Summary progress report on "Water for all project" for 5th Lunan Catchment Management Group meeting, 24th October 2017.

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1. Introduction

Upgrading of an existing hydraulic structure at the outlet to Balgavies Loch on the Lunan Water, Angus, Scotland, to allow more active management of water flows, eg. using a lateral tilting weir on the lade, has been proposed (Vinten et al., 2015; 2017) as a practical means to deliver improved water management in the catchment. In order to obtain consent for this proposal from both riparian owners and regulators, it is necessary to demonstrate benefit to the water environment across a range of pressures. In the Scottish Government funded "water for all" project (see http://www.hutton.ac.uk/research/projects/payments-ecosystem-services-lessons) we are focusing on 3 main areas of potential benefit – mitigation of flooding, mitigation of low flows and improvement in wetland ecology through management of nutrient and sediment loads to sensitive areas. It is necessary to satisfy requirements for a practical long term plan for governance, especially if a tilting weir is to be submitted for consent. There is a firm view among riparian farmers that dredging should be the first step in respect of alleviating flooding issues. It is also necessary to meet regulatory Agency requirements for intervention in the water environment. This report provides an update to the work described in Vinten et al (2017) with respect to (a) governance of improved water management (b) hydro-ecological characterisation, focused mainly on Chapel Mires, a marginal wetland downstream of Balgavies Loch that may benefit from improved water management and (c) assessment of impacts of proposed potential hydraulic structures and their management, focusing on the introduction of a tilting weir and a penning structure in the outlet area of Balgavies Loch and dredging of the lade to remove sediment. Figure 1 shows the location of these structures and an indicative management plan.

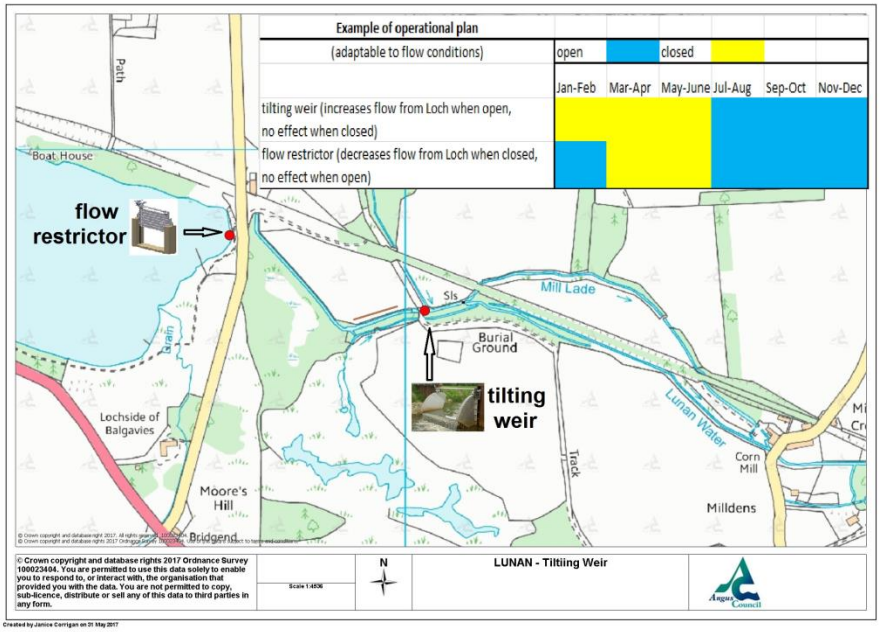

Figure 1. Potential location of proposed hydraulic structures at the outlet to Balgavies Loch, to provide improved water management. The line along the north shore of the lade shows the main proposed area for dredging.

2. Governance of improved water management

2.1 Social science research on governance and evaluation of water resources.

Understanding the social norms and values of stakeholders in the Lunan catchment is an important part of the research project as they influence which solutions can be implemented to solve water issues. The "water for all" project was proposed as a follow up to a round of interviews with stakeholders in a 2014 survey on attitudes to water management issues in the catchment. A summary of the results of these interviews is shown here.

Following on from this work, we recognised the need to gain practical insights into the likely level of interest in a water management scheme in the catchment and how this would be governed. The framework used for development of this social science work is presented in Figure 2.

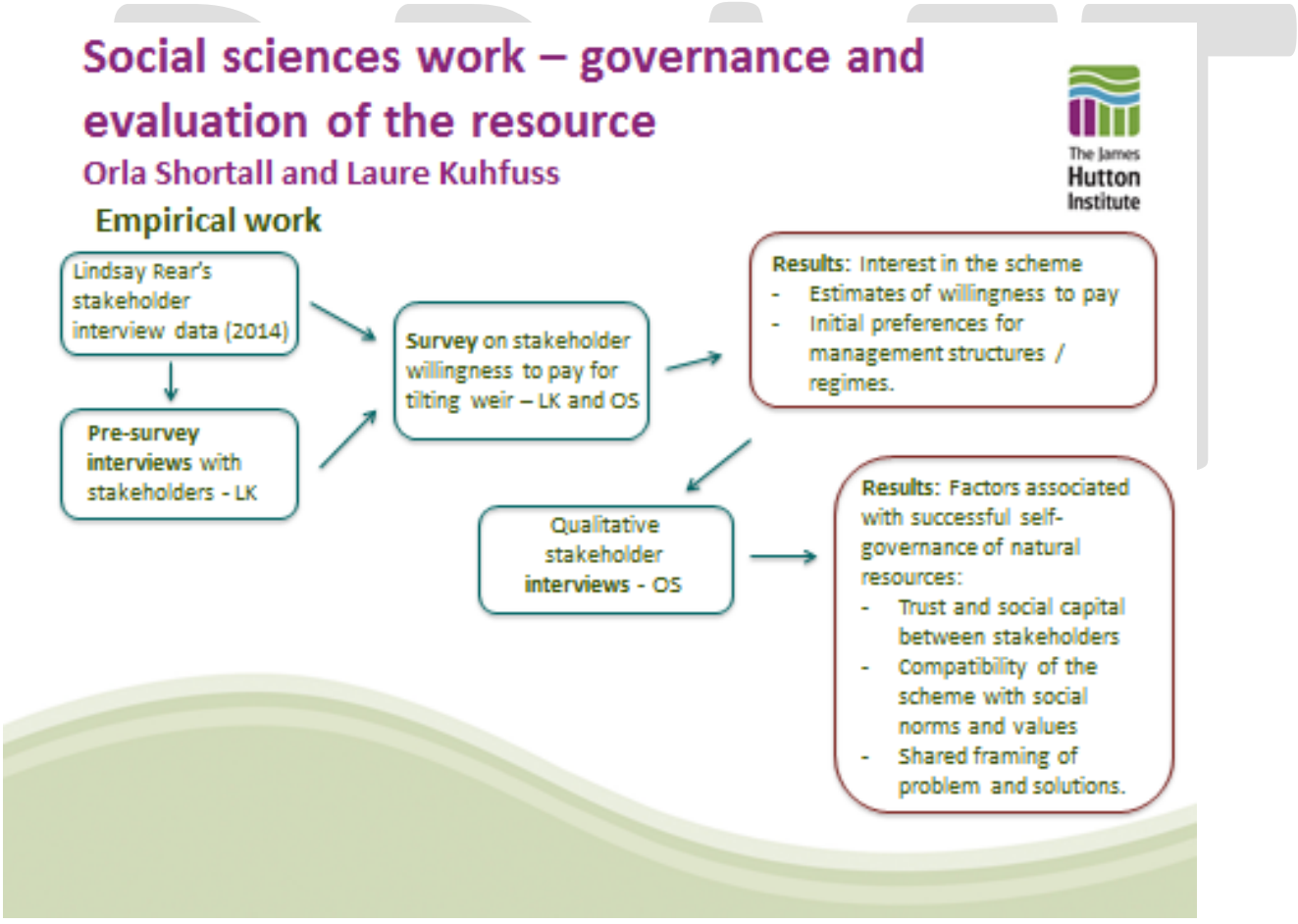

Figure 2. Framework for participatory social science work in the "Water for All" project.

A first step was to carry out scoping interviews, building on this prior work, to help frame a survey of willingness to pay for proposed measures, and of attitudes to governance. The slides used for these pre-survey interviews are available here. This led to an online and paper survey of stakeholders and residents

in the catchment. An online version of this questionnaire will be made available in the near future at: www.linktosurvey.co.uk.

The objective of this survey was to measure quantitatively the support to the "water for all" project, which proposes the installation of a tilting weir and a flow restrictor at the outskirt of Balgavies loch for water management. The postal survey was sent to 60 farmers and 200 residents from the Lunan Water catchment. 5,000 leaflets were distributed in mailboxes and advertised in the catchment area to advertise the online version of the survey. 12 farmers and 61 residents responded, for a total of 73 responses, including 39 from the postal survey and 34 from the internet survey. 62 of the 73 respondents live on the catchment; the 11 remaining ones live in Angus. A preliminary summary of report findings will be made available in the near future here.

Results highlight support to the project with 70% of respondents stating that the project should probably or definitely be implemented, but also identifies 2 types of concern: (1) About the project itself, with 25% of stated WTP being null, (2) About its governance, illustrated by the high level of protest zeros, due to either the lack of confidence that the project will be managed correctly under the proposed governance mechanism, a belief that others should fund it and/or a preference for another way of funding.

The preferred governance scenario appears to be that of a local government management, even though the differences in preferences need to be analysed further through (i) the analysis of open ended questions and (ii) in-depth qualitative interviews.

The next phase of this work is now underway, with participants in the survey being invited to contribute their knowledge and experience to the process of improving understanding of water management issues in the catchment by participating in an hour long interview. The interviews will take place between November 2017 and March 2018.

2.2 Feedback from potentially consenting parties for hydraulic structures at the outlet to Balgavies Loch

Running in parallel with the above social science survey work, the project has aimed to pursue consent for proposed water management structures, as it was anticipated that this would be a complex process, which would provide many lessons for implementation of such schemes. A paper was submitted to Balgavies Loch Management Committee in July 2017, including a draft consent application (available on request), prepared by Janice Corrigan of Angus Council Roads department and Andy Vinten of James Hutton Institute, for their comment. This committee includes riparian owners, representatives of the SWT reserve at Balgavies Loch, and is also attended by SNH. An extract of the minute of that meeting is provided. The minute emphasised the need for further evidence that the proposed structures would be effective for management of water across the diverse range of water interests, and the need for more information on how such structures would be financed, managed and governed. The social science work described above will help to deliver evidence for the second of these concerns. With respect to the requirement for further evidence, our recent work has focused on further characterisation of the hydro-ecology of Chapel Mires, a wetland that could potentially benefit from improved water management, on more in-depth analysis of the hydraulics of the proposed system, and on approaches to forecasting the impact of management decisions on upstream and downstream hydrology.

3. Characterisation of Hydro-ecology of wetlands in the area.

3.1 Mapping of mire and swamp classes for Chapel Mires

A draft map of National Vegetation Classes for Chapel Mires was prepared during summer 2017, with the help of SNH (Peter McPhail). This shows the prevalence of nutrient loving and sediment tolerating species, such as *Phalaris arundinaceae* (NVC S27a) and *Spargimun erectum* (NVC S14) close to the river, with more oligotrphic, Carex-rich classes such as NVC 28a, and transitional M28 Iris/Filipendula mire further away, where groundwater is likely to be a larger contributor to the overall water balance. In the central part of the wetlands a transitional mosaic of these communities occurs, as shown in Figure 3.

Figure 3. M28 Iris/Filipendula mire and a small area of S28 Phalaris mire in the central part of Chapel Mires wetland.

While such mosaics may be stable, there is a concern that current hydrological processes may be favouring the acceleratedl eutrophication of these Mires, through ingress of sediment and nutrients (see Holaday et al., 2015; Werner and Zedler, 2002. This concern is shared by SNH, who have observed such change in other parts of the wetlands, specifically the area of Clocksbriggs, to the west of Rescobie Loch. They have provided aerial photographic evidence of change in extent of *Phalaris* in this area since 1988 (McPhail, pers. Comm).

3.2 Analysis of mixing of water sources to Chapel Mires

The discharge, suspended sediment, N and P content of the waters leaving Balgavies Loch vary strongly through the year and our hypothesis is that it may be possible to reduce the ingress of such eutrophying waters into the Chapel Mires by management of a new weir with greater capacity for

water level control (or by improved management of the existing structures). Estimation of the current contribution of the water flowing from Balgavies Loch along the common lade into the Chapel Mires is key to assessing this. To make this estimation we have employed end-member mixing analysis (EMMA) methods similar to those outlined by Christopherson and Hooper (1992) and Hooper (2016). The potential end members that we considered initially were spillage from the common lade of the Lunan Water, rainfall, local groundwater (as indicated by the ponds in woodland adjacent to Chapel Mires and runoff from the road and farmland to the south west of the area. Figure 4 shows an example of such mixing analysis for water samples taken in May to July 2017. Further analysis of the available data from 2015-2017 suggests that the large pond in the middle of Chapel Mires has a 70-80% contribution from river water, while the large pond further south has only a 40-50% contribution from river water. The contribution over river water to the area of oligotrophic Carex rich S27a wetland in the south of the chapel mires is <10%, but there is a significant input from the road (NaCl) into the western part of this area. This quantitative data thus confirms the vegetational data which suggests a transitional fen that may be vulnerable to addition of nutrient and sediment water from the river.

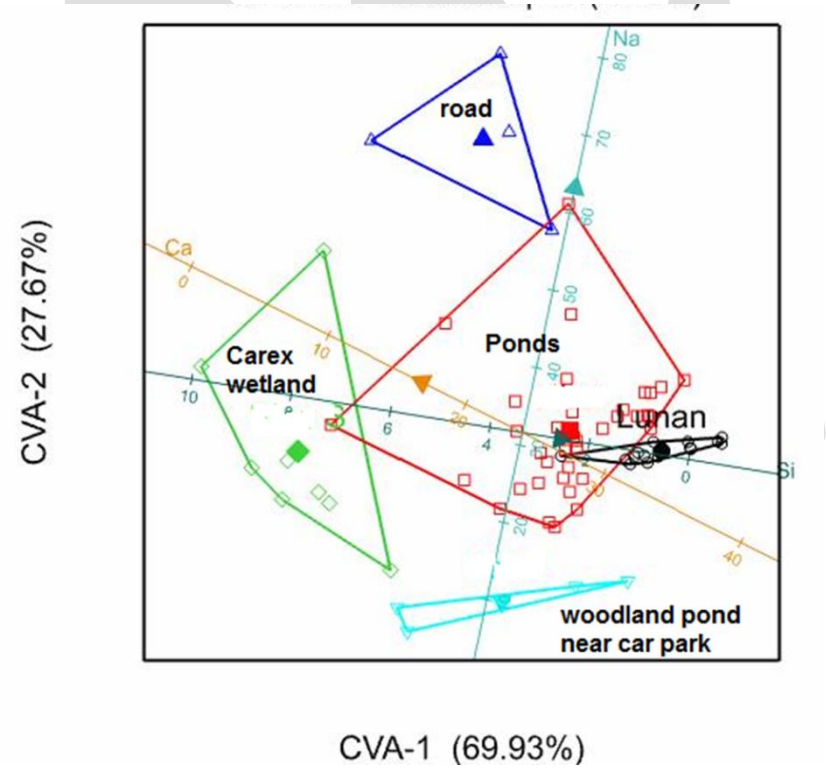

Figure 4. Water chemistry bi-plot for samples taken in and around chapel mires during May-June 2017.

North

More information on this analysis is available **here**. Note that the area of Carex wetland is partially protected at low water levels by a culvert (see figure 1), but not at high water levels. A rule base could be developed, using this mixing information and knowledge of how tilting weir management impacts the distribution of flows between the common lade and the spillway into Chapel Mires, to reduce inputs of nutrient (N and P) rich water into the wetlands.

3.3 Survey of aquatic plants in inlet pond, Pond 1 (Western pond) and pond 2 (Eastern pond) in Chapel Mires by Iain Gunn, Mattie O'Hare and Justyna Olszewska (CEH, Edinburgh).

The full text of this report is available **here.** Main highlights are summarised**.** Ponds 1 (i.e., the easternmost pond) and 2 (i.e., the largest and westernmost pond) were surveyed from an inflatable boat by means of visual assessment supplemented by regular sampling of the submerged macrophyte communities by use of a double-headed rake. This took place on September 11-12th 2017. The macrophytes in the Inlet Pond (i.e., the northernmost pond) and the Inlet were sampled from the bank using throws of the double-headed rake. There were no previous aquatic macrophyte data available to compare with. Pond 2 was the largest and most diverse water body in the Chapel Mires site with eight aquatic macrophytes species recorded; Ceratophyllum demersum, Elodea canadensis, Lemna minor, L. trisulca, Nuphar lutea, Potamogeton obtusifolius, P. pusillus and Utricularia vulgaris agg. (Figure 5).

Figure 5. Utricularia vulgaris agg. collected from Pond 1

The majority were characteristic eutrophic species (all of which have been recorded in Balgavies Loch in recent years) although the presence of Utricularia vulgaris agg. indicated more nutrient poor conditions (as did the presence of emergents such as Carex rostrata and Menyanthes trifoliata). The western half of Pond 2 was dominated by the non-native Elodea canadensis while the eastern half was co-dominated by both Elodea and Ceratophyllum demersum. Pond 1 had a smaller surface area but a greater water depth than Pond 2 but lacked the two Potamogeton species and Elodea canadensis was rare. However, in the Inlet pond and the sampled section of the Inlet from the Lunan Water, Elodea was the dominant submerged plant species. Unlike Rescobie and Balgavies Lochs, there was no evidence of cyanobacterial blooms in any of the sampled water bodies in the Chapel Mires site and water clarity was excellent with Secchi Disc readings of 2.20 recorded in Pond 1. Evidence of this better water quality was reflected in the lower PLEX scores calculated for Pond 2 and the other sampled waterbodies in the Chapel Mire site, compared with the PLEX scores recorded in the recent surveys of Rescobie and Balgavies Lochs (see Tables 1-3 **here**).

It has been suggested that Phalaris arundinacea is invasive at the site. While it and Sparganium erectum are tolerant of more fertile conditions, both species are found in a very wide range of conditions. P. arundinacea, in particular, is nearly ubiquitous along British river and lake margins, and is only absent at the most oligotrophic of sites (Preston and Croft, 1997). It should be considered a natural element of the assemblage at Chapel Mires and not thought as an aggressive invasive species. Any reduction in nutrient inputs may disadvantage S. erectum but the response from P. arundinacea is likely to be more muted. It should be noted that fine sediment builds up around S. erectum and is likely to hold nutrients. Therefore, any response to a reduction in nutrient inputs will be tempered by the internal supply from deposited fines. The authors of this report conclude that there is likely to be little or no negative impact to the

qualifying interests from the introduction of a tilting weir and any significant reduction in nutrients to the systems should be considered as potentially beneficial.

3.4 Assessment of impact of proposed water level changes on Balgavies Loch and Rescobie Loch by Iain Gunn, Mattie O'Hare and Justyna Olszewska (CEH, Edinburgh).

The full text of this report is available **here.** Main highlights are summarised**.** For a number of decades the qualifying interests of the Rescobie and Balgavies Lochs SSSI have been compromised by eutrophication. The lochs and fenlands are both affected. There has been no improvement in recent years. Currently, Balgavies Loch (Figure 6) water levels fluctuate by c. 60 cm per annum (Vinten, pers comm.) and exhibits a classic seasonal pattern with the highest levels in winter and the lowest in summer.

Figure 6. Eastern end of Balgavies Loch. The outlet to the Lunan Water is marked by an arrow.

The water management plan for the upper reaches of the Lunan Water, proposed by the James Hutton Institute (JHI), envisages installing two hydraulic structures: a flow restrictor at the outlet from Balgavies Loch and a tilting weir on the downstream mill lade (Vinten et al. 2017). The aim of this plan is to allow for more active management of the Lunan Water in order to deliver improvements for flood and low flow mitigation, as well as wetland water quality objectives. JHI are advocating an increase in the water levels in Balgavies Loch of c. 10 - 20 cm in early summer to support low river flows later in the summer (Vinten pers comm.). Although JHI do not intend to lower the base level of the two lochs, they are also interested in an assessment of the likely impacts of reducing the loch level by, say, 10 cm (Vinten pers comm.). SNH and SWT had also expressed concerns over the impacts of any water level change on the ecology of the lochs as a result of changing management; Based on a recent review, the available information on the effects of water level fluctuations on lake macrophytes, suggests that fluctuations of the magnitude proposed for Balgavies Loch are likely to have relatively minor impacts on aquatic plant communities (Moe et al., 2017). The direct effects on the plant community of any water level changes are likely to be limited to those species inhabiting the upper littoral (eg Potamogeton filiformis,last recorded in 2007 at Balgavies Loch)

4. Hydraulic and hydrological modelling of the Lunan Water reach downstream of Balgavies Loch

4.1 Hydraulic modelling of impacts of introduction of a tilting weir.

The goal of this work is to determine the impact of introducing a modified water management regime to the outlet of Balgavies Loch, for example by using a tilting weir on the common lade on (i) upstream water levels and (ii) the

distribution of flow and sediment between chapel mires wetland and the Lunan Water downstream of the lade system. We also want to assess the impact of dredging sediment from the lade system, in conjunction with modified water management. Impact of a penning structure at the outlet to Balgavies for management of low flows has not been considered further at this stage. Preliminary 1-D hydraulic modelling using HECRAS of the lade d/s of Balgavies suggests a tilting weir could be useful in delivering reduction of flow to Chapel Mires at times when the Lunan Water carries a large burden of sediment and nutrients. There is a clear beneficial impact of dredging the mill lade *upstream of Milldens weir. See figure 6.*

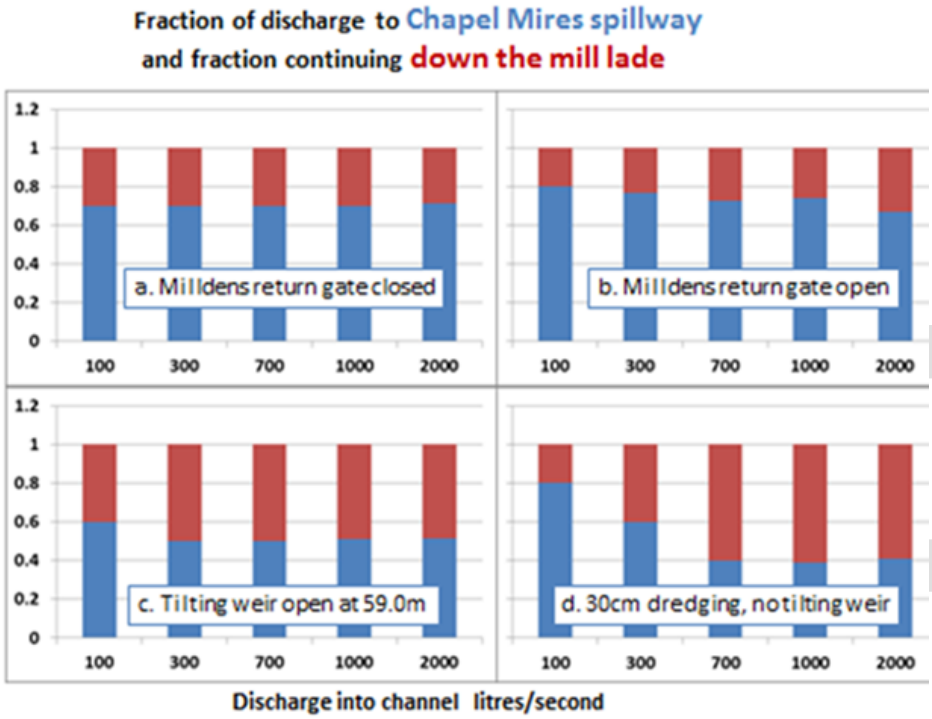

Figure 6. Illustrative example of impact of a 1.8m tilting weir on distribution of flows in litres/sec between the spillway into chapel mires and the mill lade as a result of different management scenarios.

A tilting weir appears to be less useful for delivering reduction in water levels upstream. To confirm this, 2D modelling which includes upstream standing water bodies (Balgavies Loch and Chapel Mires ponds) and Balgavies Burn is needed. Also, to maintain the benefit of the dredging through time, a management scheme needs to consider how to deal with the further ingress of sediment. A tilting weir, or other hydraulic structure to promote flushing, is likely to be beneficial. There is minor indication of a backwater effect of opening the return gate at Milldens weir, and for this reason, it may be better to maintain both the return gate and the gate to Milldens lade in closed position during winter. To improve our modelling of the actual channels, a detailed survey of the channel cross sections for both the lade and Lunan Water is recommended, to supplement existing data. We are recommending that a separate consent application to deliver dredging of the mill lade (see Figure 7) be drawn up, while the above hydraulic modelling is completed. For more information, see ***interim report on hydraulics modelling*.**

Figure 7. (a) lateral spillway from Common Lade into Chapel Mires and Lunan Water (b) Sediment and vegetation on the Common Lade 50m downstream of (a)

4.2. Whole catchment hydrological model (Ina Pohle)

The objectives of this work are: (i) to generate an analysis of the changes to flows in the Lunan Water, and hence risk of low flow abstraction restriction and flooding, as a result of changes in water management (ii) to provide a management tool, which forecasts the changes in flows and water levels as a function of water management, on a weekly timescale. A methodology for this has now been developed, which can make use of changes in the stage-discharge relationship at the outlet to Balgavies loch predicted by the hydraulic modelling.

5. Conclusions and recommendations

The Scottish Government funded "Water for all" project on the Lunan Water has proposed a novel approach to water management and assessed likely impacts on low and high flow conditions and on selected elements of wetland ecosystems in the upper catchment. It has also assessed attitudes to governance and valuation of water resources in the catchment. Further work is now required on (a) appraising the hydraulics of existing and proposed structures using HECRAS model (b) developing a viable potential governance structure (c) tools for management based on forecasting of impact of management decisions. A consent application for the proposed system is not feasible at present, but as an interim measure, we proposed that a separate consent application to carry out dredging of the mill lade be drawn up. This will deliver short term benefit, especially for flood risk mitigation, and also for ecological conservation of Chapel Mires. However this benefit can only be maintained if upgrading of the hydraulic structures and their management takes place. Such upgrading and associated management requires further work with stakeholders and physical works are very unlikely to be feasible in the current financial year. For this reason requests for deferral of some of the allocations of budget for works need to be made to funding bodies (Scottish Government and Angus Council).

6. References

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7. Acknowledgements

We thank Mr Tom Sampson of Mains of Balgavies Farm, Mr James Osborne of Balmedies Estate and Scottish Wildlife Trust (Mr Alban Houghton) for permitting us access to Chapel Mires and Balgavies Loch to collect water samples, carry out vegetation survey, and for useful discussions about the practical and governance issues associated with the scheme.
We thank Peter McPhail of SNH for helping with identification of NVC classes on site.
We also thank Scottish Government for the funds to carry out the Payments for Ecosystem Services – Lessons research project, of which this "Water for All" project forms an important part. This project is part of Work Package 1.4.3.

AV 6.11.2017