Oxford Flood Alleviation Scheme: assessment of impacts on species-rich floodplain meadow habitat

March 2018

Contents

Introduction

The Floodplain Meadows Partnership (FMP) were asked to undertake work in response to concerns relating to impacts on Hinksey Meadow and other species-rich floodplain meadows around Oxford as a result of the proposed Oxford Flood Alleviation Scheme.

The original scope for the work is presented in Appendix X. Each element of the scope is addressed in turn in the following document, with specific tasks as set out by the Environment Agency as listed below:

> **Task 1:** Undertake a one day site visit with relevant members of the Oxford FAS project team to see the proposed channel marked out on the ground and to look at the wider area with a view to undertaking Tasks 2-8, as set out below.

1. **Mitigation for the Impacts of the Oxford FAS on Existing Floodplain Meadow**

A: Direct Physical Effects of the Scheme on the Floodplain Meadow

> **Task 2:** Provide advice on the potential translocation of the MG4a grassland. Suggested methodology, timing, range and suitability of possible receptor sites, including literature review and assessment of site suitability.

B. Indirect Hydrogeological Effects of the Scheme on Floodplain Meadow

> **Task 3:** Review the Environment Agency's assessment of potential effects on other groundwater-sensitive sites.

> **Task 4:** Use the findings of the Groundwater Report and the Ground Investigation Report to explain how the anticipated change in groundwater levels are likely to affect the MG4/MG4a floodplain meadow at Hinksey Meadow in terms of species composition, NVC classification and long-term viability.

2. **Opportunities to create Floodplain Meadows as part of the Oxford FAS**

Floodplain meadow within the 2-Stage channel

> **Task 5:** Provide recommendations on how we should be monitoring and assessing the ecological trial areas and using existing features in the landscape, to gain a better understanding of which parts of the channel (if any) will be suitable for MG4/floodplain meadow.

Floodplain meadow outside the 2-stage channel

> **Task 6:** Provide recommendations on which areas within the wider floodplain might be most suitable for the creation of floodplain meadow/MG4 and the work that would be required to enable us to identify, prepare and establish such areas.

3. **Maintenance and Monitoring Work Required**

> **Task 7:** Provide recommendations on the type of monitoring that should be undertaken on the existing floodplain meadow in order to ensure that the environmental objectives of the scheme are being met.

> **Task 8:** Provide recommendations on the maintenance and monitoring that should be undertaken on any translocated floodplain meadow and newly created floodplain meadow in order to ensure that the environmental objectives of the scheme are being met.

1. Mitigation for the impacts of the Oxford FAS on existing floodplain meadows

A: Direct physical effects of the scheme on the floodplain meadow (Hinksey Meadow) including looking at translocation potential.

> ***Task 2:*** *Provide advice on the potential translocation of the MG4a grassland. Suggested methodology, timing, range and suitability of possible receptor sites.*

1.1. Brief literature review of grassland translocation in the UK and policy summary

2. Translocation policy in UK

The current policy for habitat translocation is outlined in 'A Habitats Translocation Policy for Britain in 2003' (JNCC), which is considered to be still relevant (*pers comm*. Richard Jefferson, Natural England National Grasslands Specialist). This policy clearly states that habitat translocation is not an acceptable alternative to maintaining habitats *in situ*, that evidence shows that the intrinsic value of habitats is not retained after translocation and that translocation should not therefore be seen as a substitute for *in-situ* conservation. Habitat translocation should not be seen as a mitigation for loss through development, and may only be able to offer partial compensation, as many examples of habitat translocation clearly show changes in the final habitat achieved.

The policy lists the reasons why habitat translocations cannot be an acceptable substitute for *in-situ* conservation of sites. Those relevant to Hinksey Meadow are reproduced here:

- All ancient habitats are fragile, non-transferrable and cannot be re-created in short timescales.
- The species composition of assemblages changes as a result of the disturbance resulting from the translocation process
- Structure and physical conditions will be different in the new location (geology, soil conditions, hydrology, aspect, topography etc.)
- The history of specific locations (which results in distinctive assemblages of species found in particular locations) cannot be re-created.
- The historical, cultural and other human associations with the original location are severed.

3. Objectives and aspirations for translocation at Hinksey Meadow

It is important to be clear about the aim of the translocation from the start of the project. Lack of appropriate objectives was an issue in many of the examples of translocation reviewed by Bullock (1998). If an objective is to **preserve** the habitat through translocation, this is not likely to be met, as in all cases examined by Bullock, community changes were recorded and in most cases these were substantial.

More realistic and achievable aims would be:

- Turf survival (at the most basic)
- Mitigation for loss (by preserving the main features of a community)

Bullock concluded that the mitigation aim was achieved in many of the cases examined, but this was more successful in dry grasslands than wet grasslands.

In the context of Hinksey Meadow, turf survival would be a sensible objective if any translocation is to be pursued with the aim of rescuing turves that would otherwise be lost, in some form of restoration scheme. Mitigation may be achieved, but there are few or no examples in the literature of a wet grassland has been translocated successfully.

4. Current best practise advice (and in relation to Hinksey, recommendations for proceeding)

Box (2003) evaluated 8 case studies of turf translocation in the UK and Bullock assessed 24 case studies (1998). The main recommendations from these reviews to consider are:

a. Similarity between donor and receptor sites

Features including aspect, slope, soil drainage, soil nutrient status and hydrology need to be as similar as possible. In several of the case studies described by Box, the hydrological regime was unsuitable at the receptor site, and similarly in the floodplain-meadow example described by Ward (1995) where the receptor site was hydrologically different, resulting in a drier sward.

Recommendations for assessing suitability for translocation receptor sites. The recommended monitoring should be applied at both Hinksey Meadow and potential receptor sites..

1. Soil-water elevation (to assess similarity in soil-water regime) using soil wells.

    Dipwells have now been installed in several areas thought most likely to support MG4 vegetation. These have been in place since April 2017.

2. Soil-moisture release curve (to assess soil porosity)

    Soil cores have been taken from Hinksey Meadow, but not from other sites. It is recommended that this is done in autumn 2017, to allow some assessment of the similarity of possible receptor sites to Hinksey Meadow in terms of soil structure.

3. Nutrient analyses (to assess soil fertility)

    We do not currently hold information on soil fertility, but it is our understanding that appropriate soil analysis is on-going. These data, when available, should further refine the choice of sites for receiving translocated turves.

4. Soil profile assessment (information available from groundwater report and Drilling logs from installation of boreholes by CH2M)

    The soil profile at Hinksey meadow is variable, with some areas having less than 0.8 m of alluvial soil above the River Terrace Deposits (OA74 indicates just 0.4 m), therefore the receptor site should have similarly shallow deposits in order to reproduce a comparable water regime.

5. Topographical information (to assess flood recession routes)

    The surface topography at Hinksey shows a shallow gradient towards the Hinksey Stream, which is relevant as it facilitates the recession of floodwaters and should ideally be reproduced in receptor sites.

Engineering some of these variables may be feasible as part of the relocation exercise if no exactly suitable sites can be found. For example, removing topsoil from receptor site to reduce soil fertility, or to ensure the turves are laid at the correct height in relation to the local soil-water regime.

b. Translocation technique

There are a number of different ways that grasslands can, and have been translocated. The two main ones described in the literature are outlined below:

a) Turf translocation. This maintains underlying soil profile if turves are deep enough and minimises damage to individual plants. However some critical points are:
   - Do not store turves, move them on the same day to avoid desiccation of the sward and changes to the soil nutrient composition.
   - Move turves as thick and as large as possible. Translocating sub soil may be considered, but it is not recommended to move thin turves
   - Lay turves in same arrangement and position as originally. Lay them tightly together to avoid gaps, press down on each turf with the bucket, and roll after they have been laid to ensure contact with sub-soil and to remove air gaps. Fill in gaps with soil from receptor site and consider grazing after rolling to increase contact between turves and sub-soil, and reduce gaps.
     - We would add that in the case of a community as hydrologically sensitive as that at Hinksey, pressing on turves with the bucket and rolling the turves is only acceptable in dry conditions, if the soil moisture is above the plastic limit of the soil then compaction is liable to occur, compromising the soil's structure in the medium to long term.

b) Translocating a mix of soil and vegetation (i.e. not as complete turves). This technique has proved even less successful than turf translocation and it is recommended that it is only used to move grasslands of lower value than Hinksey.

Other considerations

- Machinery needs to be appropriate. The 'Translocating wildlife habitats; a guide for civil engineers' (Box and Stanhope, 2010) recommends the use of low ground pressure tyres and large buckets to maximise the size of the turves that can be removed in one go.
- Timing of translocation. Timing needs to be considered so the grassland is not actively growing and the sward is short. Best time is probably Feb/March if conditions are dry enough, or early autumn, after a hay cut and grazing, when soil is still sufficiently dry to avoid compaction and associated damage to soil structure.
- Work on a rolling method, re-profile one section and place turves from a previous section straight away.

c. Post translocation habitat management

Perhaps surprisingly, this was a major factor in the failure of many of the case studies looked at (although usually in combination with other factors). There are very few examples indeed where post translocation habitat management was actually the desired method and therefore not prohibitive to a successful project. Therefore in the context of Hinksey, we recommend that translocation is only considered to sites where the post translocation management can be guaranteed as an annual hay cut and aftermath grazing, in a similar regime to that of Hinksey currently, and where the objectives are for mitigation for the loss of a substantial part of Hinksey Meadow. This may involve the requirement for appropriate legal agreements. Otherwise it really is not worth the effort and expense.

d. Evaluation

Box (2003), Bullock (1997) and the JNCC Translocation policy (2003) strongly recommend both pre-project baseline monitoring and long-term post project monitoring to determine success against set objectives. The view is that even after 7 years post-project monitoring at Brocks Farm (Devon), one of the more successful and better monitored case studies, the community was still changing and that a period of at least 10 years is recommended to fully understand long term changes to a community. A point made in both case studies is the lack of assessment of the invertebrate assemblage, something intrinsically related to grassland quality. The National Vegetation Classification (NVC) is suggested as a suitable framework for assessment of plant community change.

Recommendations for evaluation at Hinksey Meadow include (for both translocation receptor and donor sites):

- NVC survey as a baseline (before translocation), and then 5 years and 10 years post translocation. Use King (2016) for the baseline assessment.
- Repeatable botanical monitoring quadrats, monitored before work starts then annually for five years to guide post translocation management.
- Invertebrate surveys as a baseline and then 5 and 10 years post translocation

References

Box, J. 2003 Critical factors and Evaluation Criteria for Habitat Translocation. *Journal of Environmental Planning and Management*, 46, 839-856.

Box, J. and Stanhope, K (2010). Translocating wildlife habitats: a guide for civil engineers. Proceedings of the Institution of Civil Engineers – Civil Engineering 163 (123-130).

Bullock, J.M. 1998 Community translocation in Britain: setting objectives and measuring consequences. *Biological Conservation*, 854: 199-214.

Joint Nature Conservation Committee 2003 A Habitats Translocation Policy for Britain. Joint Nature Conservation Committee in conjunction with the Countryside Council for Wales, English Nature and Scottish Natural Heritage. JNCC, Peterborough

Ward, L. K. (1995). M3 Bar End to Compton, Botanical Monitoring: Flood Meadow Restoration 1995. NERC/Mott McDonald Civil Engineering Ltd

1.2. Identifying possible sites for translocation and/or restoration

Ideally to give a fully informed judgement of the relative suitability of potential sites for restoration, we would have the following information:

- a measure of phosphorus availability in the topsoil for those sites where green hay or seed spreading is being considered
- several years' worth of groundwater data for the top 1 m of the soil profile.
- a predicted regime of monthly stage levels in the newly created channel

However, we currently only have a couple of months' worth of soil water regime data, no phosphorus measurements for the areas with potential for restoration and no firm prediction for how the stage levels in the new channels will respond. We can only advise on site suitability based on the currently available data. The areas that have been assessed in terms of their suitability for either translocation or recreation of species rich floodplain meadow are summarised in Section 2 (Tables 1 and 2) and shown in more detail in Appendix A.

1.3. Comments on Alaska's method (Appendix B) for turf translocation in Hinksey Meadow in advance of possible Archaeological investigation.

Two trenches 25 m x 2 m x 1.2 m depth may be dug on the western edge of the MG4 area in Hinksey Meadow in October 2017. This is within the area planned for construction of the two-stage channel. Trenches would be dug and then backfilled once an archaeologist has inspected the holes.

- Possible receptor sites outlined above (as suggested by estimates of water regime based upon at groundwater measurements, topography and depth to gravel)
- Machinery should be low ground pressure tyres.
- The donor site should not be driven on outside of the two-stage channel area, and in the short term, risk of compaction should be minimised by limiting vehicle movements to the immediate area of the trenches.
- Timing should aim to minimise compaction, i.e. when the soil is dry. However, due to unavoidable disruption of root systems/mycorrhizal networks during translocation, a means of watering the turves once re-lain would be essential

If this archaeological investigation does need to go ahead, it will be before the start of construction of the two-stage channel, therefore a receptor area outside of the proposed channel would need to be identified, otherwise the turves would need to be kept in an alternative location until their final destination was available.

B. Indirect hydrogeological effects of the Scheme on floodplain meadows in the area

There are a number of groundwater-sensitive habitats close to the proposed scheme, including Port Meadow (part of the Oxford Meadows Special Area of Conservation (SAC)) to the north, Iffley Meadows Site of Special Scientific Interest (SSSI) to the south-east, Hinksey Meadow and some of the smaller river channels, including the introduced colony of creeping marshwort in North Hinksey Meadow. Understanding the potential effects on these is an important part of the Environmental Impact Assessment.

Task 3: Review the Environment Agency's assessment of potential effects on other groundwater-sensitive sites.

1.4. FMP response to the ground water models

The groundwater modelling report[1] was read closely and its appropriateness for guiding management of floodplain-grassland sites within the study area assessed. It bases its conceptual model on that of Dixon (2004) and uses a finite difference model to explore the effect on groundwater of various events across a range of flood-return periods and the effect of a dry year. The model was not coupled to a surface-water model, but rather took its input from one. This separation is not perceived as a problem in the system under investigation and the assumption of Q_{95} flow in a dry year seems sensible. The grid size, convergence criteria and choice of 2011 as a typical dry year all seem appropriate.

My main concern is with the assumption that the rivers and associated water courses are in good connection with the gravel aquifer. This is certainly true for some reaches, but it is not a safe universal assumption. The work on Port Meadow (Dixon 2004; Gowing and Youngs, 2005) clearly suggests that the groundwater under the site drains to the Seacourt Stream, by-passing the Thames, which is assumed to have isolated itself from the surrounding aquifer through deposition of fine silts. I agree with the authors that data on river bed permeability is not currently available across the area and to assume different permeabilities in different reaches would add substantially to the complexity of the model and would not necessarily be justified in terms of the model's current objectives. However, it should again be borne in mind that the model is not necessarily suitable for use in future assessments of areas such as Port Meadow, where its assumptions do not hold. It is not necessary for further modelling work to assess the local effect of the new channel on Port Meadow at a finer scale, however it should be noted that the potential weakness of the model should be recognised such that the model is not relied upon to address future questions relating to Port Meadow. The issue need only be re-opened if changes to the Stage level in the Seacourt Stream north of the Botley Road are envisaged by a future scenario.

The current model may not identify such a risk because it assumes the stage level in the Thames would act to buffer drainage. There may be a need to mitigate for such drainage by ensuring any low-flow channel in the environs of Binsey and Medley Manor is not deeper than can be avoided and that water levels in it are retained to minimise any increase in head differential between Port Meadow and the new channel.

A general note is that the model (as described in section 3.10.1) only claims to achieve a precision in the range of 0.2 m, which is good in the context of a hydrogeological model, but poor for an ecohydrological one. Therefore, if there are perceived to be threats to the protected sites, a field-scale hydrological model using site-specific estimates of conductivity and porosity would be needed

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[1] ESI Ltd. (2016) Oxford Flood Alleviation Scheme: Groundwater Flood Modelling. Prepared for CH2M. 53pp.

to give adequate precision. However, for the current purpose of estimating future groundwater flooding and for targeting broad areas in terms of their suitability for grassland restoration, the current model seems adequate.

Given the provisos above, the output of the model was inspected in the context of conserving valued plant communities on the Oxford Meads SAC and Iffley Meadow SSSI. The changes to the hydrographs of the relevant modelling points (WR3, PX5, PX27, PTM1, PTM11, IF2, IF3) are barely changed even in the 1 in a 100 year flood scenario, suggesting no great added risk of anoxia or loss of flood sediment as a result of the new scheme. Of the points assessed, the greatest effect of the scheme is seen at IF2, where the flood peak would be reduced by 10 cm. Looking more generally across the area (Figure 3.38,) the model is suggesting that the maximum flood level across the protected sites would be reduced by less than 10cm in general, with only a small portion of Iffley Meadows being indicated as experiencing a reduction of up to 20 cm. These relatively minor changes to levels during an extreme flood are considered unlikely to have an impact on the sites' ecology.

With respect to the modelling of a dry year, Figure 3.51 indicates that the protected areas would not generally be affected by the new scheme. Only small areas of Iffley Meadows are considered to be affected. However, it is noticeable that the non-protected Hinksey Meadow, which does nevertheless hold plant communities of ecological interest, would be affected by the new channel running on its western and southern boundaries. The indicative drawdown of 10 to 50 cm would be ecologically significant and would lead to a change in plant-community composition. I would support the report's Recommendation 3, which suggests finer-scale modelling of protected areas at the detailed design stage.. I would recommend this exercise be extended to include the species-rich areas of Hinksey Meadow, which although lacking a statutory designation, holds ecological interest of comparable value to some of the protected areas and it is the area most likely to be affected by the scheme. The area supporting the *Apium repens* re-introduction could be included in the more detailed exercise, though the ecohydrological requirements of that species tend to be less exacting than the species-rich sward.

Delivery of sediments to meadows

In terms of the importance of the periodic inundation of meadows (e.g. Iffley) in delivering sediment-bound nutrients to the system, it is not possible to specify a target frequency because it is the size of the individual events rather than their frequency that controls sediment delivery. For sites managed as meadows, there is an annual export of phosphorus in the hay (approximately 5 kg ha^{-1} y^{-1} of elemental P). This needs to be replaced somehow and historically it has been done via river sediments. The amount of P deposited is primarily a function of event size, but typically one large flood per decade is sufficient. Pastures (such as Port Meadow) do not require sediment in the same way. Creeping marshwort sites are not necessarily reliant on sediments either, as they occur in pasture, but they do require surface flooding (may be from high precipitation onto the site and not involve the river) in order to elicit periodic grass kills. Such flooding is a rare event, the soil-moisture regime is underpinned by groundwater not surface water.

On sites that are not managed as meadow, then the input of sediment is less critical and on all sites of biodiversity interest, there is a danger of excess deposition casing the eutrophication of the system. Therefore such sites should only be used to "store" floodwater with care.

Task 4: Use the findings of the Groundwater Report and the Ground Investigation Report to explain how the anticipated change in groundwater levels are likely to affect the MG4/MG4a floodplain meadow at Hinksey Meadow in terms of species composition, NVC classification and long-term viability.

1.5. FMP response to groundwater models and impacts on Hinksey Meadow

Based on the information presented in ESI's November 2016 report "Oxford Flood Alleviation Scheme: Groundwater Flood Modelling" (referred to as the "Groundwater report,") we have considered how the anticipated changes in groundwater levels are likely to affect the MG4/MG4a floodplain meadow at Hinksey Meadow in terms of its species composition, NVC classification and long-term viability.

To help inform this deliberation, we collected six undisturbed soil cores (each 100 cm^3) from the surface horizon of the meadow to characterise how freely draining the soil is and therefore how the vegetation is likely to respond to water-table fluctuations. We analysed these cores on a sand-table and have generated a soil-moisture-release curve (Figure 1,) which demonstrates the upper soil layer to be very porous, free draining and well structured. We have not investigated the full profile in this way (as that would have involved digging pits in a sensitive area,) but the implication is that the root zone of the meadow is likely to be connected to and responsive to the water regime of the underlying gravel aquifer, especially as the alluvial thickness in some parts of the meadow is expected to be approximately 0.5 m (Richard Winstanley *pers. comm.*, 24/03/17).

The Groundwater report suggests (Figure 3.53) that the water table beneath the meadow will be 12 cm (well OS1) and 14 cm (well OS 5) lower with the scheme than without the scheme and that this difference will be constant throughout the year. We have not been able to find an absolute ground-level elevation at these points to calculate absolute water-table depths, which we would need to do a full analysis of the water regime and to determine likely vegetation response. In the absence of absolute values, we can interpret the relative values shown in Fig 3.53 to show the change in the Sum Exceedence Value for soil drying (Silvertown et al, 1999; Gowing et al, 20002) would be an increase of approximately 4 metre.weeks over an annual cycle. This increase represents a very substantial change and would almost certainly lead to a shift in plant-community type. The expected changes would be that drying tolerant species such as cocksfoot (*Dactylis glomerata*) would increase in abundance at the expense of species such as great burnet (*Sanguisorba officinalis*) and the community as a whole in NVC terms would be likely to transition from MG4a to MG5.

In response to the specific question posed by the EA:

1. *Is there likely to be a discontinuity between the groundwater levels in the gravels and the overlying alluvium that acts as a 'buffer' to changes in groundwater levels?*

   There is unlikely to be a discontinuity because the alluvium is relatively shallow (<1 m deep) at the site and its soil-moisture release curve shows it to be very well structured. It is therefore likely that the root zone will be directly affected by any change to the piezometric head in the gravel aquifer.

2. *Are the MG4/MG4a species at the wet end or the dry end of their tolerance range?*

From the 2016 NVC map supplied by Dr. T. King, the vegetation has been classed as subcommunity type a, which is the driest variant of the MG4 community, suggesting the current soil moisture conditions are at the dry end of the water-regime range typified by that community. If ground-surface elevation data for the modelled positions (OS1 and OS5) are available, we could calculate absolute measures of the water regime at those locations based on the model output and make a more definitive statement about where the site falls within the tolerance range.

3. *Does the groundwater report provide sufficient information to allow a confident prediction of how the scheme will affect the hydrological regime of the remaining part of Hinksey Meadow in the growing season?*

   As suggested above, the Groundwater report contains relevant data to address the question, but the level of interpretation is limited by the lack of ground-surface elevation data for the relevant wells. The report sets out its assumptions and model structure clearly and all these seem to be sensible, but we would query why the dry-year model did not use actual river-level data from 2011 so as to allow the outputs to be validated against observation. The use of "synthetic" data precludes validation, so we are unable to ascribe a level of confidence for the outputs. The flood model was validated against observation and showed the residual errors to be in the order of 20 cm. If the dry-year model run generated comparable residual errors, then little confidence could be placed in the detail of the output.

4. *Should we be putting piezometers within the MG4 on Hinksey Meadow this winter and if so, how many and where?*

   We believe gathering actual baseline information would be useful and we have already had discussions with CH2M about potential locations to maximise data value without causing undue disturbance to the site. We tried to emphasise that the very highly structured nature of the soil (now borne out by the results of the soil-moisture-release curve) make it highly fragile and susceptible to compaction damage if vehicles are run on it whilst wet, so we suggest a high priority for the scheme is to protect the soils from disturbance. Structural damage can take decades to repair.

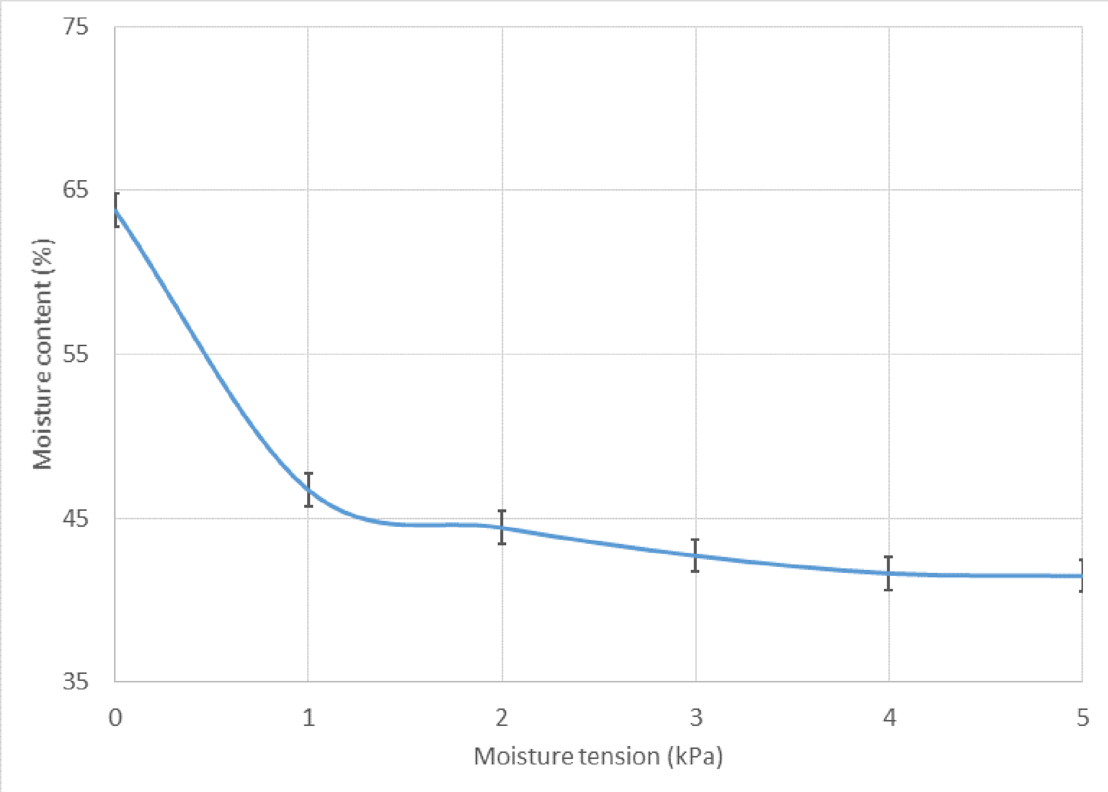


Figure 1. Soil-moisture-release curve for the upper soil horizon of Hinksey Meadow. The curve represents the mean values from six separate cores (sampled from across the meadow,) which were analysed on a sand-table. The error bars represent one standard error of the mean.

1.6. Addendum March 2018

A revised groundwater model has been produced (ESI, 2018) which includes assessment of a proposal to raise the bed level of the Bulstake Stream in order to mitigate lowering of groundwater in Hinksey Meadow. The FMP have reviewed this new model and conclude that we are satisfied that the modeling in the main report has addressed the Hinksey question. If Scenario B, as it is termed, can be delivered on the ground, it would appear to allay concerns about the future ecohydrology of Hinksey Mead.

2. Opportunities to create Floodplain Meadows as part of the Oxford FAS

A: Floodplain meadow within the two-Stage channel

Task 5: Provide recommendations on how we should be monitoring and assessing the ecological trial areas and using existing features in the landscape, to gain a better understanding of which parts of the channel (if any) will be suitable for MG4 floodplain meadow.

2.1. Ecological trial areas and existing depressions

The trial pit areas should be used to assess whether the guidelines for creation of floodplain meadow within the two-stage channel and assumptions are correct. In their current state however, the assessment is not straightforward because it is not clear that the batter is the same as for the two-stage channel, and some of them have been covered with top soil of high fertility.

Trial pit 4 gives a good indication of groundwater levels. At a visit in December 2016, the ground water was between 0.5 and 1 m below the surface, and after the dry year we have had, from a second visit in June 2017, the groundwater was approximately 1 m below the surface. This suggests that in the trial pit 4 area, groundwater levels are suitable for MG4 restoration.

Trial pit 4, June 14th 2017

However, in order for the trial areas to be most useful it is recommended that:

- The trial pits on the river bank are re-profiled to give a cross section equivalent to that expected in the two-stage channel.
- The trial pits are monitored for groundwater elevations.
- Trial pits are not covered with top soil, especially where gravels are exposed, and are sown with a selection of seed or green hay from MG4/8 sources.
- The results are monitored for as long as the scheme timescales allow.

Existing interest in the trial pit areas, and other depressions.

The Jubilee channel in Hinksey Meadow is described as *Cynosurus cristatus – Caltha palustris* grassland (MG8) in the NVC survey from 2016 (King, 2016). This gives a reasonable indication that the two-stage channel may be able to support this type of vegetation. However, the likely drop in groundwater, as a result of drainage by the low-flow channel, may mean that the vegetation currently in the Jubilee Channel could shift toward MG4 if managed appropriately. This situation may reflect the possible vegetation communities in the upper parts of the planned two-stage channel more generally.

A survey of Trial pit 4 in June 2017 showed that there was some germination of meadow species, but it was too early to conclude anything about the suitability of the site for community establishment.

For the trial pits to have the best chance of success, those areas that have been sown with green hay/seed should be mown where there is sufficient growth, and possibly throughout the growing season in 2018. Mowing will help vegetation establish good root structure and prevent invasion of weedy species. Arisings should be removed.

2.2. FMP assessment of potential for creation of floodplain meadow within the 2 stage channel

In approaching this question, we have looked at various different pieces of data including:

- preferred-option modelled depth to groundwater in a dry year,
- depth of gravels
- existing topographical data
- predicted final land levels for the bottom of the two-stage channel based on cross-section drawings.

We have made some recommendations for where these requirements come together within the proposed channel, and where therefore creation of species-rich grassland is possible, based on the data we have. The areas suggested as suitable for *Alopecurus pratensis – Sanguisorba officinalis* grassland (MG4) would also act as suitable receptor sites for any turfs that are removed from Hinksey Meadow. We have also looked at the trial areas to see how they have responded, and made some recommendations based on available data.

2.3. General principles for species-rich meadow creation in the two-stage channel

The general principles we have used to ascertain whether the two-stage channel is likely to support MG4 or MG8 communities are outlined below:

Hydrological guidelines for creation of species rich floodplain meadow within the two-stage channel

1. a thin (<1.5 m) layer of alluvium over gravel
2. a depth to groundwater is generally in the range 0.5 - 1.0 m during the hay growing season (March-June)(March to June) when above-ground competition between species is at its greatest.

If the depth to groundwater is shallower than 0.5 m and/or the low-flow channel is to be kept at bankfull, then it is likely that a wetter community will develop, for example MG8.

It is likely that there will be a gradient of depth to gravel and depth of groundwater across the two-stage channel, creating conditions suitable for a range of plant communities from *Agrostis stolonifera – Alopecurus geniculatus* inundation grassland (MG13) at the wetter end, through MG8 to MG4 or even *Cynosurus cristatus – Centaurea nigra* grassland (MG5) at the drier end.

Management Guidelines for the creation of a species-rich floodplain meadow within the two-stage channel

1. If the objective is to create MG4 and particularly if turfs from Hinksey Meadow are to be used in the upper channel, then it is essential that the two-stage channel has an annual hay cut. Aftermath grazing is desirable but not essential, if replaced by a second hay cut in September when the re- growth warrants it. Arisings should be removed after each cut. This latter scenario would obviate the need for fencing along the channel or between ownerships.
2. If the objective is to create wet-grassland habitat, but not specifically MG4, and particularly if MG8 or MG13 were more suited to the hydrological regime, then management through grazing alone would be an option. These communities can exist as either meadow or pasture.

Figures showing the possible different scenarios for floodplain meadow creation, depending on the level at which water is to be held in the two-stage channel:

Fig 1a: water level and management requirements for creation of MG4 community

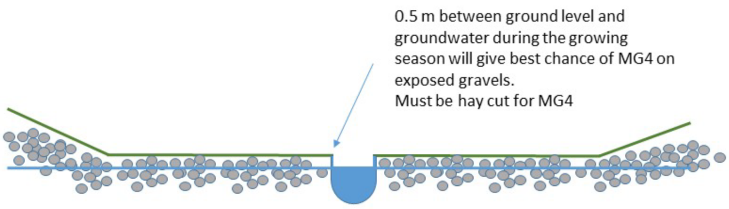
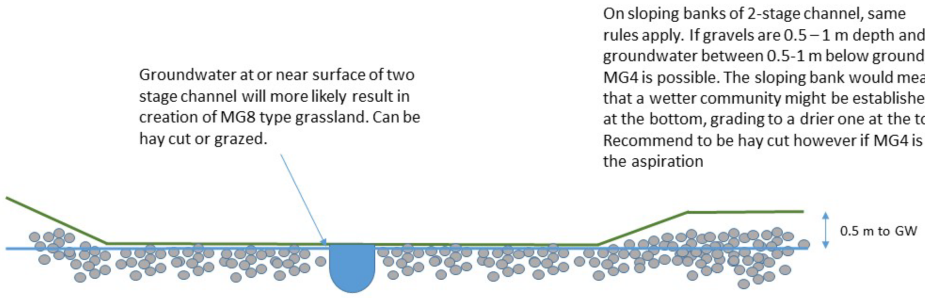


Fig 1b: water level and management requirements for creation of MG8 community



Specific areas where data has been analysed for re-creation of species rich floodplain meadow within the two-stage channel area.

In each area where we have information on the following, we have made an assessment of the likely potential for re-creation of species rich floodplain meadow within the two stage channel. Data used as follows:

- Existing ground elevation (left and right banks)
- Existing ground elevation inside proposed channel area
- Depth of two stage channel (from drawings provided by EA; Draft indicative outline design 22/07/2016), at points where cross section data are present on these drawings, giving depth of two stage channel.
- Depth to gravel, based on nearest available information
- Depth to groundwater (modelled preferred option, dry year). We are assuming the modelled option includes any drainage effect of the low-flow channel.
- Depth to groundwater (from McDonald and Dixon 2007).

For each area, we have provided a predicted plant community (or range of communities where the hydrological conditions change substantively along the transect) based on best current information. The details of these predictions may change if more specific information becomes available. The data and predictions can be found in detail in the spreadsheet in Appendix A, and the cross section locations in Appendix E and are summarised in Tables 1 and 2 below.

For creation of species-rich floodplain meadow inside the two-stage channel (below the off-take/spillway south of the Botley Road) the hydrological and soils data suggest the following:

Table 1. Summary of areas where potential for creation of species rich floodplain meadow has been assessed within the two-stage channel, showing expected plant community, based on available data. Refer to Appendix E for maps showing cross section locations.

Location of cross section within proposed two-stage channel	Expected range of plant communities within new two-stage channel
New spillway to Willow Walk (x-section A-A)	MG4 – MG5
New spillway to Willow Walk (x-section B-B)	MG4 – MG5
New spillway to Willow Walk (x-section C-C)	MG4 – MG5
Willow Walk to devil's Backbone (x-section A-A)	MG5
Willow Walk to Devil's Backbone (x-section B-B)	MG4 – MG5
Willow Walk to Devil's Backbone (x-section C-C)	MG4
Devils Backbone to Old Abingdon Road (x section A-A)	MG4
Devils Backbone to Old Abingdon Road (x section D-D)	S7 – MG4
Devils Backbone to Old Abingdon Road (x section (x-section E-E)	MG4

B: Floodplain meadow outside the two-stage channel

Task 6: *Provide recommendations on which areas within the wider floodplain might be most suitable for the creation of floodplain meadow/MG4 and the work that would be required to enable us to identify, prepare and establish such areas.*

2.4. FMP assessment of potential for creation of floodplain meadow outside the 2 stage channel in the wider floodplain

In approaching this question, we have looked at various different pieces of data including:

- Preferred option modelled depth to groundwater in a dry year,
- depth of gravels
- land levels where available
- existing plant community

We have made some recommendations for where these requirements come together in fields adjacent to the proposed channel, and where therefore the restoration or creation of species rich grassland is possible, based on the data we have.

2.5. General principles for species-rich meadow creation outside the two-stage channel

The general principles to follow to see whether these areas are likely to support MG4 are outlined below:

Hydrological guidelines for creation of species rich floodplain meadow outside the two-stage channel

1. The depth to groundwater is generally between 0.5 -1.0 m
2. The depth to top of gravel is between 0.2 and 1.2 m
3. The soil is well structured and free-draining

Management Guidelines for the creation of a species rich floodplain meadow outside the two-stage channel

3. If the objective is to create MG4 and particularly if turfs from Hinksey Meadow are to be used then it is essential that any fields targeted for restoration have an annual hay cut. Aftermath grazing is desirable, but if it is not feasible, it could be replaced by a second hay cut, in years when the aftermath re-growth warrants it. Arisings should be removed.
4. If the objective is to create a species-rich plant community, but not specifically MG4, and particularly if MG8 or MG13 are more likely hydrologically, then management through grazing would be an alternative option. MG8 and MG13 are typically found in both meadow and pasture situations.

Soil fertility requirements for the creation of a species-rich floodplain meadow

Typically phosphorus levels should be within 5 - 20 mg/l^{-1} (Olsen's extractant), correlating with phosphate indices 0 and 1. Values above 20 mg/l^{-1} will result in species richness declines and therefore whilst the site may still be suitable for MG4 restoration, it may not be suitable for translocation purposes.

Soil phosphorus availability from within Hinksey Meadow ranges from 6 - 12.4 mg/l^{-1} (based on 3 samples), therefore for the purposes of translocation, fields with phosphorus availability within a similar range should be sought. Phosphorus levels are often only elevated in the top 200 mm of the profile, but this would need to be checked on a case by case basis.

Phosphorus is the nutrient whose variability tends to correlate with species composition of these grasslands. Nitrogen is important in that it is often the yield-limiting nutrient in these grasslands, but its availability is so dynamic that measurements are rarely useful. It is our understanding that phosphorus regulates the rate of nitrogen mineralisation in such systems and as such is the key nutrient to monitor.

Table 2 shows which plant communities are likely to develop at different locations, given the hydrological regime expected once the two-stage channel is built and assuming soil fertility and habitat management regime are optimised for species-rich grassland. See in combination with maps in Appendix E upon which the locations are identified. Where data on depth to the River Terrace

Deposit is unavailable, it has been assumed to be within 1.2 m of the surface because that is the general situation for this part of the floodplain.[2]

[2] We have not assessed the impact of altered flooding frequency on silt deposition on the meadows, but this could be a potentially important consideration. If the meadows are still inundated by major events (larger than a one in ten flood) then the traditional balance between sediment inputs and cropping outputs should sustain itself. If the meadows cease to receive these sediments, then mitigation would be required. We are not aware of data that predicts these changes. It should be noted that only over-bank flooding is relevant here, groundwater flooding or ponding of surface water from a local catchment is not equivalent.

Significant reduction in silt deposition may also result in a reduced pH, which would affect the species composition. Soil analysis should record the major cations, including K, Ca and Mg. When such data are available, we can assess the sensitivity of the system.

Table 2. Summary of areas where potential for creation of species rich floodplain meadow has been assessed outside the two-stage channel, showing expected plant community (or communities where there is spatial heterogeneity), based on available data. Refer to Appendix E for maps showing field locations.

Location of field area outside of two-stage channel	**Field location number**	**Existing plant community**	**Expected plant communities**
North of Botley Road	1	No info	MG4-MG5-MG7C
Willow Walk to Devil's Backbone	2	MG7b	MG7C
Willow Walk to Devil's Backbone	3	MG7b	MG7C
Willow Walk to Devil's Backbone	4	MG7b	MG7C
Willow Walk to Devil's Backbone	5	MG7b	MG7C
Willow Walk to Devil's Backbone	6	MG9b	MG4-MG5-MG7C
Willow Walk to Devil's Backbone	7	MG9b	MG4-MG5
Willow Walk to Devil's Backbone	8	MG6c-MG6a	MG4
Willow Walk to Devil's Backbone	9	MG6a	MG7C
Willow Walk to Devil's Backbone	10	MG6a	MG7C
Willow Walk to Devil's Backbone	11	MG6a	MG4
Willow Walk to Devil's Backbone	12	MG6a	MG4-MG5
Willow Walk to Devil's Backbone	13	MG6a	MG7C
Willow Walk to Devil's Backbone	14	MG6c	MG4-MG5
Willow Walk to Devil's Backbone	15	Not known	MG4
Willow Walk to Devil's Backbone	16	Not known	MG4
Willow Walk to Devil's Backbone	17	MG6a	MG4
Willow Walk to Devil's Backbone	18	MG6a/MG9a	MG4
Willow Walk to Devil's Backbone	19	Not known	MG4
Devils Backbone to Old Abingdon Road	20	Not known	MG7C
Devils Backbone to Old Abingdon Road	21	Not known	MG7C
Devils Backbone to Old Abingdon Road	22	Not known	MG7C
Devils Backbone to Old Abingdon Road	23	MG7b	MG4
Devils Backbone to Old Abingdon Road	24	Not known	MG4

Devils Backbone to Old Abingdon Road	25	Not known	MG4-MG5

2.6. Additional data required to establish potential areas for restoration outside the two-stage channel

In order to establish more precisely the most likely plant community to develop in those areas where the hydrological information from the initial modelling exercise indicates that MG4 is feasible, direct monitoring of the water regime, a measure of soil phosphorus availability and information on soil porosity should be collected and the suitability analysis re-visited using the larger data set before restoration is attempted.

3. Maintenance and Monitoring Work Required

***Task 7:** Provide recommendations on the type of monitoring that should be undertaken on the existing floodplain meadow in order to ensure that the environmental objectives of the scheme are being met.*

3.1. FMP recommendations for post-scheme monitoring

Table 3. Monitoring at Hinksey Meadow post-scheme

To monitor	Mechanism	Outcome	Timing
Groundwater level	Dipwells (already installed)	Are groundwater levels behaving as predicted? Are GW levels still expected to deliver anticipated plant communities?	Monthly (or continuous if automatic dataloggers available))
Plant community composition	Fixed location quadrats (typically 5 per stand)	To determine extent of any changes and to identify if any further mitigation required in representative areas.	Annually, pre and post scheme construction.
Plant community	NVC	To determine extent of community change across the whole area affected by the works	Every 5 years. Baseline already completed (King, 2016), then start 5 years post construction
Soil fertility	Soil samples	Is soil fertility still within range of target plant community? If soil fertility changing, management changes may be required.	Every 3 years (baseline already completed for Hinksey), the start 3 years post-construction
Pollinators	Structured walks	To assess impacts on populations of invertebrate pollinators	Monthly during selected seasons (or more frequently with volunteer support)

***Task 8:** Provide recommendations on the maintenance and monitoring that should be undertaken on any translocated floodplain meadow and newly created floodplain meadow in order to ensure that the environmental objectives of the scheme are being met.*

The final list of sites that should be targeted for monitoring has not been agreed yet. The recommended sites listed in Table 2 are based purely on the predicted groundwater regime post-scheme. However, the soil chemistry data, (to be provided) will refine this list further, as will landowner negotiations. The final list of sites where monitoring should be instigated will be based on whether the hydrology, soil chemistry, land owner agreement and potential future management are all favourable. Once this refined list has been agreed by the project team, a more detailed monitoring plan can be developed, focussing on very specific sites, with very specific recommendations.

All sites targeted for restoration/re-creation outside of the two-stage channel should have as a minimum the following monitoring:

Table 4: Monitoring at restored or re-created meadows

To monitor	Mechanism	Outcome	Timing
Groundwater level	Dipwells	Are groundwater levels behaving as predicted? Are GW levels still expected to deliver anticipated plant communities?	Monthly (or continuous if automatic data loggers)
Plant community	Fixed location quadrats	Are expected plant communities developing? Plants that have established can tell us about GW levels and soil fertility	Annually
Soil fertility	Soil samples	Is soil fertility within range of target plant communities? (Gilbert *et al*, 2009) If soil fertility is increasing, management may require amendment	Every 3 years
Soil profile	Soil auger	Will demonstrate exact depths to gravels and other horizons to refine our understanding of the soil water regime. *Only needed where no soil profile is currently available.*	Once at start
Soil porosity	Undisturbed soil cores	At each site targeted for restoration, it is advisable to characterise the soil structure in order to interpret the groundwater regime.	Once at start

4. References

ESI Environment Specialists. Report reference 63294 R2. February 2018. Oxford Flood Alleviation Scheme: Groundwater Model Update.

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Wheeler, B.D., Gowing, D.J.G., Shaw, S.C., Mountford, J.O. and Money, R.P. (2004) *Ecohydrological guidelines for lowland wetland plant communities* (Eds. Brooks, A.W., Jose, P.V. and Whiteman, M.I.) Environment Agency (Anglian Region), Peterborough.