HYDROLOGICAL INCONTINENCE AT NORTH WYKE'S DAIRY NORTH

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SUMMARY

Water movement at Dairy North cannot be entirely accounted for through the balance of discharge via the flume on the paddock's french hydrological boundary drains and evapo-transpiration. This review examines likely reasons of soil structure and hydrology.

Miss-matches between expected water discharges and those measured at the weir, can be accounted by the percolation of water to depth and its movement as shallow groundwater in the rubbly Head above the bedrock. It is likely to bypass the clayey subsoils, and hence the french drain collection system, via localised natural breaks in the otherwise impermeable clay cover, or by bypass flow following relatively short-lived, summer shrinkage and cracking. The possibility that relatively deep artificial drainage channels, installed in the past, breach the clay subsoil layer, should not be overlooked.

SOIL SURVEYS OF NORTH WYKE

In 1957 North Wyke was occupied by Fisons Fertilisers and run as their grassland experimental and demonstration farm. The soils were surveyed by the Soil Survey of England and Wales [Findlay and Clayden, 1957]. When GRI, later IGER, took on North Wyke, plus the new acquisition at Rowden Moor, the additional land was surveyed in detail [Harrod, 1982]. In these surveys, along with sections 3.5 and 4.2 of Harrod and Hogan [2008] observations were made down to about 1 m depth, around normal land drain depth, with an emphasis from the perspective of agricultural management and environmental impacts. In the period between 1957 and 1982 mapping of soils over rocks similar to North Wyke's had been carried out in the Middle Teign Valley [Clayden, 1965], Exeter [Clayden, 1971], Holsworthy [Harrod, 1978] and Chulmleigh [Harrod, 1981] districts. Consequently, the classification of the 1957 mapping by Findlay and Clayden at North Wyke was revised to conform with the Teign Valley and subsequent surveys. Meanwhile formalisation of SSEW's soil classification was under way, to be eventually published by Avery [1980] and Clayden and Hollis [1984]. The reorganisation of soil series names, necessitated by the need for a nationally robust classification [after Clayden and Hollis], resulted in some changes of map unit names between Harrod [1982] and Harrod and Hogan [2008], Tedburn becoming Hallsworth, Dunsford becoming Denbigh, while Stanley has been replaced by Cherubeer, mostly following a policy of published "primogeniture".

N.B. So far, a copy of Findlay and Clayden's map and report has not been traced in the Cranfield SSEW /SSLRC/ NSRI archive.

It may be helpful to the reader of this text to clarify a point about nomenclature. Soils are conventionally named using place names, e.g.*Halstow*, much as with animal breeds. The basic unit of soil profile description of about 1 m^3, the soil *series*, has that place name coupled with the word series, e.g. *Halstow series*, and might be seen as analogous to the biologist's species. The distinction needs to be kept in mind between this concept of the soil series and soil *map unit*, e.g. *Halstow map unit*. That characterises the occurrence of soils in space, as mapped across a field and hill slopes, more akin to the concept of a plant community, in which subsidiary species may be present.

SOILS IN DAIRY NORTH, observed Feb 2018

This review of the soils in the Dairy North field at North Wyke and its hydrology follows anomalous performances, after its isolation by french drains to enable hydrological monitoring. The shortfall of a larger proportion of the incoming precipitation than might be expected due to evapotranspiration needs to be accounted for. Likely explanation may be through soil morphology and soil hydrology.

Unlike following the dry winter of 2016-17, in February 2018 the soils had thoroughly moistened up after a wet autumn and winter, so that conditions for soil examination have been ideal. Within Dairy North the predominant soil observed was Cherubeer series, the fine loamy over clayey stagnogleyic brown earth noted as present sporadically in the Denbigh map unit elsewhere at North Wyke. Although surface horizons are clay loam in texture, Cherubeer profiles typically have a more clayey horizon, with coarse columnar of prismatic structure, below 30-60 cm. A minority of the Cherubeer series profiles observed intergrade to Halstow series, since the loamy, upper layers thin and its clay content increases. Within the paddock other profiles present as minor elements include the Denbigh series over shale at 40-50 cm and the Papworth series, a fine loamy stagnogleyic brown earth with negligible textural change down the profile. Apart from the Denbigh series, all profiles had gleying [indicative of degrees of seasonal waterlogging] below 40 cm, with some manganese flecking in most of them.

Overall soils in this field seem intermediate between the Halstow and Denbigh map units of the 1982 mapping, with too much gleyed soil for Denbigh map unit, but not heavy enough in the surface and immediate subsurface for the Halstow map unit.

HYDROLOGY OF SOILS AT NORTH WYKE

A] Down to about 1 m

With the exception of the relatively small area of freely draining Denbigh series, clayey, slowly or very slowly permeable subsoils constitute the overriding hydrological property of North Wyke's soils. The distinction between Halstow and Hallsworth series is one of degree, not of kind.

Halstow soils have dense subsoils with few pores and as a consequence are only slowly or very slowly permeable. Undrained they are in the Soil Wetness Class IV *[commonly wet]* of Hodgson [1997], with suitable drainage improving to Class III *[occasionally wet]*.

Halstow series' clayey nature brings about a hydrological character which changes from the state dominating between October to May in average years, to the drier condition of summer and early autumn. Shrinkage of the subsoil at dry times gradually opens the vertical fissures between the prismatic aggregates in the subsoil horizons, allowing unsaturated flow down the profile into the Head, which makes up the substrate above the bedrock. This by-pass flow continues until autumn when the clayey subsoil gradually rewets and, by swelling, closes the fissures. Then lateral saturated flow through the better aggregated, more porous topsoil and surface runoff resume as the pathways until the next summer. This involved soil hydrology ensures that Halstow soils make differing seasonal contributions to stream discharges, to base flow in the summer and through runoff during the field capacity season.

The dense clayey subsoils make the Hallsworth series very slowly permeable. When undrained the soil is in Hodgson's [1997] Soil Wetness Class V[*usually wet*], since the profile is wet for much of the year. Effective artificial drainage for agricultural purposes can improve the water regime to Wetness Class IV [*commonly wet*]. While these soils show classic surface-water gley morphology, it should be pointed out that in places, particularly near the upslope boundary to more readily draining soils, spring water can rise to the surface, complicating the soils' hydrology. There are seasonal changes in the hydrological pathways of Hallsworth soils, akin to those in Halstow series. Similarly there are inputs to both base flow and to higher level discharges.

The Denbigh soils are permeable and, in places, on pronounced slopes. Modal profiles are Wetness Class I *[rarely wet]*, although dip-well measurements by Clayden [1971, Appendix II, p230] show a Dunsford series [the local name for these soils over Carboniferous Culm Measure rocks prior to Clayden and Hollis, 1984] site with a slightly wetter regime than a Denbigh soil [at that time called Highweek series] over Devonian slates. The principal hydrological pathway in Denbigh soils is unsaturated vertical flow into the substrate of Head or shale. In very wet conditions, or where soil structural damage is acute, surface runoff may be possible. Since the substrate has only limited fracturing, both base flow and higher discharges receive moderate contributions. Associated with Denbigh soils are sporadic occurrences of Cherubeer profiles, whose clayey lower horizons have hydrological properties analogous to Halstow subsoils.

B] Hydrology below 1m

Standard soil descriptions, as by Findlay and Clayden [1957] and Harrod and Hogan [2008] extend down to about 1 m depth, around normal land drain depth. However, further insights into the issue of unaccounted for hydrological losses from North Wyke are provided by considering water movement at greater depths. This is not easily observed, but widespread “deep” drainage schemes in Devon and north Cornwall, under grant aid, during the 1960-80s were revealing, as summarised by Harrod [1978 and 1981]. The Hydrology of Soil Types classification of Boorman *et al.* [1995] provides further context.

Over much of the Carboniferous outcrop in the Southwest the soils have formed in the upper part of Pleistocene solifluction Head. This is a rubble of fragmented, variably porous, but otherwise little weathered, rock, in places a few metres thick, which rests on the more or less intact bedrock. Here and there the Head thins and the bedrock approaches the surface. A proportion of rainfall penetrates and can accumulate in the rubbly Head, either percolating through more porous soils upslope, via bypass flow within clayey soil horizons seasonally cracked by summer drying, or from deeper groundwater moving along geological fault lines. The widespread clayey subsoil horizons provide an impermeable cap, effectively containing the water within the Head. Harrod [1981] concluded that while the Head can be permeable and highly charged with water, individual shallow groundwater bodies are limited in extent and are not interconnected to any degree.

There has been a long tradition among farmers and land drainage contractors, in those parts of Devon with heavy, surface water gley soils, of “deep” drainage. Trenching at depths up to 3 or 4 metres was often carried out to eventually intercept “under water”, frequently in impressive, sometimes prodigious, quantities. This approach conflicted with the conventional method of clay land drainage using shallow drains, back-filled with permeable gravel, into which mole channels were drawn.

At an FDEU study site [Ryecroft, 1971] at Strawberry Bank, Bridgerule, Holsworthy, piezometers were driven deep into subsoils of Hallsworth soils. These revealed hydrostatic heads, capable of raising water above the ground surface. Harrod [1981] reported similar effects among 20 sites across the Carboniferous outcrop in Devon on soils essentially similar to those at North Wyke. In the latter study there was a range from strongly positive hydrostatic heads sustained year around, [although effectively held below the ground surface by impermeable Bg horizons], to potentials limited at various depths below the surface. Harrod [1981] showed that hydraulic conductivity in the solifluction Head below the Bg horizons was highly variable, from a few cm per day to tens of metres a day.

The pattern of water levels in most of those piezometers reflected the annual cycle of winter excess rainfall over evaporation and the development of a soil moisture deficit in summer, albeit to varying degrees. At some sites shallow dip-wells were used to monitor surface wetness. While there was a similar reflection of the seasonal cycle of wet conditions in winter and drier ground in the summer, there was no clear, direct correspondence of dip-well water levels and piezometric heads, indicating that the groundwater there had negligible effect on surface wetness.

With this background, it is clear that the soils over the Carboniferous outcrop in the southwest, and by implication those at North Wyke, differ in their overall hydrology from clayey surface water gley and related soils formed over Mesozoic and Tertiary clayey formations or glacial tills elsewhere in the country. That difference comes primarily through the presence of discontinuous aquifers in the Head between the subsoils and the bedrock.

For a demonstration of the operation of groundwater beneath the clayey subsoils underlying the ground in Dairy North itself, there is no need to go further than the woodland downslope and to the east. There an obvious spring line runs more or less along the boundary with the Hallsworth map unit. A similar spring line occurs on many of the junctions between the Halstow and Hallsworth soils at Noth Wyke, although some of them are likely to have been reduced in their effect in the past by agricultural land drainage schemes.

SOILS AND HYDROLOGICAL BUDGETING

Discrepancies between monitored water discharges and those expected, seem explicable in terms of the percolation of water to depth and its movement in the rubbly Head above the bedrock. It is likely to break through the clayey subsoils due to localised natural ruptures in the clay cover, or by bypass flow resulting from its relatively short-lived, summer cracking. Furthermore, the possibility of artificial drainage channels, installed in the past, breaching the clay cover, cannot be discounted.

Although hydrological budgeting should provide a reasonable estimate of amounts of losses to these shallow aquifers, there may be a need to sample the groundwater chemistry. Sampling of emerging groundwater in the woodland downslope of Dairy North would risk complications from processes within that very different soil and ecological regime. An array of piezometers sunk close to the lower boundary of the paddock would avoid this difficulty. In addition these would provide an opportunity for measurements of flow, hydrological conductivity etc, placing any chemical measurements in a firm context. There may be implications in all this for other hydrologically isolated sites at North Wyke.

The design of piezometer used by Harrod [1981, p108] effectively isolated ground water from surface water on similar soils and might be usefully followed. Installation should be carried out under dry, summer conditions, with the borehole 10 cm or greater in diameter, in depth, either to water or to the base of any porous material. One of the conclusions from that piezometer study, and from many observation of deep drainage trenching, was that the aquifers in the Head are small and discontinuous. It is for that reason that a group of piezometers may be warranted, rather than a single one.

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