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WICKEN FEN

HYDROLOGICAL STUDY

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Introduction

Wicken Fen is a 304-hectare patch of calcareous fenland lying on the periphery of the Black Fens, and in the ownership of the National Trust. The Fen owes its preservation, in the face of increasing agricultural use of the East Anglian peatlands, to early designation as a nature reserve and its position adjacent to a high-level channel, Wicken Lode, which is linked directly into the internal dyke system of the Fen. Wicken Fen represents a remnant of a once-extensive landscape, an almost vanished habitat and a traditional way of life which is now known to the general public only through rural museums.

Wicken's historical associations and conservation value are further enhanced by the detailed scientific work carried out on the Fen over the years. Some of the results of these investigations, particularly those of Godwin and his associates, have been used in the maintenance of the semi-natural habitats of the Fen, by careful cutting and cropping practices; nevertheless changes have occurred in the fen vegetation since the 1920's when the most significant studies were performed. Large areas of the Fen have developed carr vegetation, a trend noted by Godwin (1931), and there are now signs of acidification of the surface horizons, indicated by the presence of acidophilous mosses. It is probable that these changes are associated with a decline in the fen water table relative to surface level, or a change in the variation of water levels over the year. A recent management proposal for part of the Fen, based on scientific conclusions by Godwin and Bharucha (1932), was the removal of peat by a commercial extractor, followed by the replacement of the surface peat containing the seed bank. The fen community could thereby be recreated at a lower level, with a higher relative water level. However, the scheme was not without its dangers, not least of which was the possibility of the establishment of a new fen community less diverse than the old.

The hydrological behaviour of Wicken Fen was first investigated by Godwin and Bharucha over the years 1928-30, and has since been the subject of rather discontinuous work, summarised by Gowing (1977). Thus, when the new management proposal was advanced, it was without the support of the archive of hydrological information that could have been built up over the last fifty years if the early work had been followed up on a routine basis and related to Ordnance Datum.

The Institute of Hydrology was commissioned to conduct a further investigation of the water regime of Wicken Fen, to establish a firmer basis from which to examine management proposals. The IH work was to take place over three years, and to cover four aspects of the natural behaviour and possible management of the Fen:

(i) the significance of water quality to the fen community, and its relationship with present and possible water sources

(ii) investigation of leakage around the periphery of the Fen, and the relationships between the fen water table and dyke water levels

(iii) technical solutions involving civil engineering work, liaison with the Water Authority, use of the Fen as a flood storage area, or supply from groundwater

(iv) management recommendations on control of seasonal fluctuations in the water regime.

This interim report summarises the first year's work, which has comprised installation of hydrological instrumentation on the Fen, and the collection of regular measurements by National Trust staff. A provisional interpretation of the first year's data will be attempted, though clearly this may be revised as the study proceeds.

Installation of equipment

When the IH study started, there was no routine measurement of water level at Wicken, in spite of its obvious importance as a controlling variable. The first priority was the establishment of a network of stations for water level measurement, at which frequent and regular observations could be made. For reasons of cost and travelling time, it was not possible for IH staff to be involved in the routine collection of data on the Fen, so it was agreed that the National Trust would provide a person to undertake the measurements, generally on a weekly basis.

In May and June 1984, a team from IH installed a network of shallow boreholes for groundwater level measurement, staff gauges on the Lode and principal dykes, and two continuous water level recorders on boreholes near the centre of the Sedge Fen. So that the boreholes could be used to study the relationships between dyke levels and fen groundwater levels, they were not distributed evenly around the site, but were generally grouped in straight transects perpendicular to dykes, with an interval of about 10 metres between the boreholes in each transect. This layout provides a basis for comparisons between the new data and Godwin's early work. Two observation pits dating from Gowing's (1977) work were included in the observation network, and one of these had been located by Gowing at the site of one of Godwin's more significant recorder stations. Thus a small element of continuity has been incorporated into the study, though conclusions on long-term changes in water level must necessarily be guarded.

Figure 1 shows the locations of stations in the network, while the following is a brief description of the stations in the order in which they appear on the observer's data form:

(i) Wicken Lode 'near' gauge board (Sg 1)
A 1-metre staff gauge was installed in the Lode a short distance from the William Thorpe Building. This gauge, fixed to a stake and concealed among emergent vegetation, has been read daily, and often more frequently.

(ii) Gowing's triangle recorder site (Bh 0).
The floats for Gowing's continous recorders were mounted in shallow pits with wooden linings. One of these pits, connected by a pipe with Drainer's Dyke, was located in a triangular patch of scrub at the junction of Drainer's Dyke and the Lode. In recommissioning this pit, it was subjected to the same 'development' procedure as freshly-installed boreholes: a pump was used repeatedly to extract all the water in the pit, until the accumulated sludge had been removed. A good hydraulic connection with the surrounding peat was indicated by a steady influx of relatively clean water. Measurements of depth to water level are taken in this pit and the boreholes of the network using an electrical contact gauge, referring all measurements to a marked point on the rim of the casing. This station is considered as an indication of the level of the Dyke.

(iii) Drainer's Dyke borehole transects (Bh 1-11)
A transect of boreholes was installed at each side of the dyke, that on the east extending into sedge fen freshly cut in spring 1984, that on the west into sedge fen cut in 1983. Each borehole was excavated to a depth of two metres using a Jarrett auger, and a perforated plastic casing was inserted. The boreholes were developed by pumping, and capped to exclude rainfall.

(iv) Wicken Lode/Malcarse Drain staff gauge (Sg 2)
Another staff gauge was installed at the junction of the Lode and Malcarse Drain, to give another indication of Lode levels, and to show if there were seasonal changes in water surface slope.

(v) Malcarse Drain borehole transect (Bh 12-17)
A transect of six boreholes was installed in carr to the east of Malcarse Drain, south of Cross Dyke.

(vi) Godwin Main Drove recorder (Bh 18)

Godwin, and much later Gowing, sited a recorder on a pit near the junction of Drainer's Dyke and the Sedge Fen Drove. This pit, now surrounded by carr, was developed in the usual way, and is dipped on a weekly basis.

(vii) Drainer's Dyke 'top' staff gauge (Sg 3)
A staff gauge was installed at the northern end of Drainer's Dyke, close to the point at which pumped drainage water from adjacent agricultural land is introduced.

(viii) Continuous recorders (Bh 19 and 20)
Two Ott R16 continuous groundwater level recorders were set up on boreholes in an area of 'litter' adjacent to the Sedge Fen Drove. The more easterly of the two boreholes (Bh 20) was in 'litter' vegetation that had been cut in 1982, while the other (Bh 19) was in a field that had been cut in 1983. It was intended that these two fields should be cut in alternate years.

(ix) Godwin wrecked recorder (Bh 21)
North of the Sedge Fen Drove, close to a sinuous drove cutting through to the Spinney Bank, the wreckage of what may have been one of Godwin's water level recorders was found. One of Godwin's recorder pits (number 6a) was sited some 100 metres to the west of this spot. A borehole was installed near the wreckage to form a link between the Drainer's Dyke transect, the newly-installed recorders and the Spinney Bank stations.

(x) Spinney Bank borehole transect (Bh 22-26)
The Spinney Bank forms the northern boundary of the Fen, against agricultural land at a much lower level. A farm ditch at the foot of the Bank drains the agricultural land, and a ditch in a rather overgrown condition separates the reserve path from the summit of the Bank. Five boreholes were installed in the first instance, extending from the Bank into the carr, and, with the farmer's permission, into the field towards the farm ditch. However, one of these boreholes (Bh 23) was damaged, probably by a vehicle, and was not used after the first few weeks.

(xi) Spinney Bank staff gauges (Sg 4 and 5)
Staff gauges were installed on the reserve ditch at the top of Spinney Bank, and on the farm ditch at the foot of the Bank.

(xii) New Dyke borehole transect (Bh 27-33)
New Dyke is the most westerly and probably the newest (Evans 1925) of the north-south dykes dividing the Fen, and was recently cleared over part of its length. While the work was proceeding, it was noticed that the Dyke was channelling Lode water rapidly into an area adjacent to the western edge of the Fen, along Howe's Dyke, and work was stopped. The southern end of the Dyke is now blocked by a wooden dam. At the northern end of the Dyke, near Howe's Dyke, a transect of boreholes was installed leading from the New Dyke into the fen. A second transect, perpendicular to Howe's Dyke, could not be set up, as the carr bordering the fen was impenetrable.

(xiii) New Dyke staff gauge (Sg 6)
A staff gauge was fixed to the Dyke side of the New Dyke dam, to indicate the difference in levels between the Dyke and the Lode.

Variations in water levels during 1984-5

Water level measurements have been made at weekly intervals over the majority of the network of staff gauges and boreholes, and fortnightly at the less accessible stations near New Dyke. The results, reduced to Ordnance Datum according to the results of surveys in May and June 1984 (table 1), are presented in tables 2, 3 and 4.

A full rainfall record has not yet been obtained, but the Water Authority will be approached for data from nearby stations. Climate data are now being collected at the William Thorpe Building, and should provide a very valuable background resource, not only for the hydrological study, but for other scientific work at Wicken. The rainfall record is presented in table 4, and at the foot of figure 3.

In the interpretation of the water level record, it would be difficult to better Godwin's scheme of dividing the analysis into the effects of rainfall, diurnal fluctuations and seasonal drift. A fourth aspect, considered inferentially by Godwin (1931), and in more detail by Godwin and Bharucha (1932), is the form of the water table surface, which is of great importance in management. The seasonal fluctuations in level and gradient can be seen in the weekly readings: in the main the record for each borehole shows a decline in the summer of 1984, between the end of June and the beginning of September, a rise, initially rapid, from then to the beginning of November, and relatively stable levels during the winter of 1984-5. The variation in Lode and dyke levels is much less evident.

The effect of rainfall

The immediate effect of rainfall on the fen is a rapid rise in the groundwater level, followed by a slower decline. The rise in groundwater level is caused by the filling of unfilled pores in the peat, and a consequent rise in the phreatic surface, represented by the water level in an open borehole. The pheatic surface lies some distance below the interface between saturated and unsaturated peat, and the change in water stored can only take place by a movement of this interface. Between the phreatic surface and the interface between saturated and unsaturated zones lies a 'capillary fringe' in which soil water under tension fills the pores. The ratio between the input of water to the groundwater body and the rise in water table, normally expressed as a percentage, is the 'effective porosity'. The effective porosity of peat, which varies with compaction and hence with depth, is a fundamental parameter which determines the quantity of water stored in the peat, and the rate of lowering of the water table over drought periods.

Godwin (1931) noted that when the water table was in the upper 20 cm of the peat, the rise in water level was between 7 and 12 times the amount of rainfall, indicating an effective porosity of 10%. Gowing (1977), working with more recent data gathered at Godwin's recorder site, derived a range of values for the effective porosity, varying from 10% to 33%, and concluded that the figure of 10% should be revised to 15%.

The records from the continuous recorders mounted on boreholes 19 and 20 have been analysed in relation to the rainfall figures available to date. These rainfall data comprise measurements from the pumping station at Upware, for May to September 1984, and from Wicken Fen for January to May 1985 (tables 5 and 6). When those rises in groundwater level that could be attributed directly to rainfall events were examined, it was found that a wide range of effective porosity figures was obtained, from 9% to an impossible 121%. The highest values were found when the water table was at its highest, as could be expected, the effective porosity of litter and loosely compacted plant material approaching 100%, but this is not the full explanation. The method of comparison of rainfall and groundwater rise necessarily assumes that all rainfall is available to top up the groundwater store, where in fact the processes of interception on vegetation and takeup of water into the unsaturated zone to satisfy any soil moisture deficit account for a significant proportion of the rainfall, particularly in light showers and summer storms. The actual input to the groundwater store is thus rather less than the rainfall, and the value obtained for the effective porosity will tend to be an overestimate. Values computed from high rainfall events should tend to be lower, and approach a 'true' value. In figure 2, the values found are plotted against water table elevation, this elevation being the the mean of initial and final water levels. The points on the diagram are annotated with the total rainfall for each event. It is clear that those points with rainfalls in excess of 15 mm define an envelope line towards the left of the diagram. Over much of the profile an effective porosity of 10% would appear to fit the observations, while in the top 15 cm higher values are indicated. As a reasonable estimate, a linear variation from 10% at 15 cm depth to 20% at the ground surface is suggested. This diagram will be refined as the study proceeds, and more data become available.

Diurnal fluctuations

A persistent feature of continuous records of mire groundwater levels is the presence of diurnal fluctuations. The general form of the fluctuations is a decline during late morning and afternoon, followed by a full or partial recovery or a constant level during the night. Godwin correctly identified these variations, recorded at Wicken, as indications of evaporative loss from the groundwater body. At the recorder site now included in the IH network as Bh 18, a recovery during the night was attributed to recharge from Drainer's Dyke 50 m away, and Godwin hypothesised that water levels far from a dyke would remain constant during the night. This was confirmed at his pit 6a, close to the IH continuous recorder sites. An experiment with a lysimeter or 'insert phytometer' confirmed that a soil mass isolated from lateral replenishment did indeed show little change in level during the night. Provided allowance was made for replenishment, and that a reliable estimate of effective porosity were available, the fluctuations in the fen water level could be used to determine the evaporative loss.

Close examination of diurnal fluctuations on the records obtained from boreholes 19 and 20, discernible between mid-June and late September 1984, shows that the variations take three distinct forms, illustrated in figure 3. During June and the first part of July, a high evaporative demand produces fluctuations of large amplitude, characterised by a rise in the latter part of the morning. This rise could perhaps be interpreted as a redistribution of soil water after a high daytime demand from roots penetrating below the water table. As the water table declines, and transpiration demand lessens, the constant nighttime portion of the curve becomes more evident. At the lowest groundwater levels, the fluctuations become ripples on a continuous decline. This could be interpreted as a dispersion of the diurnal wave of water demand, the processes of redistribution of soil water requiring more time as the unsaturated zone becomes deeper. Thus the demand on the groundwater body is spread throughout the day, and diurnal fluctuations beome less obvious.

Well-defined fluctuations throughout the summer of 1984 have been used to provide estimates of daily evaporation, using the effective porposity distribution suggested above: 10% for peat below 1.80 m OD, increasing linearly to 20% at the surface. The results are plotted, along with midnight water levels in borehole 19, abstracted from the recorder charts, in figure 4. A missing bar in the evaporation section of the diagram indicates that the record was unsuited to the analysis, and not that no evaporation occurred on that day. The division of the summer into periods of high and moderate transpiration demand is clear. It will be interesting to compare the picture emerging in following summers as the study proceeds. With some refinement of the method for determining effective porosity, the diurnal fluctuation method is a promising means for estimating actual evaporation from mire communities.

Seasonal changes in water level

Boreholes and staff gauges at 31 stations of the network have been read at weekly intervals since May 1984, and a further eight at fortnightly intervals since July 1984: at this stage one complete year's data, up to the end of May 1985, are to hand. It is simplest to consider the water levels in five groups: the two sedge fen transects (Bh 1-5 and Bh 6-11), the carr transect (Bh 12-17), the Spinney Bank transect (Bh 21-26) and the New Dyke transect (Bh 27-33). Each transect can be associated with relevant staff gauges, to indicate the relationship between open water and groundwater.

(i) eastern sedge fen transect (Bh 1-5)

Figure 5 shows the records from selected stations on the borehole transect, and from the Gowing pit (Bh 0), which may be taken as an indicator of the level of Drainer's Dyke. There is close agreement between this borehole and staff gauges on the Lode and at the northern end of the Dyke. The transition between dyke-controlled and evaporation-controlled behaviour is clear, and the records support Godwin and Bharucha's (1932) assertion, based on a series of water level pits about 250 metres north of the sedge fen transect, that the dykes exercise control only over a 50-metre strip around the perimeter of fen areas. In the figure it can be seen that the dominance of the seasonal evaporation factor is well established within 10 metres of the Dyke. The range between maximum and minimum levels in Bh 1 is 0.84 m, compared with 0.88 m for the continuous recorder on Bh 19. It is not possible at this stage to state whether the slightly smaller range in Bh 1 is due to the proximity of the Dyke or to the difference in vegetation community: Bh 19 is in litter, Bh 1 in sedge. By contrast, the Dyke water level varies over a range of only 0.18 m.

(ii) western sedge fen transect (Bh 6-11)

Figure 6 shows records from selected boreholes on the second sedge fen transect. While it is not immediately apparent from the figure, a feature of this transect, when compared with the eastern transect, is its smaller range of variation: the total ranges of levels in Bh 9, 10 and 11 are 0.73 m, 0.75 m and 0.74 m respectively, in contrast with 0.80 m, 0.81 m and 0.84 m respectively for the similarly positioned boreholes, Bh 3, 2 and 1. This difference in range is entirely due to lower winter and spring levels, especially in the four weeks after installation: summer levels in analoguous boreholes follow each other closely. It is too early to say whether this effect is due to soil factors or to the stage in the cutting regime. The sedge around the eastern transect had been recently cut at the time of installation, while that around the western transect was mature. A longer data set is necessary before this or similar questions can be resolved.

(iii) carr transect (Bh 12-17)

This transect extends from Malcarse Drain eastwards into rather unhealthy Rhamnus carr. While the behaviour of water levels (figure 7) is broadly similar to that in the sedge fen transects, the evaporative regime appears to be established more quickly with distance from the Drain, and the range is again more subdued. However, at thiis site the reduction in variation is spread throughout the year, and there is evidence enough to suggest a difference either in evaporation rates or effective porosity. Godwin (1931), comparing the amplitude of diurnal fluctuations in groundwater level, concluded that Rhamnus carr had evaporation rates less than half those of litter, and that carr communities could be expected to have groundwater levels higher than those of similarly situated litter communities. The data from the carr transect, while suggesting less extravagant transpiration rates than those of litter, do not indicate so large a difference as Godwin's evidence would imply.

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(iv) Spinney Bank transect (Bh 21-26)

Spinney Bank forms the northern boundary of the reserve, and consists of a raised bank of Gault with ditches above and below. On the farm side the ditch at the foot of the bank is deep and is pumped into the Drainer's Dyke at times during the winter. On the reserve side the ditch is shallow and overgrown. The purpose of the Spinney Bank transect was to determine the hydraulic gradient from the reserve, and to provide information which would help towards estimating the leakage through the Bank. Three boreholes (Bh 24, 25 and 26) were installed in mature alder carr, two (Bh 22 and 23) were installed in pasture land on the farm side of the Bank. Additionally, staff gauges were placed on the farm ditch and the reserve ditch. Borehole 21, adjacent to the Sedge Fen Drove, is also regarded as belonging to this transect. Figure 8 shows a subset of the data collected so far: borehole 23 was abandoned, and borehole 22 has an average water level of between -0.13 and -0.67 m OD. It is clear that the levels in the boreholes on the reserve side of the Bank are dominated by the same processes as those in the other transects considered so far, although the range is rather greater. There are no obvious differences between those stations close to the Spinney Bank and borehole 21, as near to the centre of the Sedge Fen as it is possible to be. The comparison of levels to estimate the hydraulic gradient is rather complicated by disturbance, accidental and deliberate, to boreholes 24 and 26, which has changed the datum, but prior to this disturbance there was close agreement between boreholes 24, 25 and 26, and no sign of the steep hydraulic gradient which could be expected if the Bank were leaky. It may be concluded on the basis of the data so far available that leakage through Spinney Bank at this point is negligible, and that the large seasonal range in levels is due to distance from the open water of the dyke system, and increased transpiration and interception by the mature trees of the vegetation cover.

(v) New Dyke transect (Bh 27-33)

By contrast with Spinney Bank, there is strong cause to doubt the watertightness of Howe's Dyke, at the western end of the reserve. It also appears, from the evidence of water movement northwards along New Dyke when it was cleared, that the land surface is lowest in this part of the reserve. A transect of boreholes, from New Dyke through open carr into litter vegetation, has been read fortnightly, in conjunction with a staff gauge on the New Dyke side of the wooden dam. One of the boreholes, Bh 27, was installed in the overgrown New Dyke: clearance had been stopped when the flow was noted. The much wetter nature of this area is shown well by figure 9. While summer levels fall below that of the Dyke, the fall is much less than that in other fen areas, the minimum level was reached in July, and the rainfall in September was enough to establish the winter regime, which was not completely attained until November in the sedge fen transects. Winter water levels show little change with distance or time, indicating the uniformity associated with the inundation of a large proportion of the fen. The survey of borehole rim elevations appears to be at fault in this transect, and results have been corrected by assuming complete inundation and a uniform level on 31 January 1985. This manipulation can be justified by noting that the top of the casing of Bh 30 was 0.13 metres below the water level on this day. The isolation of New Dyke from the main drainage system is demonstrated by its seasonal variation, not observed in other dykes, but it is clear that the Dyke is still receiving water during the summer, probably by leakage through or around the wooden dam.

It is not possible, from the records of the New Dyke transect, to come to any definite conclusion about the effectiveness of Howe's Dyke, but the restricted summer decline in levels appears to indicate a surplus of water in this area, rather than a loss. There can be little doubt, however, that the lower land level around New Dyke and Howe's Dyke will pose problems to any future dyke management scheme.

The form of the water table over the Fen

Godwin and Bharucha (1932) used records from a series of pits near Drainer's Dyke that the water table in the fen changed its form between winter and summer. During winter the water table was convex, and by inference drained towards the Dyke: during summer the shape was reversed, and there was a steep gradient from the Dyke, becoming gentler with distance from the open water. Assuming that this behaviour extended to other areas of the Fen bordered by dykes, Godwin went on to show that this water table form provided a certain amount of recharge from the dykes, to limit the fall in water level beneath fen vegetation near the dykes. Records from the present borehole transects show a similar behaviour, but the greater extent of the network and the length of record increases the confidence with which this simple model can be advanced. Figure 10 shows a selection of profiles of the water table near the dykes, illustrating the change of form over the seasons. A notable feature is the much more rapid drawdown of water table under the recently cut sedge of the eastern sedge fen transect: the interpretation of this and similar effects must await the collection of more data.

Notwithstanding the imperfections in the initial topographic survey, the records from the borehole network can also be used to show the variation of the water table over almost the whole of Wicken Fen. The interpretation is based on the assumption that the model of control by dyke level and summer transpiration is correct, but serves to show in broad outline the significance of the drainage network and the land surface elevation in controlling the depth to water, which Godwin showed to be one of the most important factors defining the constitution of the plant community. At the eastern end of the reserve, a general fall in land surface from the Lode towards Spinney Bank gives rise to a fall in winter maximum levels from about 2.1 m OD near the Lode to about 1.95 m OD at the Bank. Summer minima are also lower towards the northern edge of the reserve, about 1.0 m rather than 1.3 m, but this is caused by distance from open water bodies, and the absence of lateral replenishment. Towards the western end of the reserve, land levels at the northern boundary are lower, and the winter maximum, which is defined by the ground surface, falls to about 1.6 m OD. Summer levels are still sustained by lateral flow from New Dyke, and have a minimum of about 1.2 m OD. New Dyke levels vary between 1.5 and 1.6 m OD, where the Lode and its associated dykes vary between 1.7 and 1.8 m OD.

The imperfection of the survey is shown up by a comparison between the various stations taken as indicators of Lode or dyke levels; the records from these stations are shown in figure 11. It is likely that staff gauges 1, 2 and 3, and boreholes 0, 6 and 12 should have the same level for much of the year. The closest to the true level should be borehole 0, which is nearest to the Ouse Drainage Board benchmark. Apart from the discrepancies between the annual averages, changes with time are evident: staff gauge 1 reads higher after mid-January, as does staff gauge 3. It appears that the staffs have been pushed down: this may be due to the effects of ice or human interference. Such problems should not affect the boreholes in close proximity to the dykes, for instance 0, 6 and 12, which could be used to correct the records from the daily-read gauge Sg 1. However, the need for a better level survey is evident.

The future of the hydrological study

The measurement network at Wicken Fen seems to be broadly satisfactory, and promises to provide more reliable information as a longer sequence of seasonal and short-term fluctuations is recorded. However, there are certain stations that add little to the network, not because their data are inaccurate, but because their water level variation follows closely that of other stations. While some replication is desirable, a judicious pruning of the network could save time and effort in the weekly observation round. To effect such a saving, it is recommended that readings be stopped at boreholes 2, 6, 10, 14, 16, 30 and

32. The staff gauges on the Spinney Bank ditches (Sg 4 and 5), and at the north end of Drainer's Dyke (Sg 3), have been of limited value, and could be discontinued. Removal of the hardware should wait until a new survey is completed.

This report has shown the use of the records in describing hydrological behaviour and estimating parameters. A longer sequence of data will clarify the effects of cropping, and permit more detailed modelling work aimed at predicting the effects of management of dyke levels. An important aspect of the results, the interpretation of the variation of land and water levels across the site, depends on a more reliable survey, and it is expected that the survey of borehole and staff gauge datum levels will be repeated in 1986. The new survey will take a similar form to that in 1984, relying on a network of benchmarks on bridges and other permanent structures: the new seats erected at various points may prove useful if they are firmly fixed.

Gowing (1977) alluded to the difficulties of deducing long-term changes from the discontinuous information available. A more extensive base of historical climatic and hydrological data, and information relating to sluice operation, awaits collection from the Anglian Water Authority, and effort must be directed towards setting the current study in a long-term context, and making fuller use of comparisons between recent work and the studies of Godwin and his colleagues. In particular, the question of changing retention levels in the Lode, and its significance for dyke and fen levels, must be addressed.

Little attention has been given in this study to the problem of water quality, which may ultimately prove to be more important than dyke water level in maintaining the character of Wicken Fen. Gowing (1977) gave a number of possible remedies for the surface acidification of the Fen, none of which was simple or inexpensive, and it is clear that the adoption of any expensive schemes must depend on more definite knowledge of its consequences. There is a need for more detailed information on the variation of acidity throughout the peat profile, and it may be that an approach through measurements of calcium concentrations rather than pH would be a better indication of leaching of bases. A programme of sampling peat at the surface and at depth could help to indicate the significance of leaching processes in producing acid conditions at the surface. The hypothesis that surface flooding has been an important factor in the past could be tested by comparisons between eastern and western parts of the Fen.

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Though a visitor to Wicken in summer would find it difficult to imagine, Cambridgeshire in the wild wintry days has little to recommend it. Thanks are therefore due to the observers, M Bentley and R Fisher, who have managed to get around the network in all weathers and conditions, and to return data of a high

standard of consistency. They should also have my apologies for making it such a long walk!