IH/S-184/DWR

FLOOD WARNING SYSTEM, DUMFRIES
FEASIBILITY STUDY

5 October 1984

CONTENTS

1. REVIEW OF FLOOD WARNING PROBLEM

1.1 INTRODUCTION

The process of flood warning has three main elements:
information gathering (data collection)
analysis (flood forecasting calculations)
action (preparation & dissemination of warnings)
A microprocessor controlled flood warning scheme for Dumfries would encompass the first two elements and, if required, part of the third. While other factors - such as communication, management and funding - inevitably impinge on the final design of a flood warning scheme, the principal considerations are the nature of the warning problem and the hydrology of the catchment.

1.2 THE PROBLEM

The requirement is to give improved warning of flooding in Dumfries. A reasonable aim is to forecast inundation six hours before it occurs; this is a typical objective in UK flood forecasting problems and allows (say) two hours for preparation & dissemination of the warning and four hours for action by recipients.

A characteristic of the Nith in Dumfries is the weir known as the Caul. In normal conditions the river is tidal below the Caul and non-tidal above. In the most recent serious flood (Dec. 1982), inundation occurred both upstream of the Caul (at Greensands) and adjacent to, and immediately downstream of, the Caul (at Whitesands). It is evident from records at Whitesands that the water level there is susceptible to tidal influence. If the flood warning scheme is to cater reliably for properties throughout Dumfries then it is probably necessary to take some account of the tidal effect.

Earlier studies

Three recent reports relate to the flooding problem at Dumfries:

SANDERS (1984) This B.Sc. dissertation discusses the flood hazard at Whitesands, with particular reference to the December 1982 event and its impact. The report makes a number of interesting points. First, the properties inundated in December 1982 were business premises not residences. On the basis of an intensive survey (by questionnaire), Sanders comments that the traders affected have a resigned attitude towards the problem: "the river is extracting its natural rent". A further point arising from the survey was that many believed that improved flood warning was

either not needed or would not help. One interpretation is that the standard of flood warning received in recent events has been quite satisfactory. Finally, several traders believe that flooding is exacerbated by tides. This is indeed sometimes the case and Sander's rejection of tide as an influence on flooding at Whitesands is unjustified.

BABTIE, SHAW & MORTON (1983) This report resurrects proposals for flood alleviation works to reduce the frequency of inundation. It is clear that any practical scheme will merely make inundation a little less frequent. Should a flood alleviation scheme go ahead then the need for an effective flood warning scheme will be increased, since the flood behaviour of the river will be denaturalized and public awareness of flood risk inevitably confused. The report confirms that flooding at Whitesands is influenced by tide but suggests that the effect is relatively less important in an extreme event. However, given that the flood warning scheme is required to work for both major and minor events, there remains a need to take account of tidal conditions in the forecasting method.

WILLING (1984) This M.A. dissertation is concerned primarily with rainfall/runoff modelling. It is rather inconclusive. The model structure chosen is somewhat similar to that proposed below for forecasting flows on one of the tributaries of the Nith; however, the analysis - particularly with regard to the time delay parameter of the model - is flawed.

1.3 THE CATCHMENT

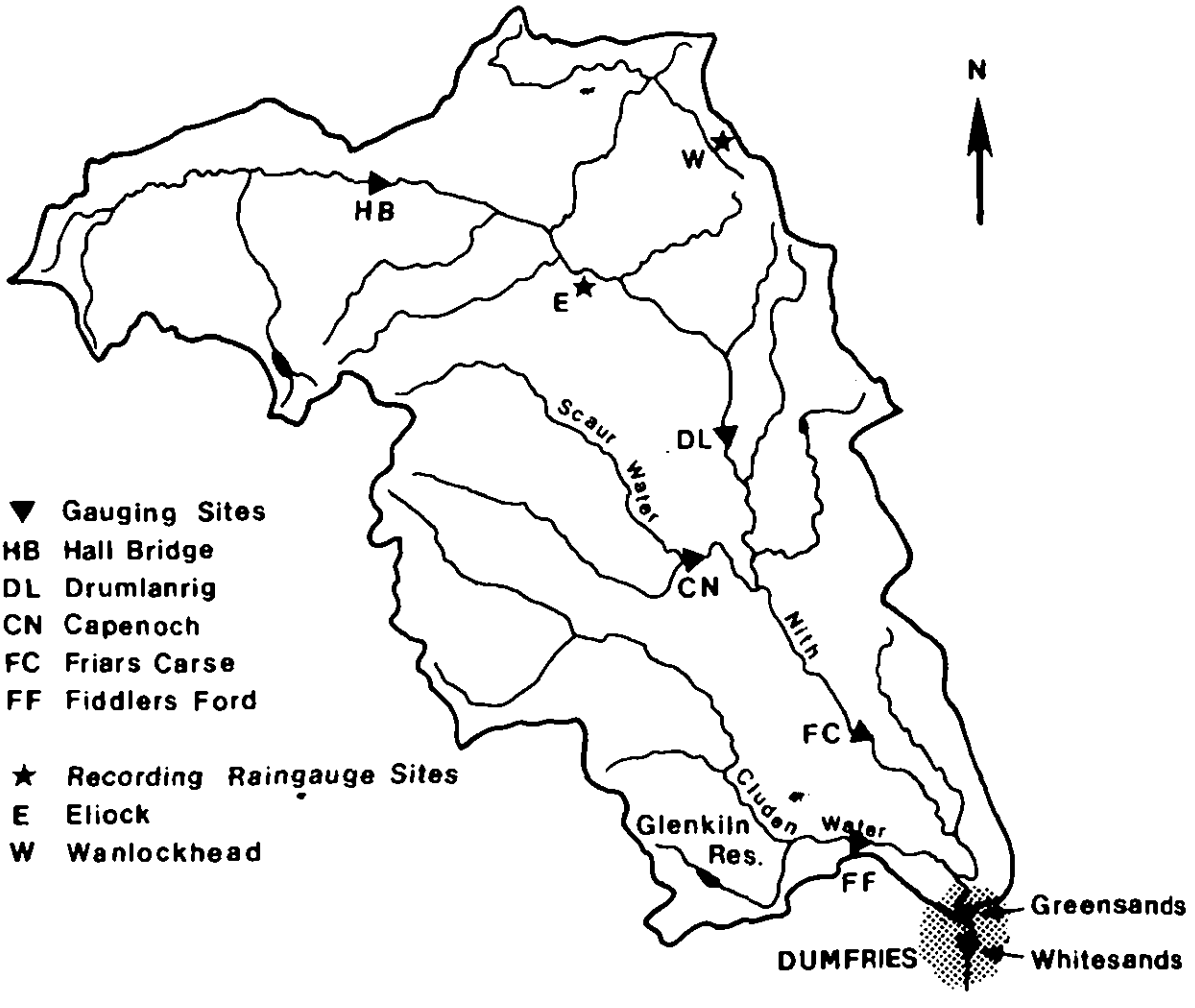
The Nith catchment can be considered in two parts: a Northern area draining through the Southern Uplands to Drumlanrig, and a Southern area contributing runoff between Drumlanrig and Dumfries.

Comparison of river level hydrographs at Drumlanrig and Greensands (Dumfries) shows a reasonable correspondence in response shape. Generally, the flood peak at Dumfries occurs six to nine hours after that at Drumlanrig. This delay is sufficient to make the Drumlanrig gauging station very relevant to flood warning for Dumfries. In this context the gauging station at Friars Carse is of less value (since it can provide a warning time of perhaps only three hours) and that at Hall Bridge is largely irrelevant (since the flood wave travel time from Hall Bridge to Dumfries is much greater than the required period of warning). By placing reliance on the Drumlanrig gauging station it is possible to dispense with rainfall measurement and rainfall/runoff modelling of the Northern area.

Tributaries that join the Nith downstream of Drumlanrig are of some significance for flood warning. The gauging station on the Scaur Water (Capenoch) is highly relevant, since the travel time

of flood peaks from Capenoch to Dumfries is only a little shorter than from Drumlanrig. However, the gauging station on the Cluden Water (Fiddlers Ford) provides insufficient "lead" time to be of prime importance for flood warning for Dumfries. To achieve a 6 hour warning time it is necessary to forecast flows on the Cluden from rainfall, as it is for the remaining ungauged tributaries between Drumlanrig and Dumfries. It is relevant to note that the response (to rainfall) of the Cluden Water is characteristically slower than that of other tributaries of the Nith, making the short-term forecasting of flow from measured rainfall quite practical.

FIG. 1 Nith catchment



2. PROPOSED FLOOD WARNING SCHEME

2.1 OUTLINE

The proposed method of flood forecasting considers the Nith catchment in five parts:

NAME	GAUGING STATION	SUBAREA (km**2)	TOTAL AREA (km**2)
Upper Nith	Drumlanrig	471	
Scaur Water	Capenoch	142	
Middle Nith	Friars Carse	186	799
Cluden Water	Fiddlers Ford	238	
Lower Nith	Greensands(Dumfries)	75	1112

Figure 2 summarizes the basic model structure.

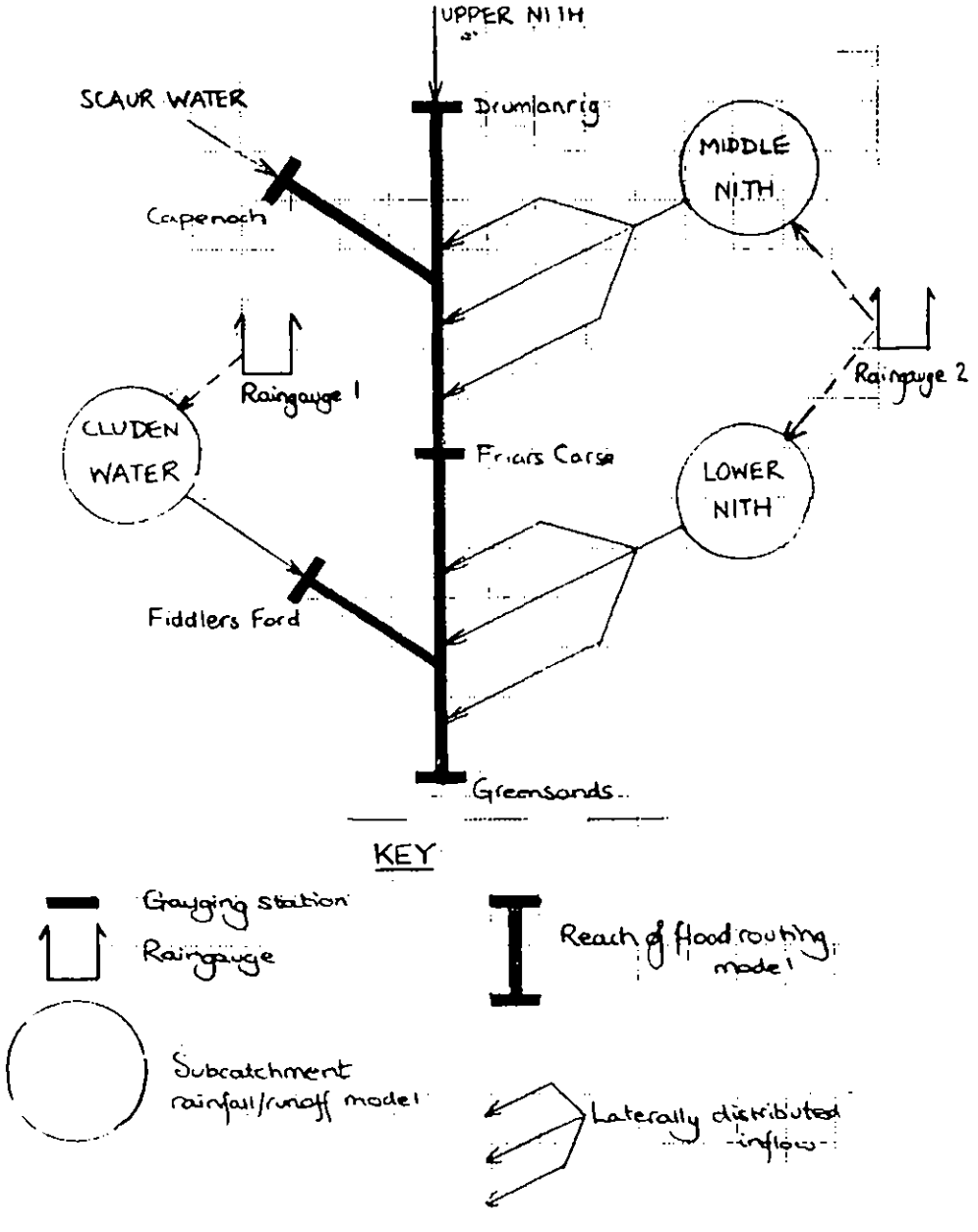


FIG. 2

2.2 OUTSTATIONS

Eight outstations are proposed in the system: four gauging stations (Drumlanrig, Capenoch, Friars Carse and Fiddlers Ford), two river level gauges (Greensands and Whitesands), and two raingauges (new sites). As explained above, rainfall in the Upper Nith is largely irrelevant to 6 hour ahead forecasts for Dumfries. It is not therefore proposed to telemeter the existing automatic raingauges at Eliock and Wanlockhead. Two new automatic raingauges are required as follows:

Raingauge 1 : Cluden Water subcatchment (eg. Dunscore)
Raingauge 2 : Middle/Lower Nith subcatchments (eg. east of Thornhill)

A suitable interface for the gauging stations will work from an Ott optical shaft encoder fitted to the existing float wires. Similarly, an additional pressure transducer sensor will be installed in the common airway of the 'bubbler' river level gauges.

It is envisaged that a data storage capability will be provided at outstations, to avoid the need for very frequent interrogation by the basestation.

2.3 BASESTATION

It is proposed that the basestation should be sited at the River Purification Board's new main office to the north of Dumfries. The principal item of equipment will be an 8-bit or 16-bit microcomputer whose main tasks will be to:

control the telemetry system
execute the flood forecasting software
issue necessary status and alarm messages.

2.4 TELEMETRY

There are two basic options for telemetry: radio or telephone. In large communications systems there may be merit in a combined approach: eg. using radio for the 'spine' of communications and telephone for the peripheral parts. However, in a small and specific application such as a flood warning scheme for Dumfries, a mixed system is inappropriate.

The radio option

Radio telemetry is a feasible option for the Dumfries flood warning scheme but is not the preferred one (see below). Some design factors affecting application of the radio option to the Dumfries problem are noted in Appendix A.

The telephone option

Use of the British Telecom (BT) telephone network offers a relatively simple solution to the telemetry problem. Compared to radio, a telephone system is much easier to design since the details are to a large extent independent of site. Several manufacturers offer semi-standard equipment and system software for flexible interrogation of a network of outstations using BT communication.

The one site-dependent factor is the ease or difficulty with which a telephone line can be brought to the outstation. For the base-station (at the RPB offices) and the two town stations (Greensands and Whitesands) there is patently little problem. In other cases, for example at Fiddlers Ford, there is perhaps more expense than at first appears. (Telephone lines pass close to the gauging hut but a connection entails a road-crossing and possibly a considerable run to the nearest junction box.) In one instance (Drumlanrig) there may well be considerable expense in providing a connection; relevant factors may be distance, crossings, visual impact & land ownership.

Preliminary discussion with regional staff of BT indicate that there will be no insurmountable problems and that connection charges will range from £85 for the simplest cases to £500-1500 for the more difficult ones (namely: Fiddlers Ford, Friars Carse, Capenoch & Drumlanrig). BT will provide free estimates on request.

Comparison of radio and telephone options

The advantages of radio include fast response and low running costs, which are particularly relevant if very frequent interrogations are required. However, this requirement can be avoided if (as in the proposed system) outstations with a limited degree of intelligence are deployed. A further advantage of a radio system is that it is relatively self-contained and generally under exclusive control.

Radio propagation is not usually affected by flooding although equipment can sometimes be disabled by electrical storms. Aerials in particular can be a target for vandalism.

The telephone option has the advantage of flexibility (site changes being relatively easy to accommodate) and robustness (there is a certain degree of design redundancy in BT telephone networks). Although historically rather unreliable and prone to disablement by flooding, telephone communication is now fairly reliable and there appear to be no undue difficulties in the

Dumfries area.

There are two decisive factors which come down in favour of telephones. Firstly, both capital and maintenance costs are significantly less for telephones than for radios. Part of this is inherent in the nature of the equipment; but there are particular difficulties in constructing a radio system for the Dumfries application (see Appendix A). As regards maintenance costs, in the case of telephones these are met out of the standing quarterly charge (which is fairly minor) whereas it is estimated that the radio option would require a maintenance contract of about £2000 per annum.

The second influential factor in the choice is the difficulty of gaining the necessary frequency allocations and approvals for a radio system. It appears likely that Department of Trade and Industry regulations will become even more restrictive in 1985 for this type of application.

It is therefore manifest that telephone telemetry is the appropriate choice for the Dumfries system.

2.5 FLOOD FORECASTING METHOD

The flood forecasting method proposed comprises a flood routing model , one or more rainfall/runoff models, and "real time correction" of forecasts by use of telemetered river level data.

Flood routing

It is proposed to use the variable parameter Muskingum-Cunge (VPMC) method of flood routing to represent the river network downstream of the Drumlanrig, Capenoch and Fiddlers Ford gauging stations (see Fig. 2). This will require survey data for the channel and flood plain at representative sections of the river (eg. about every 1 km). A simple empirical method of flood routing will also be calibrated to confirm that the VPMC method is providing a useful refinement.

Rainfall/runoff

Experience suggests a nonlinear storage model for the Cluden Water subcatchment. Various forms are possible, of which the modified IEM (used in the Haddington flood warning scheme) may be appropriate. Depending on the outcome of the flood routing study, a rainfall/runoff model may also be calibrated to represent ungauged tributary and lateral inflows between Drumlanrig and Friars Carse and between Friars Carse and Dumfries.

Real time correction

Opportunities for "real time correction" of forecasts are provided by the Friars Carse and Fiddlers Ford gauges. It is anticipated that the latter will be best used to "state-update" the Cluden Water subcatchment model forecasts; this means that the forecast made by the rainfall/runoff model will always agree with, and project from, the latest telemetered flow. Observations from Friars Carse might be used to correct flood forecasts in several ways. However, it is proposed that the Friars Carse flow should merely be monitored by the system to provide an independent check on the flood routing model. Should the simulated flows at Friars Carse deviate by a significant amount, the system will flag the occurrence and, if necessary, raise an alarm based on the Friars Carse telemetered reading.

Interpretation of forecasts

Finally, there is the crucial question of interpreting the forecasts made for Dumfries. The flood routing model will yield a flow forecast for Greensands which will be converted to river level using an approximate rating equation. (The latter will be developed in collaboration with the Board.) Successive observed river levels at Greensands will be compared with the corresponding modelled values, and a corrected forecast constructed by "blending" the two sources of information. Should the observed and

modelled values differ seriously, the system will flag the occurrence and, if necessary, raise an alarm.

Tidal interaction

The main product of the flood forecasting method will be river level forecasts for Greensands. However, some allowance for tidal interaction is desirable in respect of flood warnings for Whitesands. It is impractical within the scope of a fairly simple, self-contained system to model the tidal influence in detail; a particular difficulty is the forecasting of storm surges. However, the existence of tide level records for Glencaple provides a means of predicting the astronomical component of the tide with considerable accuracy. It is therefore proposed to derive a model (based on harmonic analysis) for predicting the tide level at Glencaple. This work will benefit from the considerable expertise gained by the Institute of Oceanographic Sciences, a sister body to IH. It is envisaged that the flood warning scheme will check the possible coincidence of a forecast river flood with a high 'spring' tide. In such an eventuality a special alarm message will be triggered advising of the likely tidal interaction and requesting the duty officer to obtain a forecast of the storm surge (eg. through the 'Operation Neptune' system run by North West Water).

A utility program will be provided to enable the Board to adjust the criteria for raising alarms and flood warnings in the light of experience with the system.

2.6 DATA REQUIREMENTS FOR MODEL CALIBRATION

Rainfall and river level data

Records from the following gauges will be relevant to model calibration:

River level (hourly)	79006	Drumlanrig
	79004	Capenoch
	79002	Friars Carse
	79005	Fiddlers Ford
		Greensands
Rainfall (hourly)	610123	Eskdalemuir ***
	620785	Wanlockhead
	621335	Eliock
	624348	Lochruttan W. Wks.
	629433/4	Glenlee ***
Rainfall (daily)	620168	Afton Filters No.4
	621206	Euchan Filters
	621335	Eliock
	621736	Drumlanrig Castle No.1
	621742	Drumlanrig Castle No.2
	621983	Kettleton Filters
	622644	Capenoch
	622885	Blackwood
	623619	Maxwelton House
	623954	Glenkiln Res.
	624032	Newtonairds
	624179	Dumfries, Crichton Royal
	624348	Lochruttan W. Wks.
	624438	Dumfries, Drungans Factory
	628177	Cornharrow
	628309	Fingland
	649970	New Kirkhope
	649972	New Crookburn
	650291	Peden Res.

*** Only required for events for which none of three nearest gauges (viz. 620785, 621335 & 624348) is available.

Data will be required for as many recent flood events as possible, eg.:

27sep80	20nov80	4jan82	18oct82
7oct80	20sep81	13feb82	6nov82
28oct80	24sep81	24sep82	19dec82
14nov80	2oct81	27sep82	2jan83

plus selected major historic events, eg.:

jan62 sep62 aug66 dec72 oct77

The Institute already holds considerable quantities of the above data, together with details such as rating equations. However, no data are held for the Lochruttan and Glenlee recording raingauges, of which the former is particularly relevant. The additional data will be sought primarily through the Board; the attached cost estimates make no allowance for special visits to inspect and extract data, and only limited allowance for further chart digitization.

Channel & flood plain survey

The attached cost estimates assume that the required survey data (see Section 2.5) will be obtained by the Board's own staff, in collaboration with the Institute.

Tide data

It is assumed that data from the tide gauge at Glencaple will be available to the project. A minimum of 1 year's continuous data is required for calibration of the tide prediction model. Copies of the tide gauge record for many of the recent flood events are also desirable so that comparisons can be made between tide behaviour at Glencaple and that at Whitesands.

3. COST ESTIMATES FOR RECOMMENDED SCHEME

MODELLING (IH)

ACTIVITY	MAN-MONTHS
Mapwork, digitizing, data processing etc	1
Calibration & testing of basic models	3
Tidal analysis (data processing & harmonic anal.)	1
Construction & testing of real time version	1
Preparation of report on modelling work	0.75
Implementation on basestation computer	1
Contribution to manual describing system use	0.25
TOTAL	8.0

	£K
STAFF COSTS : 6.5 SSO man-months :	15.2
(FEC rate, 1984/85) : 1.5 ASO man-months	1.6
SUB-TOTAL	16.8
COMPUTER COSTS (mainframe)	3.0
TRAVEL, SUBSISTENCE ETC :	0.4
TOTAL (MODELLING SUBPROJECT)	20.2

SYSTEM (CONTRACTOR)

Microcomputer controlled telemetry scheme comprising:
- 8 outstations
- 1 basestation

using BT telephone communication, and providing:
- instrument interfaces
- user interfaces
- systems software
- facilities for executing modelling software

	£K
TOTAL (SYSTEM SUBPROJECT)	60.0

SYSTEM CONSULTANT (OPTIONAL-IH)

System specification, selection of contractor & acceptance testing

COST ESTIMATES FOR RECOMMENDED SCHEME

		£K
STAFF COSTS (FEC rate, 1984/85)	4 SSO man-months :	9.3
TRAVEL, SUBSISTENCE, ETC.		0.6
TOTAL (CONSULTANCY SUBPROJECT)		9.9
GRAND TOTAL		90.1

4. ALTERNATIVE SCHEMES

Alternative A

Omit telemetering of Friars Carse & Fiddlers Ford gauges. This would reduce hardware costs (by two outstations) and eliminate the modelling work dealing with real time correction (say, 1.25 man-months). However, the approach would place great reliance on the flood routing and rainfall/runoff models , preventing any independent check. The option is not recommended.

Alternative B

Telemeter only the Friars Carse, Fiddlers Ford & Greensands gauges. This would reduce hardware costs (by four outstations), greatly reduce the modelling work (say by 4 man-months), and possibly allow some simplification in basestation design. However, the forecasting method would be capable of providing only a relatively short period of warning (say 2 hours) and might be viewed as only an automation of present arrangements for short-term forecasting. The option is not recommended.

5. RECOMMENDATIONS

The study has confirmed that a formal, modern and automated flood warning scheme for Dumfries is feasible. It is believed that such a system is highly appropriate to the present aspirations for improved forecasting of floods in the town. Were a flood alleviation to be undertaken then the value of the flood warning scheme would in no way be diminished, since warning of overtopping of the defences would remain a crucial concern.

The recommended flood warning scheme is as described in Section 2. The main features to note are the choice of telephone telemetry and of a moderately sophisticated flood forecasting method. The method proposed takes limited account of tide conditions in making forecasts of water level at Whitesands.

Cost estimates for the proposed scheme are given in Section 4. The modelling work - which IH would seek to undertake - has been costed in detail. However, no attempt has been made to obtain a precise estimate for the system itself, since the cost will depend on the detailed specification of the system and the choice of supplier. An optional consultancy on system specification, selection of contractor & acceptance testing has been costed at £9.9K. Alternatively the customer might undertake this work.

A grand total cost of £90.1K is estimated for the entire scheme, including the optional consultancy.

Two suppliers of microcomputer controlled telemetry systems are suggested:

Dynamic Logic
Doncastle House
Doncastle Road
Bracknell
Berks
RG12 4PE

Tele: 0344-51915

Delta Technical Services Ltd.
Asser House
Airport Service Road
Portsmouth
Hants
PO3 5RA

Tele: 0705-697321

It is probable that within the next 6 months a local company will be licensed to manufacture and supply telemetry equipment to IH design.

APPENDIX A

Notes on radio option for Dumfries

General

The Nith valley to the north of Dumfries curves to the north-west and is bounded by hills to the east and west, with a narrow gap at Auldgirth. The gauging station on the Scaur Water is tucked into a valley and direct communication from there to the basestation is not practical by VHF radio (which requires near line of sight). Similar difficulties are met for telemetry from Drumlanrig and the suggested raingauge site east of Thornhill. It is therefore necessary to use a second basestation sited south-west of Thornhill in order to relay communications from these outstations. From here it is possible to reach - through the Auldgirth gap - the Friars Carse site. The Friars Carse outstation would act as a special link station to route communications on to Dumfries. Direct radio communication to the main basestation appears practical for the two town sites (Greensands & Whitesands), for Fiddlers Ford, and for the other raingauge (providing that a favourable site is chosen - eg. Glenkiln Reservoir).

The two basestations would operate on a time division multiplex system with the main basestation in full control.

Mast requirements

Several of the sites would require sizable masts. For example, masts at least 20m high would be needed at the main basestation and at Friars Carse.