

# Support for Integrated Groundwater / Surface water Monitoring and Assessment for Sustainable Catchment Management

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**ABSTRACT:** Sustainable management of groundwater at the catchment scale requires conceptual and possibly subsequent numerical and/or analytical models to be developed. These depend on an understanding of the key hydrological, hydrogeological and geomorphological process interactions. Recent initiatives have indicated: 1) a shortage of the basic data relating to these processes, 2) uncertainty as to what additional data may be required, how and where to collect them. A new research initiative will develop and test methodologies to produce guidelines for monitoring and assessment at the catchment scale. This will be achieved by addressing key scientific and technical issues in a series of carefully instrumented lowland permeable catchments.

## 1 INTRODUCTION

Lowland catchments (<300m AOD) are subject to a complex set of environmental pressures and associated management problems, and yet approaches to monitoring have generally been fragmented and undertaken on a reactive basis to operational problems. A strategic approach to monitoring is not yet the norm in most European countries at the river basin or even the catchment scale. As environmental awareness has grown, monitoring has increased in scope and breadth but has remained centred on fixed sampling-point and fixed time-interval sampling, often with little interpretation of data. However, this is not just a European issue.

Worldwide, past monitoring efforts were not generally able to provide early warning of:

- The wide effects of eutrophication in the 1960s;
- The effects of acidic deposition on water quality in the 1970s & 1980s;
- The movement through soils and occurrence in groundwater and surface water of a range of pesticides in the 1970s & 1980s
- The widespread occurrence of selenium in irrigation return waters in the western USA;
- The impact of water abstractions on wetland habitats through into the 1990s;

Furthermore, vast sums of money have been spent worldwide on treatment of municipal and industrial wastewaters, reclamation of degraded rivers and wetlands and re-establishment of characteristic floral and faunal communities. However, in many cases the existing monitoring systems have not been able to provide the scientific evidence to judge

whether the required or expected improvements in environmental status have been achieved. Whilst large sums of money have been spent on monitoring, policy and management results are often lacking.

This situation illustrates the difficulty of collecting, interpreting and using data adequately to address a range of objectives and issues which may as yet not be apparent. A truly comprehensive assessment system must address the current, known water issues and provide background information necessary for the early detection of future changes in surface and groundwater status (and the associated impacts on the environment) from whatever causes.

This paper describes a unique initiative being undertaken in the UK to gain improved understanding of the hydrological cycle at the meso-catchment scale. The Lowland Catchment Research programme (LOCAR) will focus on two pairs of catchments on the Chalk (England's prime aquifer in terms of public water supply) and one catchment on Permo-Triassic sandstone (England's second most important aquifer), see Figure 1.

Proposed European legislation (The Water Framework Directive) requires establishment and maintenance of good ecological, quantitative and qualitative status of surface waters and good quantitative and qualitative status of groundwaters. It is evident that any human intervention in the hydrological cycle (e.g. groundwater abstraction, changes of land use, introduction of treated sewage into surface waters) will have an impact on the extant status of surface and/or groundwaters. To be able to predict the impact that such interventions will have and also

to be able to plan measures to recover “good status” has implications for data requirements and also the degree to which the processes involved are understood.

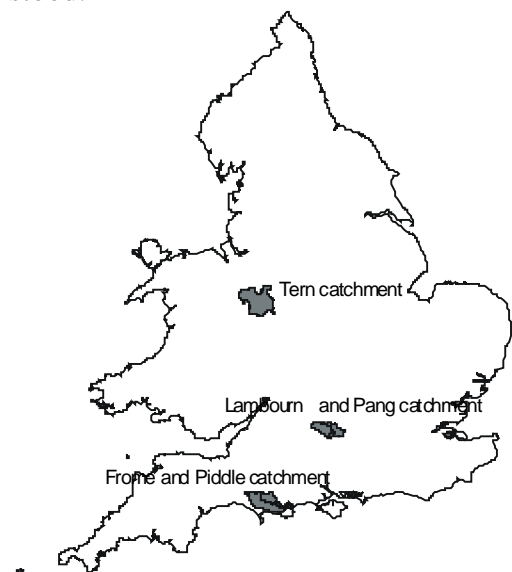


Figure 1. Locations of the LOCAR research catchments

In addition, the perceived impacts of future climate change have important implications for water resources management. In the south and east of the United Kingdom winters are expected to be wetter (with generally more intense storm events) and summers drier whilst in the north-west rainfall is expected to increase throughout the year. There is evidence to suggest an amplification of the current monthly distribution of both rainfall and runoff through the year (Marsh 1996). However, the precise response of catchments depends on the current climate, catchment geology and land use.

Recent plans announced by the UK's Department of the Environment, Transport and the Regions (DETR) indicate that some 4 million new homes will be required by 2016 in the South of England to meet the predicted future demand for housing. This will inevitably put a much greater demand on water resources in this part of the country – an area where groundwater currently provides up to 80% of public water supply.

## 2 THE LOCAR PROGRAMME

The lack of an integrated science base for lowland catchments has been recognised in a number of recent national and European reviews within the water sector (e.g. Acreman & Adams 1998, European Commission 1998, Dept. of Environment 1996, Grey et al. 1995). There is limited understanding of the underlying surface and subsurface hydrological processes and their interactions, the effects of land-use change on water, sediment and solute fluxes, the

associated transport and degradation of contaminants, the hydrological controls on ecological systems (in particular with respect to aquatic, riparian and wetland habitats), and the effects of climatic variability. Integrated models are required to provide a focus for integrated science and to combine understanding of process interactions for predictive studies. The LOCAR programme will address the following issues:

- 1 What are the key hydrological processes controlling surface water-groundwater interactions and the movement of groundwater in lowland catchments?
- 2 What are the key physical, chemical and biological processes operating within the valley floor corridor which affect the surface water and groundwater?
- 3 How do the varying flow regimes control in-stream, riparian and wetland habitats?
- 4 How does land use management impact on lowland catchment hydrology, including both water quantity and quality?
- 5 How can the hydrological, hydrogeological, geomorphological and ecological interactions resulting from natural or anthropogenic changes be predicted using integrated mathematical models?

The long term results from the five-year research programme will include improved characterisation of subsurface flow and transport processes. It will also provide improved knowledge of the impacts of land use, better understanding of the hydrological controls on stream and wetland ecology, and new holistic methods to evaluate the impacts of natural and anthropogenic change on lowland catchment systems.

The meso-scale (200-500 km<sup>2</sup>) catchments were chosen to encompass the two main aquifers in UK, the Cretaceous Chalk and Permo-Triassic sandstones and on the basis of availability of data.

A review of existing hydrological, hydrogeological and ecological data for the three catchments was carried out (Peach 2000). In spite of the relatively large amount of previous work that had been carried out in these catchments there was still a significant lack of knowledge on various aspects of, for example, the hydrogeology. In the Pang catchment there is uncertainty over both the location of a groundwater divide and the importance of karstic groundwater flow in the Chalk below Palaeogene cover. Whilst the local geology is fundamental to understanding the hydrogeology, some parts of these catchments were last mapped some 70 or more years ago and geological models and mapping techniques have changed significantly since then (Bristow et al. 1998).

In summary, results of the review indicated a great variability of data availability, both in type and space, e.g. good monitoring of groundwater in part

of one catchment, no automatic weather stations on any catchment, very patchy ecological information, basic conceptual models based on very incomplete knowledge of processes or even groundwater catchment size/boundaries, poorly understood geology and no integration of monitoring systems between groundwater, surface water, ecological and meteorological measurements.

From a groundwater perspective the knowledge that is required to develop a quantified conceptualisation of a groundwater catchment and its behaviour encompasses: - geological and hydrogeological boundaries, physical structure of the aquifer(s), recharge, discharge, groundwater flow patterns and mechanisms, rock-groundwater interactions and effects of the unsaturated zone.

Both catchment scale and local scale monitoring is inadequate to serve the research needs of the LOCAR programme. It was clear therefore that monitoring instrumentation would need to be installed to assist in the evaluation of:

- 1 Definition of groundwater catchment boundaries,
- 2 Determination of recharge processes in the inter-fluve areas,
- 3 Definition of three-dimensional groundwater flow across the catchment,
- 4 Characterisation of fracture flow,
- 5 Evaluation of heterogeneity and scaling effects,
- 6 Determination of the mechanisms of groundwater-surface water interaction near discharge points.

The monitoring infrastructure proposed seeks to achieve these aims by:

- 1 The augmentation of the existing monitoring networks in order to achieve a minimum standard of baseline monitoring e.g. by the installation of additional boreholes, rain gauges, fish counters, flow gauges etc.
- 2 The establishment of individual monitored facilities to enable research into particular aspects of catchment processes e.g. wetlands, surface water/groundwater interaction, fissure flow and recharge (Figure 2), and one off surveys of ecology, hydrology (incremental flows) and geology (revised mapping including Drift cover where present).

Broad consultation with the research community over several field trips and full day workshops demonstrated the difficulties of defining "baseline" monitoring. Inevitably, budgetary constraints rather than scientific research requirement determined the final extent of the planned monitoring networks. Initial cost estimates for instrumentation and works to provide these facilities amounted to approximately £6.7M (approx. US\$10M). In order to retain a proportion of the £9.75M overall budget for the scientific research programme a revision down to about £4M was necessary. A further £1M will be required

for management of the catchment over the 5 years of the programme.

In summary, the proposed infrastructure was costed at £5 million (to include specification/design and installation of equipment/facilities, supervision of the installation, project management monitoring activities and project management). A sum of some £4.75 remains for the 5-year research programme, for which integrated research proposals will be invited from within the scientific community.

### 3 CONCLUSIONS

In order to achieve the aims of the LOCAR programme two pairs of Chalk catchments and one Permo-Triassic sandstone catchment have been chosen and reviewed for the design and installation of an upgraded monitoring system. In spite of the knowledge base relating to these catchments the review showed that current monitoring systems were not adequate to provide baseline hydrological, hydrogeological, meteorological or ecological data to address the environmental, scientific and management issues. Significant investment is required to provide a minimum standard of baseline data to enable researchers to improve our understanding of the catchment processes occurring. The need for this investment in basic infrastructure is indicative of the responsive, rather than strategic, approach to monitoring that is not uncommon throughout Europe. The LOCAR programme is designed to enhance understanding of the processes occurring within lowland permeable catchments through a programme of integrated monitoring and research initiatives. This in turn will enable optimisation of future strategic monitoring programmes.

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### 4 REFERENCES

- Acreman, M.C. & Adams, B. 1998. Low flows, groundwater and wetland interactions – a scoping study. *Report to the Environment Agency (W6-013), UKWIR (98/WR/09/1) and NERC (BGS WD/98/11)*
- Bristow, B., Mortimore, R. & Wood, C. 1998. Lithostratigraphy for mapping the Chalk of southern England. *Proc. Geologists' Association*. 109: 293-315.
- Department of the Environment and Welsh Office. 1996. Water resources and supply: Agenda for action. *HMSO London*.
- European Commission, JRC-DGXII. 1998. Freshwater, a challenge for research and innovation – a concerted European response. *Environment-Water Task Force EUR 18098 EN*.

- Grey, D.R.C., Kinniburgh, D.G., Barker, J.A. & Bloomfield, J.P. 1995. Groundwater in the U.K. A strategic study. Issues and research needs. *Groundwater Forum Report FR/GF 1*.
- Marsh, T.J. 1996. The 1995 U.K. drought – a signal of climate instability? *Proc. Instn. Civ. Engrs. Wat., Marit., & Energy*. 118, pp 189-195.
- Peach, D. (Editor) 2000. Proposals for infrastructure and monitoring on the LOCAR catchments. *Unpublished report to Natural Environment Research Council*. pp114.

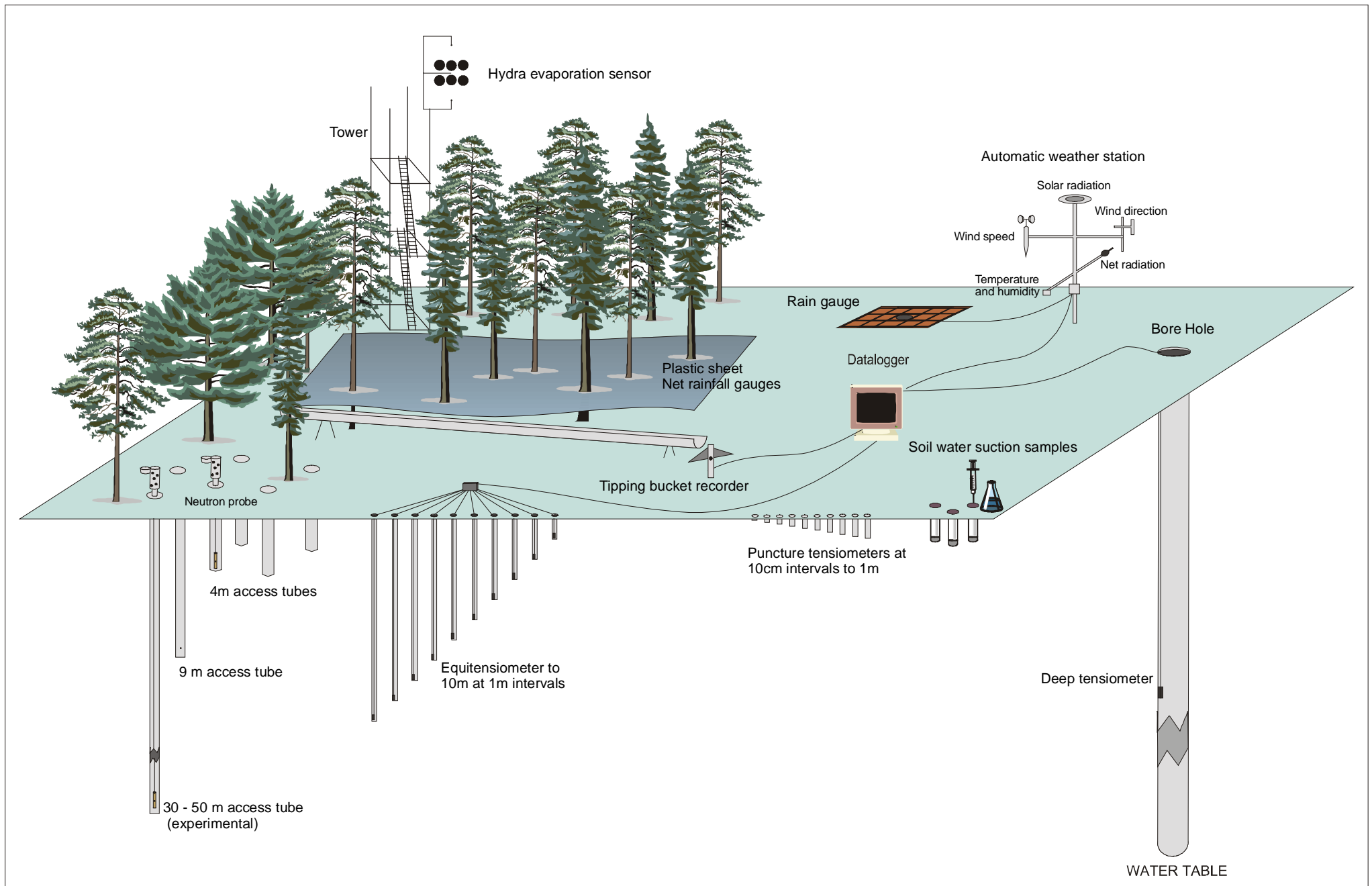


Figure 2. Proposed instrumentation at recharge investigation sites in the LOCAR programme (Peach, 2000)