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Environment Agency
Anglian Region

# Ely Ouse - Essex Water Resource Investigations

## Scoping study for Denver naturalisation

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## Contents

## Executive Summary

Essex & Suffolk Water and the Environment Agency (Anglian Region) are carrying out a joint project to develop a new computer model of the Ely Ouse - Essex Transfer Scheme. A review of the hydrometric data which feeds the model forms part of this work. This report investigates the options for naturalising the flow record from Denver on the Ely Ouse.

The upper reaches of the Ely Ouse are a series of chalk streams in Norfolk, Suffolk and Cambridgeshire. Further downstream, the river flows into the fens. This is one of the most productive farming areas in the country, and there is great demand for water for arable crops. In summer, water leaves the main river channel in a variety of ways. These include:

- direct abstraction for spray irrigation by licensed abstractors
- flow through slackers
- seepage through the banks of high level drains.
- evaporation from the surface of the river and from riparian zones.

Some of this outflow is quantifiable from licence returns, but slackers, sub-irrigation and evaporation are difficult to measure. The net result of this flow from the river channels is that gauged flow at Denver is often zero for prolonged periods during dry summers.

Naturalisation is the process of adjusting the gauged record for artificial influences (usually abstractions, effluent, interbasin transfers and reservoirs) to produce a naturalised river flow record. The primary reason for naturalising Denver flows is to enable the production of a denaturalised daily time series of flows for future conditions. These will be used in Ely Ouse - Essex modelling.

It is proposed that the Denver flows should be naturalised by decomposition. This is the process of removing artificial influences from the gauged record to produce a natural record. It is suggested that Denver naturalisation should initially cover the period from 1980 onwards, because of the difficulty of understanding changes in the Fens over the historic gauged record. The method used will be to naturalise the flows to the Fen-edge gauging stations using decomposition, and to estimate losses in the Fens using a water balance approach. This will give sufficient flexibility to allow the calculation of flows for future scenarios.

The project will take about 110 days work, and could be completed in 5 months. The methods suggested build on existing best practice for naturalisation, and will also allow denaturalisation for future conditions. They should be relatively easy to apply because they use existing data. Depending on the success of the naturalisation, it may be possible to extend the naturalised sequences. This could be done either by further decomposition, or by developing a catchment model which relates rainfall to flow.

It is possible that the project will demonstrate that it is not possible to naturalise Denver flows. This is still a positive result. The calculation of the yield of the Ely Ouse - Essex system must be based on the best possible information. If the existing gauged Denver flow record is the best information, the current method can be used with more confidence. Therefore, despite the risk of failure, it is worth attempting this project.

# 1 Introduction

Essex & Suffolk Water and the Environment Agency (Anglian Region) are carrying out a joint project to develop a new computer model of the Ely Ouse - Essex Transfer Scheme. A review of the hydrometric data which feeds the model forms part of this work. This report is the scoping study for naturalising the flow record from Denver on the Ely Ouse.

# 2 Background

The 1968 Ely Ouse - Essex Water Act permitted the construction of a scheme to transfer water from the Ely Ouse at its tidal limit at Denver to the headwaters of the Stour, Colne and Blackwater. This scheme is known as the Ely Ouse - Essex transfer scheme. The main purpose of the transfers is to support abstractions by Essex & Suffolk Water from the Stour and Blackwater; some of the water goes directly to treatment works for public supply but the main benefit is to provide water for the ESW reservoirs at Abberton and Hanningfield. The Ely Ouse - Essex transfer scheme is owned and operated by the Environment Agency.

To predict the behaviour of such a complex system, a computer based numerical model is essential. The existing model evolved from a mainframe model first developed in the late 1970s, and has been used for a variety of studies, including evaluating the impact of the construction of a new reservoir somewhere in the transfer scheme. While the modelling work has been successful, the model itself is difficult to modify and does not have the flexibility required to simulate all possible development options. In January 1996, Essex & Suffolk Water and the NRA agreed to start a project to develop a new model of the Ely Ouse - Essex Transfer scheme. Project objectives are:

- investigate the feasibility of developing a method for the naturalisation of recent and future Denver flows
- identify uncertainties in the understanding of the hydrology of the Essex rivers, and implement investigations to investigate these uncertainties
- ensure that the operation of the relevant components of the Essex & Suffolk Water abstraction system is understood
- develop a specification for a new computer model which meets the needs of both the Environment Agency and Essex & Suffolk Water
- develop this new computer model

This report investigates the feasibility of developing a method for the naturalisation of recent and future Denver flows.

## 2.1 The Ely Ouse catchment

The Ely Ouse catchment is shown in fig. 1. The main tributaries are the Cam, the Lark, the Little Ouse and the Wissey. The Ely Ouse is separated from the Bedford Ouse by a lock at Earith; the Bedford Ouse flows to sea through the Old Bedford River and the Hundred Foot

Drain. Flow from the Bedford Ouse through the Old West to the Ely Ouse is minimal.

The Denver complex is situated at the tidal limit of the Ely Ouse, and marks the point at which the Bedford Ouse and the Ely Ouse join. The Denver complex was built to provide flood protection for the South Level. It consists of a series of sluices which prevent tidal water entering the South Level rivers, and also allow management of flood water by either allowing it to pass through Denver Sluice into the tidal river, or through the AG Wright Sluice into the Relief Channel. The Relief Channel has a steeper gradient than the tidal river and therefore can evacuate water from Denver effectively. The Cut Off Channel meets the Ely Ouse at Denver. This channel was also constructed as a flood alleviation measure, and it diverts flood water from the Lark, Little Ouse and Wissey so that flooding in the South Level is minimised. The gradient of the Cut Off Channel is very shallow, and by raising the water level at the Impounding Sluice the normal flow direction can be reversed. This reverse flow of water is used to provide the first stage of the transfer from the Ely Ouse to Essex. At Blackdyke Intake (near the Little Ouse), water is drawn into a 2.5 m diameter tunnel. At Kennett Pumping Station the water is lifted into a 1.8 m diameter pipe in which it flows to Kirtling Green Outfall, in the Upper Stour. Further down the Stour at Wixoe, a pumping station allows water to be reabstracted for transfer to the upper reaches of the Blackwater.

In their upper reaches, all of the rivers which make up the Ely Ouse are chalk fed streams, and they display the typical high baseflow of such rivers. Although this is one of the driest parts of the UK, baseflow can maintain summer flows in the chalk streams at a reasonably high level, although the upper reaches can suffer when water tables drop. The topographic relief is generally moderate in the chalk catchments. However, at the Fen edge, roughly at the location of the Cut-Off Channel, catchment characteristics change significantly as the rivers flow onto the peat. Channel bed gradients are low, and the rivers run in embanked channels, often above the level of the surrounding land. The South Level Fen is one of the most productive farming areas in the country, and there is great demand for water for arable crops. In summer, water leaves the main river channel in a variety of ways. These include:

- direct abstraction for spray irrigation by licensed abstractors
- abstraction through slackers. These are structures in high level channels which allow water to flow to low level drains. They are not usually licensed or controlled, although subsequent direct abstraction from the low level drains is controlled by licences. Sub-irrigation from the low level drains is not controlled by licences.
- seepage through the banks of high level drains.
- evaporation from the surface of the river and from riparian zones.

Some of this outflow is quantifiable from licence returns, but slackers, sub-irrigation and evaporation are difficult to measure. The net result of this flow from the river channels is that gauged flow at Denver is often zero for prolonged periods during dry summers.

## 3 Flow naturalisation

Naturalisation is the process of adjusting the gauged record for artificial influences (usually abstractions, effluent, interbasin transfers and reservoirs) to produce a naturalised river flow record. Natural flow records are useful for many purposes. They allow estimation of the natural variability of river flows in the catchment, and help to quantify the impact of abstraction on the natural flow regime. They are essential in reservoir yield analysis.

A daily simulation model is used to calculate the yield of the Essex reservoirs. Reservoir yield is calculated as the volume of water which can be taken out of the reservoirs on each day of the historic record without reservoir failure. Failure is defined as the emptying of one of the reservoirs. For pumped storage reservoirs where water is drawn from catchments with significant artificial influences, it is necessary to naturalise river flows.

The naturalised record can be denaturalised for a future year of interest, by estimating abstractions and effluent for that year and adjusting the natural record accordingly. The yield of the system can be calculated for the year of interest, which is chosen according to water resource planning requirements. Running the whole denaturalised flow record through the model examines the behaviour of the reservoir system through the complete range of climatic inputs experienced during the historic record.

In the Ely Ouse - Essex system, naturalised flow records have been calculated for the Essex rivers back to 1933, when gauging began in Essex. The flow record at Denver starts in 1922, but has not been naturalised because of the problems of understanding how the Fens behave. In the model, the gauged record has been used; this is considered to be a weakness of the current approach. It presents a particular problem because the critical drought in the Ely Ouse - Essex system occurs during 1933 and 1934; there is little understanding of how catchment changes have affected flows since 1933, and therefore it is not clear how river flows would respond to a repeat of the 1933/34 climatic conditions. Watts (1994) compared the rainfall and flows of 1933/34 and 1990/91. Rainfall totals and patterns were roughly similar, and Denver flow was also similar. This implies that net change in the catchment had not affected flows in very dry years, and probably has had little impact on the historic yield of the system. This is at least partly because in dry summers there is little or no flow at Denver and the yield is controlled by flows in the Essex rivers. However, when evaluating the benefits of additional capital developments, the enhanced reliability of supply through droughts less severe than the worst becomes important. For this purpose, a naturalised flow record for Denver is essential. Naturalised Denver flows are also important in the comparison of drought severity and will be essential if an estimate of the impact of climatic change on flow and Essex yield is to be made.

Watts (1994) concluded that it may not be possible to produce accurate naturalised flows for the complete Denver record, because of the difficulty of understanding the complex interaction between the river and the Fens. However, it should be possible to gather sufficient information to naturalise recent and future flows.

## 4 Purpose of naturalisation of Denver flows

The primary reason for naturalising Denver flows is to enable the production of a denaturalised time series of flows for future conditions. These will be used in Ely Ouse - Essex modelling. To meet this purpose, naturalisation needs to account only for those artificial influences that have changed in the past, or may change in the future. Influences which can change only slightly do not need to be quantified.

A secondary reason for naturalising Denver flows is to compare drought severity and to estimate the impact of potential climate change on flow. This may be done by feeding a rainfall-runoff model with different rainfall and evaporation series and comparing the resulting flows with those of the existing climate. To calibrate such a model, a fully naturalised flow sequence would be necessary.

# 5 Possible methods for naturalisation of Denver flows

Two main methods are available for flow naturalisation. These are catchment modelling, and decomposition.

## 5.1 Catchment modelling

Naturalisation by catchment modelling involves setting up some sort of simulation model to represent the complete catchment, including artificial influences. The model uses rainfall and evaporation time series as input, and produces estimates of flow. The model is calibrated to produce an acceptable representation of gauged flows, and then run again but with all of the artificial influences set to zero. The resulting flow sequence represents natural conditions.

Catchment modelling is often a good way to naturalise flows. If the right model is chosen, groundwater abstractions are handled in a physically meaningful way. The resulting catchment model can also be used for scenario analysis, answering questions about the potential for additional resource development or climate change. It can also be used to extend flows to period for which a rainfall record but no flow record exists.

There are some drawbacks associated with the use of catchment modelling for naturalisation. Rainfall-runoff models are often used for simplicity; however, these tend to smooth flow variability so that they overestimate low flows and underestimate floods. It is often difficult to make the model represent the gauged flows accurately, with the result that the naturalised flows can not be considered to be reliable. Applying a catchment model also requires a good understanding of the way that artificial influences affect flows in the catchment. Therefore catchment modelling is a good way of estimating natural flow sequences in simple catchments where the way that artificial influences affect flows is well understood, and where it is shown that the model calibrates well.

## 5.2 Decomposition

Naturalisation by decomposition is an alternative to rainfall-runoff modelling. Decomposition is the term used to describe the process of adjusting gauged flows to create a natural flow sequence. Adjustment is done by consideration of actual abstraction and effluent values. A time series of net artificial influences is created; this can be added to the gauged flows to create a naturalised record. Care must be taken when dealing with groundwater abstractions because their impact on river flow is lagged and smoothed by the aquifer. Usually a simple model which relates impact on the stream to aquifer properties and distance from the stream is used to calculate the impact of time-variant groundwater abstractions. Groundwater abstractions which vary only slightly over time can be dealt with more simply.

Naturalisation by decomposition requires a good understanding of the time series of artificial influences (as does naturalisation by modelling). It often makes oversimplified assumptions about the impact of groundwater abstractions, but it does have the advantage of being simple and replicable. Decomposition can not be used to extend naturalisation beyond the period of gauged record, but it is reliable and easy to understand. Decomposition can legitimately be used to produce semi-naturalised flow sequences, where account has been taken only of some influences. In a flow sequence naturalised by hydrological modelling, it is implied that all significant artificial influences have been included. This is reasonable for simple catchments but may present problems where there are major unquantifiable influences, such as in Fenland areas.

# 6 Options for naturalisation of Denver flows

In a system with the complexity of the Ely Ouse, naturalisation by decomposition is the logical way forward. While it will not directly allow extension of the naturalised record, the advantages of transparency and an ability to deal with partial naturalisation make this the most satisfactory approach.

Having selected decomposition as a naturalisation method, there are two main options. These are:

- partial naturalisation for known influences based only on Denver record
- partial naturalisation for known influences for each subcatchment, and analysis of gauged records and meteorological data to identify behaviour of the Fens

## 6.1 Naturalisation based on Denver record

Naturalisation of the Denver record would be carried out by identifying all artificial influences upstream of Denver (including those in the subcatchments above the Fens), and naturalising the Denver flow for these. This would be relatively simple, but there are some problems with this approach. There are losses from the Ely Ouse in the South Level which will still be unquantified. If all abstraction in the catchment were to stop, it is unlikely that all of the extra water would reach Denver; during summer some of it would probably be lost by evaporation and seepage. This would lead to particular problems for future abstraction scenarios. The impact of decreased abstraction (or increased effluent) would be overestimated. Alternatively, if abstraction were to increase in one of the catchments upstream of the Fens, the resulting denaturalised flow sequence at Denver would be negative, which is unreasonable.

Naturalisation for known influences alone would provide no extra information about the behaviour of the Fens and would be unsuitable for the prediction of the response of the catchment to future artificial influence scenarios. This does not meet the needs of the project.

### 6.2 Naturalisation for subcatchments and Denver, with data analysis

This option involves naturalisation of flows at the downstream gauging stations of the subcatchments of the Ely Ouse, together with the production of a time series of known artificial influences for the Fens. Decomposition will be used for naturalising flows in the river subcatchments. Abstractions and effluents in the Fens will be aggregated to produce a time series of other known artificial influences. Influence data is available monthly for most abstraction types; this resolution is probably appropriate for the Fens where the direct impact on the main river channel will not occur at the same time as an actual abstraction from a Fen drain. Analysis of gauged flows from the subcatchments together with the time series of Fen artificial influences will help to show the water balance of the South Level. In particular, it will be important to try to define how much water can be lost from the river channel. This is probably related to climatic and catchment conditions; relationships between the time series of unaccounted water and temperature, potential evaporation and soil moisture deficit will be sought. The result should be a time series of potential outflow from the channel. This will be used in denaturalisation for future conditions. The natural flows at the bottom of the subcatchments will first be denaturalised for the future conditions. These will provide a series of flows arriving at the South Level. The potential outflow time series will be used to identify how much of the flow arriving at the South Level would be lost from the river channel. Combining this with the time series of Fen artificial influences will allow the estimation of a time series of flows arriving at Denver under the future scenario.

The analysis described here will make the fundamental assumption that there is little or no change in the characteristics of the South Level that affect the volume of water arriving at Denver. Depending on the result of the analysis relating losses to catchment conditions, it may be possible to identify factors which have a clear influence on the volume of water arriving at Denver. However, this may not be possible, and therefore the initial analysis should be limited to a period over which the assumption of little change in the South Level is reasonable. The period from 1980 onwards should be suitable. While this method will not provide a complete natural flow record for Denver, it will be a great improvement on what is currently available, and it should be possible to update the analysis routinely. The improved understanding of catchment processes will also allow further studies which may help to identify more closely the factors that influence Denver flow.

### 6.3 Preferred option

The preferred option is that described in Section 6.2; to naturalise the Fen edge gauging station records and use these to create a naturalised Denver record. This option is flexible and meets the requirements of the project.

## 7 Field investigations

It has been suggested that field investigations are necessary before Denver naturalisation can be contemplated. The investigations would try to assess otherwise unquantified losses from the catchment, by looking for uncontrolled slackers and assessing flow through them. In principle, it would also be possible to gauge the main channel at different locations to try to assess losses or gains.

It is clear that such additional information would add to the confidence of any naturalisation results, and would help greatly in the interpretation of catchment behaviour. However, to be sufficiently comprehensive, the field programme would have to be extensive. Many kilometres of river would have to be investigated closely to identify slackers. With existing technology, gauging the main channel of the river with any accuracy would be very difficult. Developments in Acoustic Doppler profiling may make this task more practical; the Environment Agency National R&D project will help to indicate the feasibility of this.

At this stage it would be very difficult to design a field programme that addressed the problems of Denver naturalisation. After the initial naturalisation based on existing data has been carried out, it may be possible to target field investigations more accurately. It is proposed that at this stage no field investigations should be carried out, but that part of the naturalisation project conclusions should address the need for further work.

# 8 Project plan

In summary, it is proposed that Denver naturalisation should initially cover the period from 1980 onwards. The method used will be to naturalise the flows to the Fen-edge gauging stations using decomposition, and to estimate losses in the Fens using a water balance approach. This will give sufficient flexibility to allow the calculation of flows for future scenarios. Detailed tasks are:

### i Configure naturalisation software for Ely Ouse

It is proposed that flow naturalisation should be carried out using decomposition software (known as NATFLOWS) developed by the Institute of Hydrology for the Essex Rivers naturalisation study. This software combines the map interface of Micro LOW FLOWS with the time series database of HYDATA. Configuration for the Ely Ouse will simply require the map interface for the catchment to be loaded. This may already have been carried out by the time the naturalisation work starts.

### ii Load artificial influence data for the Ely Ouse

Loading artificial influence data from the licensing and discharge consents database is relatively straightforward. However, it is also necessary to check that the data is correct, and to fill gaps in actual abstraction and discharge data. Particular problems occur where abstraction licences have more than one source. Discharges always present problems, because there is little information available about actual flows. Strategies for reducing the size of the task include identifying those licences and discharges which are significant based on some threshold criteria. However, verifying artificial influence data is still time consuming and difficult. This will be a major task.

### iii Produce natural flow sequences for the Fen edge gauging stations

NATFLOWS will produce natural flow sequences readily, once the artificial influence data has been loaded. These will have to be verified using double mass plots to ensure that they are consistent and sensible. At this stage some revision of the artificial influence data will probably be necessary. The production of naturalised flows using NATFLOWS tends to be an iterative process.

### iv Produce artificial influence sequence for the South Level catchment

NATFLOWS will be used to develop an artificial influence sequence for the South Level catchment between the Fen edge gauging stations and Denver. This will be a time series of known artificial influences in the catchment. Some of these will be abstractions from Fen drains; while these are not direct abstractions from the Ely Ouse, they will still be included because they must have an indirect impact on river flows.

### v Calculate unquantified catchment flows

Using gauged flows at the Fen edge stations and the South Level artificial influence series, the unquantified catchment outflows can be estimated. These will be positive in summer, and negative in winter. The winter values reflect pumping from the low lying Fens, and should be related closely to winter rainfall totals. The summer outflows are made up of evaporative losses from the channel and riparian zones, and subirrigation (which needs no abstraction licence).

### vi Relate catchment outflows to other factors

All summer outflows are the result of net evaporation from the catchment, whether it is from the river itself, from the riparian zone, or from crops irrigated by subirrigation. As such it should be possible to relate the outflow sequence to either MORECS potential evaporation or temperature. Catchment rainfall will also have to be taken into account. Until this analysis is carried out, the nature and strength of the relationships developed is uncertain. It is possible that no clear relationships will be present. If this is the case, Denver naturalisation will be uncertain. However, it should be possible at least to produce a maximum outflow series, which can be used to provide a pessimistic future denaturalisation flow.

Outflows need to be related to other factors in order to estimate whether the sequences experienced in the past were constrained by climatic conditions or by water availability. This has important consequences for naturalisation. If climatic conditions controlled outflows, naturalisation can use the actual outflows to estimate what would have happened in the Fens. However, if outflows were constrained by water availability, it will be necessary to use maximum potential outflows in naturalisation and denaturalisation.

### vii Naturalise Denver flows

Assuming that a reasonable estimate of losses in the Fens can be made, Denver flows can be naturalised. There are two methods, depending on the outcome of the calculation of maximum potential Fen outflows. If the maximum potential Fen outflows are the same as the actual outflows, the Denver flow record can be naturalised directly. However, maximum outflows will probably not be equivalent to actual outflows. In this case, an indirect method for Denver naturalisation must be used. The combined naturalised record of the upstream gauging stations will be adjusted according to the potential outflow series to give a naturalised Denver flow record.

The derived natural Denver flow record is mostly of academic interest, since in reservoir yield modelling a denaturalised flow record will be needed.

### viii Denaturalise Denver flows for future years

In this project, the most important part of this task will be to establish methods for denaturalisation. To a certain extent, the methods used will depend on the results of previous parts of the study. However, it is most likely that an indirect method for the denaturalisation of Denver flows will be necessary. The Fen edge gauging station records will be denaturalised for the future conditions. If necessary, the potential Fen outflow series will be adjusted for future conditions. The combined Fen edge denaturalised record will be adjusted according to the future potential Fen outflow series to give a denaturalised Denver record.

### ix Make recommendations about accuracy and the potential for further work

It will be necessary to assess the accuracy of any derived records, compare them with the gauged Denver record, and make recommendations about how the derived records should be used. At the same time, the potential for further work should be considered. This will address the possibility of extending the naturalisation process, or deriving long naturalised records by modelling. The possibility of increasing the accuracy of the work as a result of field investigations should also be investigated.

## 9 Timetable

A proposed project plan is given in Figure 2. The duration of the later stages of the plan is highly dependent on the results of earlier stages, but the plan gives a reasonable indication of how long the work should take. It should be noted that all times in this plan are based on task time, rather than elapsed time. The plan suggests that the project will take about 110 days work, and could be completed in 5 months. However, some margin is built into the times for each stage and it is possible that the complete project could take less time.

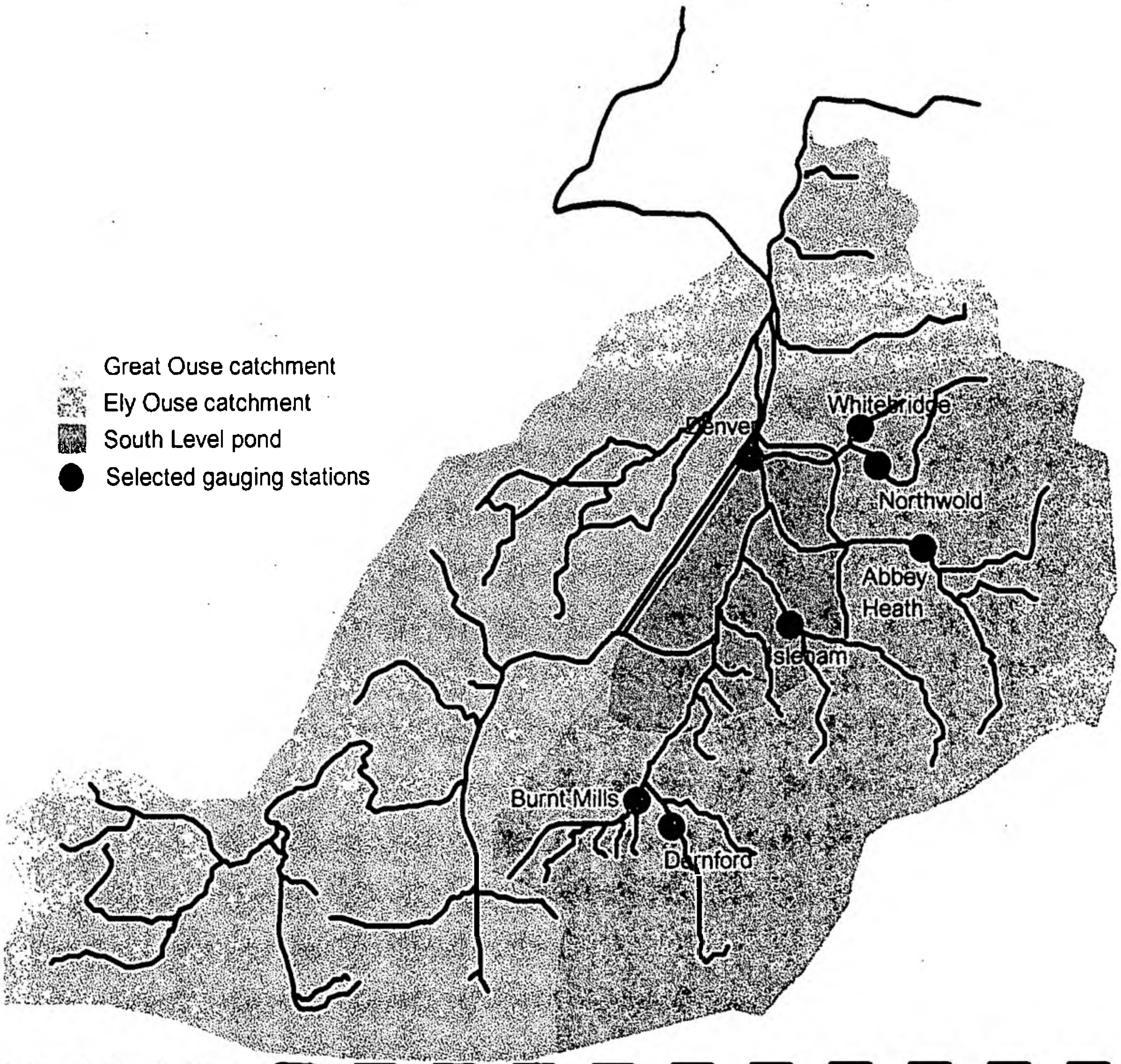
# 10 Conclusions

This report identifies a way to produce an estimated natural time series of Denver flows. The methods suggested build on existing best practice for naturalisation, and will also allow denaturalisation for future conditions. They should be relatively easy to apply because they use existing data. In the first instance it should be possible to naturalise flows from 1980 onwards. Depending on the success of the naturalisation, it may be possible to extend the naturalised sequences. This could be done either by further decomposition, or by developing some sort of catchment model which relates rainfall to flow.

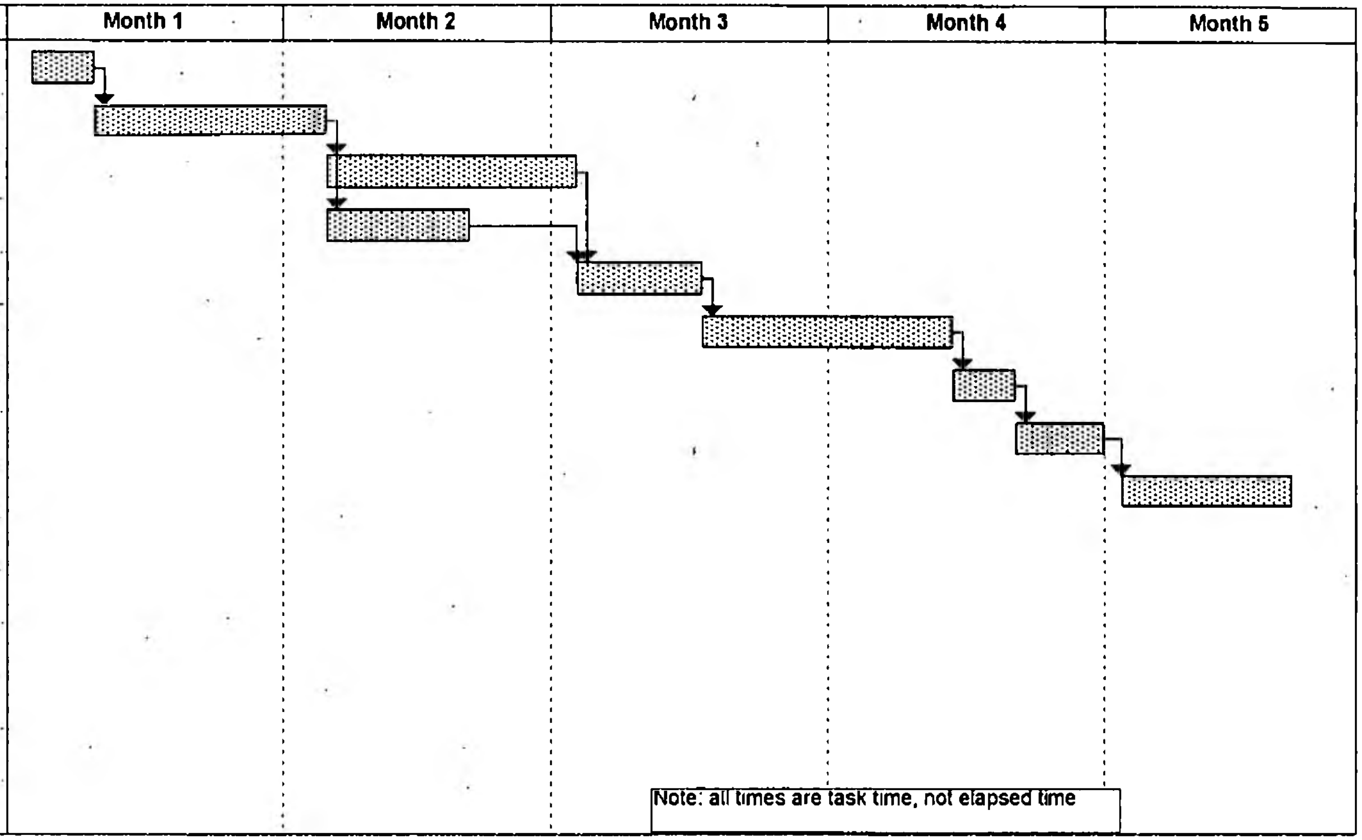
It is possible that the results of the work will suggest that Denver naturalisation is not feasible given the current state of information about the catchment. It may be possible to gather more information by a programme of fieldwork. Even a firm conclusion that Denver naturalisation is impossible is still a positive result. The calculation of the yield of the Ely Ouse - Essex system must be based on the best possible information. If the existing gauged Denver flow record is the best information, the current method can be used with more confidence. Therefore, despite the risk of failure, it is worth attempting to naturalise Denver flows.

There has been no discussion of who might carry out the naturalisation process. The NATFLOWS software belongs to the Environment Agency and can therefore be used for the project. Configuration of the software for the Ely Ouse catchment will have to be carried out by the Institute of Hydrology, although this may have already been done by the time the project starts. Some of the work involved in loading the artificial influence data will have to be carried out by Environment Agency staff, although some input from the Institute of Hydrology may also be necessary. Because of the commercially confidential nature of the artificial influence data, it may not be possible to allow Essex & Suffolk Water to be involved in any detail in this part of the project.

Once the influence data has been bulk loaded, other modifications are carried out within the NATFLOWS software. The rest of the project could be carried out by any competent hydrologist. It would be logical for the Environment Agency to manage the project because experience in flow naturalisation has already been developed. The exploratory nature of some of the later phases of the work may make it difficult to let the project as a fixed price contract. Some way of dealing with what will inevitably be an iterative process needs to be developed. Discussion of this and many other aspects of the project is essential.


Great Ouse catchment
Ely Ouse catchment
South Level pond
Selected gauging stations
Denver
Whitebridge
Northwold
Abbey Heath
Isleham
Burnt Mills
Darnford

| ID | Task Name | Duration |
|---|---|---|
| 1 | configure naturalisation softw | 5d |
| 2 | load artificial influence data | 18d |
| 3 | produce Fen edge nat flows | 20d |
| 4 | produce S Level art influence | 12d |
| 5 | calculate Fen outflows | 10d |
| 6 | relate outflows to other factor | 20d |
| 7 | naturalise Denver flows | 5d |
| 8 | Denaturalise Denver flows | 8d |
| 9 | Recommendations & report | 15d |



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