# FIRST REPORT OF THE NERC STEERING COMMITTEE ON THE HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

JANUARY 1988

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January 1988

Natural Environment
Research Council

Institute of Hydrology

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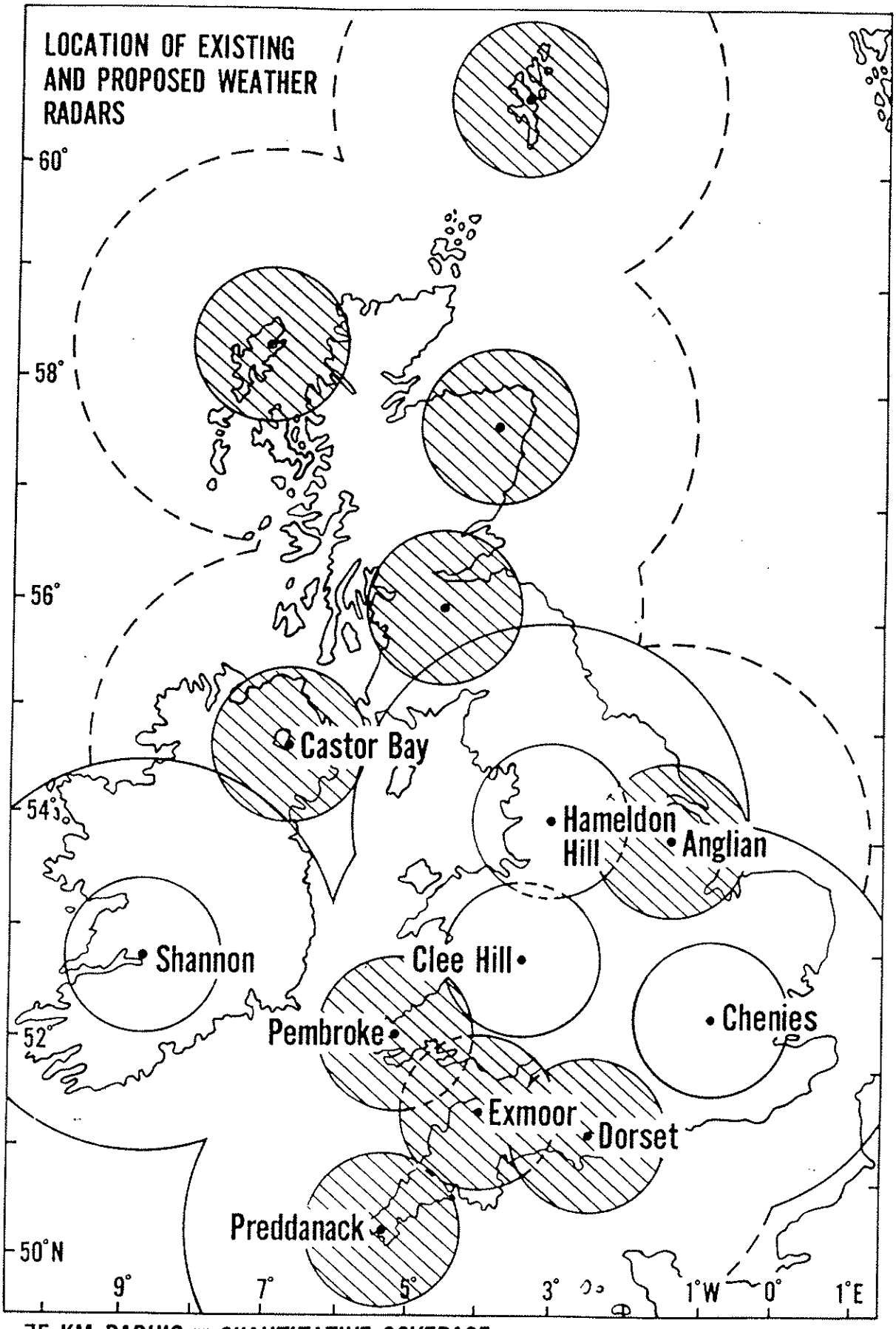
## 1. Introduction

Following discussions at the Lancaster Symposium on 'Weather Radar and Flood Warning' in September 1985 and the subsequent request by Mr H Fish (Chairman, Natural Environment Research Council) to Dr J S G McCulloch (Director, Institute of Hydrology) a Steering Committee on Hydrological Applications of Weather Radar was established under the aegis of NERC. The Committee held its first meeting on 18 March 1986 under the chairmanship of Dr J C Rodda (Institute of Hydrology), with the membership shown in Annex A.

The rationale behind the formation of the Committee was that while the meteorological applications of weather radar were well catered for and properly coordinated, the hydrological aspects were not. In particular, there was a need for a concerted approach to research, in view of shortage of funds and the similar requirements of the customers for this research. It was seen as particularly vital for hydrologists to capitalise on the great potential offered by the rainfall data from the UK weather radar network (Fig. 1). There was also the expectation that if the UK lead in the meteorological aspects of weather radar could be coupled to hydrological systems for water resources planning and management, these systems could have considerable export




75 KM RADIUS ≡ QUANTITATIVE COVERAGE
200 KM RADIUS ≡ EXTREME THEORETICAL RANGE

(Note - the proposed radars are shown by the hachured circles)

FIG 1

potential.

## 2. Committee Activities

The Committee met on five occasions during the year. Initially it reviewed the interests of members in the field of weather radar and hydrology. Government departments (MAFF and DOE) listed their responsibilities, the central bodies concerned with operations and research (Met Office and IH) provided an overview of their activities, the water authorities (TWA, NWWA, STWA, WWA) relayed their interests and the university members (Lancaster and Birmingham) discussed their research programmes. The Committee noted the importance of the DOE report 'Water Research in the Long Term' and of the report of the MAFF Research Consultative Committee on Flood Protection to its deliberations.

Following these initial discussions, the terms of reference of the Committee were agreed and these are listed under Annex B. The opportunities for funding for research were then considered, including the possibilities of funds coming from DTI, ODA and WRC and other sources, some external to the UK. A comprehensive list of research topics was drawn up, discussed, and agreed by the Committee, including the meteorological aspects important to the hydrological applications of radar. This list is attached as Annex C: it contains the duration of the particular item of research, its cost and overall priority.

Members from departments identified their particular areas of

priority. MAFF, for example, was concerned primarily with flood warning, design flood estimation and the land drainage aspects of river basin management, while DOE's responsibilities centred on reservoir safety and water resources, but with interests in estimation of rainfall input to the North Sea and the national raingauge network. Discussion of these priorities and others listed and reinforced by the authority members led to the establishment of four subgroups to look at the selected areas in detail. These subgroups were:

| | | |
|---|---|---|
| 1. | Calibration | the different problems of translating the radar signal into rainfall amounts using raingauge data. |
| 2. | Flow forecasting | linking the radar derived rainfall to the techniques of real-time flow forecasting and to design flood estimation. |
| 3. | Urban Applications | the design and management of storm water drainage systems. |
| 4. | Common data requirements | consideration of the Met Office products from the radar network of most value to hydrologists and the provision of an historical database of these products for future research and design. |

These subgroups each met twice or more during the year and their discussions resulted in the definition of detailed research proposals in number which are contained in Annex D and as agreed by the Steering Committee at its later meetings.

3. Water Authority Expenditure on Weather Radar Applications

To establish the level of interest amongst water authorities, a survey was undertaken by the Committee of their past and present expenditure. Although a complete coverage was not obtained and Scotland and Northern Ireland were not included, the total spend (over £1.8m) indicated a considerable commitment to radar (Table 1)

TABLE 1 : Water Authority expenditure on weather radar applications

| WATER AUTHORITY | PAST CAPITAL EXPENDITURE £K | REVENUE EXPENDITURE £K | FUTURE CAPITAL EXPENDITURE £K | RESEARCH £K | TOTAL £K |
|---|---|---|---|---|---|
| STWA | 35 | 40 (1985/86) | 70 (+25-50?) | 5 | |
| AWA | 20 | 15 | 210 | 70 | |
| TWA | 300 | N/A | included in research | 60 | |
| NWWA | 76 | 10 | " | 100 | |
| YWA | 43 | 13 | 70 | 0 | |
| WWA | 144 | 35 | 480 | 71 | |
| Total | 618 | 113 | 830+ | 306 | 1867+ |

4. UK Funding for Research

Discussions in the Committee focussed on the need to secure new funds for research on the hydrological applications of weather radar. Several members detailed their existing research expenditure, but it was noted that these contracts, mainly at IH, and the Universities of Birmingham, and Lancaster, were modest by comparison with the funding requirements envisaged in Annex C. The availability of new sources of money was considered and several possibilities targeted. Amongst these were NERC, the departments represented on the Committee and others such as DTI, ODA, the Commission of the European Communities and the water authorities themselves.

An approach was made to NERC to obtain 'Special Topic' funding for research on hydrological applications of weather radar. Such funding is in the directive mode and is generally initiated by NERC to stimulate activity in selected scientific areas identified as requiring additional research as a priority. Current special topics range from £50K p/a to about £450K p/a. This approach was made through the relevant grants committee (the Atmospheric & Aquatic Physical Sciences) and at the Terrestrial and Freshwater Sciences Committee and discussed at higher levels within the Council. However, the approach was unsuccessful: even a small amount of money to be used as seed corn was not forthcoming. All or part of these funds, depending on the amount allocated, could have gone to a Radar Data Facility at the University of Birmingham. Alongside the research being performed this

facility would have had the task of archiving high resolution data from weather radars, utilizing the extensive software and expertise developed at Birmingham and providing these data to hydrologists undertaking research in this area. An example of the type of data that might be archived is shown in Figure 2. The possibility of funding for this Facility from NERC and other sources is still being explored: at the same time Meteorological Office policy on in house archiving of these high resolution data and making these data available to users is being established.

The approach to DTI's Research Technology Group was unsuccessful. There was no assistance available other than to the private sector where 25% of development costs were available. A similar approach to ODA was equally unsuccessful. Several members of the Committee representing departments and water authorities considered that they were already committing (or planned to commit) an appropriate level of funding to this area of research (Table 1). Others felt that they might be persuaded to provide more money for suitable projects at the sharp end of their requirements. The possibility of a Link project was also being explored.

## 5. CEC Funding

In October 1986 a proposal was submitted to the Commission of the European Communities by NERC under the terms of the 1986-1990 research and development programme in the field of the environment (climatology and natural hazards). The project, drafted by IH in conjunction with the universities of

Birmingham and Lancaster and with the support of the other members of the Committee, envisaged a research programme spread over 4 years costing a total of £398K on 'Applications of Weather Radar for the Alleviation of Climatic Hazards' (Annex E). Similar and coordinated proposals were made by research groups in Italy, Portugal and France for roughly the same amounts of money. The four groups of bodies cooperating in the overall European project each anticipated that 50% of the funding would come from Brussels and 50% from sources within the country concerned.

Notification of the success of the submission was received on 19 May 1987, but the project had been reduced in size and duration. The CEC was to contribute a sum totalling £57K for a period of 36 months: the cooperating bodies on the Continent received similar notifications. Discussions have subsequently taken place between the UK partners on how the proposed programme could be tailored to the reduced budget. A meeting of the national groups involved is planned for Brussels in the autumn to coordinate activities.

## 6. Other International Contacts

During the year members of the Committee had a number of contacts with groups and individuals undertaking or planning to undertake work on the hydrological applications of weather radar. There was, for example, an Italian project centred on the R. Arno where the proposed flood forecasting scheme would employ a weather radar. There were several groups of visitors

to the Meteorological Office, North West Water Authority and other authorities and to the Institute of Hydrology, including a high level delegation from the German Democratic Republic headed by the Deputy Chairman of the Council of Ministers.

7. Related Initiatives

The Committee discussed several planned projects where weather radar was to be involved. One concerned the University of Birmingham, Software Sciences and Hydraulics Research Ltd in a project to produce a real-time river basin management system. Another was a separate proposal to the CEC for funds for a project on the water quality aspects of urban storm drainage made by the University of Birmingham and collaborating bodies in France and Germany. Another was a bid made by NERC to the Advisory Board for Research Councils for marginal funds for research on urban hydrology.

The Committee agreed to sponsor a follow-up to the Lancaster Symposium at the University of Birmingham from 14-16 August 1989. The Symposium would be entitled 'The Hydrological Applications of Weather Radar' and its timing, immediately after the International Association of Meteorology and Atmospheric Physics 5th Scientific Assembly at the University of Reading, would ensure a sizeable body of foreign participants.

Following the notification of the success of the bid to Brussels, the NERC Press Office circulated a press release featuring the news of the CEC contract and outlining the

work that was expected to be carried out.

LIST OF ANNEXES

Annex A

List of Members

| | |
|---|---|
| Dr K Browning | Meteorological Office |
| Mr R Buckingham<br>(Mr B R Streeten) | Ministry of Agriculture, Fisheries and Food |
| Mr V K Collinge<br>(Dr K Bevan) | University of Lancaster |
| Dr R Bailey<br>(Mr R Goodhew) | Severn Trent Water Authority |
| Mr C Haggett<br>(Dr G Phillips) | Thames Water |
| Dr I Cluckie<br>(Prof M J Hamlin) | University of Birmingham |
| Mr R J Moore | Institute of Hydrology |
| Dr J C Rodda | Institute of Hydrology (Chairman) |
| Mr J Tinkler | Wessex Water Authority |
| Dr P Walsh | North West Water Authority |
| Mr C Wright | Department of the Environment |
| Dr J Finch<br>(Mr R V Moore) | Institute of Hydrology (Secretary) |

Annex B

# TERMS OF REFERENCE FOR A STEERING COMMITTEE ON HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

1. To identify, in association with users, the main features of a prospective research programme for the application and development of weather radar data for hydrological purposes and to co-ordinate its implementation.

2. To seek funding for research on hydrological applications of weather radar and to use this to increase support.

3. To provide a forum for the exchange of ideas and information and to foster closer links between research on weather radar, its application for hydrological purposes and its commercial exploitation.

4. To review the existing system for the collection and archiving of weather radar and other data for hydrological uses and to advise on developments to meet research purposes.

5. To promote and establish international contacts with other organisations concerned with the hydrological application of weather radar.

6. To report on its work annually to NERC, MAFF, DOE and Met Office and the Water Industry generally.

Annex C

# SURVEY OF RESEARCH TOPICS

Note

This is a list of areas of research foreseen as relevant to the hydrological applications of weather radar. Their likely costs (1986 prices), duration and priority are shown

SURVEY OF RESEARCH TOPICS – HYDROLOGICAL APPLICATIONS OF WEATHER RADAR

| Main topic heading | Project | Duration years | Cost p/a | Priority | Remarks/Recommendations |
|---|---|---|---|---|---|
| 1. Radar Calibration | 1.1 Synoptic type dependence<br>(a) Frontal rain<br>(b) Convective rain | 3 | 100K | 1 | |
| | 1.2 Range dependence<br>(a) Local calibration<br>(b) Domain calibration<br>(c) Long range calibration | 3 | 200K | 1 | |
| | 1.3 Real-time calibration | 3 | 100K | 1 | Use of filtering theory and time series anlysis to obtain combined estimates of rainfall from raingauge and weather radar |
| | 1.4 Off-line re-calibration (PARAGON)<br>(a) hourly/2km<br>(b) hourly/5km<br>(c) daily/5km | 3 | 100K | 1 | |
| | 1.5 Accuracy and space/time resolution | 3 | 100K | 3 | |
| | 1.6 Automatic storm event recognition | 2 | 25K | 1 | Efficient data acquisition |
| | 1.7 Snowfall calibration | 3 | 100K | 2 | |
| 2. Modelling of rainfall fields and rainfall forecasting | 2.1 Short-term rainfall forecasting incorporating storm linear advection and extrapolation, rotation, and development/decay. | 3 | 50K | 1 | Use of multivariate time series models to forecast rainfall over time and space using grid square weather radar data |
| | 2.2 Statistical modelling of rainfall fields (eg. using the turning bands method) and its extension for rainfall forecasting. | 3 | 50K | 2 | |

| Main topic heading | Project | Duration years | Cost p/a | Priority | Remarks/Recommendations |
|---|---|---|---|---|---|
| 3. Storm precipitation mechanisms | 3.1 Use in models of storm dynamics | 10 | 50K | 2 | Application to estimation of probable maximum precipitation for design storm studies; rainfall forecasting |
| | 3.2 Physics of melting layer | 3 | 25K | 2 | |
| | 3.3 Studies with dense raingauge networks | 3 | 30K | 2 | |
| 4. Design of rainfall measuring networks | 4.1 Different applications eg. operational management, design | 2 | 30K | 3 | |
| | 4.2 Different environments<br>(a) climate<br>(b) hydrologic | 2 | 30K | 3 | |
| 5. Radar data specification and archiving | 5.1 Specification for real-time weather radar data acquisition systems | Con-tinuous | N/A | 1 | Important to consider provision of grid square data for river basins in addition to basin integrated value |
| | 5.2 Archive specification<br>(a) daily<br>(b) hourly or sub-hourly<br>(c) automatically-detected heavy rainfall | Con-tinuous | N/A | 1 | Important to choose appropriate intervals of space and time data to be archived<br>Design storm studies (see 7) |
| 6. Real-time flood forecasting and control | 6.1 Simple distributed flood forecasting models for use with grid-square weather radar data | 3 | 60K | 1 | |
| | 6.2 Intercomparison studies<br>(a) radar and raingauge<br>(b) lumped and ditributed models | 3 | 100K | 1 | |
| | 6.3 Sensitivity analyses to assess the influence of rainfall spatial variability on the flood hydrograph | 2 | 30K | 1 | |

| Main topic heading | Project | Duration years | Cost p/a | Priority | Remarks/Recommendations |
|---|---|---|---|---|---|
| 6. Real-time flood forecasting and control (continued) | 6.4 Use of recursive state/parameter estimation procedures for flood forecasting using weather radar data | 3 | 20K | 2 | |
| | 6.5 Affect on model calibration of the replacement of raingauge measurements by weather radar measurements of rainfall | 1 | 20K | 2 | |
| | 6.6 Snowmelt forecasting using weather radar | 3 | 25K | 2 | |
| | 6.7 Use of weather radar data in the control of river regulation schemes | 5 | 50K | 2 | |
| | 6.8 Case studies of flood forecasting and control systems incorporating weather radar | 5 | 50K | 1 | |
| | 6.9 Design of rainfall measuring networks incorporating weather radar for flood forecasting systems | 3 | 25K | 3 | |
| 7. Rainfall analysis for design flood estimation | 7.1 Design rainfall estimation<br>(a) areal reduction factor<br>(b) design storm profile<br>(c) probable maximum precipitation | 3 | 50K | 1 | Important for risk assessment studies of upland reservoirs |
| | 7.2 Short-term rainfall statistics (eg. Frequency/Intensity/Duration statistics) | 3 | 50K | 1 | |
| 8. Urban storm drainage | 8.1 Operational management of stormwater drainage systems | 3 | 25K | 1 | Reduce costs/pollution |
| | 8.2 Design of stormwater drainage systems<br>(a) areal reduction factor<br>(b) design storm profile | 3 | 25K | 3 | Use of weather radar in WASSP<br>Smaller space/time scale than 7.1 |

| Main topic heading | Project | Duration years | Cost p/a | Priority | Remarks/Recommendations |
|---|---|---|---|---|---|
| 9. Use in hydrometeorological and water quality models | 9.1 Operational use of weather radar in soil moisture deficit models (eg. MORECS) | 3 | 10K | 1 | |
| | 9.2 Climate models | Continuous | 50K | 2 | Application to climatic change |
| | 9.3 Physics-based distributed hydrological models (eg. IHDM). | 3 | 25K | 2 | Design, land use change, environmental impact assessment studies |
| | 9.4 Water quality models | 3 | 25K | 2 | Time of travel of pollutants; diffuse sources |
| 10. Operational river basin management | 10.1 Operation of regulating reservoirs (see 6.7) | 5 | 50K | 2 | |
| | 10.2 Control of pump operations | 3 | 20K | 2 | |
| | 10.3 Control of stormwater overflow and sewer systems (see 8.1) | 3 | 25K | 1 | |
| 11. Evaluation of weather radar for hydrological applications | 11.1 National evaluation based on different applications and synoptic types | 3 | 150K | 2 | |
| | 11.2 International evaluation across a range of climate, hydrology and applications | 5 | 250K | 1 | Collaboration with WMO |
| | 11.3 Frontiers | 3 | 100K | 1 | |
| 12. Combined use of weather radar and satellite imagery | 12.1 Frontiers | 5 | N/A | 1 | Precipitation forecasting; contaminant inputs to the Irish Sea |
| 13. Hardware developments | 13.1 Doppler radar | 10 | N/A | 3 | |
| | 13.2 Clutter canceller | 3 | N/A | 1 | |
| | 13.3 New radar installations | 10 | N/A | 1 | |

| Main topic heading | Project | Duration years | Cost p/a | Priority | Remarks/Recommendations |
|---|---|---|---|---|---|
| 14. Software developments | 14.1 Bright band correction | 3 | N/A | 1 | |
| | 14.2 Calibration (see 1) | - | - | - | |
| | 14.3 On-site data processing | 3 | N/A | 1 | |
| | 14.4 Display systems | 3 | N/A | 1 | |
| | 14.5 Expert systems | 5 | N/A | 1 | |

Annex D

# PRIORITY AREAS OF RESEARCH

Note

This is a list of the most urgent areas of research taken from Annex C and drawn up in detail by the four sub groups of the Committee.

**Research Proposal No. CSG-A** **RADAR CALIBRATION SUB GROUP**

**TITLE:**

ASSESSMENT OF ACCURACY OF RAINFALL MEASUREMENT AND DIAGNOSIS OF ERRORS

**GENERAL DESCRIPTION:**

Steps are being taken and will continue to be taken for several years to improve the quantitative performance of the total radar system. A continuing programme is required to monitor the performance of the system. This is an area of work addressed by the Meteorological Office (Met O 3). Performance assessment is required not only in an overall sense but also in ways which are tuned to identify the impact of specific changes. Extensive use will need to be made of case study evaluations on those occasions when for one reason or another the impact of specific factors can best be assessed. In depth studies are important if a physical understanding is to be achieved of the factors affecting accuracy.

**OBJECTIVES:**

A1: Derivation and mapping, on a nationwide 5 km resolution format, of representative distributions of real-time measurement accuracy of daily rainfall (bias and random errors), for

(a) the individual radars in the UK network, and

(b) existing networks of telemetering raingauges, stratified according to

(i) type of rain system (stratiform versus convective),

(ii) vertical extent of rain system (deep versus shallow), and

(iii) height of OC level,

and continually updated to identify changes associated with modifications to the real-time data processing system.

A2: Investigation of the spatial distribution and physical causes of errors in the radar measurements (i.e. low level growth, low level evaporation, shallow precipitation, bright band, non-standard drop size distribution, anomalous propagation, radar error, ....) for individual cases

(i) for which the radar data are identified as being particularly misleading (form for use by WAs attached)

(ii) which are hydrologically significant (e.g. very heavy rain)

and (iii) for which a meteorologically homogeneous situation prevailed throughout the wet part of an entire rainfall day.

**PROGRAMME OF WORK:**

To be specified by B May and C G Collier

**RESEARCH by:** Meteorological Office

**FUNDED by:** Meteorological Office

**COST:** 1 person (£25K) per year from Meteorological Office, ongoing

**PRIORITY:** H

[This relates to CSG-A]

Standard form to be filled in by WAs for each event when radar data are misleading

(To be sent in to immediately after each event)

**Date:** Month..... Year.....

**Time** (local) Start..... End.....

**Which Radar?** .....

**Picture data:** ..... and/or sub-catchment totals .....

**Nature of radar problem as perceived by user:**
over-reading .....
under-reading .....
missing data .....

**Geographical location to which the misleading data applies:** .....

**Operational task affected:**
flood warning .....
reservoir control .....
sewer operation .....
navigation advice .....
hydropower control .....
water situation assessment .....
other .....

**Name of Duty Officer:** .....

**Department:** .....

Research Proposal No. CSG-B RADAR CALIBRATION SUB-GROUP

TITLE:

IMPROVEMENT OF ACCURACY OF RADAR MEASUREMENTS (Taking into Account Orographic Aspects)

GENERAL DESCRIPTION:

The use of radar to measure rainfall quantitatively is in some ways more challenging in the British Isles than in many other countries because of the common occurrence of frontal situations with strong moist low level winds. This leads to orographic rain generated in the lowest kilometre or so, i.e. below or partially below the radar beam. Such orographic effects are to some extent recognized within the domain-based real-time calibration procedure . This procedure selects appropriate domains on the basis of a simple objective recognition of rain type and applies a calibration using gauges affected to some extent by orography. This procedure requires further development. Detailed climatologies of orographic rainfall increment for different wind velocities show a great deal of spatial variability in orographic rainfall the details of which go undetected by the simple domain-based procedure. Climatological Orographic Fields need to be adjusted by a scaling factor to take into account the fact that there is more (less) orographic enhancement overall when the relative humidity of the low-level air is high (low). It is not easy to assess this scaling factor from meteorological data alone and so it is desirable to devise ways of using ground truth from real-time calibration raingauges sited in highly orographic locations.

OBJECTIVES:

B1: Devise improved ways of determining rain type.

B2: Assess the applicability of existing domain boundaries and redefine as necessary.

B3: Assess the applicability of, and update/refine as necessary, the detailed orographic enhancement fields derived by Hill for different wind velocities and investigate the variation of the orographic scaling factor due to variations of wind speed and humidity.

B4: Determine optimal sites for orographic raingauges (with regard to areas of maximum orography and taking into account variable wind drift) and derive ways of using such gauges (whether in or upwind of the areas of interest) to determine in real time the appropriate orographic scaling factor.

PROGRAMME OF WORK:

To be specified by C G Collier in consultation with other parties.

RESEARCH by: Meteorological Office, Severn Trent Water Authorities, North West Water Authorities, Lancaster University

FUNDED BY: Meteorological Office/Water Authorities

COST: £30K (3 year @ £10K)

PRIORITY: H

**Research Proposal No. CSG-C** **RADAR CALIBRATION SUB-GROUP**

**TITLE:**

IMPROVEMENT OF ACCURACY OF RADAR MEASUREMENTS (Taking into account non-orographic factors)

**GENERAL DESCRIPTION:**

The spacing of radars is now (and is likely to remain for the foreseeable future) such that many hydrological applications have to be met using data from beyond the nominal limit of quantitative coverage (75 km). The problem then is mainly that the radar beam overshoots low-level precipitation and so under-estimates the surface rainfall rate increasingly with range. A climatological range-dependent correction is applied but this over-corrects at long range for deep thunderstorms and under-corrects at long range in the case of some frontal precipitation, especially in certain synoptic situations where the precipitation generation is restricted to the lowest levels of the atmosphere. Appropriate range correction relationships have been derived for different depths of precipitation: the problem is to identify which is the appropriate one to use on a given occasion. Therefore, methods need to be developed and tested for identifying and applying appropriate range correction relationships. These methods must take into account the possibility of different types of precipitation co-existing, so that the corrections applied can be biased towards the hydrologically more important heavy rain areas. The latter consideration must be kept in mind for all aspects of the calibration procedures.

**OBJECTIVES:**

C1: Derive ways of increasing accuracy at long range using

(a) estimates of the type and vertical extent of the rain system,

and (b) long-range gauge measurements,

to derive range normalization law appropriate to each occasion.

C2: Derive procedures for ensuring that radar calibrations are biased in favour of the hydrologically more important areas of heavier rain.

(See also footnote)

**PROGRAMME OF WORK:**

To be specified by the Lincoln Weather Radar Consortium

**RESEARCH by:** Meteorological Office/Severn Trent Water Authorities/ Anglian Water Authority/Yorkshire Water Authority

**FUNDED by:** Meteorological Office/Water Authorities

**COST:** £30K (3 years @ £10K)

**PRIORITY:** H

**FOOTNOTE:** Implementation of on-site procedures for minimising errors due to anaprop and bright band is being carried out by the Meteorological Office (Met O 16).

**Research Proposal No. CSG-D** **RADAR CALIBRATION SUB-GROUP**

**TITLE:**

INVESTIGATIONS OF THE MAN-MACHINE INTERFACE

**GENERAL DESCRIPTION:**

The purpose of the FRONTIERS system now being used for operational trials at the Meteorological Office compositing centre at Bracknell is to allow a human operator to exercise judgement in quality controlling the radar rainfall fields, in blending them with satellite patterns and in deriving very-short range rainfall forecasts therefrom. The primary purpose of the quality control step is to eradicate spurious echoes and other major defects so that the forecasts are derived from a reasonably clean sequence of initial data. Opportunities also exist for the FRONTIERS operator to improve the quantitative accuracy of the data by ensuring for example that orographic corrections and range dependent corrections are applied which are consistent with his understanding of the meteorological situation. These corrections can be applied to the central FRONTIERS product. Given two-way communications between FRONTIERS and the radar sites it will also be possible for operator-derived judgements to be sent to the radar sites and applied to the data at source. However it will be necessary to streamline the FRONTIERS procedures to enable these opportunities to be realised. This is not a trivial task and it has to be decided how far to take it. It has to be realised that the FRONTIERS products are up to ½-hour late and only one picture every half hour is generated. Although this delay is tolerable for forecasts of rainfall, it may not be in some circumstances for actual rainfall. It may be desirable for further manual intervention intended to optimise quantitative accuracy to be carried out by the hydrological user for the areas of greatest concern and using any supplementary information available to him. The balance between the needs for accuracy and timeliness of the data needs to be investigated.

**OBJECTIVES:**

D1: Develop methods of manual intervention leading to improved accuracy of rainfall analyses and forecasts, develop automated procedures to supercede these where and when practicable, and keep under review the optimal balance between the two types of approaches.

D2: Undertake a user survey to identify the relative importance of timeliness and accuracy with regard to both actual and forecast (1, 3 and 6 hours) rainfall.

**PROGRAMME OF WORK:**

To be specified by C G Collier

**RESEARCH by:** Meteorological Office Nowcasting Group (D1)

**FUNDED by:**

**COST:**

**PRIORITY:** H(D1), M(D2)

Research Proposal No. CSG-E RADAR CALIBRATION SUB-GROUP

TITLE:

ASSESSMENT OF ACCURACY OF SNOWFALL MEASUREMENT AND OPTIMISATION OF RADAR CALIBRATION GAUGES DURING SNOWFALL

## GENERAL DESCRIPTION

A significant proportion of widespread floods are associated with melting snow. Forecasting of these floods relies heavily on a correct assessment of the water equivalent of lying snow and on the type and intensity of current precipitation. Telemetry raingauges block with snow if unheated and are unable to correctly represent rainfall falling on the melting snowpack. Calibration raingauges are affected in a similar manner unless heating is provided. Delayed melt in unheated raingauges also produces spurious calibration rates. An assessment programme is required to apply the results of work already underway on heating of Water Authority telemetry raingauges to the radar calibration gauge network.

## OBJECTIVES

E1: Assess the accuracy of snowfall measurement by radar (stratified according to whether convective or stratiform and deep or shallow) using detailed ground truth snow depth surveys.*

E2: Investigate the frequency of occurrence of errors due to snow/ice in calibration gauges and evaluate the effectiveness of heated raingauges.

E3: Evaluate the cost-effectiveness of the new optical devices for discriminating between rain and snow and measuring the instantaneous precipitation intensity.

## PROGRAMME OF WORK

First Year: Performance Assessment for past three years, evaluation of shortcomings.

Second Year: Solutions to shortcomings, off-line testing.

Third Year: On-line tests. Report.

**RESEARCH by:** Severn-Trent Water Authority/North West Water Authority/ Yorkshire Water Authority/Meteorological Office/Institute of Hydrology.

**FUNDED by:** Water Authorities

**COST:** £50K (two years at £20K, one year at £10K)

**PRIORITY:** M

***FOOTNOTE:** Possibility of benefiting from ground truth surveys carried out as part of a DOE/Bristol University study of satellite measurement of snowfall.

Research Proposal No. CSG-F RADAR CALIBRATION SUB-GROUP

TITLE:

BLENDING OF RADAR DATA WITH DATA FROM EXISTING DENSE TELEMETERING RAINGAUGE NETWORKS WITHIN THE USER'S ENVIRONMENT

GENERAL DESCRIPTION

Telemetering rain gauges have been used for many years for flood forecasting purposes, and all the Water Authorities have networks of these gauges, with differing network densities. These gauges can be used in two ways. A small number of them could become additional calibrating gauges to improve domain calibration procedures, and here there would be limitations imposed by the on-site computing facilities and software. Alternatively the data from these gauges could be merged with the calibrated radar data automatically using existing software, or by a man/machine interaction process.

OBJECTIVES:

F1: To identify for each radar the 'optimum' number of primary calibration gauges and their locations by reference to both hydrometeorological and hydrological criteria.

F2: To identify the options for incorporating data from telemetering gauges.

F3: To determine the most cost-effective of the above options.

PROGRAMME OF WORK:

To be determined

RESEARCH by: Institute of Hydrology/Universities

FUNDED by: NERC/Water Authorities

COST: £75K (3 years @ £25K)

PRIORITY: M

| | Research Project | Research Body | Funding Body | | Cost | Priority |
|---|---|---|---|---|---|---|
| | | | Existing | Potential | £K | |
| 1. | Calibration procedures for flow forecasting | IH, UL | | AWA, TW | 30 | H |
| 2. | Assessment of FRONTIERS data for flow forecasting | UB | MO | | ? | M |
| 3. | Real-time rainfall forecasting at small time and space resolution for flood forecasting | IH | | MO, WA's | 50 | H |
| 4. | Snow measurement and snowmelt forecasting using weather radar | IH, UB | | STWA | 75 | M |
| 5. | Distributed models for flow forecasting using weather radar data | IH, UB, UL | MAFF, WWA | AWA | 60 | H |
| 6. | Weather radar and simple alarm procedures for flood warning | IH | | TW | 27 | M |
| 7. | Weather radar for real-time river basin management | IH, UB, UL | | WA's | ? | M |
| 8. | Data provision for research on hydrological applications of weather radar | MO or UB | | NERC | 10 | H |

TABLE 1 Research Projects proposed by the NERC Subgroup on Flow Forecasting Applications of Weather Radar Data

**Title** Calibration procedures for flow forecasting

**General description**

Many real-time flood warning systems operated by water authorities have an independent network of telemetering raingauges in addition to those gauges used for radar calibration. Research is needed on how best to use these additional gauges to improve the precision of flood forecasting models. Techniques would be developed in which the relative precision of raingauge and radar measurements of radar is taken into account, probably through an informal empirical space-time filtering procedure dependent on synoptic type, rather than using a more formal statistically-based Kalman filter approach. Evaluation of the techniques developed would be performed with respect to their ability to improve the precision of flood forecasts.

**Objectives**

The main objective is to develop techniques for combining radar and raingauge measurements of rainfall to forecast floods with greater precision and robustness. A secondary goal would be to establish guidelines on network design and use of radar/raingauge measurement systems for flood forecasting e.g. the number and location of raingauges required, and when and where to give preference to gauge as opposed to radar estimates of rainfall.

**Programme of work**

(a) Work to be completed in year 1

Choice of two catchments in upland (eg. near Hameldon Hill) and lowland (eg. near Chenies) Britain and preparation of data (raingauge & radar rainfall and flow measurements for selected events). Literature review. Preliminary development of techniques.

(b) Work to be completed in year 2

Evaluation of techniques and further development. Possible extension to other catchments (eg. small and large). Completion of report.

**Cost** £30,000.

**Title** Assessment of FRONTIERS data for flow forecasting.

**General description**

Rainfall forecasts are required to extend the lead time of flood forecasts made using rainfall-runoff models. The FRONTIERS programme aims to produce such rainfall forecasts on a 5km grid (although initially at 20km) up to 6 hours ahead at ½hr intervals. This project would aim to evaluate these rainfall forecasts when used as input to rainfall-runoff models for flood warning purposes. Inadequacies in the resulting flood forecasts encountered in the evaluation process would be used to guide FRONTIERS research to obtain an improved product. The adequacy of the space-time resolution of the FRONTIERS data for catchments of different area and response time would also be investigated.

**Objective**

To assess the value of FRONTIERS data to extend the lead time of flood forecasts, and to assess its usefulness as a function of catchment size and topography.

**Programme of work**

(a) Work to be completed in year 1

Selection of catchments and storm events, and establishment of storm event data sets including weather radar.

Frontiers, raingauge and flow data. Preliminary evaluation.

(b) Work to be completed in year 2

Continued evaluation. Collection of further storm event data sets.

Final evaluation and report writing.

**Title** Real-time rainfall forecasting at small time and space resolution for flood forecasting.

**General description**

The FRONTIERS programme aims to provide rainfall forecasts at a resolution of 5 km and at half/hour intervals for lead times up to six hours; the techniques used are part statistical, part meteorological, and part based on human judgement. This project proposal is complementary to the FRONTIERS programme in aiming to produce forecasts at a resolution of 15 minutes for 2 km grid areas for lead times of up to one or two hours for use in flood forecasting. Such a product has the potential to be of great value for flood warning, particularly for flooding in small catchments where the FRONTIERS product will be of little value. At these smaller lead times of concern here, it would be expected that the predictive ability of a technique would derive primarily from statistical space-time associations, and modelling of these associations is where research would be mainly directed.

**Objective**

To extend the warning time of flooding in small, rapidly-responding rural and urban catchments.

**Programme of work**

(a) Work to be completed in first year

Storm event data collection and identification of synoptic type. Statistical analysis of space-time structure of storm rainfall fields. Preliminary development of space-time models for frontal storms.

(b) Work to be completed in second year.

Evaluation of space-time rainfall predictors, revision, and re-evaluation. Feasibility for convective storms, and development of predictors if feasible. Completion of report.

**Cost** £50,000.

**Title** Snow measurement and snowmelt forecasting using weather radar.

**General description**

Snowmelt has been an important contributory cause of flooding over recent years in some areas of the UK and has concerned water authorities whose flood warning systems have been better equipped to deal with conventional rain-induced floods. Weather radar has the capability to measure snow as well as rainfall whereas snow measurement with conventional raingauges remains problematic. Research is required on the calibration of weather radar to measure snow and on the development of models to use radar-derived distributed measurements of snowfall for forecasting snowmelt-induced floods.

**Objective**

To calibrate weather radar to measure snowfall and to assess its value as part of a system to forecast snowmelt-induced floods. This project would probably utilise STWA's network of circa 80 heated raingauges, possibly complemented by instrumentation developed at IH to measure snow amounts, together with data from Clee Hill weather radar.

**Programme of work**

(a) Work to be completed in first year

Collection of event data in the form of heated raingauge, temperature, flow, and weather radar measurements. Enhancement of data collection system to incorporate IH snow sensors. Comparison with ground truth snow measurements.

(b) Work to be completed in second year

Development of snowmelt flood forecasting models and evaluation. Data collection using enhanced network.

(c) Work to be completed in third year.

Final evaluation and report writing.

**Cost** £75,000.

**Title** Distributed models for flow forecasting using weather radar data.

**General description**

Models for flow forecasting would be developed specifically to exploit the benefits of grid-square weather radar data, whilst compensating for their lack of precision as a function of radar range and rainfall event type. A number of different approaches would be considered including grid-square models, river network/sub-basin models, and models for ungauged basins. Model performance would be evaluated for upland and lowland basins of differing area.

**Objective**

To improve the precision of flood forecasting models through the use of distributed weather radar data.

**Programme of work**

(a) Work to be completed in first year

Selection of catchments and data preparation. Development of simple distributed models. Sensitivity analysis of flood forecasting models to spatial variability of rainfall.

(b) Work to be completed in second year

Evaluation of models in simulation-mode and in a real-time updating context. Completion of report.

**Cost** £60,000.

**Title** Weather radar and simple alarm procedures for flood warning

**General description**

Flood forecasting models can be of limited value on fast responding catchments, and especially where flooding occurs at upstream locations, due to the limited time available to initiate a warning. Rainfall measurements can be used directly in such circumstances to initiate a warning. Research is required on relating the intensity of extreme rainfall and its variation in space with the extent of flood inundation, through analysis of historical records. The localised nature of thunderstorm rainfall can be detected by weather radar and then used to trigger a flood warning, where likely severity has been ascertained through analysis of previous thunderstorm events.

**Objective**

To provide objective assessment of flood risk in upstream locations of rapidly responding catchments subject to short duration thunderstorms.

**Programme of work**

(a) Work completed to date

Preliminary work on inundation extent, and extreme event identification

(b) Work to be completed in year 1

Data collection for storm events of particular intensities, including levels of flooding and extent of inundation. Development of procedure.

(c) Work to be completed in year 2

Evaluation of procedure & revision where necessary. Completion of report.

**Cost** £27,000

**Title** Weather radar for real-time river basin management

**General description**

The role of weather radar in the real-time management of a river basin would be tackled through a case study of a water resource system which presented problems of common interest to the water industry. The case study might, for example, be the control of a flood storage lagoon, the control of a river regulation system, the control of pumping in a Fenland drainage system, or the prediction and control of sewer network inflows to a waste-water treatment plant.

**Objective**

To develop techniques using weather radar data for the real-time management and control of river basins, and to evaluate the benefits accruing.

**Programme of work**

(a) Work to be completed in first year

Feasibility study, selection of case study, and data preparation.

(b) Work to be completed in second year

Development of techniques for operational control using spatially distributed weather radar rainfall data. Evaluation of the benefits accruing from the use of weather radar data.

**Cost** Case study dependent.

**Title** Data provision for research on hydrological applications of weather radar.

**General description**

Weather radar data in calibrated and uncalibrated form are required to underpin research programmes on weather radar for hydrological application. This project would provide a facility to archive weather radar data and to disseminate data to users in research establishments and the water industry. The facility would complement the existing PARAGON system by archiving 2 km, 5 minute data for selected storm events from the national network of weather radar.

**Objective**

To provide an effective and efficient means of supplying fine resolution weather radar data to users in the water industry and research establishments.

**Programme of work**

(a) Work to be completed in year 1

Rapid feasibility study to decide (i) where requests for radar data would be best met; (ii) whether re-location of existing staff could meet the requests adequately; (iii) if not, employment of a new staff member at an appropriate location. Servicing of outstanding requests.

(b) Subsequent years

Servicing of requests from users. Development of software to keep pace with new radar products and different types of data request.

**Cost** Subject to feasibility study (preliminary estimate £10,000 p.a., and possibly less in subsequent years).

## URBAN APPLICATIONS SUBGROUP.

**PROJECT TITLE :**

URBAN DRAINAGE NETWORK STUDIES USING WASSP AND WEATHER RADAR DATA.

**GENERAL DESCRIPTION :**

This study is designed to incorporate the existing urban drainage network studies in the North West with a study of the potential benefit of quantitative weather radar data in the context of WASSP model studies by comparing the capabilities of network analysis using radar derived and conventional precipitation input data. The current practice in urban drainage design in the UK is to rely predominantly on the effective verification of a WASSP model of the existing system using rainfall and flow data collected over a short period of time. The system is then simulated in a variety of potential future states using the verified model of the system. It is proposed that the existing WASSP study areas are re-examined using radar data in an attempt to investigate the potential for radar derived data in such studies. Existing preliminary work could be extended to include an appreciation of storm structure and its effect on local verification procedures and its impact upon urban storm hazards in general. In addition the detailed knowledge to further develop the fundamental understanding of the relationship between, and benefits obtained from, the application of regional storm time series and the more detailed spatial information provided by radar is required. This could then provide a valuable input to the water industry review of sewer networks as outlined in the the WRC Sewerage Rehabilitation Manual. The level of capital investment in this area is likely to be at a high level for the remainder of the century and this increases the importance of this study in relation to the more effective use of economic resources on such a large infrastructure refurbishment program.

**OBJECTIVES :**

A. To establish the benefits of using radar data in WASSP drainage network modelling.

B. To improve and further develop the local radar calibration process in the urban setting.

C. To initiate a longer term study of off-line high resolution radar data to better determine the urban storm hazard potential over a number of selected major urban areas. These areas to include the conurbations covered by the high resolution radar data obtained from at minimum the following radar sites, - Hameldon Hill, Clee Hill and Chenies in Buckinghamshire.

D. To evaluate the benefits of distributed storm effects as described by radar data on the design storm structure. This work would also focus attention on the development and use of regionally based storm time series for sewer network design purposes.

E. To constuct a limited high resolution radar data archive specifically for the study of urban areas. This objective to be absorbed into the NERC/Met. Off. Radar Data Facility if support provided by NERC.

*Note :* The overall area of activity specified in A and D will include collaboration with existing research groups working on regional time series rainfall ( e.g. University of Newcastle ) in order to establish the benefits provided by radar data in defining the effects of spatial variation in relation to drainage network analysis.

***RESEARCH BY : WRC, HR, University of Birmingham, IH.***

***FUNDED BY : SERC/WRC/Water Authorities/NERC.***

***APPROXIMATE COST : £50k/year for 3 years. ( 2 persons )***

***PRIORITY : H***

## URBAN APPLICATIONS SUBGROUP.

**PROJECT TITLE :**

REAL-TIME CONTROL OF AN URBAN BALANCING POND.

**GENERAL DESCRIPTION :**

Balancing Ponds are used to mitigate the effects of rapid and often highly polluted runoff from urban areas on the downstream environment. Since the value of land in urban areas is often given a high premium there is pressure to limit the size of such facilities by providing better real-time control of both inflows and outflows. For this active control strategy to be successful it is required that reasonably accurate estimates of storm runoff be obtained at short timescales. The potential of Weather Radar for the provision of fast and accurate assessments of the temporal and spatial variation of Rainfall and thus the development of better flow forecasting procedures must be assessed. This will directly impact upon the future development of active control procedures which can be applied within urban drainage systems. This proposal in particular is aimed at the examination of the improvements in real-time control strategies that could be made at a large balancing pond at Milton Keynes using radar data from the Chenies radar site.

**OBJECTIVES :**

A. To develop and prove techniques for the real-time control of urban runoff balancing ponds using weather radar.

*RESEARCH BY : IH.*

*FUNDED BY : AWA / CIRIA / MAFF.*

*APPROXIMATE COST : £25k per year for 2 years. ( 1 person )*

*PRIORITY : M to L*

## URBAN APPLICATIONS SUBGROUP.

**PROJECT TITLE :**

USE OF WEATHER RADAR IN MODELLING RAINFALL-RUNOFF IN MIXED URBAN/RURAL CATCHMENTS.

**GENERAL DESCRIPTION :**

The problems of Bracknell newtown are typical of many urban areas in Southern Britain. Bracknell is a new town in a mixed agricultural/woodland setting which extends to about 20km$^2$ and is composed of industrial, residential and commercial areas. Separate surface water and foul sewerage systems are employed with numerous balancing ponds used to control surface runoff in a passive manner. The pressures for further development and concerns about the effectivness of the existing system has produced an interest in more detailed hydrological modelling studies within the area and in particular on the utilisation of weather radar data in such a setting.

**OBJECTIVES :**

A. Determine areal rainfall patterns and their effect on catchment runoff.

B. To establish the interaction of the different responses between the urban and rural sub-areas of the catchments using radar data.

***RESEARCH BY : IH, TWA, Middlesex Polytechnic.***

***FUNDED BY : NERC / TWA / DOE / ??***

***APPROXIMATE COST : £40k/year for 3years + £150k of equipment. ( 1 person at IH + 1 person at Middlesex Polytechnic )***

***PRIORITY : M***

## URBAN APPLICATIONS SUBGROUP.

**PROJECT TITLE :**

REDUCTION OF POLLUTION FROM URBAN DRAINAGE NETWORKS BY ACTIVE CONTROL PROCEDURES.

**GENERAL DESCRIPTION :**

Efforts for reducing the pollution of rivers have been mainly concentrated on improving the quality of residential and industrial effluents whereas the reduction of the pollution caused by combined sewer overflows and the discharge from separate stormwater sewer systems has mostly been neglected. This pollution, however, has in many cases exceeded the effluent load from sewage treatment plants. As an additional problem for the receiving waters, combined sewer overflows are not discharged at a constant rate over the year but concentrated in finite pollution incidents which appear as "shocks"to the system. Approaches to make better use of existing systems by active operational management of both quantity and quality throughout the river basin have not yet been developed into a practical proposition because of the lack of guidelines and objective criteria for decision making in this context. However, the primary aim of the proposed study is to produce recommendations for planning, verifying and implementing water quality management practices for River Basins. These will take account of the effects of active control elements such as detention tanks, gates, pumps etc. configured via telemetry. The work will be orientated to the large urban areas (eg Manchester, Liverpool and Birmingham) where considerable investment is to be directed in infrastructure renewal programmes. This proposal also envisages close cooperation with the University of Hannover in West Germany and a French group at the Ecole Nationale des Ponts et Chaussees near Paris.

**OBJECTIVES :**

A. To develop operational management techniques which allow better use to be made of existing sewer network models and the use to which they are put in conjunction with control possibilities.

B. To produce recomendations on the benefits obtained and guidelines for the use of weather radars when applied to urban areas for use in real-time sewer network control.

C. A comparison will be made between the resolutions at which radar data is available (ie 300mx300m every 1 minute-available from France ,the 800mx800m every 1 minute from Western Germany and the 2kmx2km every 5 minutes obtainable in the UK) in order to identify any benefits associated with high resolution data in the urban application area.

*RESEARCH BY : University of Birmingham, NWWA, WRC, HR, IH.*

*FUNDED BY : EEC, SERC, Water Authorities*

*APPROXIMATE COST : £60K/year for 3 years. ( 2 persons )*

*PRIORITY : H*

Annex E

# PRELIMINARIES TO THE CEC RESEARCH PROPOSAL

COMMISSION
OF THE
EUROPEAN COMMUNITIES

Directorate-General
for Science, Research and Development

R & D PROGRAMME
IN THE FIELD OF THE ENVIRONMENT



# PROPOSAL DATA SHEET

*(Please use English preferably)*

ENVIRONMENTAL PROTECTION ☐
CLIMATOLOGY AND NATURAL HAZARDS ☐

Proposal No. [ ]

Topic [ ] FOR COMMISSION USE

Total cost £398000

Starting date 1 1 87

Duration 48 Months

Requested EEC Contribution £199000

Proposer Natural Environment Research Coun
Institute of Hydrology, Crowmarsh Gifford,
Wallingford, Oxon, OX10 8BB, UK

Project leader Dr. J.C. Rodda

Tel. 0491 38800

Telex 849365

Title (maximum 80 characters + spaces)

APPLICATIONS OF
WEATHER RADAR FOR THE
ALLEVIATION OF CLIMATIC HAZARDS

Objectives and Description of proposed research *(1 ½ page maximum.)*

Significant advances over the last 20 years have put the UK in the forefront of weather radar technology at an international level. These advances have been achieved primarily by meteorologists and have been concerned mainly with developing technology to improve the accuracy of radar measurements of rainfall. Application to the alleviation of climate hazards of the distributed rainfall estimates that weather radar provides has not received the same attention, since priority has until now been given to meteorological objectives. Advances in the measurement of rainfall by radar and the availability of weather radar data from the integrated network over England and Wales means that the way is now clear for a concerted research effort on the use of weather radar to understand the spatial variability of climatic hazards and to develop methods aimed at alleviating their effects. Climatic hazards such as floods and droughts caused by rainfall extremes can be of a highly localised nature. Only through the use of weather radar can continuous measurements in space, as well as time, be achieved to permit studies of the spatial variability of climatic hazard, and to develop techniques to lessen their impact.

Research on the application of weather radar data to alleviate the effects of climatic hazards will be tackled on three broad fronts. First, the problem of calibration in different synoptic and topographic situations will be addressed. The conversion of radar signals to rainfall estimates is still far from being satisfactory, and there is an urgent need to understand the variability in the relationship in order to devise techniques for improved calibration. This research will focus on data from the Hameldon Hill radar in Lancashire which was the first operational unmanned weather radar in the UK

Second, the extremes of flood and drought will be examined through the use of flow forecasting models which have been constructed on a grid square framework suitable for use with 2km square weather radar estimates of rainfall. Evaluation of these models using real-time weather radar data will be complemented by sensitivity analyses designed to investigate the influence of spatially variable rainfall on the flood hydrograph. Third, the impact of climatic hazards in urban areas will be explored through a case study of the city of Manchester. Research under this heading will focus on smaller scale hazards in both space and time which have greatest impact in urban areas. The greater understanding gained will be used to develop improved techniques for the operational management and design of urban stormwater drainage systems.

The UK proposal will be managed as part of the function of the NERC Steering Committee on Hydrological Applications of Weather Radar, and will bring together researchers from the Universities of Lancaster and Birmingham, and NERC's Institute of Hydrology. In addition, the proposal is one of five from Community Countries the others being from Italy, the Netherlands, France and Portugal. These form a European Collaborative Programme on the Application of Weather Radar for the Alleviation of Climatic Hazards. A programme of workshops and meetings in each member country is envisaged in order to exchange research findings and to encourage collaborative research between the participating countries and to assist the process of disseminating the operational use of radar for purposes other than weather forecasting.