Institute of Hydrology

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Critical Assessment of the Proposed Improvements to the Meteorological Observation networks in the Catchment Areas feeding to the Cumbrian Coast in the Sellafield Area.

II. Report on the second field visit to assess the final Installations

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Site Visit

The meteorological installations were visited in the company of two Entec Hydrotechnica staff on 31st January and 1st February, 1995. Prior to the visit the instrumentation had been in operation for between 5-10 months. Entec's initial experience with the instrumentation has been reported in a document produced for Sir Alexander Gibb and Partners (Entec Report No. TR172), a copy of which was made available for perusal before the visit.

It was intended to inspect all six of the installations during the follow-up two-day inspection. However, the timescale of the construction, which was not completed until August and September 1994, and the need for Entec to collect some data from the sites before the appraisal could take place, dictated that the first available opportunity to visit arrived in mid-winter. Weather conditions prior to the visit included a considerable amount of snow, some of which remained in drifts on the catchment, but fortunately none of the sites visited had any snow left on them during the visit. The weather during the visit was poor - windy, wet and low cloud - so, with due regard to safety, within the framework of the Entec field programme and in the time available, it did not prove possible to visit all the high level sites.

The mid-winter timing of the trip caused problems of access and also made it difficult to inspect sensitive electronic and logging equipment without risking water ingress. Whatever the time of year it is always difficult to assess the routine field operations, particularly in such poor conditions, as the field staff are required simultaneously to concentrate on the job in hand and also interact with the inspector. In spite of this drawback, mid-winter is probably the best time to visit the sites. As much of the instrumentation is geared to collecting the sort of precipitation associated with winter - snow, hail and occult deposition - the antecedent and ambient weather gave an opportunity to study field operations and instrumental performance in typically adverse conditions.

Of the six sites, it was possible to inspect four - Farmery, Grike, Long Grain and Brayshaw Farm. This meant that at least one example of each type of site, i.e. stations with or without an AWS, was inspected. Of these four sites, three had been visited on a previous occasion prior to installation of the instruments. The exception was Brayshaw Farm, a new site introduced after Castley Hill was dropped from the network for various reasons.

General Installation

Some of the problems noted were unique to individual sites, but most of them are generic and therefore relevant to all sites of a particular type. Given the acknowledged difficulties of installation at all sites, and the limitations imposed by the type of gauges chosen, the standard of installation was in all cases very high. All fences around the sites were well secured and very neat, all pits were well drained and the drain lines turfed over. All gauges were installed vertically, a feature that is checked on each visit. The weather stations were well guyed, with their cross members at the requisite heights above the ground and the net radiometers pointing in the right direction. The logger box and integral solar panel supplied by Didcot Instruments was unfamiliar but appeared to be a particularly neat piece of kit if a little susceptible to driving rain when opened.

Precipitation Gauges

Ground Level Gauges

The main areas of uncertainty seem to be associated with the type of gauge chosen and the rationale behind the mode of installation. The precipitation gauges are manufactured by Didcot Instruments, but rather than the familiar 8" funnel gauge as used on Institute of Hydrology AWSs, a 5" gauge is used of a type not hitherto encountered. The choice of 5" gauge is sensible because of the clear advantage of having smaller volumes of water collecting in the storage container. This makes volumetric measurement easier than with the 8" variant and in periods of heavy rainfall results in a manageable quantity where the 8" volumes would not be. However, the funnel shape is unusual, with the traditional sharp rim and 45° outside angle replaced by a wide rim made from stainless steel plate formed at an angle that appears to be considerably less than 45°, especially near the orifice. Didcot Instruments will presumably have tested this gauge against Met. Office recommended types under various conditions and must have found its performance satisfactory. However it would appear to be a design that is particularly susceptible to insplash and snow accumulation and bridging, even though it appears to have some aerodynamic advantages over a conventional funnel as part of a ground level installation.

The heating system for two of the gauges is by propane gas burner, fired by spark ignition according to the setting of an internal thermostat. The heat is concentrated onto the snow in the funnel by the fitting of an insulating jacket around the outside of the gauge. The spark ignition is a far more reliable technique than using a pilot light system which is prone to blowing out. However at a number of the sites visited on this occasion, Long Grain in particular, the operation of the heating system does not appear to have been satisfactory. The gas bottles were found to be empty on arrival, but it was not clear at the time whether this was the result of a leaking valve system or problems with the thermostat.

The heater is designed to melt the whole contents of the gauge rather than simply to keep the tipping buckets free of ice ready for the melt phase. If snow bridging occurs this application of heat could have the unwanted effect of producing a melt hollow above the gauge, subsequently causing drifting into the gauge and eventual overcatch. It is noted that in the report (TR172) there has been considerable discussion of the rationale behind the position and setting of the thermostat. It appears there may be times when the gauge is being heated unnecessarily, and to very high temperatures, which may cause problems of evaporation from the buckets as well as being a waste of precious gas. In view of the fast response of the chamber to input heat, the current setting of 5°C would seem to be an excessively high threshold for ignition.

The tipping bucket is the 0.2mm variant, and it has an unusual shape such that the width of the bucket is little, if any, wider than the bore of the feeder from the funnel. This arrangement could be susceptible to spillage, particularly if there is any air movement inside the gauge that could blow rainwater away from the bucket. The tipping bucket mechanism is necessarily lightweight and made from thin gauge steel. Although the ground level configuration is designed to minimise air movement within the pit, it is not impossible that winds from particular directions or not parallel to the ground surface could cause some movement within the pits, and hence within the gauges, possibly causing the buckets to tip when no rain is falling. It is also possible that the air movement could be exacerbated by heating one side of the tipping bucket chamber and setting up a convectional airflow within the gauge. When sufficient data becomes available it would be interesting to check whether any discrepancies between the heated tipping bucket gauges and heated volumetric gauges (and these appear to be large in some cases) can be tied down to snow, temperature or wind effects. The bucket chamber clearly cannot be made absolutely airtight to prevent this without affecting its operation in other ways, but it appears as if further airflow restriction is called for.

Net precipitation gauges

These gauges have the ambitious function of collecting and allowing the accurate measurement of rainfall, snow and occult precipitation. The gauge is essentially a conventional ground level with the Didcot Instruments tipping bucket unit set a little way below the plane of the anti-splash grids. The grids are covered with a geotextile that has a structure that was chosen to allow the snow to accumulate as if it were on the surrounding vegetation, and also to have a surface roughness that would intercept cloud water moving across the top of the gauge as if it were vegetation.

It is difficult to assess the effectiveness of the textile for either purpose in its present configuration, mainly because of the way it is laid on top of the grids and proud of the ground surface. This setup effectively forms a wall to the prevailing wind which, although <10cms high, is bound to cause increased turbulence over the gauge. To exacerbate this problem, on one or two of the gauges the textile is not held down very securely. At most sites the windward edge was being lifted and strained against the ties, while at Brayshaw Farm the ties had unfastened and it was flapping freely in the very strong wind. From the aerodynamic point of view and to improve its resistance to windlift it would be better if the top of the geotextile is set in the plane of the ground surface and better secured.

The geotextile is also very sensitive to being moved. To gain access to the gauge the two grids and textile assembly have to be lifted clear by two people, and this has the effect of causing drops to enter the gauge that may not otherwise have done so. At Long Grain this action caused the tipping bucket to tip a number of times, although it was unclear at the time whether this was caused by extra drainage from the textile or by the effect of the wind when the pit was exposed. If the tipping buckets are sensitive to wind, this could be a serious source of error, however the droplet problem is unlikely to cause an error of more than 1mm (i.e. 5 tips) over the sampling period.

Gauge Catch

Volumetric Estimates

The Entec report (TR172) showed a table of catch comparisons between the various gauges at individual sites. For both periods covered the agreements between tipping bucket gauge volumetric totals and check gauge volumetric totals at Farmery, Grike, Lairfold Rig and Long Grain were good. However at Brayshaw Farm and Boat How the check raingauge volumetric was much higher than the tipping bucket volumetric on both occasions. This suggests either that:

(i) both check gauges were subject to human interference on both occasions, or

(ii) the check gauge volumetric containers are systematically overcatching at both sites.

The former seems to be an unlikely coincidence and can probably be discounted. The way the volumetric container locates underneath both gauges is a source of some concern as it is not possible to check whether the outflow of the gauge is wholly entrained to the container or whether extraneous water is entering the container not having passed through the gauge funnel. The latter could happen if drips run under surface tension across the underside of the baseplate. However it would also have to be a coincidence for this to be the complete explanation for systematic overcatching of the check gauges. It is more likely that it is the different route taken by rain water or melt moving through the check and tipping bucket gauges that is the source of the problem. A thorough bench inspection of both feeder systems would be required to isolate the cause of this problem; it is not something that can be done easily in the field.

Another possible source of error is systematic siting differences between the two types of gauge, but as these look essentially the same from the outside this is unlikely. It has been noted that the volumetric catches from the tipping bucket gauges follow a sensible pattern of precipitation increasing with altitude, while for the check gauges the pattern is reversed. This would normally suggest that it is the check gauges overcatching rather than the tipping bucket gauges undercatching, but insufficient is known about rainfall distribution in the area to rule out the possibility of a real reverse gradient of precipitation with altitude.

This reverse gradient was also seen in the catches measured at the various sites during the visit being reported, with both gauges at Long Grain for instance having a much lower volume than both gauges at Brayshaw Farm or Farmery (this was an impression gained at the time as the exact figures are not to hand). The discrepancy on this occasion could have been caused by the snow that had fallen in the previous month, forcing the more exposed upper gauges to undercatch, but this would not apply to or explain the discrepancies in the earlier data collected in autumn 1994.

The siting of individual gauges is a problem that is of some concern at all sites, particularly those on the steeper slopes. Ground slopes can be misleading and the impression gained from the reconnaissance visit to the sites in 1993 was that some build up would be required but not nearly as much as has turned out to be the case. At all the sites visited there is a steep wall of turf in front of the gauges, and whether by chance or not, this wall tended to be on the windward side of the gauges. In some instances the turf has started to shrink or slump away from the boxes leaving a vertical wall, a common occurrence that nevertheless needs a prompt remedy. This type of installation can be subject to considerable wind effects, usually resulting in rainfall undercatch. It may be that the effect is greater at the more exposed sites, which also tend to be the higher altitude sites (Grike and Long Grain of the ones visited), and this can result in an apparent reversal of rainfall gradient with altitude.

Tipping Bucket Records

With the notable exception of Long Grain, the tipping bucket records do not appear to show agreement with volumetric catches at any sites. The result from Long Grain shows that with a good installation agreement is possible, and begs the question why the other ground level tipping bucket gauges have performed so badly. There may be a clue in the fact that the agreement between the tips record and the volumetric totals for the net precipitation gauges has generally, with one or two exceptions, been very good. This finding suggests that it is not the calibration of the tipping buckets that is causing the problem, unless by chance all the poorly calibrated buckets are on the standard tipping bucket gauges, while all the well calibrated buckets are on the net precipitation gauges.

While the undercatch of tipping buckets can usually be explained by poor reed contact, overcatch is not so easy to explain. Double reed contact is not unknown, and this can be intermittent so the number of tips need not necessarily be double that expected. Perhaps another explanation could be that the discrepancy is a wind effect, whereby the net precipitation gauge is better sheltered by the covering geotextile than the ordinary gauge which just has the grids? If this is the case it will be difficult to check without being on site during windy but dry conditions to see if the wind alone can tip the buckets.

Alternative Check Gauges

The nature of the investigation is such that a certain amount of innovative design has had to be incorporated in the instrumentation and their installation. Unfortunately this approach has also left the study without underpinning standard techniques for comparison. Most water balance studies in Britain, certainly those carried out by IH, have used a Met. Office standard 5" storage raingauge either set at 30cms above the ground in sheltered conditions, or in a pit at ground level in exposed conditions. On hillslopes it is possible to install this type of gauge in the plane of the ground surface so as not to interfere with the flow of wind over the gauge, in a way that the tipping bucket gauge cannot unless it has a secondary funnel system fitted that can be tilted to the ground slope. This type of standard gauge does not have the complication of a tipping bucket mechanism that can affect the gauge catch, or the problems caused by using a gauge originally designed to incorporate a tipping bucket but with the bucket removed. In such a gauge the route for transfer of rain from funnel to collector can be over-long, which increases the chances of leakage or inflow occurring in an unpredictable and inconsistent way.

The catch of the Met. Office recommended gauge can act as an unequivocal standard against which the innovative gauges can be assessed. Rather than modifying the existing gauges, as these are justified in their present form as an integral part of the experimental design, it is recommended that extra ground level gauges are installed adjacent to the existing ground level gauges but set flush with the ground surface. Maybe this could be done at a few of the sites to start with and later expanded if found necessary.

Automatic Weather Stations

There is little that can be said about the Didcot AWS that hasn't already been said.

The setup in Cumbria is very similar to that used by IH, and the field operations also very similar, with the same potential problems and causes of malfunction. The only things to note are:

(i) the wick on the wet bulb thermometer at both sites appeared to be migrating off the thermometer. This might be a wind effect and needs to be checked each time.

(ii) the silica gel indicator had turned pink/colourless on one of the AWSs. This is a problem that had been noted by the operators as having happened on this particular AWS on a number of previous occasions, without apparently affecting the operation of the main silica gel reservoir which still appeared to be doing its job of keeping the domes free of condensation. This same problem has been noted on IH stations. For some unknown reason certain net radiometers are susceptible to this and others aren't; the situation just needs to be watched carefully.

(iii) there have been problems with logger breakdown. On numerous occasions on IH stations a similar problem has been traced to premature failure of the internal rechargeable 12V battery on the Campbell. It is now the policy to replace these every 12-18 months rather than 2 years as was the case in the past.

Field Operations

As noted previously, it is difficult to assess field operations during a routine field run because of the effect of the observer on the behaviour of the operators. In spite of the obvious intrusion and distraction, all of the operations I saw performed were carried out with a high degree of care and consistency in fairly atrocious conditions. The main worry I had was the difficulty experienced by staff in emptying the contents of the plastic containers under the raingauges into measuring cylinders. In such high winds and with such an awkward pouring spout some spillage is bound to occur, and this happened on a number of occasions (including when I tried it myself!). However no spillage was on the scale that would have affected the accuracy of the estimate to any great degree, and could in no way be implicated in the differences found between various gauge catches.

When there is such a large distance between base and field sites there is an overwhelming temptation to perform field operations in adverse conditions to fit in with the timetable of the trip. It should be remembered that there are times it is better to leave well alone, and this is particularly true when downloading data from sensitive electronic logging equipment. The ingress of moisture has been found to be the single most common cause of problems with the Campbell Scientific equipment run by IH, not only the flimsy connections between logger, storage modules and keypad, but also inside the logger box itself and on any interface connections which are exposed to the atmosphere. Exposure to bad weather should therefore be minimised, although it is appreciated that this is not always possible when conditions are bad throughout the trip and the data storage capacity of the loggers will be exceeded if left until the next time.

Suggestions and Recommendations

In summary the following actions should be considered. It is appreciated that not all will be easy, financially or logistically viable or guaranteed of success.

(i) Extra check volumetric gauges should be installed at all sites to act as unequivocal standards.

(ii) The thermostat setting should be reduced on heated gauges to minimise gas use, air circulation and excess temperatures within the gauges.

(iii) Efforts should be made to make the gauges as windproof as possible without restricting air supply to the burners.

(iv) The effect of wind on the action of the tipping buckets should be investigated.

(v) The gauges should be individually bench tested to check on the correct passage of water through the gauge to the volumetric container. Ingress of water from outside the gauge should also be checked.

(vi) The net precipitation gauges should be set at ground level and the geotextiles better secured.

(vii) All turf slopes in front of the ground level gauges should be repaired and some thought given to smoothing the profile of the ground in front of the gauges. Alternatively, the gauges would have to be buried lower in the ground and a false tiltable funnel used that is set in the plane of the natural ground surface.

(viii) Batteries in all Campbell loggers should be replaced at least every 18 months to minimise possibilities of data and program loss.