 'Low' Option. Thus with this option we assume a smaller risk of rejection and a greater chance of uptake by EA staff and stakeholders. The resulting expected present value of the benefits of the project under the 'Intermediate' Option is therefore equal to £1 557 643, around two and a half times greater than the value of the 'Low' Option benefits (Section 6.4.1).

Benefit-cost Ratio
The total expected present value of the costs of the project under the 'Intermediate' Option is equal to £770 412. The total expected present value of the benefits is equal to £1 557 643. This gives a benefit-cost ratio of 2.02, and an expected net present value of £787 231 (Table 6.6).

6.4.3 'High' Option

Costs
The 'High' Option (see Section 4) involves a number of extra tasks for Stage 1 which have been identified as desirable for completeness and security (river profiling, additional geological mapping, full model appraisal, and reanalysis of pumping tests). These are estimated to require additional labour input of 770 staff days, giving a total required input for Stage 1 of 1770 staff days. The total undiscounted cost of this labour input is equal to £541 653. Data purchase costs are equal to £40 000. Thus, the present value of the costs of Stage 1 under this option is equal to £556 781, assuming an 18 month Stage 1 duration and even cost distribution.

The expected tasks required and related probabilities for Stage 2 in the 'High' Option are the same as for the 'Intermediate' and 'Low' (Table 6.4), with the same expected present value cost, equal to £195 701. In Stage 3, we assume that the regional model is developed to a higher resolution to avoid the need for local nested models, resulting in a Stage 3 undiscounted cost of £231 000, discounted to a net present value of £211 512. In Stage 4/5, we assume six scenarios are modelled and reported, at a cost of £65 340, or £52 260 in net present value terms. This gives a total expected present value of the costs of the project under the 'High' Option of £1 016 255 (see Table 6.6).

Benefits
The benefits of the project under the 'High' Option are assumed to accrue in exactly the same way as for the 'Intermediate' Option, with the same expected present value of £1 557 643.

Benefit-cost Ratio
The total expected present value of the costs of the project under the 'High' Option scenario is equal to £1 016 255. The total expected present value of the benefits is equal to £1 557 643. This gives a benefit-cost ratio of 1.53, and an expected net present value of £541 388 (see Table 6.6).

6.5 Summary and Selection of Preferred Option

Table 6.6 summarises the overall costs and benefits of the options for the project, together with calculated benefit-cost ratios and expected net present values. The benefits are effectively the anticipated savings from the estimated Net Present Value of the 'Do Nothing' costs of approximately £7.8m.

Table 6.6 Summary of the Costs and Benefits of the Project under Each Option

Option	Costs	Benefits	Benefit-cost Ratio	Expected Net Present Value
Low	641 763	635 938	0.99	-5 795
Intermediate	770 412	1 557 643	2.02	787 231
High	1 016 255	1 557 643	1.53	541 388

From this summary, we can see that all but the 'Low' Option are associated with a benefit-cost ratio greater than unity, and positive expected net present value. Even with the 'Low' Option, the benefit-cost ratio is very close to one. Any of the positive options could be recommended on cost-benefit grounds, and the arguments put forward above in support of the project clearly receive some validation.

However, of the three options considered, the 'Intermediate' Option shows the highest benefit-cost ratio and the highest expected net present value. The 'Intermediate Option' is therefore preferable on economic grounds.

6.6 Financial Appraisal

The realisation of the Essex Groundwater Investigation should result in reduction of costs through more effective and less contentious resource allocation. If the presently favoured option for the project is implemented the anticipated costs at 2000 prices are as follows:

Main Stage 1: September 2000 - November 2001 inclusive, £365 122 (≈£24 341 per month);

Stage 2: December 2001 - December 2002 inclusive, £207 900 (≈£15 992 per month);

Stage 3 January 2003 - December 2003 inclusive, £207 900 (≈£17 325 per month); and

Stage 4/5 January 2004 - December 2004 inclusive, £43 560 (≈£3 630 per month).

This projection is based on the Stage 2, 3, 4 and 5 scenarios presently judged to be most likely.

6.7 Sensitivity Analysis

The preferred option can be subject to a sensitivity analysis to assess whether its selection is robust to worst-case assumptions about the costs of implementing it. This has been calculated as follows:

- Stage 2 is assumed to require the full range of tasks identified above as being potentially necessary for the achievement of the project objectives. This gives a total discounted cost of £777 142;
- Stage 3 is assumed to require the higher resolution regional model with 40% overrun. This gives a total discounted cost of £274 183;

- Stage 4/5 is assumed to involve the modelling and reporting of six scenarios, giving a total discounted cost of £52 260.

The maximum spend possible with the preferred option is therefore estimated at £1 456 877 (see Table 6.7).

Table 6.7 Cost Sensitivity

Worst-case cost	Benefits	Benefit-cost ratio	Expected net present value
1 453 094	1 557 643	1.07	104 549

We assume that the expected benefits of the preferred option are unchanged in this analysis since it is felt that fully conservative estimates were used in the first instance, and that the extra costs assumed to be necessary in this assessment are likely to reinforce the achievement of those benefits. The benefits are therefore given as before: £1 557 643.

Comparing the costs and benefits in this worst-case scenario gives a benefit-cost ratio of 1.07, and an expected net present value of £104 549. Thus we can see that the justification of the preferred option is robust to worst-case assumptions about the cost of its implementation.

6.8 Economically Unquantified Benefits

In Section 5.7 reference is made to four potential generic benefits which have not been quantified economically. An assessment of the impact of the various project options on these benefits is presented as a weighting exercise in Table 6.8.

For these benefits, greatest value (therefore highest weighting) is assigned to reduction of risks of environmental damage (weighting 10), closely followed by delay in capital expenditure associated with EOETS/SAGS (weighting 8) and identification of additional water (weighting 6). A reduced weighting is assigned to potential savings from reduced risk of resources contamination has a weighting 2, because of the perceived relatively low existing risk.

The likelihood of achieving these benefits is a function of the technical adequacy of the Essex Groundwater Investigation product(s) and the degree of consensus achieved in its acceptability. Improvement of the acceptability of resource estimates is the principle difference between the 'Low' and 'Intermediate' Option. The 'Low' Option has been identified as the minimum amount of work likely to be necessary to achieve the objective of 'sound science' in resource estimation and management. This option does not however optimise the uptake or acceptance of project products and consequently reduces the probability of benefit realisation. The likelihood of achieving the benefits is rated as follows:

- 3 points - likely;
- 2 points - likely in part; and
- 1 point - unlikely.

Results of the weighting and scoring are summarised in Table 6.8.

Table 6.8 Weighting and Scoring of Unquantified Benefits

Benefit	Weighting Factor	Do Nothing		Low		Intermed.		High	
		Pts	Wtd	Pts	Wtd	Pts	Wtd	Pts	Wtd
Additional water resources	10	0	0	2	20	2	20	2	20
Delay in capital expenditure	8	0	0	2	16	3	24	3	24
Reduced risk of environmental damage	6	0	0	2	12	3	18	3	18
Reduced risk of quality reduction	2	0	0	2	4	2	4	2	4
Total Weighted Points			0		52		66		66

Based on this assessment the value of the 'Intermediate' and 'High' Option is very similar. The zero rating for the 'Do Nothing' Option arises from its position as a baseline against which project impact is measured.

6.9 Risk

This section presents an overall risk assessment for the Essex Groundwater Investigation. More detailed Stage 1 risk registers are included in Part 2 of this PID.

The risks associated with the project implementation fall into the four following groups:

- failure to achieve a technically satisfactory product;
- failure to deliver products to project schedule;
- failure to achieve acceptance of resource estimates and analytical tools by stakeholders; and
- requirement for major programme of Stage 2 investigation before conceptual understanding sufficient to specify a credible digital model can be developed.

Within the project the principal tools adopted for risk management are as follows:

- close involvement of EA staff in project review;
- involvement of EA staff in project tasks;
- clearly specified project tasks and products;
- regular peer review;

- identified 'hold' and decision points before proceeding e.g. staged PID submissions;
- close liaison with other EA projects; and
- regular consultation meetings with the Project Working and Review Groups.

The combination of these risks and risk management approaches within each option are summarised in a risk register in Table 6.9.

Assessment of the summary risk register suggests that the 'Intermediate' Option presents cumulatively the least overall risk.

Table 6.9 Summary Risk Register

Identified Risk	Consequence	Do Nothing		Low		Intermediate		High	
		Prob	Imp	Prob	Imp	Prob	Imp.	Prob	Imp
Failure to achieve technically satisfactory product	Major reduction in benefits	-	-	M	H	L	H	L	H
Failure to deliver products to schedule	Cost increase and potential benefit reduction	-	-	M	M	L	M	H	M
Failure to achieve acceptance	Benefit reduction	-	-	H	S	M	S	M	S
Major additional investigations required	Increased costs and programme time	-	-	S	S	M	S	M	S

Key: H = High
S = Significant
M = Moderate
L = Low
Prob = Probability
Imp = Impact

Part 2 - Project Plan for Essex Groundwater Investigation, Stage 1

Entec

7. Preferred Course of Action

7.1 Introduction

This section summarises the results of the analyses of the costs, benefits and risks for the range of options analysed for the Essex Groundwater Investigation. Based on this summary, a preferred course of action is identified. Economic justification for the staged approach is also presented.

As discussed in Section 6, there is a wide range of potential costs for Stage 2 (Monitoring and Investigation) of the project. The identification of these costs cannot be reliably made until Stage 1 is well advanced as the most appropriate investigation can only be identified when data interpretation is approaching completion. Thus while identifying a preferred overall project option, the PID seeks authorisation to proceed with Stage 1 only. A further PID updating the Business Case and providing a detailed Project Plan for Stage 2 activities will be prepared towards the end of Stage 1.

7.2 Selection of Preferred Option

The project options identified in Section 4 are compared with the likely costs/benefits and risks of adopting a 'Do Nothing' approach and the results are summarised in Table 7.1. These are based on an 18 month Stage 1 duration and a twenty year project appraisal period.

Table 7.1 Summary of Economic Appraisal

Option	Costs	Benefits*	Benefit cost Ratio	NPV	Intangible Benefits	Risks
Low	641 763	635 938	0.99	-5 795	low	high
Intermediate	770 412	1 557 643	2.02	787 231	=high	low
High	1 016 255	1 557 643	1.53	541 388	=high	intermediate

*(Benefits calculated on anticipated reduction in operational management costs that are estimated at just over £7.8 million for Do Nothing).

From this summary, we can see that all but the 'Low' Option are associated with a benefit-cost ratio greater than unity, and positive expected net present value. Even with the 'Low' Option, the benefit-cost ratio is very close to one. As the project is also a component part of the EA's long term AMS, project implementation would appear to be advisable.

Of the options considered, the most favourable option is the 'Intermediate' which requires project implementation with close involvement of EA staff and their appointed peer reviewers throughout, liaison with a selected stakeholder group and assessment and analysis of most accessible and well organised data. For this option the most probable Stage 2 activity will be specific focussed investigations, AMP3 and water level monitoring of additional existing boreholes. The management tool to be developed in Stage 3 is likely to be a distributed regional groundwater model with local nested models. Stages 4 and 5 of the project entail use of the model for predictive analysis of operational and strategic options, installation of the model on EA hardware, preparation of operational manuals and finalisation of reports.

7.3 Justification of a Staged Approach

Justification for the recommendation of a staged approach can be seen from the following appraisal.

The benefit-cost ratio for the whole project relative to a baseline that includes the Stage 1 work can be calculated. This implies a change in the baseline costs and benefits against which Stage 2 of the project should be compared. It can be assumed that if the Stage 1 work were to proceed but then the project did not continue, the baseline costs would change from £7.8m to £7.3m. This amount is estimated by assuming that the 25 per cent contribution from Stage 1 to reduced determination costs accrues over the next 20 years. This reduces the annual cost of determination from £360 000 to £337 500 until 2004, and from £818 000 to £766 797 from 2005 (when the switch to time limited licences occurs). Assuming that the Stage 1 investigations alone will not be sufficient to permit increases in the duration of licences means that the present value of the benefits of Stage 1 alone are equal to £487 000, or the difference between the two baseline present values. With a cost of £349 509, this gives a benefit-cost ratio of 1.39.

The benefit-cost ratio for continuing with the project past Stage 1 can then be estimated. The costs of the Intermediate option as a whole have already been estimated as £770 412. Subtracting the Stage 1 costs (which are assumed to have already been incurred) gives a cost of continuing with the project past Stage 1 of £420 903. The benefits of the Intermediate option have already been estimated as £1 557 642. Subtracting the benefits just estimated for Stage 1 alone gives a benefit of continuing past Stage 1 of £1 070 474, and a benefit-cost ratio of 2.54. Thus, from a present day perspective, it would appear justified to implement the whole project, as suggested by the results above. Indeed, the greater proportion of the benefits would be seen to accrue from continuing the project beyond Stage 1, which explains the higher benefit-cost ratio for 'continuing' than for the project as a whole.

The Stage 2 costs are contingent on the investigations undertaken in Stage 1, and it might be the case that costs could increase significantly in Stage 2 once the Stage 1 findings are obtained. Therefore, it is also worth calculating a benefit-cost ratio for continuing beyond Stage 1 given a worst case scenario on costs for Stage 2. The worst case costs for Stage 2 have been estimated to be £777 142. If these costs were to accrue, then the costs of continuing beyond Stage 1 would increase to £1 002 343. The benefits of continuing are equal to £1 070 474. This means that a worst case scenario for continuing beyond Stage 1 could have a benefit-cost ratio of only 1.07. In other words, at the end of Stage 1 the costs of continuing with the project may only be marginally justified by the extra benefits expected. These results are summarised in Table 7.2. In fact, if the other 'worst case' assumptions presented in Section 6.8 are adopted, the benefit-cost ratio for continuing the project would actually become less than one i.e. continuing the project would not be economically justified. This is very much a worst-case scenario that could be expected to occur with only a small probability. However, such a marginal case for continuing the project is justification for adopting a staged approach to the Project given a desire to minimise risks of failure.

Table 7.2 **Justification for Staged Approach**

Scenario	Benefits (PV)	Costs (PV)	Benefit-cost Ratio
Stage 1 only	487 169	349 509	1.39
Beyond Stage 1	1 070 474	420,903	2.54
Beyond Stage 1 worst case	1 070 474	1,002,343	1.07

In view of the uncertainties surrounding Stage 2 activities, it is recommended that authorisation should be given to proceed with Stage I of the 'Intermediate' Option.

Part 2 of this PID presents a more detailed Project Plan for the Stage 1 work and resources related to the 'Intermediate' Option of the Essex Groundwater Investigation.

8. Objectives of Stage 1

8.1 Introduction

The Project Plan for Stage 1 of the Essex Groundwater Investigation is based on the preferred option summarised in Part 1 of the PID.

8.2 Objectives

The objectives and related products of Stage 1 of the Essex Groundwater Investigation are as follows:

i) to collate the available data and information and develop a project database and GIS based maps;

ii) to analyse the available data and information;

iii) to prepare total and groundwater balances and provide comparison with current resource estimates;

iv) to present a conceptual understanding of the hydrological and hydrogeological regime based on the available data and information;

v) to identify further investigation, monitoring or data collation/analysis which should be undertaken in advance of development of the preferred strategic and operational resource management tool;

vi) to provide specifications for the preferred strategic and operational resource management tool (probably a distributed groundwater model);

vii) to review the business case for the overall project and detail the Project Plan for Stage 2; and

viii) to promote the development of consensus on available resources amongst stakeholders in the project area.

Delivery of objective i) will be achieved through the databases and maps referred to in Product Description Box 12a and objective ii) the analyses of this data will be summarised in draft reports commenting on quality and significance (Box 12b). These draft reports will form the early chapters of the Stage 1 Report (Box 12c) which will present the interpretation leading to objectives iii), iv), v) and vi). A revised PID (Box 12d) will indicate delivery of objective vii). Peer review of both the Stage 1 Report and the Stage 2 PID will indicate progress towards achievement of objective viii).

Table 8.1 summarises some of the key technical uncertainties for the Essex area that will be addressed by the proposed Stage 1 Essex Groundwater Investigation.

Table 8.1 Key Technical Issues for the Essex Area

Category	Issues
Boundaries	Nature and position of southern boundary Position of western boundary Relevance of previous resource unit boundaries
Recharge	Chalk outcrop recharge and runoff mechanisms Development and distribution of land drainage Impact of historical land use change Ground and surface water interaction (including EOETS and SAGS)
Groundwater Flow	Definition of 'effective' aquifer within the Chalk Role of 'hard grounds' in the Chalk Properties and influence of 'tunnel valleys' Hydraulic continuity from unconfined to confined Chalk Water levels and flow directions in the confined Chalk Hydraulic continuity between aquifers 'Rejected' recharge at London Clay boundary
Discharge	Ground and surface water interaction (including EOETS and SAGS)

9. Technical Plan and Programme, Stage 1

9.1 Introduction

The proposed work of Stage 1 of the Essex Groundwater Investigation can be subdivided into the following four general categories:

- meetings and review;
- data collation;
- analysis; and
- interpretation.

Each of these categories constitute significant packages of work in their own right, and to enable more effective resource management and quality control they are further subdivided into tasks. These tasks and the inputs required to achieve their timely completion are discussed in the Essex Groundwater Investigation Area, Scoping Study Report, Entec, April 2000.

This subdivision of the project stage into activities and tasks should be simply regarded as a convenient means of task description and progress monitoring. The division should not be viewed as indicating strict boundaries between individual compartments of work. In reality there will be continuous overlap and exchange of views between tasks proceeding in parallel and there will be iteration back to the assembled data during both the analysis and interpretation activities. Key milestones are related to product delivery at the completion of each major category of work.

9.2 Project Tasks

A generic guide to the typical tasks of a Stage 1, Groundwater Investigations and Modelling Study is in preparation as the EA's 'National Best Practice Guide for Groundwater Investigations'. These have been amended to address the issues specific to the Essex catchment and a listing of these tasks and component sub-divisions is given in Table 9.1. A Work Breakdown Structure and a PERT Chart (for Tasks 1 to 12) are presented in Figures 9.1 and 9.2 respectively.

9.3 Quality Control and Management

It is proposed that a programme of monthly Project Working Group meetings and quarterly Project Review Group meetings is initiated. The Review Group meetings would be attended by key EA and Consultant staff and the external project reviewer(s) appointed by the EA. Each meeting would be preceded by a brief written progress report and would be formally minuted.

Table 9.1 Stage 1 Task List and Component Activities

Task	Title	Component Activities	
1	Project Meetings	1.1	Inaugural and Progress Meetings
		1.2.	Stakeholder Advisory Meetings
2	Data Assembly	2.1	Meteorology
		2.2	Hydrology
		2.3	Abstraction
		2.4	Discharge
		2.5	Groundwater levels and quality
		2.6	Topography and river bed profiles
3	Geology	3.1	Borehole logs
		3.2	Geological maps and reports
		3.3	Production of cross-sections and maps
4	Land Use and Drainage	4.1	Land use and soils data
		4.2	Surface drainage data
		4.3	Underdrainage data
		4.4	Mains and sewer leakage
		4.5	Integration with shallow geology
5	Modelling Review	5.1	Review of existing groundwater models
6	Literature Review	6.1	Review and abstract full bibliography
		6.2	Identify and summarise key documents
7	Data Catalogue	7.1	Integration with current practice and GIS
		7.2	Deliver databases and spreadsheets
	Interim Project (Collation) Review		
8	Rainfall Distribution	8.1	Distribution in space
		8.2	Distribution in time
9	Groundwater Head Interpretation	9.1.	Hydrograph analyses and comparison
		9.2	Integration with geology
		9.3	Map representation of contours at specific times and levels
		9.4	Pumping tests and hydraulic parameters
10	Interpretation of Hydrochemical Data	10.1	Spatial patterns
		10.2	Temporal trends
		10.3	Integration with geology
11	Riverflow Analysis	11.1	Hydrograph naturalisation
		11.2	Hydrograph analysis
		11.3	Contributory areas and artificial drainage
		11.4	Relationship of flows, rainfall intensity & SMD
		11.5	Accretion profiles
		11.6	Groundwater interaction

Table 9.1 (continued) Stage 1 Task List and Component Activities

Task	Title	Component Activities	
12	Effective Rainfall Calculation	12.1	Potential evapotranspiration
		12.2	Impact of current land use
		12.3	Impact of past land use
		12.4	Near surface soil processes
		12.5	Riparian zone behaviour
		12.6	Interflow processes
		12.7	Integration with geology and drainage
	Interim Project (Analysis) Review		
13	Calculation of Preliminary Water Balances	13.1	Total and groundwater balances
		13.2	Variations with time
		13.3	Evaluation and uncertainty
14	Development of Conceptual Model(s)	14.1	Presentation of conceptual model
		14.2	Assessment of plausible alternatives
		14.3	Assessment of uncertainties
15	Specification of Numerical Model(s)	15.1	Representation of concepts
		15.2	Integration with adjoining study areas
		15.3	Boundary conditions
		15.4	Space and time discretisation
		15.5	Recharge input and groundwater/surface water interaction
		15.6	Parameterisation
		15.7	Representation of flow between layers
		15.8	Initial conditions
		15.9	Requirement for local 'nested' models
		15.10	Data shortfalls
		15.11	Uncertainties
16	Define Further Investigations	16.1	Identify local monitoring needs
		16.2	Identify long term monitoring needs
		16.3	Costs and benefits
17	Formulation of Stage 1 Report	17.1	Description of work completed
		17.2	Presentation of Task 2-7 (Collation)
		17.3	Presentation of Tasks 8-12 (Analysis)
		17.4	Water balances (Task 13)
		17.5	Conceptual and numerical models (Task 14 and 15)
		17.6	Further investigation requirements (Task 16)
		17.7	Database maintenance requirements
18	Stage 2 PID	18.1	Summary of Stage 1 Report
		18.2	Review of overall project business case
		18.3	Stage 2 costs and benefits
		18.4	Programme review
19	Stage 3 PID		Provisional, depending on Stage 2 requirements
	Final Reports Review		

The proposed organisation for these activities is summarised on Figure 9.3. Following completion of each category of work a period of review of the results and deliverables by EA staff or appointed reviewers is allowed.

9.4 Data Collation

Much of the relevant data is held digitally by the EA although further checking, calibration and validation will be required as will assurance of compatibility and integration with EA GIS. Most of these datasets may also require extrapolation back to about 1960 (see Scoping Study Report).

Some key datasets, notably geology, land use and drainage, will require assembly to provide adequate spatial and temporal coverage. Integration of existing detailed modelling studies will also be required.

On completion a data catalogue, comprising meteorological, hydrological, geological and hydrogeological databases with associated maps and cross-sections will form a deliverable product (see Section 12). This product will integrate, extend and update current databases and sources. It is anticipated that digital data will be presented in standard Microsoft ACCESS format, permitting ready integration with GIS and analytical software.

9.5 Data Analysis

Analyses of the climatic, riverflow, groundwater level and water quality data can only be carried out in the context of an understanding of the geology, drainage and land use of the area and a clear identification of the shortcomings and gaps within the collected data.

To a large extent the analysis and presentation of data must initially be carried out for each specific data set or group of datasets. The product following this analysis will effectively be drafts of the first sections of the final Stage 1 Report, viewing each data set as an independent entity. An allowance for interim review on presentation of this deliverable has been made, but continuation with interpretation will proceed in parallel with this review.

Any interpretations, data processing or alterations will be fully documented to facilitate future updating of the datasets.

9.6 Data Interpretation

The interpretation of the water resource data for the area is essentially the integration of the following data sets:

- Meteorological;
- Hydrological;
- Geological;
- Hydrogeological;
- Abstractions and discharges; and

- Topography and Land Use.

This integration should result in a first pass quantification of recharge, runoff and discharge and their linking through conceptual flow (and other processes) model(s). It is likely that two clear components of these conceptual models will be as follows:

- a surface process component integrating shallow geology, topography, drainage and rainfall to provide an analysis of rainfall, runoff routing and recharge; and
- a groundwater flow component, indicating the range of values for various hydraulic parameters for the Chalk, LLT and Superficial Deposits and integrating the distribution of the active near surface groundwater zone and deeper stratigraphically influenced groundwater movement.

At this stage the concepts will contain a range of uncertainties, perhaps quantified in the water balance calculation. The specification of Stage 2 activities will be focussed on the reduction of these uncertainties.

The deliverables will be a formal PID reviewing the project business case and presenting a Stage 2 Project Plan and the Stage 1 Report with supporting Appendices. The probable Stage 1 report contents are noted in Section 12.2.2.

This Stage 1 Report will be a stand alone, fully reviewed document and is intended to provide an accessible and accepted quantified water resources review of the Essex Groundwater Investigation Area. All interpretation methods will be fully documented, so that the conceptual model can be easily updated by the EA. Any source code developed specifically for this project will be in the ownership of the EA.

9.7 Programme

The proposed programme for a 18 month duration Stage 1 is shown on Figure 9.4 with an estimate of the overall resource requirements (EA and Consultant) for each task shown below:

- Meetings and Review 155 staff days
- Data Collation 325 staff days
- Data Analysis 220 staff days
- Data Interpretation and Reporting 300 staff days.

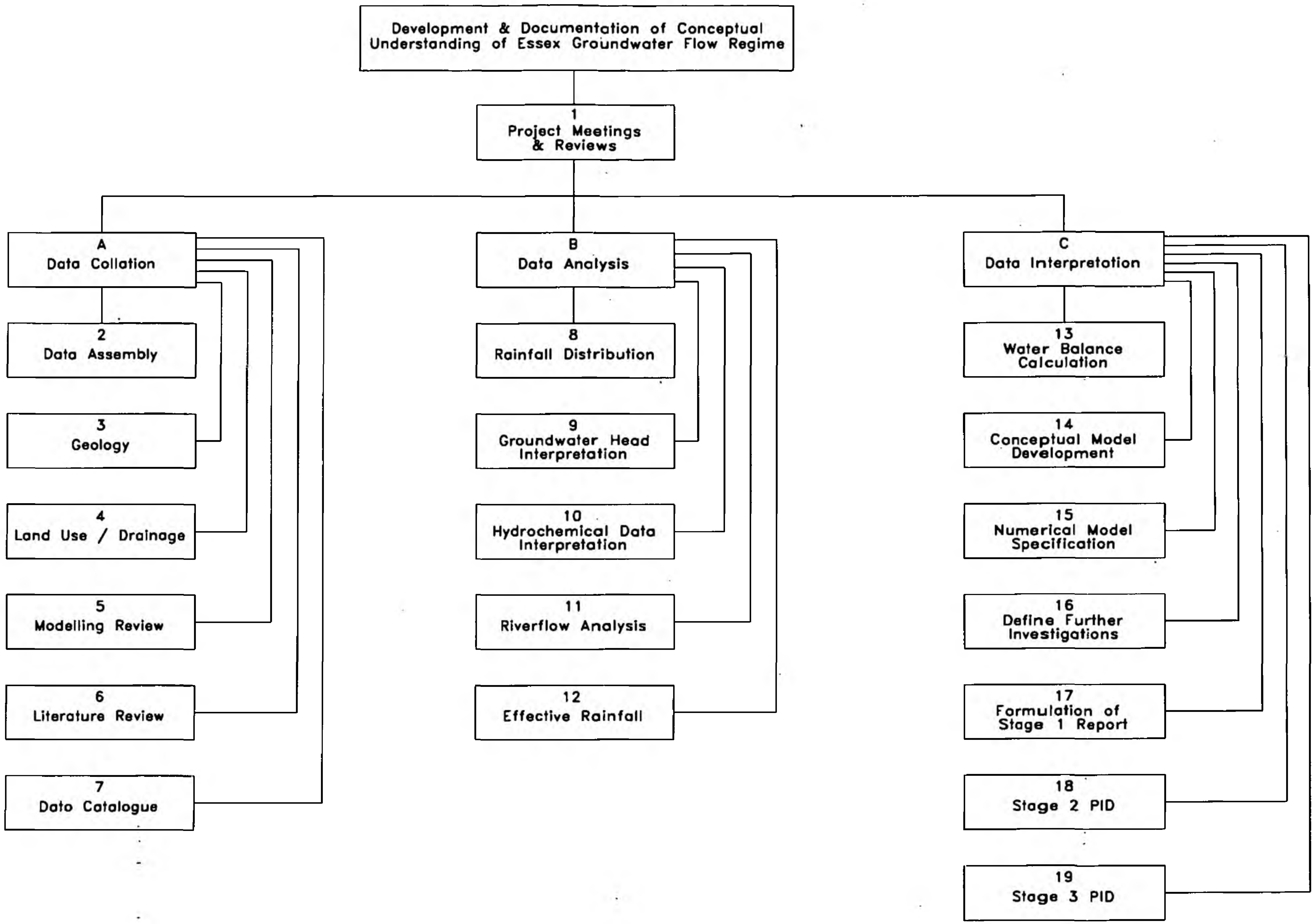

FIGURE 9.1 ESSEX GROUNDWATER INVESTIGATION. WORK BREAKDOWN STRUCTURE

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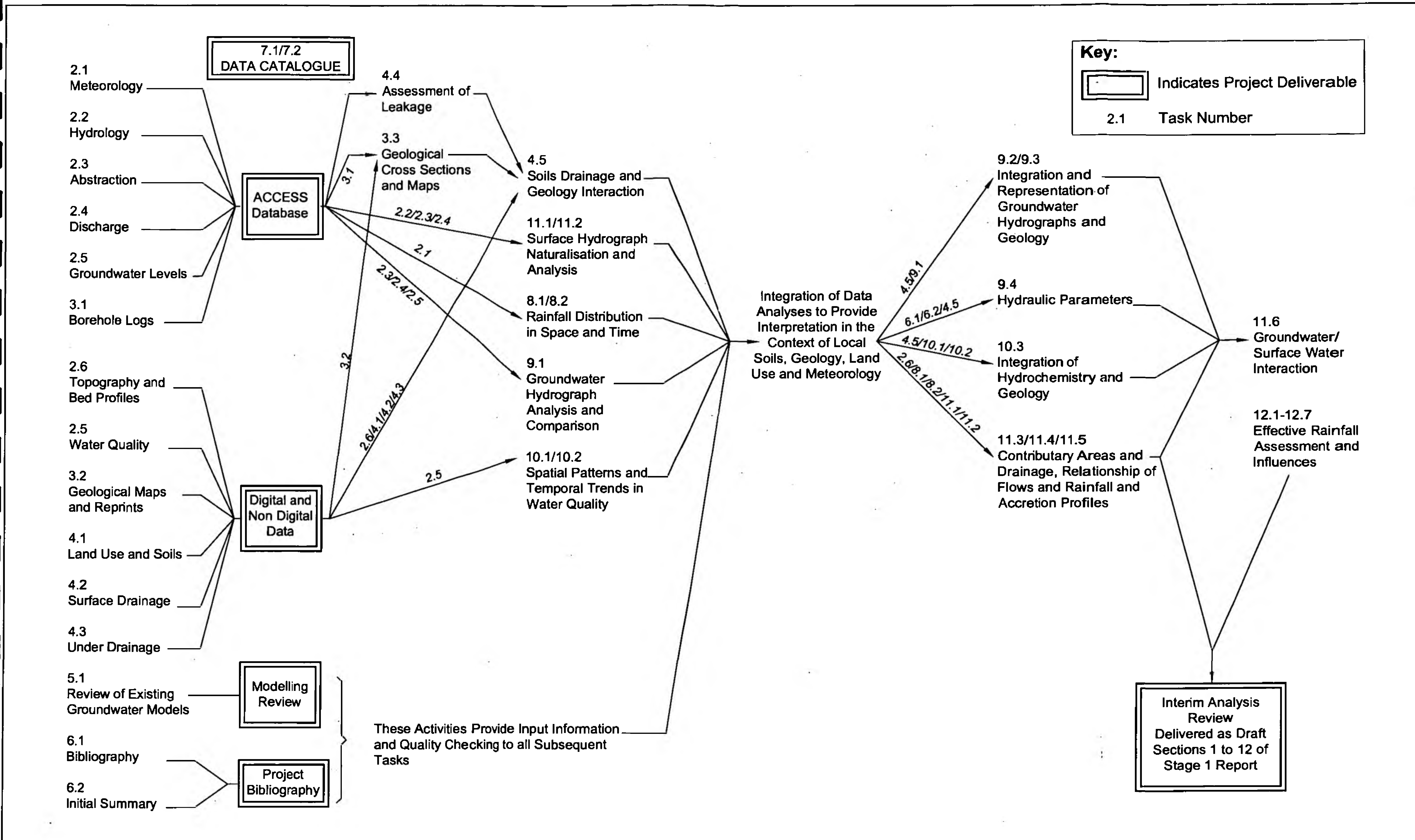

FIGURE 9.2 ESSEX GROUNDWATER INVESTIGATION. PERT CHART (TASKS 1-12).

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Entec

MANAGEMENT RESPONSIBILITY	MEETING FREQUENCY
PROJECT BOARD (Regional Water Resources Management Team)	1 or 2 Per Year
↕	
PROJECT REVIEW GROUP External Peer Reviewers Agency Project Manager Agency Area Representative Consultant Staff (Project Manager) Water Utilities English Nature NFU	Quarterly
↕	
PROJECT WORKING GROUP Agency Project Manager Area Representative Consultant Project Manager Key Consultant Staff	Monthly

FIGURE 9.3 PROPOSED PROJECT ORGANISATION

Drawing No: 02894_009_3 Date: JUNE 2000 Scale: NTS

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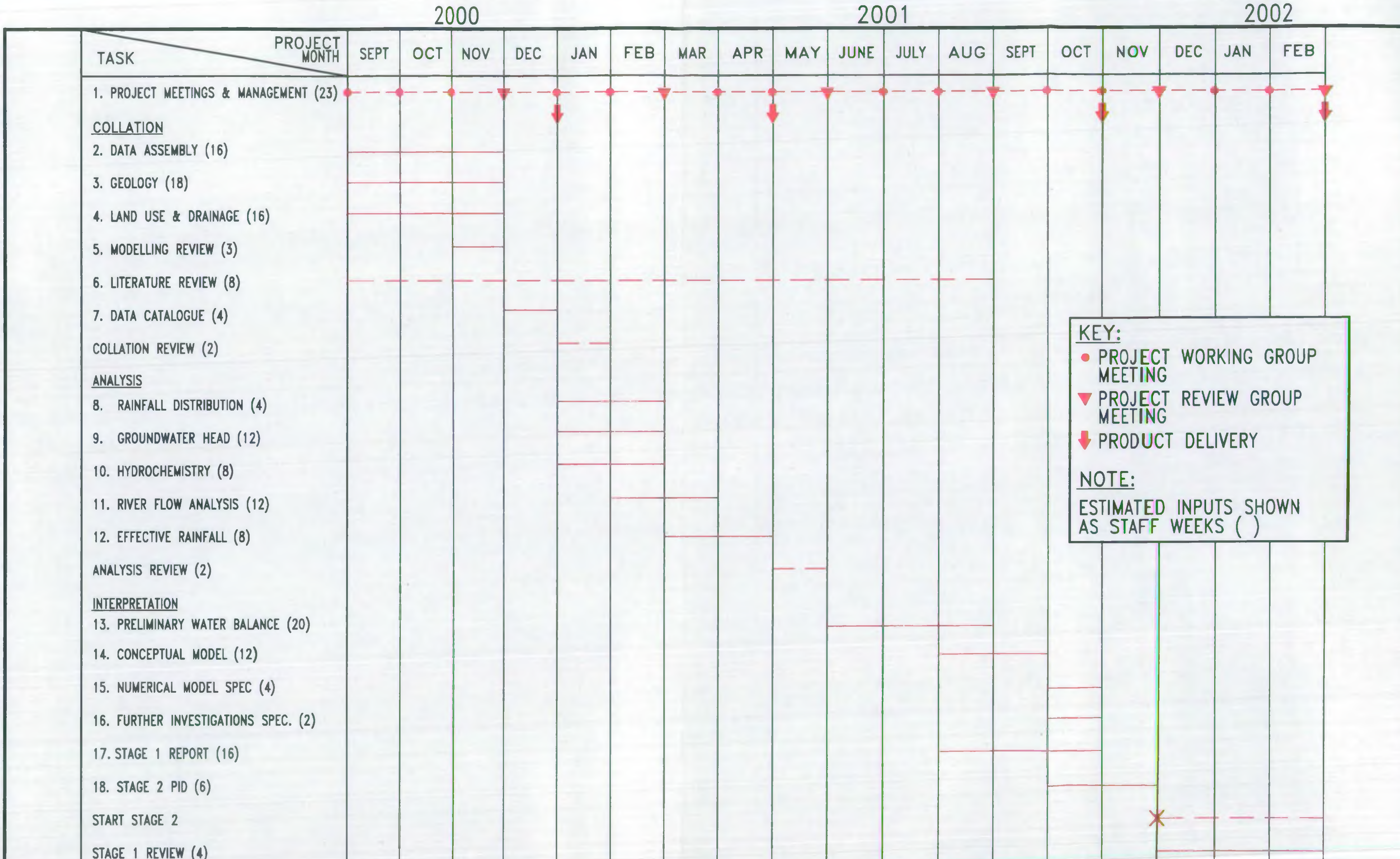

FIGURE 9.4 ESSEX GROUNDWATER INVESTIGATION: STAGE 1 SUMMARY PROGRAMME (18 MONTH PROGRAMME: 15 MONTHS & 3 MONTHS REVIEW)

Drawing No: 02894_009_4 Date: JUNE 2000 Scale: NTS

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10. Resource Plan

10.1 Introduction

Staff resource requirements for Stage 1 of the Essex Groundwater Investigation have been estimated on a task by task basis. These estimates are based on the staff grades and charge rates given in the current Term Contract between the EA and Entec and on internal staff grades and charge rates provided by the EA.

The allocation of the majority of the EA input to relatively senior staff time for quality review and management is reflected in the average (based on total estimated weeks and costs across all staff grades) daily staff costs which are £334 and £329 for the EA and the Consultant respectively.

These input estimates are based on the preferred Stage 1 options as discussed in Part 1 of this PID. For each task they represent a cautious upper bound figure for the task as presently conceived. More detailed discussion of these input estimates is contained in the Scoping Study Report and they will be formalised in response to more detailed Project Briefs. Should major unexpected task extensions arise the work will be included in Stage 2.

10.2 Project Team

The project organisation in terms of project management, project teams and informees is summarised in Figure 10.1. An estimate of hours and staff costs against each Stage 1 task is given in Table 10.1. In this table individuals are not identified. The letters at each column head are indicative of the staff grade as follows:

Consultant	A:	Technical Director for report review
	B:	Project Manager responsible for project delivery and review from the perspective of close project involvement
	C:	Senior engineers/hydrologists responsible for appropriate specialist technical input
	D:	Task Managers responsible for individual task delivery
	E:	Assistant Hydrologist(s): } Responsible for individual elements of the work
	F:	Senior Technician: } Responsible for individual elements of the work
EA	A	Regional Groundwater Manager, David Burgess; supported by senior area staff

B: EA Project Manager, Bill Morgan-Jones with some input from an Area Licensing Officer for attendance at progress meetings and from an Area Hydrogeologist for assessment of benefit uptake.

C: Area staff, particularly David Seccombe and Graham Robertson for review and management

External Advisors: Appointed by the EA, presumed to be Jane Dotteridge and Paul Shaw.

The estimated timings of the inputs required from the EA staff, based on a September 2000 start and the 18 month programme is:

David Burgess or other senior staff:	14 days through Stage 1 duration
Bill Morgan-Jones:	84.5 days throughout Stage 1 duration
Area staff including Dave Seccombe, Graham Robertson and Chris Watson from Water Resources and Licensing:	58 days review and management through the project duration
External advisors	29.5 days throughout Stage 1 duration

The Ipswich Office of the EA has been consulted concerning Area staff time inputs to the project. 58 days over an 18 month period is equivalent to 0.17 FTE, and has been included in the Area business plan.

Table 10.1 **Resource Allocation and Staff Cost Estimates, Essex Groundwater Investigation Stage 1**

			ENTEC					AGENCY	EXT ADV					
TASK	***A*(78)**	***B*(68)**	***C*(55)**	***D*(48)**	***E*(34)**	***F*(29)**	**A(57)**	**B(45)**	**C(35)**	**D(57)**	**TOTAL**	**EC COSTS**	**CY COSTS**	**FF COSTS**
1b REVIEW	4						4	12	8	12	40	2340	12969.04	15309.04
1a MEETINGS/MANAGEMENT	5	15		15	5	10	10	27.5	10	17.5	115	19425	23619.35	43044.35
2 DATA ASSEMBLY				10	40	30					80	20325	0	20325
3 GEOLOGY		5		10	25	40			10		90	21225	2618	23843
4 LAND USE & DRAINAGE		10		25		25			20		80	19537.5	5236	24773.5
5 MODELLING REVIEW		5		5				5			15	4350	1683	6033
6 LITERATURE REVIEW		10		10	20						40	13800	0	13800
7 DATA CATALOGUE				5	5	10					20	5250	0	5250
8 RAINFALL DISTRIBUTION				5	10	5					20	5437.5	0	5437.5
9 GROUNDWATER HEAD INTE		5		40	15						60	20775	0	20775
10 HYDROCHEMISTRY		5		25	10						40	14100	0	14100
11 RIVERFLOW ANALYSIS		5		20	30				5		60	17400	1309	18709
12 EFFECTIVE RAINFALL CAL		5	5		20	5		5			40	10800	1683	12483
13 WATER BALANCES		10	20	25		30		15			100	28875	5049	33924
14 CONCEPTUAL MODEL		5	15	10		15		10	5		60	15600	4675	20275
15 SPECIFICATION OF NUMER		5	10					5			20	6675	1683	8358
16 FURTHER INVESTIGATION				10							10	3600	0	3600
17 STAGE 1 REPORT	5	15	5	20	15	15		5			80	26925	1683	28608
18 STAGE 2 PID		15			15						30	11475	0	11475
0	14	115	55	235	210	185 0	14	84.5	58 0	29.5	1000	267915	62207.39	330122.39

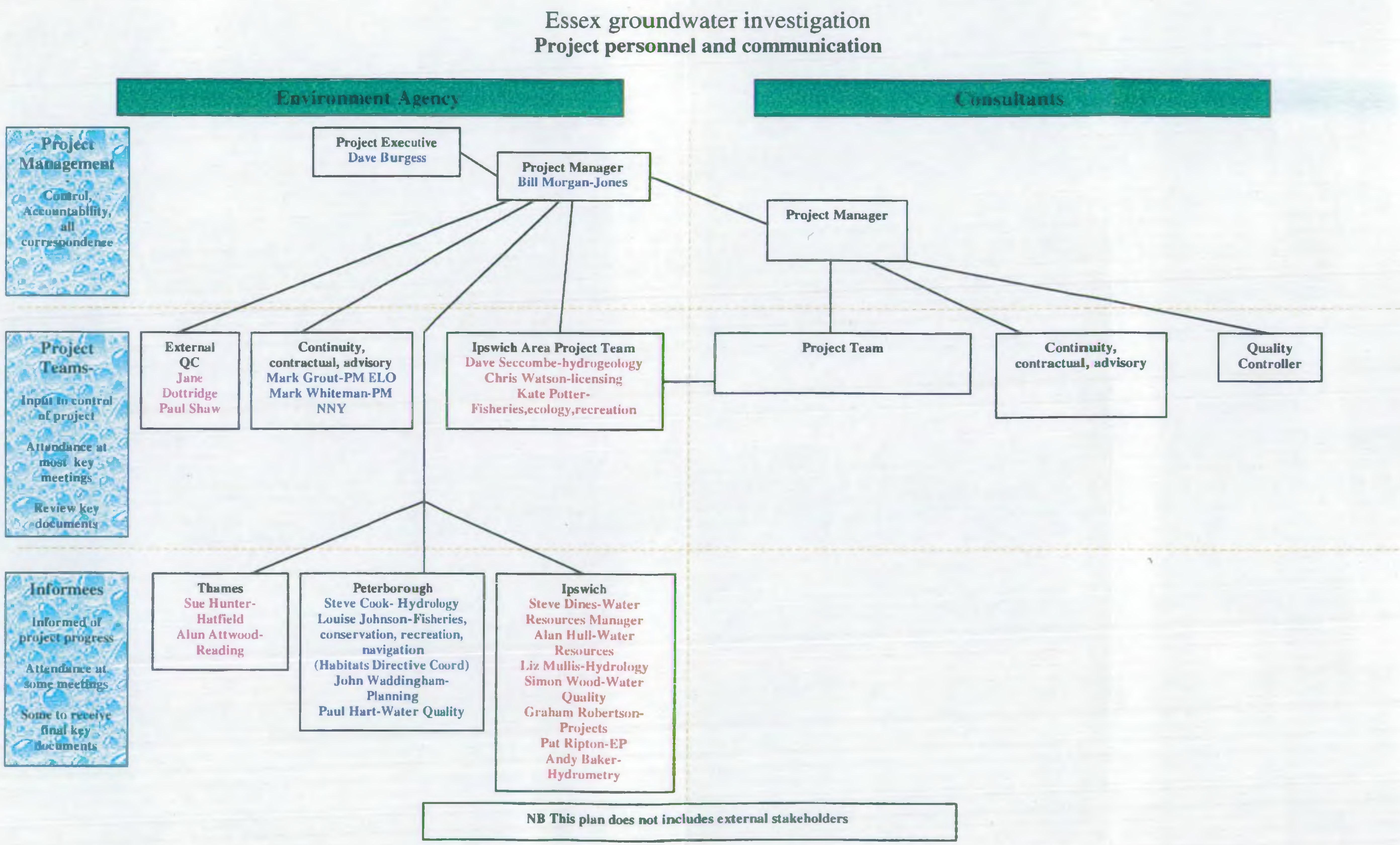

FIGURE 10.1 PROJECT PERSONNEL & COMMUNICATION

Entec

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11. Management of Risk During Stage 1

11.1 Introduction

Section 6.9 of Part 1 of this PID presents a general review of the risks related to the undertaking of the proposed Essex Groundwater Investigation. The risks within Stage 1 fall within the same generic categories:

- failure to achieve adequate technical quality;
- failure to deliver to schedule or cost; and
- failure to achieve acceptance.

During Stage 1 activities, it is particularly important that risk management procedures provide adequate assurance of avoiding these failures as Stage 1 will establish the pattern for the remainder of the project.

Throughout Stage 1 and the rest of the project, risk will be managed by a process combining the following elements:

- regular progress and task review;
- clearly defined task briefs;
- identification of, and in depth review on completion of, tasks within a specific activity;
- regular stakeholder consultation; and
- regular participation of recognised peer reviewers.

11.2 Risk Register

A brief summary of these generic risks, the most likely causes, and activities planned to minimise the risks are given in Box 11.1 a, b and c.

Box 11.1a Risk Register

PROJECT NO KVW90078/1	**PROJECT MANAGER** Bill Morgan-Jones
PROJECT NAME Review of Essex Groundwater Area: Stage 1	
BRIEF PROJECT DESCRIPTION Data Collation and Interpretation and Development of Conceptual Understanding	

Risks (Identification)	**Probability H/M/L**	**Consequence H/M/L**	**Effect of Occurrence Cost/Time/Quality/ Environment**	**Method of Control (Refer to Generic Risk Guidance)**	**Action By**
Generic Risk					
Failure to deliver to cost or schedule	M	M	Failure of project to meet long-term deadlines		
Cause					
Ill defined tasks or products	L			Preparation of project brief and regular review	PM
Time overrun on Data compilation	M			Definition and review of Intermediate products and programme	Project Board/ PM
Rigid contractual attitudes or constraints	L			EA contractual freedom to vary inputs as project develops and shared project goals	PM/Consultant

*When completing Part A it is mandatory to consider all generic risks listed.
*Having identified the PROBABILITIES AND CONSEQUENCES of risks attention should initially be focused on managing those scoring high/high followed by those risks having CONSEQUENCES of medium or high

Date:

Project Manager

Box 11.1b Risk Register

PROJECT NO KVW90078/1	PROJECT MANAGER Bill Morgan-Jones				
PROJECT NAME Review of Essex Groundwater Area: Stage 1					
BRIEF PROJECT DESCRIPTION Data Collation and Interpretation and Conceptual Model Development					
Risks (Identification)	**Probability H/M/L**	**Consequence H/M/L**	**Effect of Occurrence Cost/Time/Quality/ Environment**	**Method of Control (Refer to Generic Risk Guidance)**	**Action By**
Generic Risk Failure to achieve adequate technical standard	 L	 H	 Cessation of project at end of or during Stage 1		
Cause Inadequate Data Inadequate Performance	 L L			 Regular progress review and discussion involvement of area staff Regular internal and peer review	 PM/working and review groups PM/review groups

*When completing Part A it is mandatory to consider all generic risks listed.
*Having identified the PROBABILITIES AND CONSEQUENCES of risks attention should initially be focused on managing those scoring high/high followed by those risks having CONSEQUENCES of medium or high

Date:

Project Manager

Box 11.1c Risk Register

PROJECT NO KVW90078/1			**PROJECT MANAGER** Bill Morgan-Jones		
PROJECT NAME Review of Essex Groundwater Area: Stage 1					
BRIEF PROJECT DESCRIPTION Data Collation, Analysis and Interpretation and Conceptual Model Development					
Risks (Identification)	**Probability H/M/L**	**Consequence H/M/L**	**Effect of Occurrence Cost/Time/Quality/ Environment**	**Method of Control (Refer to Generic Risk Guidance)**	**Action By**
Generic Risk Failure to achieve acceptance and consensus	M	H/M	Reduced product usefulness and consequent benefit		
Cause					
Unfamiliar formats	L			Adoption of standard or current formats for data	PM/ Consultant
Lack of internal consultation	L			Involvement of regional and area staff throughout and in benefit assessment	PM/review group/ consultant
Lack of external consultation	M			Stakeholder meetings and external review	PM/Advisory Group/Consultant
Conflicting interests	H			Openness and consultation throughout project	PM/consultant

*When completing Part A it is mandatory to consider all generic risks listed.
*Having identified the PROBABILITIES AND CONSEQUENCES of risks attention should initially be focused on managing those scoring high/high followed by those risks having CONSEQUENCES of medium or high

Date:

Project Manager

12. Stage 1 Products

12.1 Introduction

This section summarises the products to be delivered to the EA from Stage 1.

The products from Stage 1 of the Essex Groundwater Investigation will be as follows, with dates of delivery assuming a September 2000 project start date indicated in brackets:

- return of original EA data, in the same form as supplied (January/February 2001);
- data and databases in agreed, accessible and compatible formats (January/February 2001);
- data summaries on GIS based maps and layers, cross sections and time series plots as appropriate and supporting text (June/July 2001);
- final report of work carried out and results of interpretation, water balances, conceptual model and numerical model specification (December 2001); and
- Stage 2 PID (November 2001).

Details of these products are given below and summarised on Product Description forms (Boxes 12.1a to d).

12.2 Product Description

Boxes 12.1 a to d provide brief summaries of the anticipated products of Stage 1 of the Essex Groundwater Investigation. A more detailed description of the products produced is given below.

12.2.1 Original EA Data

This will be returned to the EA in the form as supplied. A spreadsheet will be used to record the transfer of data to and from the consultant.

12.2.2 Databases and GIS Layers

Where possible and appropriate, data collated and analysed within this project will be presented to the EA in digital form, compatible with existing software. The precise format of some of the smaller data sets will be agreed with EA staff at the appropriate time.

Data deliverables can be divided into two groups: 'database tables', mainly numeric information expressed as time series or spatially distributed point values, and 'GIS Layers', spatial information which can be presented graphically. Some of the information on 'GIS Layers' may duplicate that in 'databases'. Where possible, the point data should be capable of examination from within the GIS.

The expected data deliverables are shown on Tables 12.1 and 12.2; during the course of the project this list may be amended as the usefulness of particular data sets is examined.

Table 12.1 Suggested Database Tables

Geology	Simple database of elevations of hydrogeological unit boundaries derived from borehole logs
Soil Associations	Soil Association type on 100 m grid: purchase 5-year data lease from Soil Survey.
Long Term Average Rainfall	Long Term Average 1961-1990 for each calendar month on a 1 km^2 grid: purchase 10-year data lease from Met Office (whole of Anglian Region)
Long Term Average Potential Evaporation	Long Term Average 1961-1990 on 1 km^2 grid: purchase from Institute of Hydrology/Met. Office
Refined abstraction records	Daily water abstraction figures available for many sources
Discharges from Sewage Treatment Works	Daily discharge rates available from Anglian Water Services
Surveyed River Profiles	Any additional information that can be collected
Groundwater Levels	Add information to EA database, derived from existing reports/studies, from any new installations and from historical records
Stream flow measurements	Current meter surveys to derive accretion profiles may be undertaken during this project. These will supplement data held in SFM Gaugings
Land Use	Satellite and land use survey results

Table 12.2 Suggested GIS Layers

Soil Associations	Soil Association type on 100 m grid: purchase 5-year data lease from Soil Survey
Long Term Average Rainfall	Long Term Average 1961-1990 for each calendar month on a 1 km^2 grid: purchase 10-year data lease from Met Office (whole of Anglian Region)
Long Term Average Potential Evaporation	Long Term Average 1961-1990 on 1 km^2 grid: purchase from Institute of Hydrology
Land Use	1960s Second Land Utilisation Survey information, digitised on 250 m grid 1990 and 2000 land cover map from Institute of Terrestrial Ecology (when available) Land use distributions for 1970s and 1980s derived from LANDSAT images (possibility only)
Land Drainage	Critically review and revise from EA field knowledge and attempt to distribute on 5 km grid square
Geology	Contours of elevations of hydrogeological unit boundaries derived from borehole logs (contours to be manually produced, not machine-contoured). Contours to be digitised as lines, although gridded information could be produced from them (but would need care in application). Supported by representative cross sections
Water Levels	Water level contours at selected times (manually-checked) for Chalk and, where possible, LLT and superficial deposits. Supported by time series plots
Hydrochemistry	Contours of selected determinands (most probably electrical conductivity, chloride, nitrate) at selected times

The GIS layers referred to in the table are either 'raw' data, or information derived with a minimum of interpretation. During the course of the project, it will be possible to add 'interpreted' or 'calculated' data sets to the GIS if required. Perhaps the most important of these would be long term average effective rainfall, although model construction details could be added, along with selected modelled water levels. Strict Quality Assurance procedures would have to be established to control the use of these 'calculated' data sets.

The GIS layers and time series plots will be supported by written assessment and summaries of the data which will effectively be drafts of Sections 2 to 8 of the Stage 1 Report (see below).

12.2.3 Stage 1 Report

This report will present the analysis of the datasets their integration and subsequent interpretation and conceptualisation. A generic report structure is suggested below:

- Introduction and Literature Review;
- Geological Framework;
- Topography, Land Use and Drainage;
- Meteorology;
- Abstractions, Discharges (including drainage returns and abstraction);
- Surface Water Flows (including the EOETS);
- Groundwater Levels and Hydraulic Parameters;
- Hydrochemistry;
- Effective Runoff and Recharge Process;
- Preliminary Water Balances;
- Conceptual Model;
- Proposals for Numerical Groundwater Flow Modelling; and
- Uncertainties and Further Investigations.

This report will be a stand alone, fully reviewed document and is intended to provide an accessible and accepted quantified water resources review of the Essex Groundwater Investigation Area. Final issues of databases and GIS layers will be presented as Appendices, as will details of all data processing and interpretation.

12.2.4 PID

The PID prepared during Stage 1 will present an update of the business case for the Essex Groundwater Investigations in the light of firm Stage 2 proposals and will provide a Project Plan for Stage 2.

The business case will be supported by an assessment of the realisation of anticipated Stage 1 benefits prepared in consultation with Area Office staff.

Box 12A **Product Description Part A**

Region	Anglian	Project Executive	Dr D Burgess
Function	Water Resources	Project Manager	Bill Morgan-Jones
Start Year	2000		

Project Title	Essex Groundwater Investigation Stage 1	SoD Ref	
Product Title	Original Environment Agency data	Code	

User Representative	Bill Morgan-Jones
Job Title	

1. PURPOSE / OBJECTIVES OF PRODUCT

To return original Environment Agency data in form as supplied.

2. PRODUCT OUTLINE

Original Environment Agency data.

3. ENVIRONMENTAL AND QUALITY CRITERIA

Work carried out according to Project Brief.

4. ENVIRONMENTAL AND QUALITY REVIEW METHOD

Compliance with Consultants QA procedures.

PART B (USER ACCEPTANCE) Is the product accepted? (Yes/No)

Signed		Date	
On Behalf Of			☐ Comments attached

PART C Is this the final or only product? (Yes/No)

If yes, then complete financial out-turn details for the project and submit to PAB Secretary.

Original Authorised Cost (£K)	Initial Authorised Cost (£K)	Actual (£K)	Variance (£K)	Explanation of Variance

Box 12B **Product Description Part A**

Region	Anglian	Project Executive	Dr D Burgess
Function	Water Resources	Project Manager	Bill Morgan-Jones
Start Year	2000		

Project Title	Essex Groundwater Investigation Stage 1	SoD Ref	
Product Title	Interpretative Digital Deliverables (includes Databases, Spreadsheets, GIS Layers and Other Files, see Tables 12.1 and 12.2)	Code	

User Representative	Bill Morgan-Jones
Job Title	

1. PURPOSE / OBJECTIVES OF PRODUCT

To enhance data accessibility to area staff.

To permit early review of basis for interpretation and conceptualisation.

2. PRODUCT OUTLINE

Project database utilising Excel (spreadsheet) and Access (database format) as a data catalogue.

Text description of raw data quality and analytical procedures with maps, graphs etc. illustrating variation in resource inputs, hydrogeology and outputs in time and space.

3. ENVIRONMENTAL AND QUALITY CRITERIA

Work carried out according to Project Brief.

4. ENVIRONMENTAL AND QUALITY REVIEW METHOD

Compliance with Consultants QA procedures and Review by EA Project Team.

PART B (USER ACCEPTANCE) Is the product accepted? (Yes/No)

Signed		Date	
On Behalf Of			☐ Comments attached

PART C Is this the final or only product? (Yes/No)

If yes, then complete financial out-turn details for the project and submit to PAB Secretary.

Original Authorised Cost (£K)	Initial Authorised Cost (£K)	Actual (£K)	Variance (£K)	Explanation of Variance

Box 12C **Product Description Part A**

Region	Anglian	Project Executive	Dr D Burgess
Function	Water Resources	Project Manager	Bill Morgan-Jones
Start Year	2000		

Project Title	Essex Groundwater Investigation Stage 1	SoD Ref	
Product Title	Stage 1 Report	Code	

User Representative	Bill Morgan-Jones
Job Title	

1. PURPOSE / OBJECTIVES OF PRODUCT

To enhance conceptual understanding of hydrogeology of Essex Area, and reduce costs of licence determination.

2. PRODUCT OUTLINE

Detailed report and supporting maps, cross sections, databases and appendices.

3. ENVIRONMENTAL AND QUALITY CRITERIA

Work carried out according to Project Brief.

4. ENVIRONMENTAL AND QUALITY REVIEW METHOD

Compliance with Consultant's QA.

Review by Project Review Group before formal issue.

PART B (USER ACCEPTANCE) Is the product accepted? (Yes/No) [ ]

Signed		Date	
On Behalf Of			☐ Comments attached

PART C Is this the final or only product? (Yes/No) [ ]

If yes, then complete financial out-turn details for the project and submit to PAB Secretary.

Original Authorised Cost (£K)	Initial Authorised Cost (£K)	Actual (£K)	Variance (£K)	Explanation of Variance

Box 12D **Product Description Part A**

Region	Anglian	Project Executive	Dr D Burgess
Function	Water Resources	Project Manager	Bill Morgan-Jones
Start Year	2000		

Project Title	Essex Groundwater Investigation Stage 1	SoD Ref	
Product Title	Revised PID and Stage 2 Project Plan	Code	

User Representative	Bill Morgan-Jones
Job Title	

1. PURPOSE / OBJECTIVES OF PRODUCT

To advise management and obtain PAB authorisation to proceed with additional investigations/monitoring (Stage 2) of Essex Groundwater Investigation.

2. PRODUCT OUTLINE

Revised business case for overall Essex Groundwater Investigation, detailed project plan for Stage 2 activities.

3. ENVIRONMENTAL AND QUALITY CRITERIA

Requirements of EA Project Management Manual.

4. ENVIRONMENTAL AND QUALITY REVIEW METHOD

Consultants QA.

PAB review.

PART B (USER ACCEPTANCE) Is the product accepted? (Yes/No)

Signed		Date	
On Behalf Of			☐ Comments attached

PART C Is this the final or only product? (Yes/No)

If yes, then complete financial out-turn details for the project and submit to PAB Secretary.

Original Authorised Cost (£K)	Initial Authorised Cost (£K)	Actual (£K)	Variance (£K)	Explanation of Variance

13. Stage 1 Benefit Realisation Plan

13.1 Introduction

The benefits that should accrue from the successful delivery of the Essex Groundwater Investigation are only fully realised on product completion and the delivery of an accepted practical resource management tool which can be used to support strategic and operational decisions (Section 5). Completion of Stage 1 activities and Stage 1 product delivery marks a first step along this route and provides an incremental contribution to licence determination methodology.

Realisation of other benefits should accrue incrementally from the completion of Stage 1 but again will require completion of the project for full realisation.

13.2 Measurement of Benefit Delivery

Product delivery throughout the Stage 1 activities is objectively measurable and identifiable (Section 12). Benefit delivery on the other hand is likely to be a less objective determination. This determination is perhaps best made by those representing the end users within the EA who are in regular contact with both external stakeholders and internal staff and who as such can gauge opinion across a wide group who are not directly involved in project activities.

The involvement of reviewers' external to Anglian Region will provide an objective measure of the quality of the product delivered.

The products to be delivered during Stage 1 are principally the databases and GIS layers discussed in Section 12 scheduled for delivery around January/February 2001 and May/June 2001 respectively of the project. The Stage 1 Report will effectively deliver an improved resource assessment and conceptual understanding. Responsibility for their delivery will rest with the consultants for the project and their quality and compatibility with EA requirements will be reviewed by the Project Review Group. The realisation of benefits from these products will be a function of their acceptance and integration into day to day resource management and water quality protection activities within the EA.

During Stage 1 activities this acceptance and integration will be promoted by the presence of key Area Office staff on the Project Board and by the involvement of EA staff (both Area and Regional) in project activities. The discussions during Project Review meetings and continuous less formal contact between EA and Consultant staff will ensure that integration of the project products into resource management procedures is maximised. When necessary formal product presentation and explanation to EA Staff will be implemented.

The conceptual understanding and improved resource quantification that will be presented in the Stage 1 Report represent the first step towards realisation of both the economically quantified benefit of enhanced licence determination and review and the main unquantified benefits of reduced risk of environmental damage from abstraction impacts, delay in capital expenditure (especially through more efficient use of SAGS) and the possible identification of additional water resources. This realisation of benefits requires both uptake and utilisation by EA staff and acceptance by Stakeholders.

Uptake by EA licensing staff will be encouraged by organising a 2/3 day seminar early in Stage 2 to present the Stage 1 report and understanding. This seminar will also initiate the processes necessary for defining a means of measurement of the benefits (in time and cost terms) to the licence determination/review process (see Section 6).

Acceptance by Stakeholders will be promoted through the advisory group meetings (see Figure 9.3) throughout Stage 1. A key component of the final one of these meetings will be an investigation of the degree of acceptance and a definition of most efficient means of encouraging and measuring this acceptance through subsequent stages of the project.

Appendix A
Economic Analysis Methodology and Spreadsheets

Entec

Appendix A1
Methodology

5 Pages

Entec

Methodology for the Benefit-Cost Calculation

Benefits

This section outlines the methodology used for the calculation of the benefits of the Essex Groundwater Investigation, and the assumptions underlying it. The methodology is demonstrated principally with reference to the preferred 'Intermediate' Option.

The Essex groundwater model is one of the main products of the Essex Groundwater Investigation. The model constitutes an assembly of information. Information only has economic value to the extent that its use has a demonstrable impact upon the allocation of economic resources. Thus the model could be used to improve strategic and operational water management . This improvement might result in resource savings, in which case the value of the model would be a reflection of these savings. However, it is not certain that the model would be used in this way. Thus it is necessary to recognise that the economic benefits of the model are likely to be realised only with some uncertainty. This is not only an accurate view of the situation; but also represents a conservative approach to benefits estimation.

The emphasis in this work has been to estimate money values for the likely benefits of the model which are reliable, conservative and defensible. For this reason the focus has been on the savings which might be achieved via the model through reductions in the costs of undertaking abstraction licence determinations and reviews, both directly and indirectly. It would have been possible to assign money values to a whole range of other potential benefits, for instance conservation, using methodologies that have been employed elsewhere. However, it is felt that these methodologies – and the values that would result from them – are unsound and/or too uncertain to be reliable in this context. It is better to estimate reliable lower-bound economic values than values the accuracy and validity of which are not known.

Baseline Information and Assumptions

The baseline information and assumptions employed in this benefits estimation are as follows.

In the Essex area there are 229 groundwater spray irrigation licences (26 in Chalk) and 18 public water supply licences (16 in Chalk). Currently, around 12 spray irrigation licences are reviewed each year, and 3 public water supply licences. This tallies quite closely with actual EA experience. Around 50% of these reviews would be classed as 'contentious' and requiring detailed determination. On the assumption that around 50% of reviews require determination, and with a review period of six years (the AMS review period is 6 years), this gives an average number of determinations per year of 19.08 for groundwater spray irrigation (2.17 in Chalk) and 1.5 for public water supply (1.33 in Chalk). Previous discussions with EA staff and with the National Farmers' Union suggested a total cost (Applicant and EA) for each groundwater spray irrigation determination of around £35 000, and research indicates a figure of £100 000 to be a conservative estimate for public water supply determination.

Finally, the discounting of future costs and benefits requires the specification of a discount rate. The standard Treasury discount rate of six per cent has been used.

Benefits of Reduced Determination Costs

It is expected that the Essex groundwater model could save resources needed currently for licence determinations by removing the need for separate modelling and assessment of the environmental (etc) impact of the proposed abstraction. Thus, when a licence determination is required, the EA officer could turn straight to the groundwater model and obtain very quickly a picture of the effect of the proposed abstraction on groundwater conditions in the area.

It has been assumed that resource savings from using the model in licence determinations would be equal to 25 per cent of the current resource cost. This amounts to £8 750 for groundwater spray irrigation, and £25 000 for public water supply. This results in resource savings until 2004 of £52 500 per year for irrigation, rising to £166 979 after 2005 once time-limited licences are introduced and the number of reviews required increases. For public water supply, the number of contentious reviews is expected to remain unchanged, given a resource saving of £37 500 per year throughout the life of the model. However, it is assumed that, although it is highly likely, it is not certain that the model will be able to secure all of these savings. Thus it is assumed that the probability that these savings will be achieved is 0.8. This gives a total expected annual resource savings of £72 000 until 2005, and £163 583 after that date.

It is also assumed that the model will not result in these savings in full until it is complete and operational. However, it is likely that constructing the model will result in the collection of information and knowledge which will be useful in making licence determinations. Thus, some savings will be forthcoming during the model construction stages. A profile for the proportion of the full model savings achievable in each year of model construction is therefore assumed. Thus, 25 per cent then 50 per cent and then 75 per cent of the full resource savings are forthcoming in years one, two/three and four respectively. Full resource savings are achievable from year five onwards.

The total savings in years one, two/three and four are therefore equal to £28 500, £57 000 and £80 660 respectively. A 20-year life for the model is assumed. The discounted (at six per cent) present value of these benefits is equal to £1 428 533.

Benefits of Extended Review Period

The increased knowledge and understanding of Essex groundwater resources is expected to result in greater certainty about the effects and risks associated with groundwater abstractions, independently and overall. In turn, this greater certainty could permit the period between abstraction licence reviews to be extended. Given that this would mean that fewer reviews needed to be undertaken, and that reviews are costly to undertake in terms of economic resources, this would represent a resource saving and hence a benefit associated with the construction and use of the Essex groundwater model.

It is assumed that the review period could be increased from the current six years to ten. This would be possible from mid 2005 onwards. It is likely that the review period for only a proportion of all licences might be extended, perhaps because some abstractions are in particularly sensitive areas or because the understanding of groundwater resources in that area is less well developed. Thus it is assumed that only with a 0.1 probability will 100 per cent of abstraction licences benefit from an extended review period. Fifty per cent of licences will be extendable with a probability of 0.15. The most likely option is that 25 per cent of licences will be extendable, with probability 0.75.

Finally, it is assumed that there is a basic probability that the Essex model will lead to licence review periods being extended of 0.25. This assumption is adopted for conservative reasons, and because of the genuinely greater uncertainty surrounding these savings. However, the compound result of all of these assumptions is that these benefits are calculated to be significantly smaller than those derived from savings made in the determination procedure itself. Note also that these savings are made on the basis of determination costs that have already been reduced as a result of economies generated by the model. It is further assumed that, because of the reduced levels of consultation involved, the 'Low' Option has a further 50 per cent less chance of securing these options.

The calculation is made in the following way. The assumption that only a proportion of licences benefit from an extended review period means that, depending on the scenario, a certain proportion of licences will have an unchanged six-year review period, and the remaining licences will have the extended 10-year period. Thus it is possible to compute a weighted-average review period, with the weights determined by the relative proportions. Given the number of licences in existence, this average review period determines the number of determinations to be made each year. This number can be subtracted from the existing number per year to give the number of determinations 'saved' per year. The new cost of a determination has been previously calculated. Thus, the resources saved through 'saving' determinations can be calculated. Assuming savings generated from 2005 onwards and a 20-year life for the model permit the calculation of a discounted (at six per cent) present value for each scenario. The three scenarios posited for savings can be weighted by their assigned probabilities to give a total expected value. Finally, this value is itself weighted by the assumed probability that it can be realised (25 per cent, or half that for the 'Low' Option).

The final result of all these calculations is the figure of £129 110 for savings anticipated from extending the abstraction licence review period following the adoption of the 'Intermediate' Option. Similar calculations have been made for the other options, as reported in Section 6 above.

Costs

This section outlines the methodology used for calculating the costs of constructing the Essex groundwater model, and the assumptions underlying it. The model construction is expected to proceed in a series of stages. Only in the first stage is it assumed that the project team will have a choice over what work to undertake. In subsequent stages, it is assumed that certain programmes of work will have to be undertaken to achieve a complete and operational model. Each of the possible programmes is assumed to be required with a probability. This uncertainty reflects the fact that the first conceptualisation stage is in part a fact-finding exercise, after which it will become clear what work is required to complete the project successfully. Thus, there is scope for the probabilities – and the project expected costs – to be updated as more information is gathered.

The basic information common to each stage is as follows: consultant labour cost, £1645/staff-week, EA labour cost, £1670/staff, discount rate, six per cent. When calculating present values, it has been assumed that the distribution of costs incurred during a work component is even across the duration of the component. This means that it can be assumed that all of the costs incurred in a component are incurred at a single point in time, equal to the time midpoint of the work programme. This is because, with an equal distribution of costs, for every 'item' of cost occurring x length of time before the midpoint, there is an equal amount of costs occurring x length of time *after* the midpoint. Thus, if a component is expected to start in week 52, and last 52 weeks, then the costs incurred can be discounted over 78 weeks to give a present value.

Stage 2

The calculations and assumptions made to estimate Stage 1, Stage 3 and Stage 4 costs are largely self-explanatory and are explained in the body of the main document. The assumptions made in Stage 2 require some further explanation.

The Stage 2 work programme is expected to be made up of a range of work packages. These are as follows: specific focussed studies, AMP3 investigations, water level monitoring of additional existing boreholes, additional desk study/borehole drilling and extensive field surveys. These have been combined into a series of options that have been assigned *ex ante* probabilities that they will be required/necessary. These are given in the table below. It can be seen it is expected that the programme of work that will be most necessary and likely comprises the specific focussed studies, AMP3 investigations and water level monitoring. This is seen as by far the most likely option. It can also be seen that each package is cumulative, such that each subsequent package comprises the previous one plus an extra component. From this information, it is possible to estimate probabilities that each work component will be present in the work package that is ultimately chosen.

Table 1 Stage 2 Work Package Probabilities

Package	Components	Probability
1	Specific focussed studies	0.1
2	Package 1 plus AMP3 investigations	0.2
3	Package 2 plus water level monitoring	0.6
4	Package 3 plus desk study/drilling	0.05
5	Package 4 plus extensive field surveys	0.05

Thus, since the specific focussed studies component is present in all work packages, and that the probability that any one of those work packages pertains is 1.0, then the 'specific focussed studies' component must occur, and therefore has its own probability of 1.0. On the other hand, because extensive field surveys occur only in a single package, with a probability of 0.05, then the probability that extensive field surveys occur must also be 0.05. Similar reasoning can be used for each of the other components, to provide probabilities that each of the components will be present. These are given in the table below. These probabilities can then be combined with the estimated (discounted) cost of each component to give an expected discounted present value cost of each component. Summing these together gives the expected discounted present value cost of the Stage 2 work package. This is the value presented in the main document and used as the basis for calculating model construction costs and hence the benefit-cost ratios.

Table 2 **Stage 2 Work Component Probabilities**

Component	Probability
Specific focussed studies	1.0
AMP3 investigations	0.9
Water level monitoring	0.7
Desk study and borehole drilling	0.1
Extensive field surveys	0.05

Appendix A2
Calculation Spreadsheets

5 Pages

Entec

BENEFITS CALCULATION

Interest rate	0.06

	Irrigation	PWS
Number of licences	229	18
Average length of licence	6	6
Applications/year	38.167	3
Proportion contentious	0.5	0.5
Number of determinations/year, currently	6	1.5
Number of determinations/year, from 2005	19.083	1.5

1 Reduced licence costs

Baseline costs

Current unit cost	Per year, -2004	Per year, 2005-	PV to 2004	PV 2005-	TOTAL
35,000	210,000	667,917	727,672	5,346,550	6,074,222
100,000	150,000	150,000	519,766	1,200,722	1,720,488
	360,000	817,917	1,247,438	6,547,272	7,794,710

Stage 1 only baseline costs

Current unit cost	Per year, -2004	Per year, 2005-	PV to 2004	PV 2005-	TOTAL
35,000	196,875	626,172	682,193	5,012,390	5,694,583
100,000	140,625	140,625	487,280	1,125,677	1,612,958
	337,500	766,797	1,169,473	6,138,068	7,307,541

Current unit cost	Saving %	Saving £	Number per period	Probability of saving	Expected saving
35,000	25	8,750	19.083	0.8	133,583
100,000	25	25,000	1.5	0.8	30,000
				TOTAL	163,583

Contribution

Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
0.157	0.314	0.314	0.472	1
0.25	0.5	0.5	0.75	1

	Expected present value				Expected PV, year 5 onwards		Total
	Year 1	*Year 2*	*Year 3*	*Year 4*	Undiscounted	Discounted	
	19,811	37,380	35,264	49,902	1,349,979	1,008,783	1,151,140
	7,075	13,350	12,594	17,822	303,177	226,551	277,393
Total	26,887	50,730	47,858	67,724		1,235,334	1,428,533

2 Longer review period

With 10-yr period from 2005 for			25%					
%	Length	No/period	Number saved	Expected saving	Undiscounted	Discounted	Probability	Expected value
25	10	17.175	1.908	40,075	389,218	290,847	0.75	218,135
25	10	1.35	0.15	9,000	87,410	65,318	0.75	48,989

With 12-yr period from 2005 for 50%			50%					
%	Length	No/period	Number saved	Expected saving	Undiscounted	Discounted	Probability	
50	10	15.26666667	3.817	80,150	778,437	581,693	0.15	87,254
50	10	1.2	0.3	18,000	174,820	130,636	0.15	19,595

With 12-yr period from 2005, 100%								
%	Length	No/period	Number saved	Expected saving	Undiscounted	Discounted	Probability	Expected value
100	10	11.45	7.633	160,300	1,556,874	1,163,386	0.1	116,339
100	10	0.9	0.6	36,000	349,641	261,272	0.1	26,127

Probability of longer review period		0.25
TOTAL	516,439	129,110
(low option)	258,219	64,555

[illegible]

LOW OPTION

Annual rate	0.06
Monthly rate	0.005

	Option	Entec DAYS	EA DAYS	Entec cost/day	Entec Cost	EA Cost	Preferred	PV
Stage 1	Base	720	115	329.35	237,135	38,608	275,743	
Time (months)				EA cost/day				
9				335.72				
	TOTAL	720	115	835	237,135	38,608	275,743	263,952
	Data purchase						30,000	28,717
							TOTAL	292,669

	Option	Amount	Time	PV	p	Expexcted value	Expected PV
Stage 2	Focussed studies	132,000	20	119,784	1	132,000	119,784
	AMP3	9,900	20	8,984	0.9	8,910	8,085
	Monitoring	16,500	20	14,973	0.7	11,550	10,481
	Desk study	566,000	20	513,618	0.1	56,600	51,362
	Field surveys	132,000	20	119,784	0.05	6,600	5,989
						215,660	195,701

	Option 1	Option 2	Option 3	Option 4	Option 5	
p	0.1	0.2	0.6	0.05	0.05	1
Cost	132,000	141,900	158,400	724,400	856,400	
E(Cost)	13,200	28,380	95,040	36,220	42,820	215,660
EPV(Cost)	11,978	25,753	86,244	32,868	38,857	195,701

		Amount	Time	PV	p		
Stage 3	Regional	148,500	34	125,900	1	148,500	125,900
	Local models		34	0	1	0	0
	Overrun	59,400	34	50,360	0.2	11,880	10,072
						160,380	135,972

Stage 4		Amount	Time	PV	p		
	Two scenarios	21,780	46	17,420	1	21,780	17,420

TOTAL PV	673,563	TOTAL EPV	641,763

BENEFITS

LOW OPTION

Reduced determination costs	571,413
Increased review period	64,555
TOTAL	635,968

COST-BENEFIT CALCULATION

Total benefits	635,968
Total costs	641,763
B/C	0.99
ENPV	-5,795

COSTS								
INTERMEDIATE OPTION							Annual rate	0.06
							Monthly rate	0.005
	Option	Entec DAYS	EA DAYS	Entec cost/day	Entec Cost	EA Cost	Preferred	PV
Stage 1	Base	814	186	329.13	267,915	62,207	330,122	
Time (months)				EA cost/wk				
9				334.45				
	TOTAL	814	186	1000	267,915	62,207	330,122	316,006
	Data purchase						35,000	33,503
							TOTAL	349,509
		Amount	Time	PV	p	Expexcted value		Expected PV
Stage 2	Focussed studies	132,000	20	119,784	1	132,000		119,784
	AMP3	9,900	20	8,984	0.9	8,910		8,085
	Confined	16,500	20	14,973	0.7	11,550		10,481
	Desk study	566,000	20	513,618	0.1	56,600		51,362
	Field surveys	132,000	20	119,784	0.05	6,600		5,989
						215,660		195,701
	Option 1	Option 2	Option 3	Option 4	Option 5			
p	0.1	0.2	0.6	0.05	0.05			1
Cost	132,000	141,900	158,400	724,400	856,400			
E(Cost)	13,200	28,380	95,040	36,220	42,820			215,660
EPV(Cost)	11,978	25,753	86,244	32,868	38,857			195,701
		Amount	Time	PV	p			
Stage 3	Regional	148,500	34	125,900	1	148,500		125,900
	Local models	59,400	34	50,360	1	59,400		50,360
	Overrun	83,160	34	70,504	0.2	16,632		14,101
						224,532		190,361
Stage 4		Amount	Time	PV	p			
	Four scenarios	43,560	46	34,840	1	43,560		34,840
					TOTAL PV	805,314	TOTAL EPV	770,412

BENEFITS

INTERMEDIATE OPTION

Reduced determination costs	1,428,533
Increased review period	129,110
TOTAL	1,557,643

COST-BENEFIT CALCULATION

Total benefits	1,557,643
Total costs	770,412
B/C	2.02
ENPV	787,231

COSTS								
HIGH OPTION							Annual rate	0.06
							Monthly rate	0.005
	Option	Entec DAYS	EA DAYS	Entec cost/day	Entec Cost	EA Cost	Preferred	PV
Stage 1	Base	1524	246	303.11	461,940	79,713	541,653	
Time (months)				EA cost/wk				
9				324.04				
	TOTAL	1524	246	1770	461,940	79,713	541,653	518,492
	Data purchase						40,000	38,290
							TOTAL	556,781

		Amount	Time	PV	p	Expexcted value	Expected PV
Stage 2	Focussed studies	132,000	20	119,784	1	132,000	119,784
	AMP3	9,900	20	8,984	0.9	8,910	8,085
	Confined	16,500	20	14,973	0.7	11,550	10,481
	Desk study	566,000	20	513,618	0.1	56,600	51,362
	Field surveys	132,000	20	119,784	0.05	6,600	5,989
						215,660	195,701

	Option 1	Option 2	Option 3	Option 4	Option 5	
p	0.1	0.2	0.6	0.05	0.05	1
Cost	132,000	141,900	158,400	724,400	856,400	
E(Cost)	13,200	28,380	95,040	36,220	42,820	215,660
EPV(Cost)	11,978	25,753	86,244	32,868	38,857	195,701

		Amount	Time	PV	p		
Stage 3	Regional	231,000	34	195,845	1	231,000	195,845
	Local models	0	34	0	1	0	0
	Overrun	92,400	34	78,338	0.2	18,480	15,668
						249,480	211,512

		Amount	Time	PV	p		
Stage 4	Six scenarios	65340	46	52260.47025	1	65340	52,260

TOTAL PV	1,046,793	TOTAL EPV	1,016,255

BENEFITS	
HIGH OPTION	
Reduced determination costs	1,428,533
Increased review period	129,110
TOTAL	1,557,643

COST-BENEFIT CALCULATION	
Total benefits	1,557,643
Total costs	1,016,255
B/C	1.53
NPV	541,388

COSTS

WORST CASE COST SCENARIO FOR INTERMEDIATE OPTION

Annual rate	0.06
Monthly rate	0.005

	Option	Entec DAYS	EA DAYS	Entec cost/day	Entec Cost	EA Cost	Preferred	PV
Stage 1	Base	109.5	28.5	303.11	36,064	9,568	330,122	

Time (months)	EA cost/wk
9	324.04

TOTAL	109.5	28.5	138	36,064	9,568	330,122	316,006
Data purchase						35,000	33,503
						TOTAL	349,509

		Amount	Time	PV	p	Expexcted value	Expected PV
Stage 2	Focussed studies	132,000	20	119,784	1	132,000	119,784
	AMP3	9,900	20	8,984	1	9,900	8,984
	Confined	16,500	20	14,973	1	16,500	14,973
	Desk study	566,000	20	513,618	1	566,000	513,618
	Field surveys	132,000	20	119,784	1	132,000	119,784
						856,400	777,142

	Option 1	Option 2	Option 3	Option 4	Option 5	
p	0	0	0	0	1	1
Cost	132,000	141,900	158,400	724,400	856,400	
E(Cost)	0	0	0	0	856,400	856,400
EPV(Cost)	0	0	0	0	777,142	777,142

		Amount	Time	PV	p		
Stage 3	Regional	231,000	34	195,845	1	231,000	195,845
	Local models		34	0	1	0	0
	Overrun	92,400	34	78,338	1	92,400	78,338
						323,400	274,183

		Amount	Time	PV	p		
Stage 4							
	Six scenarios	65,340	46	52,260	1	65,340	52,260

TOTAL PV	1,280,432	TOTAL EPV	1,453,094

BENEFITS

WORST CASE COST SCENARIO FOR INTERMEDIATE OPTION

Reduced determination costs	1,428,533
Increased review period	129,110
TOTAL	1,557,643

COST-BENEFIT CALCULATION

Total benefits	1,557,643
Total costs	1,453,094
B/C	1.07
ENPV	104,549

COSTS

FROM STAGE 2 FOR INTERMEDIATE OPTION								
							Annual rate	0.06
							Monthly rate	0.005
	Option	Entec DAYS	EA DAYS	Entec cost/day	Entec Cost	EA Cost	Preferred	PV
Stage 1	Base	109.5	28.5	303.11	36,064	9,568	330,122	
Time (months)				EA cost/day				
9				324.04				
	TOTAL	109.5	28.5	138	36,064	9,568	330,122	316,006
	Data purchase						35,000	33,503
							TOTAL	349,509

		Amount	Time	PV	p	Expexcted value		Expected PV
Stage 2	Focussed studies	132,000	20	119,784	1	132,000		119,784
	AMP3	9,900	20	8,984	1	9,900		8,984
	Confined	16,500	20	14,973	1	16,500		14,973
	Desk study	566,000	20	513,618	1	566,000		513,618
	Field surveys	132,000	20	119,784	1	132,000		119,784
						856,400		777,142

	Option 1	Option 2	Option 3	Option 4	Option 5			
p	0	0	0	0	1			
Cost	132,000	141,900	158,400	724,400	856,400			
E(Cost)	0	0	0	0	856,400			856,400
EPV(Cost)	0	0	0	0	777,142			777,142

		Amount	Time	PV	p			
Stage 3	Regional	148,500	34	125,900	1	148,500		125,900
	Local models	59,400	34	50,360	1	59,400		50,360
	Overrun	83,160	34	70,504	0.2	16,632		14,101
						224,532		190,361

Stage 4		Amount	Time	PV	p			
	Four scenarios	43,560	46	34,840	1	43,560		34,840
					TOTAL PV	1,161,564	TOTAL EPV	1,351,852

BENEFITS

STAGE 2 PID FOR INTERMEDIATE OPTION

Reduced determination costs	941,364
Increased review period	129,110
TOTAL	1,070,474

COST-BENEFIT CALCULATION

				Stage 1 only	
Total benefits	1,070,474			Total benefits	487,169
Total costs	420,903	Total costs (worst case)	1,002,343	Total costs	349,509
B/C	2.54	B/C (worst case)	1.07	B/C	1.39
ENPV	649,571	ENPV (worst case)	68,130	ENPV	137,660