Observations on flooding at the southern end of Port Meadow

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Oxford City Council proposes to deepen drainage channels on Port Meadow to improve the flows from storm drains in Wolvercote during intense rainfall events. There is concern that a change in the flood regime caused by these works might adversely affect the *Apium repens* plant community at the southern end of Port Meadow. There is concern that persistent flooding in recent years may already be having a detrimental affect on the *Apium repens*. The owners of animals kept on Port Meadow are also concerned about the reduction of grazing land. This note presents the output of preliminary analysis of new data on water levels in the Port Meadow area that provide insights into the flooding regime. Further analysis of data is still required and the maintenance of monitoring networks is essential so that there is an evidence-base on which to make management decisions.

Physical setting

Port Meadow is bounded to the west by the River Thames, to the east by rail track, to the north by the village of Wolvercote and to the south by allotments. Historic waste dumps are located in the east and south of the Meadow which generally remain unflooded during high water level. The Meadow is cut by a series of drainage channels, the majority of which run along the eastern side.

Port Meadow is underlain by fine-grained alluvium and beneath that a sand and gravel aquifer. These superficial deposits sit on top of the Oxford Clay bedrock. The sands and gravels are a few metres in thickness. The alluvium is of relatively poor hydraulic conductivity but is not confining. The alluvium in the Port Meadow area is generally less than one metre thick but this thickness is highly variable and the alluvium is absent in some areas.

The potential mechanisms for flooding of the southern end of Port Meadow are:

- overbanking of the River Thames;
- rainfall runoff from upslope;
- vertical upward discharge of groundwater from the underlying gravel aquifer in the area of flooding;
- groundwater level within the alluvium that is above ground surface in the area of flooding;
- lateral flow from upslope of groundwater discharged at ground surface during periods of high groundwater levels;
- flow of drainage channels to this area. The source of water in the drainage channels may be leakage from the River Thames and the Oxford Canal, rainfall runoff into the channels or the discharge of groundwater when groundwater levels are high.

Observations from other studies

The Water Level Management Plan for Port Meadow, Wolvercote Common & Wolvercote Green [redacted] Andrews Ward Associates 1997 considered that *Apium repens* was potentially threatened by a reduction of winter flooding but did note that ditches had not been maintained and so were dry in summer whereas they could be cleared and made wet thus benefiting plants dependent on wet conditions. He conceded that clearance of the ditches would increase drainage and improve sward conditions by reducing poaching and bare ground. He therefore recommended limited de-silting of isolated ditch section(s) and observation of effects on plants. This did not include clearance of blockages to drainage to the Thames so as not to affect winter flood retention. He also notes that some ditch clearance work was carried out in 1992 by the Oxford City Council.

[redacted] 'The requirements of *Apium repens* - an ecohydrological assessment' (2005) concluded that the area of *Apium repens* was primarily groundwater fed and recommended that any major alteration of river level should be scrutinised carefully as this could affect not only surface flooding but also the groundwater-fed wetland. They recommended a cautious approach to any alteration of hydrology until there is a better understanding of likely impacts on *Apium repens*.

[redacted] 'The historical ecology of some unimproved alluvial grassland in the Upper Thames Valley' (BAR British Series 441 2007) discusses at length the history of Port Meadow hydrology and concludes that the water table is higher in the eastern area of the southern end of Port Meadow compared with the 1920s, based on plant community changes. She identifies the cause of this as the ditches at the southern end of Port Meadow that are now silted up, thus impeding surface water drainage of this part of the meadow. She also states that the ditches around Wolvercote Common were last cleaned in autumn 1963 and that this caused the direction of flow within these ditches to change to the current west to east direction towards the ditch that runs along the east of Port Meadow adjacent to the railway line (Line Ditch).

Data available

Groundwater levels are available for Port Meadow dating from the 1980s, however, intensive monitoring of levels only began in late 2000. These data were collected initially for the ecohydrological assessment of the requirements of the *Apium Repens*; this monitoring network was then adopted as part of a much larger study of the controls on groundwater flooding linked with the Environment Agency's Oxford Flood Risk Management Study. The British Geological Survey led the groundwater flooding study and has initiated a further study to understand the chemistry of groundwater in floodplain sediments in peri-urban areas which is using Port Meadow as a case study site.

There are piezometers currently being monitored at 16 sites on Port Meadow and a further eight in urban areas to the east and agricultural areas to the west of the River Thames. Eleven sites on Port Meadow have multiple piezometers at two to four depths (Figure 1). Eight sites have digital water level recorders that take readings at a frequency of 1 hour or less; six of these sites have recorders in the alluvium and the underlying gravels. There are two river level monitoring sites: one at Rainbow Bridge (DMMFA) which is currently downloaded by Groundwater Monitoring and Drilled Ltd on behalf of BGS; and one at Godstow lock which is maintained and downloaded by the Environment Agency and includes recorders upstream and downstream of the lock. Some of the project-related recorders have been in place since 2002. Crucially, in October 2009 it was possible to install flood recorders at the southern end of Port Meadow (at PTM21 and close to the gap in the drainage channel bund marked of

Figure 1); the flood recorders were installed to help establish the sources of flood waters in this vicinity.

Analysis of groundwater, surface water and flood water levels

Analysis of the flow of groundwater beneath Port Meadow has been constrained by the availability of piezometers to the east. However, the data do show a general movement of groundwater from east to west being driven by discharge to the Seacourt Stream on the western edge of the floodplain. The River Thames does not appear to be a net sink for groundwater. The groundwater level contours derived from monitoring data collected in May 2008 are included in Figure 1. Time series of groundwater levels from selected digital recorders at Port Meadow are shown in Figure 2. The degree and importance of recharge to the gravel aquifer in the east from: the Oxford Canal, drainage ditches and laterally from the Second Terrace Gravels beneath Summertown and central Oxford, has still to be established.

Figure 3 presents data for the period during which the flood recorder has been in place on Port Meadow (up to when it was last downloaded in August 2010). The figure includes the flood level on Port Meadow, the level of the River Thames (DMMFA) and groundwater levels at two locations, PTM1 and PTM21 (see Figure 1). SPTM21 is also included which is a piezometer completed in the alluvium at PTM21. The daily rainfall used was measured at the Radcliffe Met Station in central Oxford. (Note, horizontal lines have been added, with the same colour as the hydrographs, which indicate the ground levels at the locations of the piezometers.)

The data show that when the River Thames levels are high and out of bank these control flood levels on Port Meadow (e.g. during the period beginning in January 2010). However levels in the River Thames typically recede within a few days, unless further rainfall events occur. The flood levels at the southern end of Port Meadow remain high at least in part due to the surrounding high ground which restricts drainage back to the river.

Figure 3 also shows that in the winter 2009/10 (as in other years – see below) the groundwater levels in the gravels at both PTM1 and PTM21 are for long periods above ground level. When the river is high, river, flood and groundwater levels are coincident. However outside of these periods groundwater levels are still seen to be above ground level. At PTM1 there are significant periods of time when there could be the upward discharge of groundwater to above ground. This would move laterally towards low-lying ground which may be flooded already.

Figure 3 shows that outside of the periods of peak river level, the flood levels at the southern end of Port Meadow in 2010 are higher than the groundwater level in PTM21. It had been thought previously that the flood waters during late spring and early summer were caused by groundwater levels in the gravel aquifer being above the ground surface but the data would imply that in 2010 the flood waters in these months were due to other sources of water. The flood water could be caused by direct rainfall recharge to the alluvium causing an associated groundwater level within the alluvium which is above the ground surface. However, a comparison of the groundwater level in late spring/early summer in the alluvium at SPTM21, within the flood zone, and SPTM25, outside of the flood zone, which would be expected to be similar, shows these to be significantly different (Figure 4).

Figure 3 shows that the water levels in SPTM21 are similar to the flood levels (the difference being within the likely error in datums) and suggests that either water levels in the alluvium are controlled by the flood waters on Port Meadow or that the completion of this piezometer has become compromised and is allowing flood waters to ingress.

Figure 5 presents hydrographs from the full set of time series data available for PTM21 and SPTM21; DMMFA data date from 2007 but it is understood earlier data are held by the Open University. The range of groundwater levels in 2009/10 is consistent with those from 2002 to 2009. The pattern of groundwater level fluctuation in 2009/10 matches that from 2002/03 to 2006/2007. Wet summers in 2007 and 2008 resulted in sustained high groundwater levels which were above ground level for much of the period. Note that in the summer months the water levels in SPTM21 can be seen to fall well below those of PTM21; it is thought that this is due to evaporation from the near-surface at a rate greater than the upward flow from the gravel aquifer beneath.

The pattern of high river levels causing SPTM21 to rise but remain high relative to PTM21 after river level recession can be seen for the period of DMMFA data. Although river level data from DMMFA prior to 2007 are not plotted it could be assumed the differences in SPTM21 and PTM21 have the same driver. If we were to hypothesise that SPTM21 reflects the flood levels at the southern end of Port Meadow then we might extrapolate that the sources of flooding in 2010 may be similar to those from 2002 to the present (excluding 2007 and 2008) and that late spring/early summer flooding is normally not groundwater flooding but due to remnant water from overbanking of the Thames and/or flow into the area through drainage channels flowing from the north of Port Meadow.

Anecdotal observations are that persistent flooding on Port Meadow into the late spring/early summer months has become more frequent in the past decade. The suggestion has been made that this is due to relatively high groundwater levels as we are in a wet period for Oxford (Figure 6). The argument made above is that groundwater may not be the cause of the persistent flooding. Indeed the few groundwater level data that exist (Figure 7) indicate that groundwater levels in recent years are not dissimilar to those in the early 1980s.

Note, there are much data that remain to be analysed. This is constrained primarily by access to digital recorders from sites that are currently flooded.

Surface drainage

The Environment Agency’s Lidar data were used to analyse the topographical controls on the movement of flood waters within the southern end of Port Meadow. It is observed that flood waters from Port Meadow drain westward through narrow channels into the River Thames. The channel which continues to flow the longest is indicated in Figure 8. Reference to the Lidar data provides an estimate of the flood water level at which drainage ceases as 56.97 maOD. The Lidar data have been used in Figure 8 to indicate the extent of flooding at this point.

The other potential outflow from Port Meadow is through a drain along the railway line which connects to the arm of the River Thames which becomes the Castlemill Stream. Drainage is currently restricted as this channel is silted up. Although analysis of the Lidar data is difficult due to masking by vegetation, it is thought that the highest point in this channel is currently about 57.3 maOD. Flow through this channel therefore ceases before the flow through the channel referred to above.

Excavating the channel that links with the River Thames (to the west) at the southern end of Port Meadow would allow flood water levels to fall to a lower level. However, it should be noted that there are isolated pockets of low lying ground within Port Meadow that are not connected to the low point of this channel and would not therefore drain any further after excavation. Figure 9 shows the areas at 56.93 maOD and below which highlights the disconnected low-lying area in the north. A larger and deeper channel would, however, generally increase the *rate* at which flood levels on Port Meadow decline. A deeper channel would allow water to enter the southern end of Port Meadow from the river when the river levels rise but these periods are short and infrequent and the water would drain away again quickly when the river levels recede (see Figure 3).

Flow from drainage channels on the eastern side of Port Meadow (west of Burgess Field) into the large flooded area has been observed to continue into the summer. The works proposed by Oxford City Council are likely to increase the flow in these channels. If this is the primary source of the flood water at the southern end of Port Meadow during the summer then without any other measures, these works risk increasing the period of flooding. Options to mitigate the risk include excavation of the railway drain and bunding of the drainage channels that discharge into Port Meadow (see Figure 1) forcing this water to flow through the railway drain. However, if the source of water within the drainage channels is addressed (breaches in the River Thames?) then no intervention may be required.

It should be noted that groundwater is shallow under Port Meadow and the deepening of the drainage channels proposed by Oxford City Council may increase the drainage of groundwater into the channels, creating a new source of water to discharge into the low-lying area at the southern end of Port Meadow during periods of high groundwater level. Groundwater levels are within a metre of the ground surface in the areas of the drainage channels; the City Council’s proposal for deepening these channels is no more than 0.3 metre.

Conclusions

The flooding regime at the southern end of Port meadow is complex. Further analysis of water level data is required, however recent data obtained on flood levels provides evidence that groundwater discharge is not the sole cause of flooding at the southern end of Port meadow during the late spring/early summer. Options are discussed for reducing flood levels by deepening drainage channels and addressing the source of flow in existing channels. Continued monitoring of the hydrological regime within the Port Meadow area is necessary to improve the understanding of the causes of flooding and to assess the impact of any mitigation measures applied.

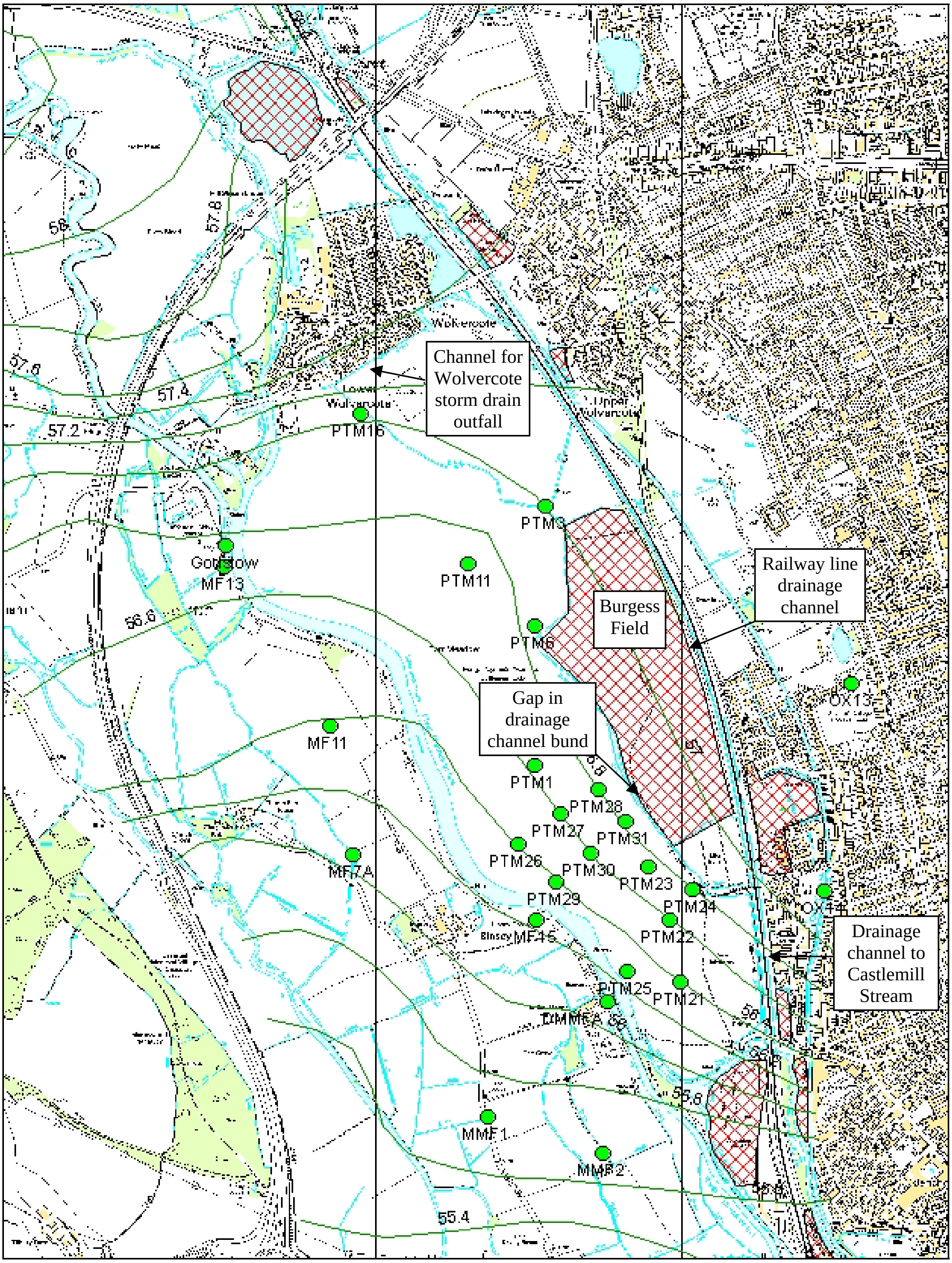

Figure 1 Location map showing monitoring sites, groundwater level contours based on groundwater levels in May 2008, locations of drainage channels referenced in this document and licensed EA waste dumps (red hatch). Note, the monitoring sites shown are only those to the east of the A34. Sites with multiple piezometers are PTM21 to PTM31.

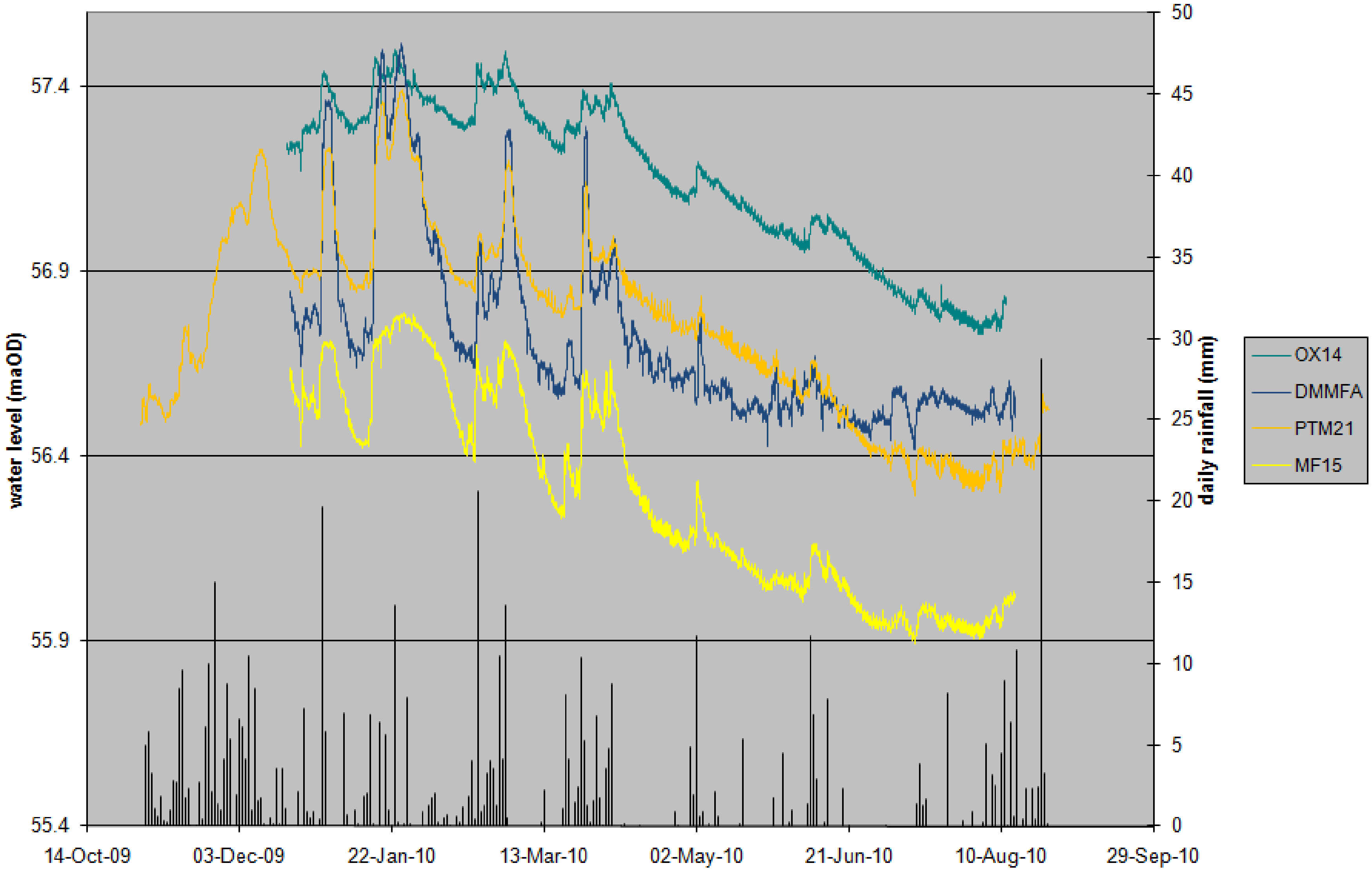

Figure 2 Groundwater levels at three locations along a transect approximately east to west across Port Meadow (OX14, PTM21, MF15) and water levels in the River Thames measured at Rainbow Bridge, Binsey (DMMFA)

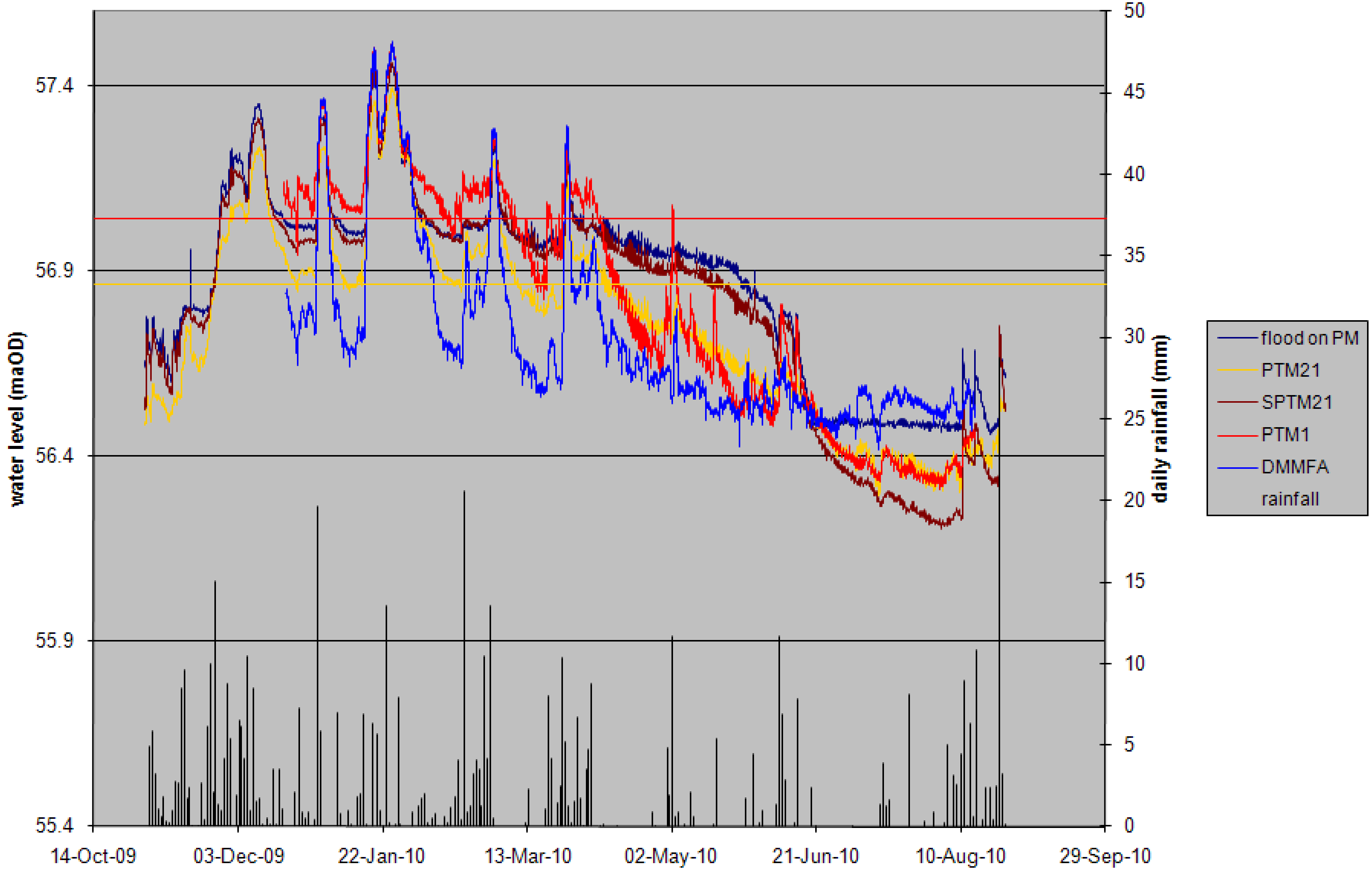

Figure 3 Flood, river and groundwater levels on Port Meadow. Ground levels at PTM1 and PTM21 are indicated by horizontal lines of the same colour

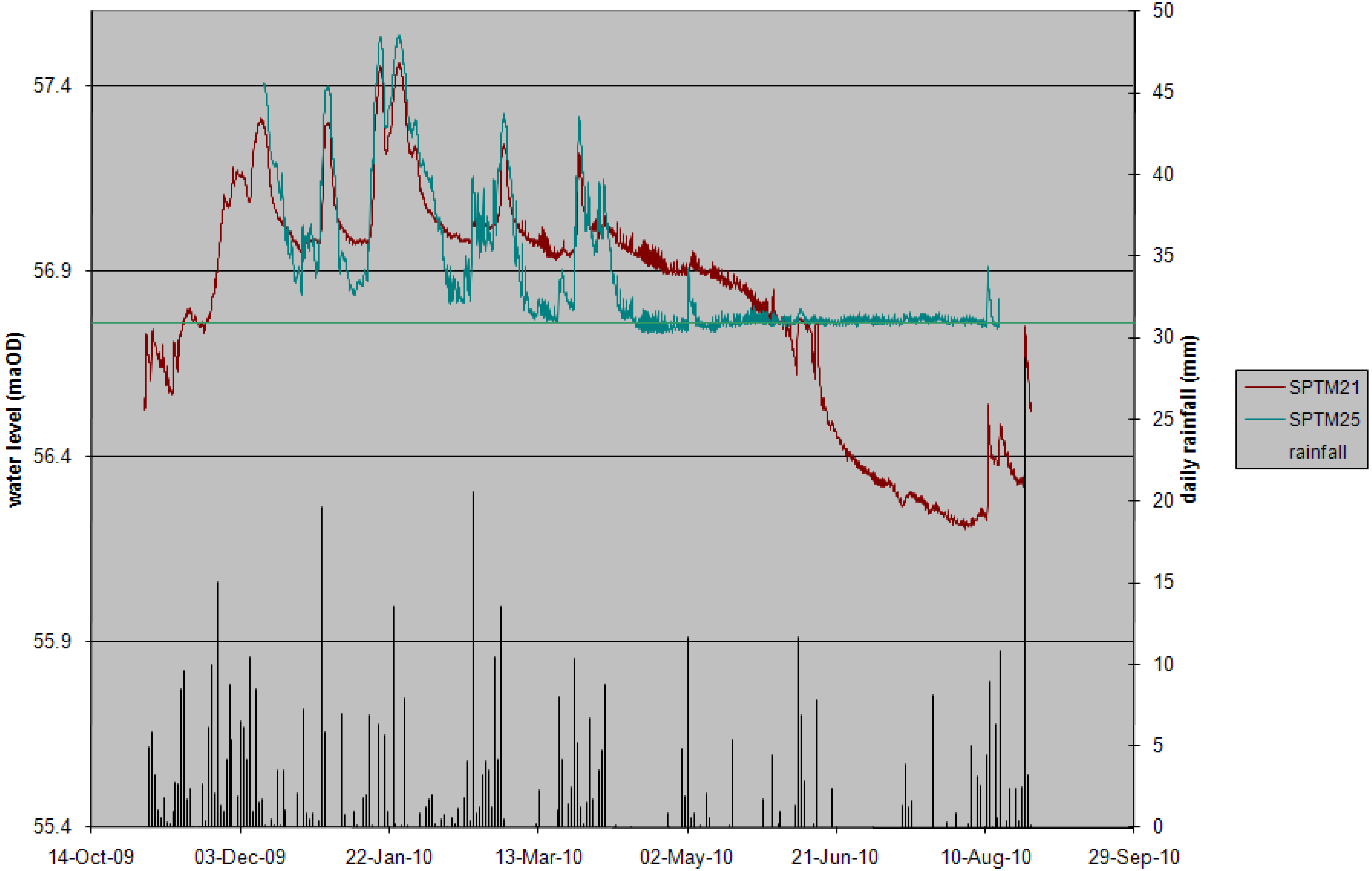

Figure 4 Water levels in piezometers SPTM21 and SPTM25 completed in alluvium. Green horizontal line is the bottom of piezometer SPTM25

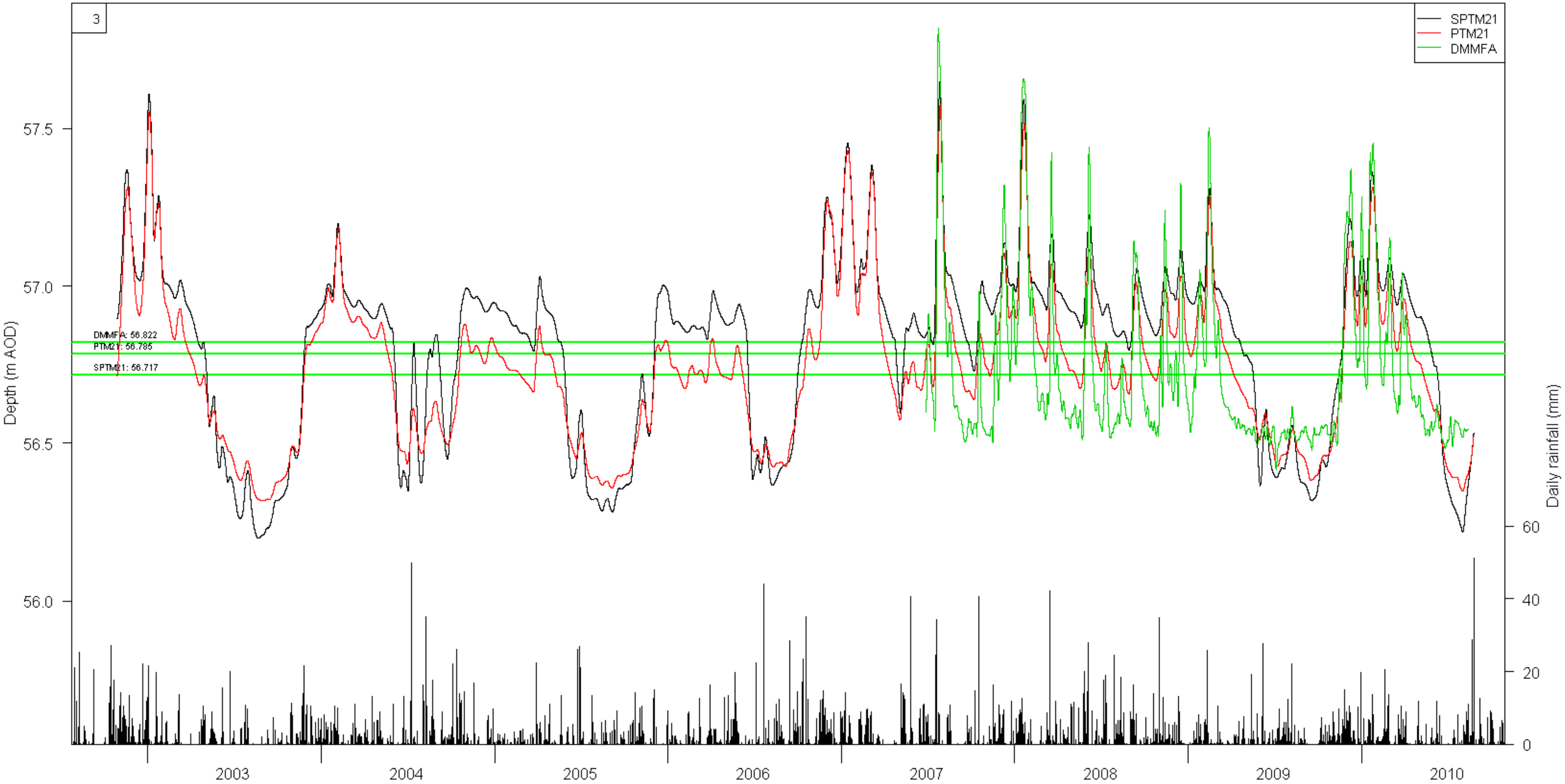

Figure 5 Longer term groundwater levels at PTM21 and SPTM21 along with the available river levels from DMMFA. Ground levels at PTM21 and SPTM21 and the datum level for DMMFA are indicated by the horizontal lines.

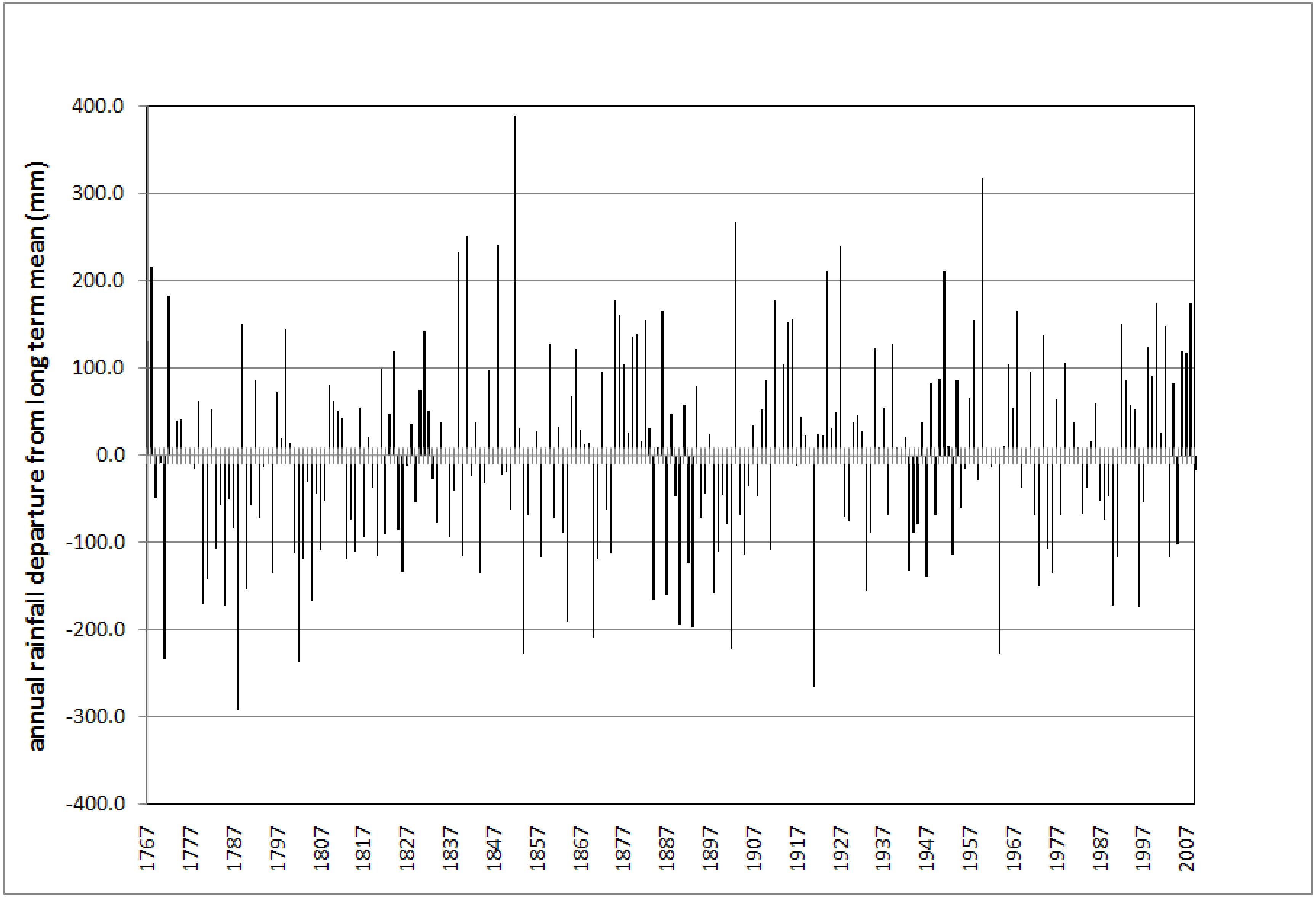

Figure 6 Departure of annual rainfall from the long term mean, measured at the Radcliffe Meteorological Station, Oxford, 1767-2009

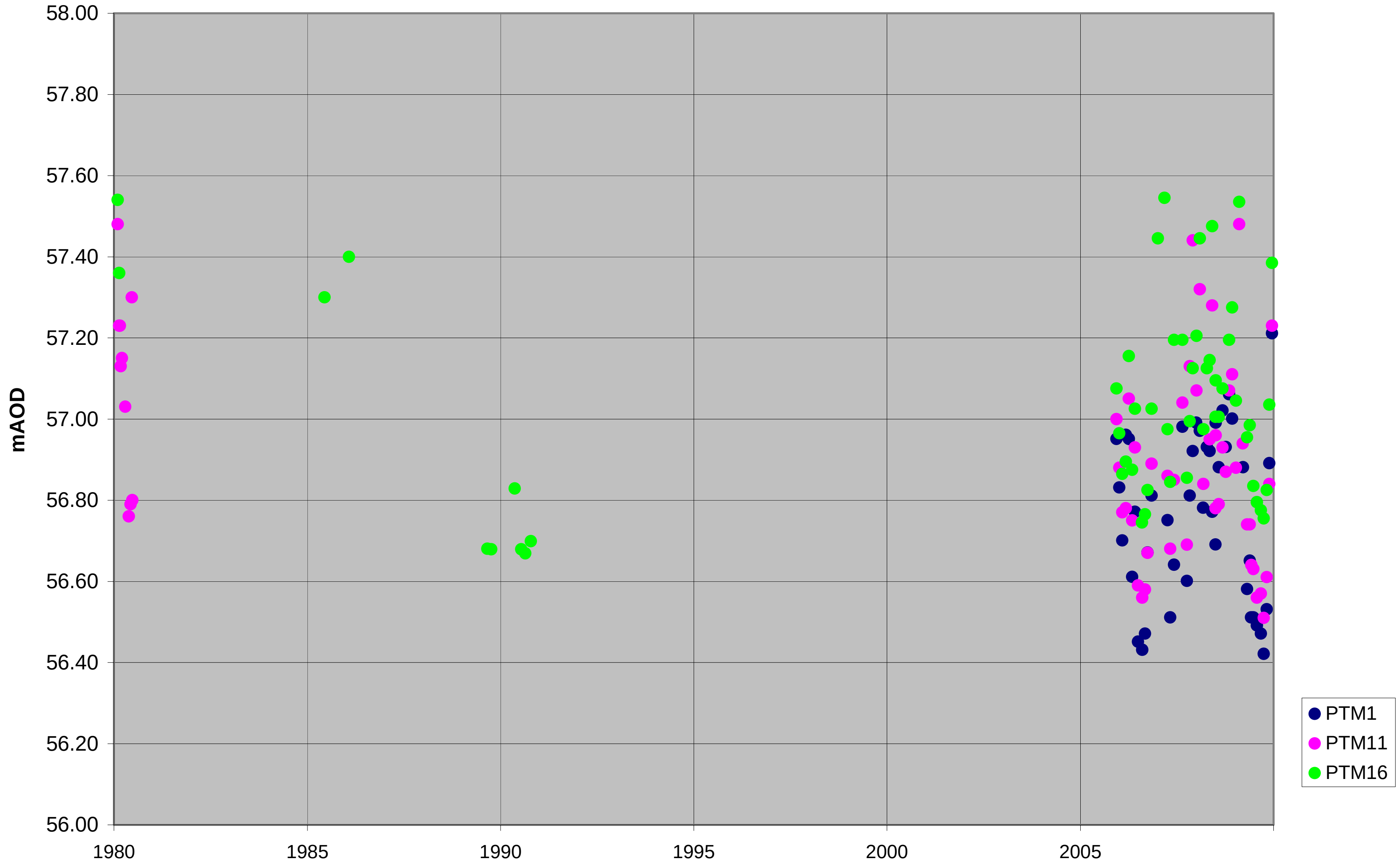

Figure 7 Manually dipped groundwater levels from two sites on Port Meadow dating from the 1980s (PTM11 and PTM16), compared with levels from PTM1.

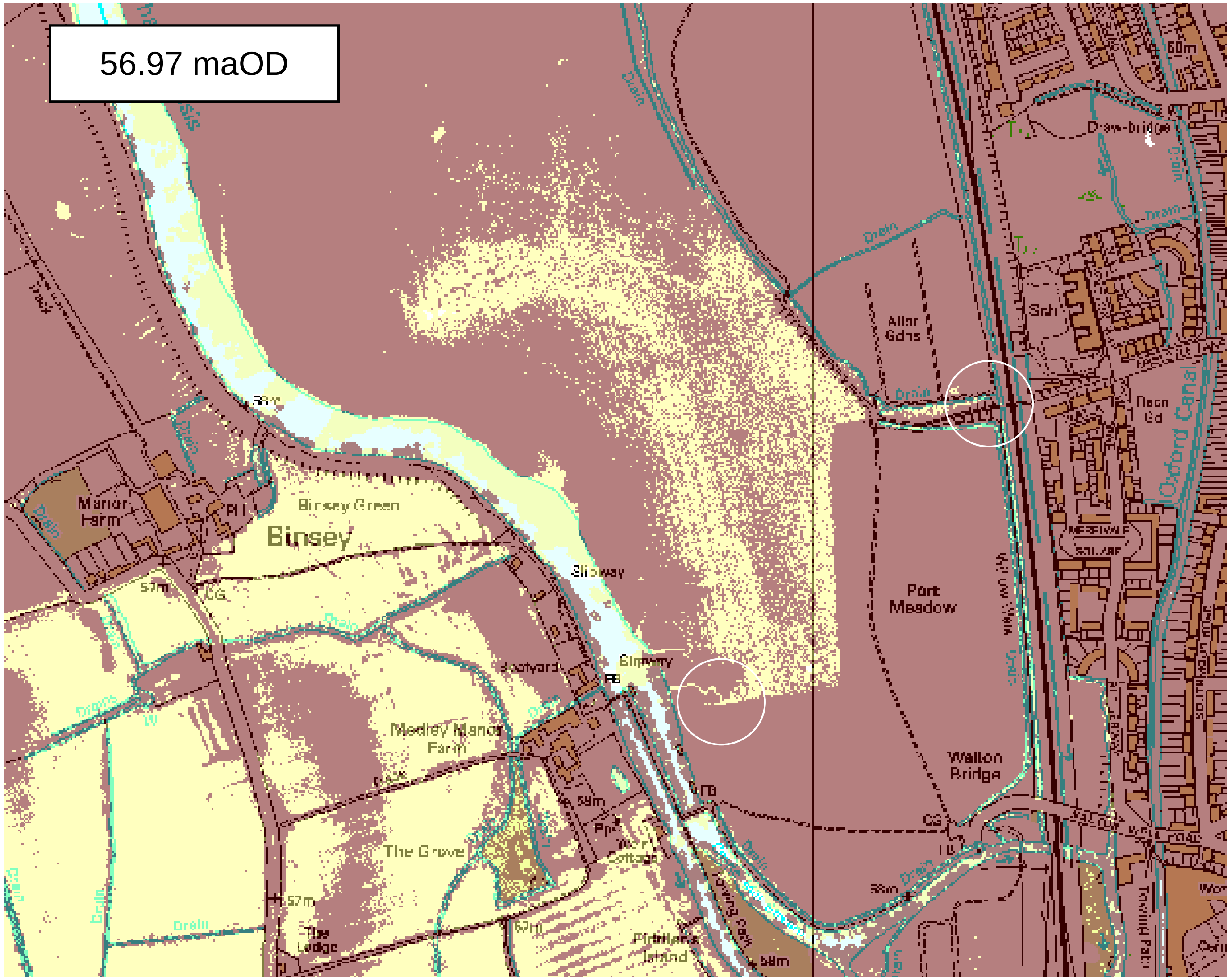

Figure 8 Ground below 56.97 maOD (yellow) at the southern end of Port Meadow. High points are indicated that limit flow of flood waters through discharge channels westward and southward to the River Thames

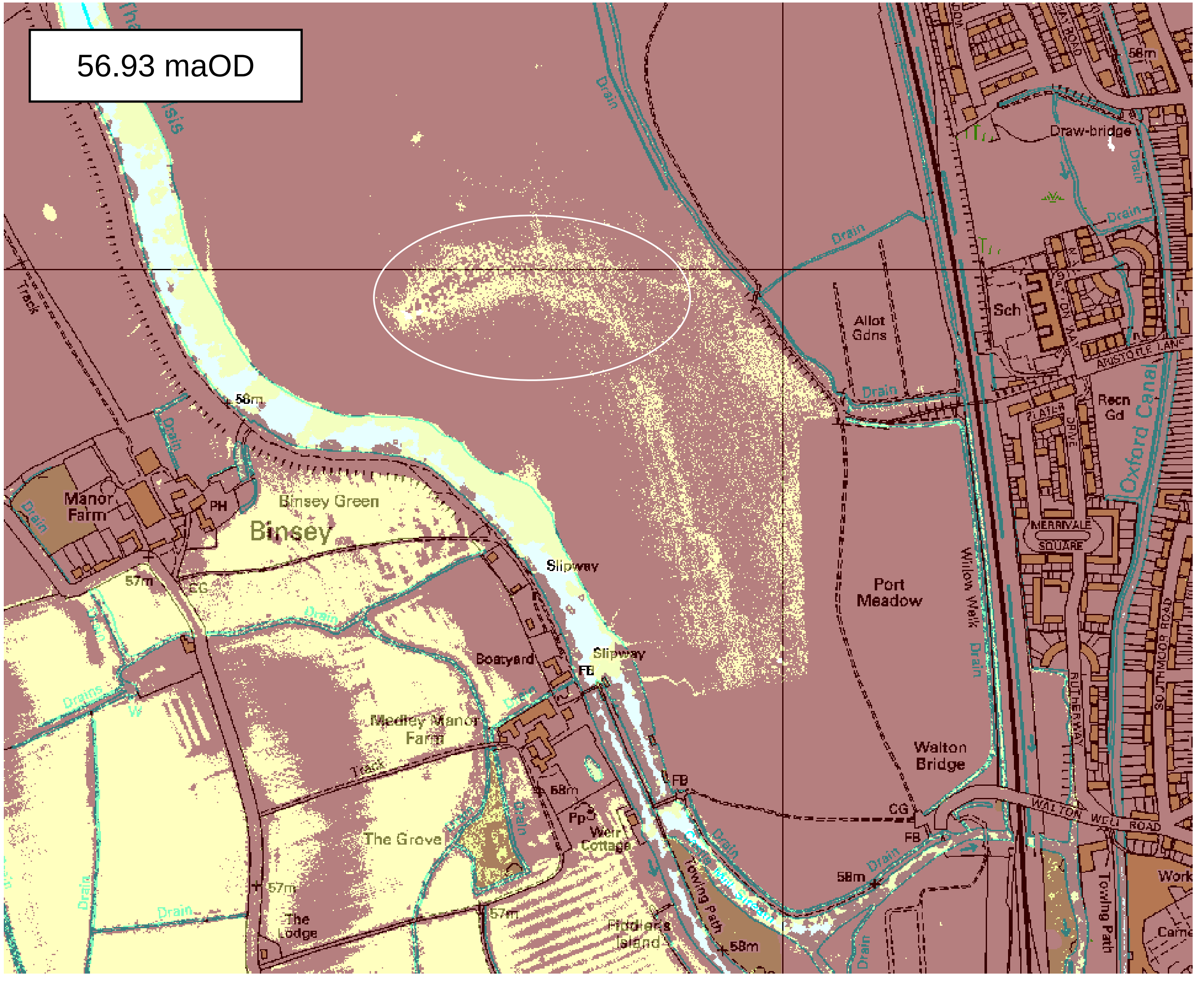

Figure 9 Ground below 56.93 maOD (yellow) at the southern end of Port Meadow. Area indicated that is disconnected from the channel linking westward to the River Thames identified in Figure 8