Final Author Comments.

The manuscript HESSD-228-2014 "Quantification of anthropogenic impact on groundwater dependent terrestrial ecosystem using geochemical and isotope tools combined with 3D flow and transport modeling" by A.J. Zurek et al.

We very much appreciate thorough review of the manuscript done by Referee #1. His insightful and comprehensive comments helped us to make numerous changes in the way how our data are interpreted, presented and discussed. The manuscript is in much better shape now. We followed large majority of the reviewer's comments and suggestions when preparing the revised version of the manuscript. In some points, however, we do maintain our views and opinions. Detailed comments addressing all questions/comments of Referee #1 are listed below.

Anonymous Referee #1

1. General comments:

1.1. 3D Flow and Transport Modelling: this is the main drawback of your paper. The use of a 3D flow model is important because the paper must provide some quantitative evaluation of the long term impact to GDE (the forest and the fen) due to pumping. The only way to provide this is by a flow and transport model but: - You must dedicate more text to describe how you have implemented and calibrated the model - You must show the results of the possible impact not only showing, in a purely qualitative way, the comparison between two contour maps but estimating the expected shortage of groundwater fluxes to the fen or the expected lowering of the water table. - Your on site investigation, through direct push drillings and sampling and by the geochemical approach, has provided you the needed data to calibrate and properly design the model but you have to use the model in a quantitative way answering the following questions: - - how much is the shortage of groundwater seepage to the fen and to the river, depending of different scenarios of expected pumping rate? - How much is the lowering of water table and the effects against the forest, depending of different scenarios of expected pumping rate? In the chapter dedicated to the model you simply talk about a generic time of piezometric delay but it is a purely qualitative chapter. But you must be quantitative in forecasting scenarios; applied hydrogeology must provide quantitative estimates. You write in the conclusions "strongly suggest that prolonged groundwater abstraction through the newly-established cluster of water-supply wells at maximum permitted capacity (ca. 10 000m^3 d^{-1}) represents significant risk to the studied GDTE. It may lead to reorganization of groundwater flow field in the study area and significant drop of water table" and in the abstract "may trigger drastic changes in the ecosystem functioning, eventually leading to its degradation" but: how much is the risk? How much is the water table drop? How intense are these changes?

We appreciate this comment . As in the meantime (July 2014) two new boreholes were drilled in the center of Wielkie Bloto fen (cf. Fig. 2 of the revised manuscript) and hydraulic heads were measured in both the shallow Quaternary aquifer and the deeper Neogene aquifer, it was possible to make additional model runs to determine the response of the system to operation of newly-established Wola Batorska wellfield, including the chosen scenario of future exploitation, and compare them with the measurements. These new model runs allowed us to be more quantitative in defining the risk to the investigated GDW associated with exploitation of Neogene aquifer (see Fig. 13 and revised text).

1.2. In the conceptual model of the site you can rely on direct drillings and geological logs or on geophysics. You begin the description of your geologic conceptual model with geophysics. It's an error: geophysics is an indirect investigation tool and can accomplish and integrate the geological direct investigations but not be the starting point. So improve the description of your conceptual model starting from geological logs and drillings. You performed direct push at shallow depth. You should have direct geological information.

We accept the criticism. Appropriate parts of the text have been thoroughly revised. New information coming from boreholes drilled in the center of Wielkie Bloto fen in July 2014 was added in the revised version.

1.3. …particularly in the introduction, the text is too much long and boring in some parts, it seems more the introduction of a master thesis. Some parts could be integrated in material and methods, some parts could be strongly reduced, some parts should be skipped (the less useful for the investigation; see the specific notes)

The Introduction has been thoroughly modified, following suggestions of the reviewer.

1.4. About vertical fluxes between the confined aquifer and the fen, have you head profile data showing how hydraulic head changes along the vertical in order to demonstrate upward seepage of groundwater from Bogucice Sands aquifer toward Wielkie Bloto?. Was you able to measure head? Comment upon that.

Availability of two new boreholes drilled in the center of Wielkie Bloto enabled measurements of hydraulic heads both in the upper Quaternary aquifer as well as in the lower Neogene aquifer. They are discussed in the revised text and shown in Fig. 13

1.5. A Piper diagram should be useful to map the hydrochemical facies in a more quantitative way.

The Piper diagram was added as a separate, new figure. It confirms the hydrochemical evolution of the analysed waters already apparent from Fig. 6 of the old version of the manuscript.

2. Specific comments:

THE STUDY AREA.

2.1. Comment upon the fact that the runoff value is higher than the difference between total precipitation and actual evapotranspiration. Express the data in a more precise way. Is evapotranspiration actual, I presume?

It should read "725 mm" instead of "...around 700 mm". The text has been modified accordingly.

2.2. The range 8-28% of coefficient of infiltration is related to outcropping lithology? Comment upon it.

Yes. Additional explanation was added in the revised version.

2.3. Comment and describe the degree of consolidation or looseness of sands (any cementation? Grain-size?), parameters important from hydrogeologic standpoint. You talk of sands but also of sandstones. Clarify better. They are sands or sandstones?

The aquifer matrix consists mainly of unconsolidated sands, locally sandstones with carbonate cement. The text has been modified accordingly.

2.4. What do you mean as "disposable resources" in hydrogeological terms? A safe yield? A maximum sustainable pumping rate? A recharge rate? Explain better and also make reference to the references and the evaluation method.

The proper expression should be "safe yield". The text has been modified accordingly
The safe yield value, originated from Kleczkowski et al. (1990), was evaluated according to Polish low taking into account recharge rate, sustainable pumping rate and environmental water requirements. That value was confirmed by Górka et al. (2010).

2.5. Is there a relationship between the vegetative assemblage and the depth to water table? Where depth to water table is higher than 2 m the typology of the forest is different from areas with shallower water table? If yes describe shortly in which sense.

Although detailed discussion of the relationship between plant assemblages and the depth of water table in the study area is beyond the scope of this work, we provided in the revised text some additional information about the typology of the forest and the water table position, following appropriate Manual worked out for forest managers

MATERIAL AND METHODS.
2.6. Change the order of description, starting with the field tools, the sampling tools and finally the analytical methods, in a logical order.

Agreed. The section "Materials and methods" has been extended and modified according to the suggestions of both reviewers.

2.7. The description of the modelling is too much detailed for a chapter dedicated to material and methods and too much simplicistic and low understandable for a chapter dedicated to the model description. If the modelling is important for your research dedicate a chapter to it, otherwise skip it. In the material and method it is enough to describe the code. Moreover the description is confusing, mixing together flow, transport, calibration, in a messy way

We maintain our opinion that the description of modelling in "Material and methods" is of adequate extent. Modeling is one of several tools used to assess the extent of groundwater dependence of terrestrial ecosystem studied. Nevertheless, we modified the text following the suggestions of the reviewer. Also, section 4.5 has been largely extended and Figure 12 was replaced by new figure summarizing the results of additional model runs (Fig. 13).

RESULTS AND DISCUSSION.

2.8. Skip completely the paragraph of introduction. It's redundant. You can integrate the informations about the goal of the various investigations in the material and method section.

Done.

2.9. Delineation of Quaternary cover It's strange to begin with indirect surveys (geophysics) that can accomplish and integrated direct data but cannot be the foundation of the conceptual model. Shallow geoelectrics has a high degree of inaccuracy in represent the structure and stratigraphy of subsoil and this is more true in your case for the very low expected thickness of clay layer and the noise that different sources (water content, grain size, organic content, air content) can provide to determination of resistivity. It's very strange to begin the conceptual model with geophysics and not with direct data.

The situation has changed because direct information about lithology and stratigraphy of the Quaternary cover, as well as underlying Neogene aquifer, became available thanks to new boreholes drilled in the center of Wielkie Bloto in July 2014. The chapter was revised accordingly, by putting in front geological information.

2.10. What about the importance of GPR? Simply to define the position of the bottom of moorsh? How this is important for your study?

The GPR surveys were carried out basically to define the position of degraded peat layers. Mineralization of peat is one of the processes which can be triggered by water table lowering.

2.11. The delineation of Quaternary cover should be completely rewritten,. Begin it starting from direct data (boreholes) and then, eventually, integrate it with geophysics. You cannot base your conceptual model simply upon geophysics

See comment to point No. 9.

2.12. Geochemical evolution A Piper diagram should be useful to map the hydrochemical facies in a more quantitative way.

Agreed. The Piper diagram was added in the revised version.

2.13. Water balance of the Dluga Woda catchment Explain why the MTT of 3.2 months is not affected by the contribution of 30% of slow recharge water (presumably with a different input signal of delta ^{18}O; see sentence at the end of 9688), whereas you see this contribution in the tritium Clarify how the flow rate measurement were taken in relationship to rainfall. Independently or not during rainfall event?

Good point. Note that tritium is in this case a far more sensitive indicator of the presence of additional component than the heavy stable isotopes are. We mix one component which has ca. 10 TU with other component which has zero tritium. This is why, with 30 % contribution of the tritium free component, the two horizontal lines in Fig. 9b are so far away. In case of stable isotopes, the difference is not that big. The expected ^{18}O isotope composition of tritium-free component is in the order of -9.8‰ (average of groundwater in the study area which is of Holocene age), to be compared with -8.61‰ of the 'recent' component (weighted mean $\delta^{18}O$ of local precipitation). The apparent difference between weighted mean $\delta^{18}O$ in precipitation for the period January 2011 - December 2013 (-8.61‰) and the mean ^{18}O content of the Dluga Woda stream (-8.84‰) seen in Fig. 9a, corresponds to ca. 20% contribution of the 'old' component. The text has been modified accordingly.

2.14. Explain better, in a short statement, how Wundt (a very old method!) determines the base flow. The term "low flow" sounds not good, also because in some months it is not so low. If the "low flow" is, as I presume, the base flow component of total runoff (coming from the discharge of the aquifer), I think, independently of Wundt, that base flow is a better term. MMBF, at the end, will be the mean monthly base flow. It's more correct from a hydrogeologic standpoint.

The fact the Wundt method is an old one, does not compromise its value. The method is based on measurements of the daily flow rates. To obtain more precise assessment of the Dluga Woda baseflow, a 2-year (instead of 1-year) hydrograph was analyzed in the revised version of manuscript. Additional explanation of Wundt method was included in the revised text. The term "low flow" is used by hydrologists to define lowest flow during the given month or year. The monthly mean annual low flow (MMALF) reflects the discharge of the aquifer and may represent the annual baseflow in the river catchment.

TABLES AND FIGURES

Table 1: badly sealed well (not “liquidated”)

Done.

Table 4: put the meaning of n.m. in the legend

Done. "n.m." signifies "not measured".

Fig.1: indicate the time of reference or date for the head measures

Done.

Fig.2: some of the terms in the legend are poorly understandable for not very specialistic experts (gyttia, moorsh) define it in more hydrogeologically meaningful terms and more widely known for wetland experts: poorly decayed peat, acrotelm, catotelm, for example, or other terms

The term 'moorsh' is used in German and Polish peat soil classification. As too specialized, the term has been changed to ‘mineralized peat soil’. Gyttja has no appropriate synonim but is a widely used term by paleoclimatologists and paleohydrologists.

The position of 11 VES soundings should be better rendered in the legend; if one dot is a VES, in the legend you have to maintain only one dot.

Done.

Fig.4: the resistivity numbers in the upper panel are too much little. In the legend the second point is b and not c.

Figure 4 has been corrected.

Fig.8: on the x axis (time) put in evidence the months of the year to better appreciate the seasonality. Explain in the legend the meaning of the small graph inside the lower diagram, there is non explanation of that (characters perhaps are too much little).

Done

Fig.11: I guess that the symbol to the right top is ground surface. Put in evidence this attribution

Done

TECHNICAL CORRECTIONS
r.8: 9674 provided better than supplemented r.11: 9674 to be assessed better than quantified

Done

r.14: 9674 Bogucice sand aquifer should be introduced before at r.28 of page 9673

Done

r.4: 9675 Badenian: which period? Miocene? specify

Done

r.17-19: 9675 I suggest to skip these unuseful oxides and traces elements if they do not affect meaningfully the discussion and conclusion of the paper

Done

r.25: 9675 aquitard is better than semi-permeable

Done

r.27: 9675 hydraulic head or piezometric surface (not water table).

Done

r.27: 9675 go to a new row after seepage.

Done

r.11: 9676 do not use the term "diffuse", related to agricultural and not industrial sources.

Related paragraph was omitted in the revised section

r.11: 9677 which kind of land improvement?.

Done. This expression was replaced by "drainage works" .

r.21: 9677 not water table, the wells pump put groundwater from deep aquifer

Done. Water head has been used.

r.1: 9678 upward leakage (or flow) is a better term (respect to diffusion)

Done. We use 'upward seepage' throughout the text

r.3: 9678 integrated better than supplemented

Done

r.6: 9678 which code was used?

The type of code and all relevant details are described in Materials and Methods section (r.13 9680).

MATERIALS AND METHODS
r.7: 9679 PVC. Describe the depth and filter position and also diameter of the tubes; open stand-pipes is a better term than tubes

Done

r.22: 9679
badly liquidated? What does it mean? Use a better term, more clear. It's not clear if the spring is natural or not. Perhaps it's not a spring but it is a flowing not properly sealed artesian well.

The notation ‘Anna Spring’ (in quotes) was used in the revised text to indicate that this is not natural spring. Information about geophysical prospecting conducted in the area in 1970s as well as chemistry and isotopic composition of water from this 'spring' strongly suggest that this is fact not properly sealed artesian well tapping the Neogene aquifer. Additional explanation has been added in the revised manuscript.

r.9: 9680 Phreatimeter

The term "water level meter" was used in the revised version.

r.18: 9680 You talk about rectangular cell but they are square in plain section

"Rectangular cell" is one of options of the grid selection in the Visual MODFLOW. Note that squares are a sub-set of rectangle family of figures.

r.20: 9681 Any measuring unit?

This is a relative quantity. Appropriate explanation was added in the revised text

r.1-5: 9683 skip these unuseful information

Done

r.20: 9683 in the study area

Done

r.26: 9683 “and shows values around 64 pMC” (comment upon this value, what does it imply?)

Additional explanation was included in the revised text.

r.22: 9684 comment upon the value and the significance of these value of partial pressures of carbon dioxide

Included in the revised text.

r.6: 9687 which kind of difficulties? Describe better and in which sense they could bias the results

The phrase was deleted. Inspection of the results of chemical analyses revealed that there was a typing mistake in Table 2 .

r.26: 9687 Maloszewski et al. is missing in the references

This reference was added to the list of references

r.9: 9688 specify “relatively to the river section used for sampling water”

Done.

r.23: 9688 explain a bit the insert graph in fig.8b and the meaning of parameters

Done.

r.7: 9691 a K of 1E-5 m/s seems to me very low for an important sandy aquifer like yours. Are you sure about this value? Comment upon it

K value of 1E-5 m/s is correct. It was estimated on the basis of the pumping tests.