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Hydrology and Earth System Sciences
Discussions

Interactive comment on "High frequency monitoring of water fluxes and nutrient loads to assess the effects of controlled drainage on water storage and nutrient transport" *by* J. C. Rozemeijer et al.

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We thank all the reviewers for their extensive review of our paper. This really helped to improve the manuscript! The response to the comments are given below.

Reviewer 1 General Comments This is a well-written paper addressing scientific questions within the scope of HESS. It reports a study of an experimental treatment of a field in The Netherlands in which the operation of tile drains was restricted except during manure spreading and harvest ("controlled drainage") in order to conserve water.

The authors are interested in the effect of this on field hydrology and N and P export (other elements were measured but not reported here). As such the paper addresses an interesting and practically-relevant question. There is a 2-year reference period followed by a 2-year experimental period, though inevitably the meteorology is different. This is an unreplicated experiment, so results must be generalized with caution, though low frequency measurements were made on 3 individual tile drains in the field (showing considerable variation). The paper presents some novel data and some substantial conclusions are reached. I have however some reservations about the experimental design and whether the conclusions are justified by the data. The Introduction states "This study aimed at quantifying the effects of controlled drainage on water and nutrient exports from an agricultural field to the surface water" and that they measured "all relevant parameters to assess the complete hydrological and hydrochemical response of the pilot field to the introduction of controlled drainage". They criticise previous studies for failing to quantify "the changes of nutrient export via other flow routes, such as shallow groundwater flow and overland flow". This is a valid criticism, but this study seems to do exactly the same, contrary to the statements above. The only nutrient fluxes reported are from the tile drains. The volume of water arriving in the adjacent ditch other than by the tile drains seems to have been recorded, though it is not reported in the paper. The chemical composition of this water is not reported either, though there are hints that it was measured. So the authors are not in a position to assess the "complete hydrochemical response of the pilot field to the introduction of controlled drainage", as the composition of this water is apparently unknown. Yet this was surely an obvious and interesting question from the start of the experiment. Why build the sheet pile reservoirs otherwise? So I think the authors should either supply some estimate of the composition of this water so they can address the aims of the study, or if unable to do so should modify the aims of the study because the experimental measurements as described cannot achieve those aims stated in the Introduction.

1. We agree that the introduction and statements like 'all relevant parameters' and 'complete hydrochemical response' may lead to too high expectations. Some of the

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fluxes (like groundwater discharge to surface water, overland flow, flow across the field boundaries) are notoriously hard or impossible to measure directly. Still, in the first monitoring period (2007-2008) we did manage to physically separate and measure the tile drain, groundwater and overland flow contributions (both flow and concentrations). These measurements have been reported by Van der Velde et al. (2010) and Rozemeijer et al. (2010a). Van der Velde et al. (2010) presented the field water balance based on these data. Rozemeijer et al. (2010a) reported the measured concentrations and load contributions from the different flow routes. During the second monitoring period after the introduction of controlled drainage (2009-2011), the monitoring setup was changed to focus more on the tile drain; we stopped the monitoring of the groundwater input and overland flow and introduced continuous concentration measurements for the combined tile drain effluent. However, to enable comparison between the water balances for both periods, we estimated the groundwater input and overland flow based on our continuous groundwater level data and their relation with the measured groundwater input and overland flow during the 2007-2008 period. Therefore, we do not agree that we did not consider all relevant fluxes, although we have not been able to measure them all for both periods.

To prevent too high expectations about what we were able to measure, we changed in the abstract “Our experimental setup yielded continuous time series for all relevant hydrological and chemical parameters, which enabled us to quantify changes in the field water and solute balance after introducing controlled drainage.” into “Our experimental setup enabled us to quantify changes in the field water and solute balance after introducing controlled drainage.”

Also, we changed in the introduction “This combination yielded all relevant parameters to assess the complete hydrological and hydrochemical response of the pilot field to the introduction of controlled drainage.” into ”This experimental setup enabled us to quantify the changes in the field water and solute balance after introducing controlled drainage.“ To be more clear about what was and what was not measured in the con-

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trolled drainage period, we changed in paragraph 2.3 (Experimental setup controlled drainage period) “After the reference period, the experimental setup was extended to study the effects of controlled drainage.” into “For studying the effects of controlled drainage, the monitoring setup for the second period (2009-2011) was changed to focus more on the tile drains. The monitoring of the groundwater and overland flow contributions towards the in-stream reservoirs was stopped.”

In general, the hydrological conclusions are based more soundly than the hydrochemical ones, and this is reflected in the Abstract, in which the final sentence “did not have clear positive effects” is about all that can be said about the nutrient fluxes.

2. We agree that the hydrological results are more straightforward or less complex compared to the hydrochemical ones. We do not agree that “did not have clear positive effects” is all what can be said about the nutrient fluxes from our results. A lot more is mentioned in the paper, but not all findings were in the same direction (both positive and negative effects). The sentence “did not have clear positive effects” may be a too short summary of these results in the abstract. We changed this into: “The N concentrations and loads increased after introducing controlled drainage, which was largely related to elevated concentrations in one of the three monitored tube drains. The P loads via tube drains reduced due to the reduction in discharge. However, this may be counteracted by the higher groundwater levels and the larger contribution of N and P-rich shallow groundwater and overland flow to the surface water after introducing controlled drainage.” In the conclusions we added: “The N concentrations and loads increased after introducing controlled drainage, which was largely related to elevated concentrations in one of the three monitored tube drains.”

The paper is entitled “High frequency monitoring of water fluxes and nutrient loads. . .” and does indeed report some high frequency monitoring. But surprisingly, the high frequency is not exploited to draw any conclusions. Annual means would have done just as well. Yet Fig. 6 shows some intriguing patterns – why do nitrate concentrations increase on imposition of controlled drainage, for instance, whereas P concentrations

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do not? Any interpretations based on processes must of course be speculative, but the authors could try to generate some hypotheses about what might be happening. The paper would fit much better within the Special Issue if some attempt was made to use the high frequency data, and I would recommend that the authors consider this.

3. We agree that we did not fully exploit the continuous measurements in terms of interpretation of the variations. We focused on the longer term changes in water and solute fluxes rather than on short term variability. Still, the high resolution measurements enabled us to report detailed tube drain load patterns that could not have been measured by low-frequency grab sampling (this was already mentioned in the discussion). In addition, the HR measurements enabled us to measure the direct response of discharge, groundwater levels and nutrient concentrations to the changes in overflow levels of the drains water quality.

We added to the methods section:" The high resolution measurements enabled us to measure the direct responses of groundwater levels, drain discharges, and drain effluent nutrient concentrations after changing the overflow levels of the drains. We added to the discussion on the monitoring setup:"The changes in groundwater levels, tube drain discTogether with the continuous registration of discharge, the high resolution measurements enabled us to report detailed tube drain load patterns that could not have been measured by low-frequency grab sampling (see also Rozemeijer et al., 2010d). In addition, the direct responses of discharge, groundwater levels, and nutrient concentrations to the changes in overflow levels of the drains were measured. These responses would not have been captured by conventional grab sampling."

To elaborate more on the concentration responses to changes in the overflow levels we've rewritten the section on Figure 6 in the results section into: "The NO3-N concentrations do not directly respond to changes in the overflow levels of the drains. However, the NO3-N concentrations increase upon the rewetting of the field and the increase of groundwater levels during November and December 2008. This increase in groundwater levels and NO3-N concentrations is a common seasonal pattern, although

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elevating the overflow levels of the tube drains further increases both the groundwater levels and NO3-N concentrations. The increase of NO3-N concentrations is related to the activation of near surface NO3-N rich groundwater flow routes towards the tube drains. The described autumn rewetting pattern is less clear in 2010, when a large precipitation event in August caused an immediate rewetting of the field and activation of NO3-rich tube drainage. For P, low concentrations were measured, both before and after the introduction of controlled drainage. Unlike NO3-N, the P concentrations did not increase during rewetting in autumn. The low P-tot concentrations are related to the P-immobilisation in the tube drains due to adsorption to iron-oxides (Van der Grift et al., 2014). During the 2010-2011 drainage season, the P-tot concentrations did increase after dropping the overflow levels with 50 cm and thereby increasing the drain flow velocities. This caused uptake and transport of the P-rich iron oxides and higher P concentrations in the tube drain effluent."

The paper is written in good English, is well-structured and contains few typographical errors. There a good number of appropriate references, showing that the authors know the literature well. There is no supplementary material.

Specific Comments Abstract "Controlled drainage" needs to be defined in the Abstract for those unfamiliar with the concept.

4. Agreed, we added "This is achieved by introducing control structures with adjustable overflow levels into subsurface tube drain systems."

6280 l.16 What was the criterion for ionic imbalance (not "unbalance")? e.g. greater than 10% of the total anion concentration?

5. We added "larger than 10%".

6280 l.21 "An evaluation of Sorbicells. . .was published. . .". The reader here wants to know in a single sentence what the evaluation showed. e.g. did it produce comparable results to grab sampling?

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6. We added: “The SC-samplers proved to be capable of reproducing the NO3 concentration levels and the seasonal patterns that were observed with weekly conventional grab sampling and continuous water quality measurements.”

Section 2.2 I found the description of the sampling setup rather confusing, though it becomes clearer on re-reading several times. A diagram as well as the existing photograph would help. I also wonder how the sampling tubes were attached to the ends of the tile drains and whether this significantly affected their hydraulic properties.

7. A diagram and picture were provided (figures 1 and 2). For a more precise and elaborate description of the setup we’ve referred to Van der Velde et al., 2010. The largest problem with connecting the drain outlet to the collection vessel is that the flow rates may be affected; the drain can discharge freely in the vessels, while the drain outlet was below the surface water level. This was solved my attaching floaters to the connection tubes. About the attachment of the drains we’ve added: “The effluent from the tube drains was separated from the other flow routes by connecting each drain outlet to a 500 L vessel using a flexible tube (Figure 2). When tube drain outlets are below the ditch water level, the surface water pressure affects the flow rates. To imitate this effect, floaters were attached to the flexible tubes that connected the drains to the collection vessels. Thus, water leaving the drain had to flow up to the ditch level before being discharged into the vessel (Van der Velde, 2010).”

Table 1 In Section 2.2, the Reference Period is defined as May 2007 to Dec 2008, and the Controlled Drainage Period as Nov 2009 to Sept 2011. For Table 1, however, the Reference Period suddenly changes to 2 Nov 2007 to 2 April 2008, and the Controlled Drainage period splits into two as Nov 2009 – 2 Apr 2010 and 2 Nov 2010 – 2 Apr 2011. There is no explanation given for this – these periods are certainly when most (but not all) the tile drainage takes place, but why only calculate the water balance for these periods? There may be a reason, but the authors need to justify it.

8. We added: The water balances of Table 1 focus on the winter drainage periods when

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the differences between conventional and controlled drainage are most pronounced.

Table 2 Periods 4 and 5. 944 mm precipitation in 10 weeks sounds more like the mountains of North Wales than the Netherlands! In Table 2, Period 5 (2 December 2009 to 12 Feb 2010) has more rain (944 mm) than the year that includes it (2 Nov 2009 to 2 Nov 2010; 910 mm, Period 2). Similarly Period 4 vs Period 1. The precipitation values for Periods 4 and 5 cannot possibly be correct. The authors need to review the values in this table and supply the correct values, and also review the conclusions drawn from the Table.

9. We agree. The precipitation figures in Table 2 were wrong. We've updated the table with the correct values.The conclusions in the text were checked, but they were still correct.

Fig.8 In Fig. 8, all the information is duplicated in the two graphs except the nutrient loads, which seems rather extravagant. Why not plot all the information on one graph so the nutrient loads can be more easily compared?

10. We agree that a lot of information is duplicated in both plots. However, we prefer to keep the N and P loads in separate plots. The N and P loads need to be plotted on a different y-scale, while the right side y-scale axis is already occupied for the water fluxes. The difference in scales would also make a comparison not straightforward.

Technical Corrections p. 6276 l.23 "algal" not "algae" 11. Agreed and changed accordingly

6279 l.15 "farmer's" not "farmers" 12. Agreed and changed accordingly

6279 l.17 170 kg N /ha. Is this per year? If not, what is the annual rate? 13. Yes, this is per year. We added "per year".

6279 l.20 "tile drain effluent". Are tile drains the same as tube drains at this site? There has been no mention of tile drains until this point. Best to stick to a consistent terminology throughout. 14. We've changed "tile" into "tube" throughout the paper.

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6279 l.22 What materials were the sheet piles made from? 15. Pinewood. We added this.

6280 l.15 “analyze method” should be “analytical method”. 16. Agreed and changed accordingly

6282 l.19 “increases” should be “increased” 17. Agreed and changed accordingly

6285 l.9 ratios not ratio’s. Also in legend to Table 2. 18. Agreed and changed accordingly

6286 l.14 “reduced” should be “increased” 19. Agreed and changed accordingly

6286 l.17 needs a hyphen between “oxygen” and “containing” 20. Agreed and changed accordingly

6286 l.19 “are” should be “were” 21. Agreed and changed accordingly

6288 l.13 “maybe” should be “may be”. 22. Agreed and changed accordingly

Fig. 1 legend “Locations of groundwater level recording” – it should say these are the points labelled B1-B7 and D1-D7, as this is not immediately obvious. 23. We added to the figure caption “in transects at 5 m from the ditch (B1-B7) and at 80 m from the ditch (D1-D7).” To the main text we added: “in transects at 5 m from the ditch and at 80 m from the ditch (Figure 1).”

Fig. 2 On figure label “Fexible hose” should be “Flexible hose” 24. Agreed and changed accordingly

Figs 5 and 6 No scale is given for precipitation or discharge. Fig. 7 No scale for precipitation 25. We are aware of this. The precipitation and discharge dynamics in these plots were just given for reference. The focus of figure 5 is on the groundwater levels and the focus of figure 6 and 7 on the concentrations. We prefer not to add an extra scale to these plots in order to keep them less complicated.âĂČ Reviewer 2 This manuscript describes experimental work in the Netherlands to investigate the

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usefulness of controlled drainage for water storage and nutrient transport mitigation. The manuscript is interesting, generally well written and adds to a body of work on applied water quality research. It fits, therefore, into the aims and scope of HESS. General comments While the work fits into the scope of the special issue on water quality and WFD related matters, the link to high-resolution nutrient monitoring is less clear. For example, what extra dimension does this give and could the work have proceeded without its use? This needs to be developed more in the justification for the experimental design, results (i.e. more descriptive stats on range of concs. found for example) and in the discussion

26. We agree. We refer to our response 1 to the first reviewer for the changes made.

Further to this, some quality assurance information needs to be provided (preferably) or referenced on both the P and N high-resolution data to enable readers to have confidence in the load estimates and general data. See Lloyd et al. 2015 Hydrological Processes (DOI: 10.1002/hyp.10574) for a critique of the method.

27. We agree. We've chosen to add reference with more details on the technology used in order to keep the methods section short and focused. We added: "More details on these technologies are provided by Van der Grift et al. (2015)."

The experiment is based on a reference period versus control period to assess the effect of changed conditions (controlled drainage). This is from one reference season and two controlled seasons. Clearly, the nuanced differences between annual and intra-annual rainfall patterns (magnitude, duration, wetting-drying etc.) can have significant influence on both runoff patterns and pollutant transport patterns. The authors need to justify the experimental design and how this could have been improved, for example, by a more parsimonious approach based on a synchronous control site and controlled site to eliminate the seasonal differences and influences in rainfall patterns.

28. We agree that a synchronous control site is a frequently used approach in many studies. However, the spatial variability in hydrology and water quality (drain effluent

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concentrations) is very large in this area. This prevents a proper comparison between a pilot and control site as was also experienced by Heinen et al. (2012,JEQ) in a nearby experiment studying the effects of buffer strips. We added to the methods section: “This approach enabled us to study the hydrological and chemical changes after introducing controlled drainage. We did not monitor a reference field were controlled drainage was not introduce. The large spatial variability in hydrology and nutrient concentrations (see also Rozemeijer et al., 2010a,2010c) would not allow for an appropriate comparison between the pilot field and a synchronous control site. This was also concluded by Heinen et al. (2012) who studied the field scale effects of buffer strips at a nearby experimental field. This involves that the differences in weather conditions during the reference and the controlled drainage periods have to be taken into account in the interpretation of the hydrological and hydrochemical differences.”

Specific comments Page 6276 line 16 amend to: “However, the introduction. . .” 29. This part of the abstracts was rephrased (see resonse 2)

Page 6276 line 22. These references need to be more up to date.

30. There are a lot of (recent) references that could be used here. We have chosen Foley et al., 2005 and Howarth, 2008 because they are the mostly cited review papers on this topic.

Page 6277 line 3. Needs referencing after “. . .Europe”. 31. The reference after the subsequent sentence also refers to this statement (Seitzinger et al., 2010). Page 6277 line 27 amend to: “This study aimed to quantify. . .”

32. Agreed and changed accordingly Page 6278 line 11. Check the grid reference to be more precise – doesn’t seem to locate to the site when checked in an online viewer.

33. The coordinates are correct; maybe a bit more precision helps. We’ve changed the coordinates into “(52°04’01.5" N 6°39’29.0" E)”.

Page 6280 lines 15-16. Syntax issue with this sentence.

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34. Agreed. We changed the sentence into: Samples with deviating results for ions measured by more than one analytical method as well as samples with an ionic unbalance larger than 10% were reanalyzed.

Page 6280 line 10. Should this be ". . .precipitation was higher. . ."? as compared with same info given on next page line 24. 35. Agreed and changed accordingly

Page 6282 lines 25-28. Syntax issue. Change to, for example: ". . .were lowered by (or to?) 50cm on two occasions (or instances). . ." 36. Agreed and changed as suggested

Page 6285 line 25 amend to ". . .load rates of change become steeper. . ." 37. Agreed and changed as suggested

Page 6286 lines 1-7. This is a conclusion. Delete from here. 38. Agreed and changed as suggested

Reviewer 3 General comments This manuscript addresses the effects of controlled drainage on transport of nutrients, phosphorus and water for a small agricultural field. The field was monitored by groundwater head sampling, drain flow and precipitation measurements and water samples. The field setup was constructed so that surface/subsurface flow and groundwater flow was separated from the drain water at the outflow. The study shows that no significant effect of controlled drainage occurred in terms of reduced nutrient losses. However, the drain discharge was reduced resulting in a reduction of phosphorus loads. The manuscript does address a topic relevant for the readership of HESS. However, it is not completely clear in what sense the study contributes with significant novel methods, results or conclusions. Generally the strongest part of the paper is found to be the considerations regarding how controlled drainage can be implemented and the different challenges with conducting controlled drainage in harmony with farming practice (for instance suggestions of larger manure storage capacity). Therefore, in order to strengthen the manuscript the discussion could be re-structured so that more focus is on the experiences gained from this study. For instance the discussion of the importance of also controlling drain overflow close to

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the stream/ditch as well as the timing of when to initiate and stop controlled drainage dependent on season, weather conditions and farming practice could be elaborated. Most of these issues are already mentioned, but they could be elaborated as this is the strongest part of the study. These issues could also be highlighted in the abstract. 39. We agree that these aspects of practical implementation deserve some more highlighting in the paper. We've restructured the discussion in order to directly start with these experiences and insights. The discussion section now starts with: "Our monitoring results produced valuable insights in the hydrological and hydrochemical effects of controlled drainage and in some practical issues for implementing controlled drainage and optimizing its effects in agricultural practice." The experiences and considerations are then described in subsequent paragraphs and illustrated by figures. We've also added the most important conclusion to the abstract and to the conclusions: "To achieve this, the overflow levels have to be elevated in early spring, before the drain discharge stops due to dryer conditions. The groundwater storage in the field would have been larger when the water levels in the adjacent ditch would have been controlled as well."

It seems as if the manuscript has been slightly rushed and it is strongly recommended that the entire manuscript is checked thoroughly for grammatical and general language mistakes as well as wrong sentence syntax. 40. The paper has been rechecked for language mistakes.

Specific comments Generally throughout the manuscript there is an excessive use of the rather informal "we", and it is suggested that the authors rephrase sentences containing "we" to more proper formal language. Some examples are given below. The authors should be consistent in their use of past and present tense, especially in the results section. Some examples are given below, but the entire manuscript should be adjusted.

41. We agree. We've rephrased the sentences with "we" and "our" and checked the use of past and present tense. Some parts of the results section rely on work already published (e.g. the SorbiCell results, hydraulic conductivity measurements and water

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balance issues), hence it is recommended that these parts and references are taken out of the results section, or used in a more direct way by referring specifically to results that can support this present study (examples given below).

42. See the responses below.

P 6276-line 13: In the abstract the term “all relevant hydrological and chemical parameters. . .” is somewhat confusing, since the reader will immediately ask which parameters are considered relevant? It is suggested that the authors rephrase this sentence so that it is precisely stated at least which type of hydrological and chemical parameters. 43. This was changed based on comments of reviewer 1 (See response #1)

P 6278 – line 6: The authors again use the non-specific term “all relevant parameters”. It is recommended to list the parameters instead, as it is most likely up for discussion which parameters are needed to accurately assess the complete hydrological and hydrochemical response. 44. This was changed based on comments of reviewer 1 (See response #1)

P 6278 – line 19: No need for the repeated reference to Wösten et al. (1985). 45. We agree. We’ve removed the second reference

P6279 – line 3 to 9: For some reason the text changes to past tense, please correct to present. 46. We agree. The entire paper was checked for the use of past and present tense.

P 6279 – line 21: Is the ditch 43.5 m wide or long? Please elaborate in the text. 47. We rephrased this into: “towards a 43.5 m long section of the ditch”

P 6279 – line 22: What is meant by the “eastern ditch”? From the figure is looks like there is only one ditch running more or less north – south? Do the authors mean the eastern side of the ditch? Please elaborate and change accordingly in the text. 48. We removed ‘eastern’ to prevent this confusion.

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P 6279 – line 23 and 26: What is meant by “in-stream”? The reservoirs are built in the same ditch as where drain water is discharging to, right? not in a separate stream? Please clarify in the text. 49. We rephrased this into: “To separate the fluxes toward the ditch via different routes, three adjacent sheet pile reservoirs were built (Figure 2). These in-stream reservoirs were constructed around the outlets of drains 1, 2, and 3 and captured overland flow, interflow, direct precipitation, and groundwater inflow from the thin aquifer above the Miocene clay.”

P 6280 – line 2 to 5: The authors write that the drain flow is measured via the vessel when a maximum level is reached. During the drainage period, how long time does it in general take for this maximum level to be reached? Do you have flow measurements representing water discharging on average during an hour, a day, a week, or? I find this information important as it has a significant impact on the precision of the estimated flow rates. 50. The time it takes to fill up the vessels depends heavily on the discharges. It was also quite different for each drain. These discharge results (also for the individual drains) are published in Van der Velde et al, 2010). On an average day during the drainage season, the vessels were filled and emptied after 2 hours. We’ve added: ”On an average day during the drainage season, the vessels filled and emptied every two hours.”

P 6280 – line 5: Please refer to the locations on figure 1. 51. We added: “in transects at 5 m from the ditch and at 80 m from the ditch (Figure 1).”

P 6280 – line 17- 21: With which resolution do these SorbiCell-samplers give NO3-N concentrations? Is it hourly concentrations, composite sampling or something else? Generally if the authors wish to include the SorbiCell measurements, you should describe briefly in the manuscript how they are working and why you are using them. Why are the cells useful compared to the other drain water sampling you are performing? When referring to another paper for a test or comparison, it is recommended to refer to the specific results; otherwise the reference is not of much use for the reader. What did Rozemeijer et al. (2010) find? Where the cells better than conventional sam-

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pling? And is that why you chose to use them? 52. We agree. We've added to the methods section: "In addition to the grab sampling, SorbiCell-samplers (De Jonge and Rothenberg, 2005) were used for monthly time-average NO3-N concentration measurements of tube drain effluent. The SorbiCell-samplers were applied to measure average NO3-N concentrations for individual drains. An evaluation of SorbiCells based on duplicate analyses and comparison to conventional grab sampling and continuous measurements was published by Rozemeijer et al. (2010c). The SorbiCells proved to be capable of reproducing the NO3 concentration levels and the seasonal patterns that were observed with weekly conventional grab sampling and continuous water quality measurements."

P 6281 – line 5 to 6: Why do you write roughly instead of just showing the exact periods where the overflow levels were adjusted? Why are you using different overflow levels? Are you not concerned that changing the overflow levels also changes the hydrology? Is it for instance possible, that you lose water to neighboring fields when the levels are at the highest? 53. In this section we only aim at describing the reasoning behind the timing of the changes in overflow levels. The exact periods and levels are presented in the results section. The impact on hydrology, including the loss of water to neighboring fields is accounted for in the results section and in the water balances. Here, we've deleted "roughly" and added: "The exact adjustment moments are shown in the results section."

P 6281 – line 7: The sentence starting with "However,.. " seems somewhat disconnected or not finished. It is recommended to delete or rephrase it. 54. We rephrased this into: "However, the field had to be dry enough for manure spreading after the end of the winter ban on manure spreading on February 15th.

P 6281- line 9 to 12: You mentioned the different cases where the overflow levels were lowered. However, it is not really clear from the text how much you lowered it? I suppose you lowered it down to the original drain level? Please elaborate in text. 55. We added: "to the original drain outlet levels". More details on the levels are given in

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the results section.

P 6281 – line 14 to 16: It is recommended that this section is deleted, as the headings in the subsequent sections explain what the main content is. 56. Agreed and changed accordingly

P 6281 – line 19 to 23: It is suggested that this section is either deleted or rephrased as it just repeats what can be seen in the figure. Instead it is recommended that the authors explain the most important message that the figure illustrates. 57. We agreed and deleted this section.

P 6281 to 6282 – line 24 to 4: Here you touch the subject I addressed above regarding the reasoning behind the different drainage levels. However, it is not clear in the text how you chose these specific levels, and why you for instance changed the level from 20 cm to 50 cm in December 2009? Why did you not just use the same level, except when farming practice required a lowering? 58. We've worked with overflow level changes of 50 cm in the second controlled drainage season to be able to measure more distinct effects on hydrology and water quality. We added:"During the second drainage season with controlled drainage (2010-2011) we elevated and lowered the overflow levels with 50cm on each occasion in order to bring about more distinct changes in groundwater levels, drain discharges and nutrient losses compared to the first season (2009-2010)."

P 6282 – line 10 to 12: The importance of this sentence is not clear. You state that total precipitation was lower in the reference period than in the period of controlled drainage. Hence, I do not see how this indicates that the higher gw levels in the period of controlled drainage are due to the increased overflow level? As I understand it: If more precipitation fell in the period of controlled drainage and if you also see higher gw levels in that period, then the higher gw levels can both be due to more precipitation and the increased drainage level. So, that the less precipitation fell in the control period is not indicating that the higher gw levels in the drainage period are caused by the ele-

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vated overflow levels? Or do I misunderstand something? Could you please elaborate also in the text, or delete the section. 59. There was a mistake in this sentence. The total precipitation was higher instead of lower during the reference period (see also our response #35 to reviewer 2)

P 6282 – line 13: A groundwater (gw) level cannot be long? Do you mean that the gw levels are above land surface for longer time periods? Please correct and clarify in the text. 60. We rephrased this into: “The groundwater levels are above the land surface more frequently and for longer periods,”

P 6282 – line 14: Did you actually observe an increase in ponding and overflow water? You stated earlier that you measure overland flow, so could you please discuss whether these measurements support this? 61. Yes, we observed both ponding and overland flow. For the reference period (2008-2009) the overland flow towards the ditch was measured and reported by Van der Velde et al. (2010). We added:”Ponding and overland flow, as well as its relation with the groundwater levels, have been observed and reported by Van der Velde et al. (2010).”

P 6282 – line 5 to 19: The authors shift between using past and present tense. In general the figures show something, i.e. present tense when you refer to a figure. However, for instance when you refer to the gw levels then they were above the tube drain level, i.e. past tense. Please adjust to correct use of past and present tense. 62. We agree. The entire paper was checked for the use of past and present tense.

P 6283 - line 1 to 3: It is suggested that this section is rephrased, as the information is not important, the text just repeats the table. Instead write what the main message is, and then refer to the table in brackets. There is no need to repeat what can be directly seen in figures or tables instead help the reader deduce the main message from the table or figure. 63. We agree and rephrased this section into: ”Table 1 enables the comparison of the field water balances of the drainage seasons during the reference and the controlled drainage periods.”

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P 6283 – line 17 to 19: You state that the net influx from regional gw flow is needed to close the water balance, but that it cannot be measured. So how did you solve this problem? 64. As all other input and output fluxes were measured accurately during the reference period, we assigned the water budget closure term to the groundwater flow across the field boundaries. More details on this were given in Van der Velde, 2010. We rephrased the section into: "The net influx (or outflux) from the surrounding fields via regional groundwater flow cannot be measured, but was likely to occur and was needed to close the water balance for which the other fluxes were accurately measured (Van der Velde et al., 2010). More details on the water balance for the reference period were reported in Van der Velde et al. (2010) and for the controlled drainage period in Winegram (2012) and Rozemeijer et al. (2012)."

P 6283 – line 19 to 21: Please delete this section or refer to some specific results of relevance for the present study. 65. We think these references are needed here to be able to accept the presented water balances without elaborating on their details within this paper.

P 6283 – line 25: Which "other differences" do you refer to? Please elaborate and be more precise. 66. We agree and changed this into "the differences in the discharges via groundwater, tube drains and overland flow"

P 6283 – line 26: You write that the gw levels rose during the reference period, but it is not clear how you come to this conclusion. In figure 5 it is seen that the gw levels both rise and fall in the reference period, so what do you mean by saying that the gw levels rose during the reference period? Do you mean the average gw level or? This issue also applies to the following section in the text. 67. This is the difference between the groundwater level at the start date and end date of the water balance period. This is the change of storage that has to be accounted for in the water balances.

P 6284 – line 4 to 9: Please rephrase this section. I assume you are making comparisons with the reference periods? However, when you for instance write that something

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is significantly lower, you need to write what you compare with. 68. We agree and added: “compared to the reference period”

P 6285 – line 6 to 8: Same comment as for P 6281 – line 19 to 23 (above). 69. We agree and shortened this to prevent duplication of the info in the figure caption.However, we still want to introduce the figure and table in the text before starting the interpretation.

P 6286-line 12: A reference to at least one example of “the frequently shown and modelled drainage concept” would be appropriate at this point. 70. We rephrased this into a “common “ drainage concept and added a reference to De Vos et al., 2001.

P 6286 – line 18: Do you mean that the infiltrating water contains nitrate and oxygen? As it is written now it says that the nitrate and oxygen are containing infiltrating water. Please rephrase to correct English syntax. 71. We rephrased this into “nitrate- and oxygen-containing infiltrating water”

Figure 1: I do not see any explanation to the naming B and D and the dots they are placed next to, neither in the manuscript text nor in the figure text. I assume they represent the locations of gw level recordings? Please add an explanation at least in the figure caption. 72. We added this explanation to the figure caption and the text. See also our response #23 to reviewer 1

Figure 4. I find it somewhat misleading that you write “Drains up/down” on the figure, as it is not the drains you are moving up or down, but the overflow level. This could be changed in the figure. 73. We agree and changed “Drains” into “Overflow levels”

Figure 5: Generally avoid using the term “The figure shows. . .” or “The plot gives..” in figure captions, as it is obvious that the text is linked to the figure. Be short and concise and only elaborate on issues that are not already explained on the figure. It is recommended that the symbol for precipitation and drain flux/discharge is deleted on the figure, and just explained in the text, as the symbols coincide with the symbols for

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the gw levels. Please use the correct abbreviation for meters above sea level on the y-axis (m.a.s.l.). 74. We changed the caption into: “The time series shown are”. We prefer to use m +MSL as abbreviation for meters above mean sea level.

Figure 9: This figure could be considered left out, as it is already explained in the text. It is probably not very surprising the the gw head curvature between drains can vary significantly among individual fields due to soil type, drainage system, drainage depth, precipitation, hydraulic conductivity and connectivity with underlying gw reservoirs etc. The fact that more steep curvatures are the ones most often seen in connection with modelling studies is probably due to the difficulties that arise if small curvatures should be modelled, rather than evidence for steep curvatures occurring more often than the less steep ones.

Figure 10: This figure could be left out, as it does not really contribute with significant information. The figure just depicts the commonly known schematic response in the gw hydraulic head due to a change in gw level close to a gw gaining stream, with the largest effect observed furthest away from the stream. 75. We prefer to keep both figure 9 and 10 in the paper as a visual explanation of the text. Technical corrections P 6276 – line 14: Please delete “field” just before “water”. 76. Agreed and changed accordingly

P 6276 – line 15: Please delete “We” and rephrase to more formal sentence. Please avoid use of we as much as possible

P 6277 – line 28: Please rephrase to more formal language (avoid using “we”). 77. We’ve rephrased all sentences with “we” and “our”.

P 6278 – line 2: Use singular “period”. 78. Agreed and changed accordingly

P 6278 – line 4: Please avoid using “we”. P 6278 – line 23: Please avoid using “we. 79. We’ve rephrased all sentences with “we” and “our”.

P 6278 – line 26: Please use correct abbreviation for meters above sea level (m.a.s.l.).

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80. We prefer to use m +MSL as abbreviation for meters above mean sea level.

P 6279 – line 13: Please avoid using “we. 81. We’ve rephrased all sentences with “we” and “our”.

P 6279 – line 15: Please use the genitive correct: farmers’ if more than one farmer, farmer’s if only one farmer. 82. Agreed and changed into farmer’s

P 6280 – line 15: Please delete “analyze” before “method”. 83. Changed into “analytical”

P6282 – line 9: Please delete “the” before “transect”. 84. Agreed and changed accordingly

P6282 – line 22: Replace “ephemerally” with “ephemeral” or replace with for instance “for a shorter period”. 85. Agreed and changed accordingly

P 6282 – line 27: Improper sentence syntax, replace “taken down” with “lowered” and rephrase “at two moments. . .”, e.g. “..were lowered with 50 cm at two instances. . .” 86. Agreed and changed accordingly

P 8284 – line 26: improper use of “dropping”, replace with for instance “lowering”. 87. Agreed and changed accordingly

P 6285 – line 2: Rephrase sentence starting with “This figure shows”, it is not the figure that shows something, it is data. 88. Agreed and changed into: “The data show”

P 6285 – line 9: Please replace “ratio’s” with “ratios”. P 6285 – line 22: Improper use of the word “dropping”. Replace with for instance “lowering”. (the same goes for line 25). 89. Agreed and changed accordingly

P 6286 – line 13 to 15: Please rephrase sentence or replace “by” with another word, as “by” is used three times in the same sentence. 90. Agreed and changed accordingly

P 6288 – line 24: Please delete “of” before “continuous”. 91. Agreed and changed

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accordingly

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 6275, 2015.