Project: Sustainable Hydro Assessments and Groundwater Recharge Projects
Project acronym: SHARP

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APPENDIX: Long version of good practices

GP 9	Quantifying groundwater/surface water interaction

Project Partner:
Institute of Meteorology and Water Management (IMGW)

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1. Description

Following the recommendations of the Water Framework Directive, water management is currently conducted within closed system, including limitations resulting from natural and ecological conditions requirements for the supply of water and also protection against drought and flood. Efforts to achieve a good ecological state of water in catchment areas have to be undertaken both for surface water and groundwater. Conducting various analyzes of dates (inter alia groundwater and surface water interaction) obtained from systematic monitoring, especially in areas of high anthropopression is essential in order to undertake appropriate action.

Analysis of the relationship of ground water and surface water in Poland has been carried out for many years. The analysis is done taking into account various aspects namely

- a cognitive determination of factors developing the dynamics of the dependence of river waters and ground waters,
- regional analysis of the participation of ground water in the process of forming the regime of river runoff in natural conditions of circulation as well as in conditions subject to anthropogenic transformations as a result of intensive water intake (among others: Kowalski 2007; Paczyński, Sadurski (ed.) 2007),
- the assessment of the underground runoff into rivers was the basis for determining the groundwater resources which can be managed (Michalak, Nowicki (ed.) 2009).

Mutual dependence of groundwater and surface water is a complicated phenomenon depending on the location of the mirror of surface water in reservoirs, which is a variable phenomenon. Additionally, the contact is influenced by different natural processes which are under the influence of many factors interacting with one another.

In Poland, the relationship of surface and groundwater under natural conditions in the active zone of exchange has a drainage nature (groundwater is drained by rivers, lakes and swamps). Infiltration of surface water to groundwater in natural conditions can be encountered locally and it is treated as an anomaly (Paczynski, Sadurski (ed.) 2007).

2. Methodology for determining the dependence of surface water and groundwater

Literature refers to several methods for determining the interdependence of surface water and groundwater, they include among others:

- Method of further application of water-table contours (Siemichatow 1960);
- Method based on observation of temperature (Siemichatow 1960);
- Method based on analysis of river flow (Pazdro, Kozerski 1990); Isotopic methods (Lewicka-Szczebak 2010);
- Numerical Methods (Kryza 2010).

The methodology which is used by IMGW PIB for evaluation of the relationship between surface and groundwater may be determined on the basis of regular observation sequences. On the basis of an observation network of ground water, surface water and precipitation, IMGW PIB assesses the correlation of surface and groundwater taking into account many observations of the variability in their levels.

Both in case of surface water and groundwater, fluctuations in water occur continuously. Furthermore, they can be caused by several factors. Observations and comparative analysis of these factors done by mapping charts of the course of their variability enable to establish a causal link between the observed phenomena. The assessment of the relationship between groundwater and surface water is carried out by an analysis of observational sequences of levels of surface water, groundwater and the amount of precipitation in a given area (Fig. 1).

In order to investigate the occurrence and strength of the relationships between variables, namely surface water level and groundwater level, a correlation coefficient was calculated for each pair of variables which gives information on the strength of the relation. The first step was to establish normal distribution so the Kolmogorov-Smirnov test was used with Lillefors's adaptation for which a null hypothesis was assumed as: H0. As a result of the analysis, this hypothesis was rejected, which means that the variables do not have a normal distribution. In this case, nonparametric Spearman's rank correlation was used, resulting in calculated Spearman's rank correlation coefficient (r_s). The interdependence of the phenomena is expressed as a linear relationship (Fig. 2).

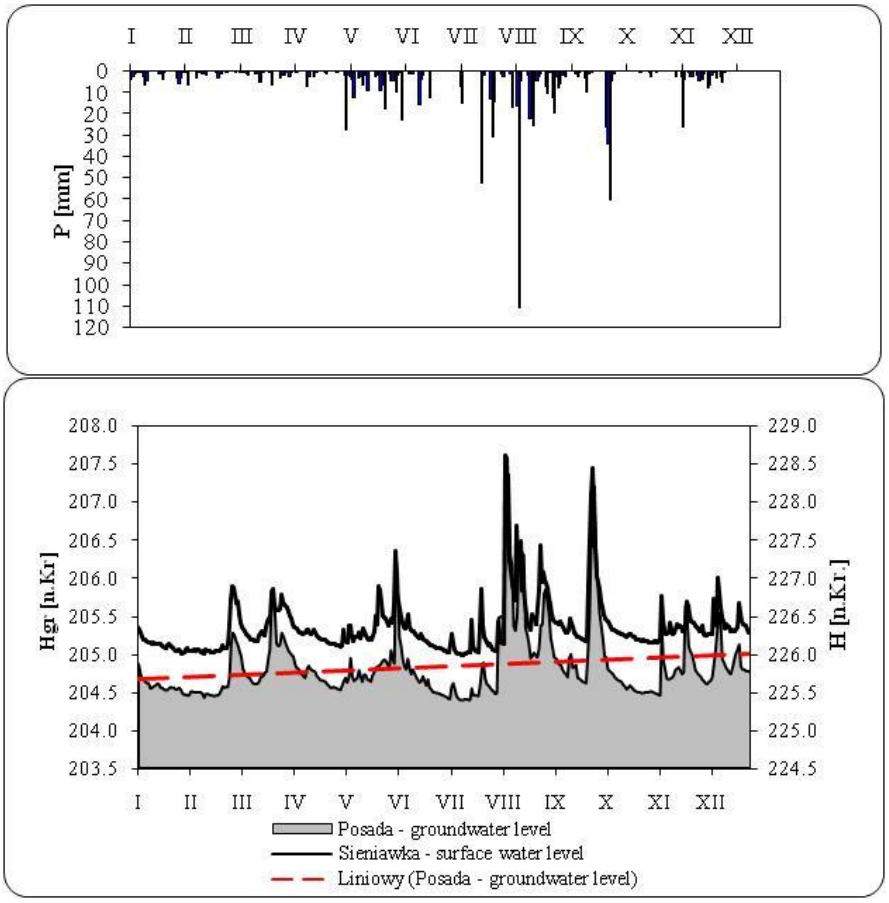

Fig. 1: Sample sequences of observational data: precipitation (top), surface water and groundwater level (bottom).

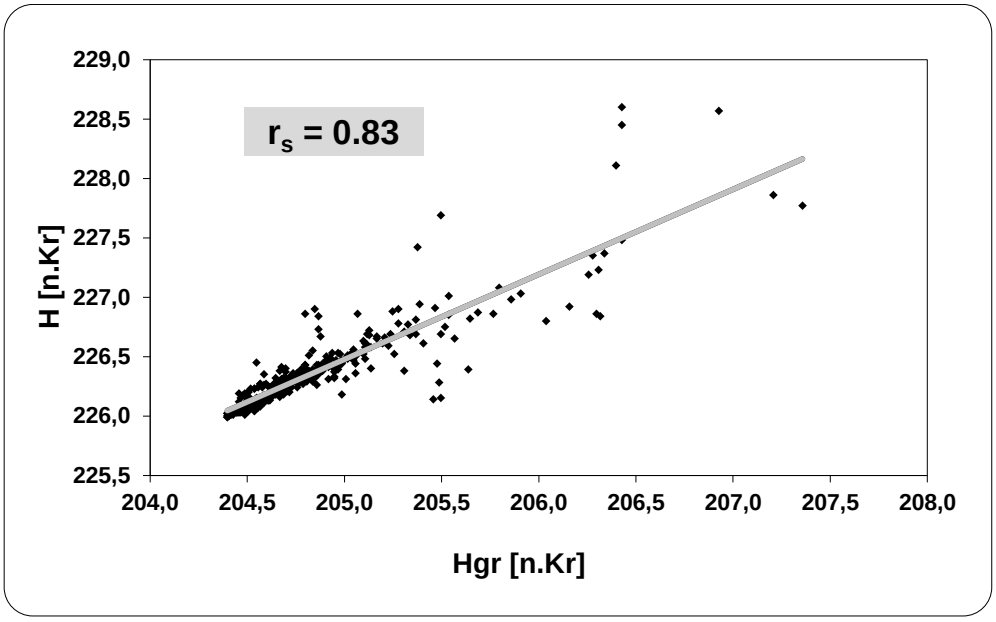

Fig. 2: An example of the relationship of groundwater and surface water from selected observation stations in the catchment of the Neisse river.

Example of an application of the methodology:

The agreed methodology for determining the interdependence of surface water and groundwater has been used in the region of an inactive, German brown coal mine Berzdorf (the Lusatian Neisse basin). After finishing the coal extraction, the German party started water reclamation of the post-mining pit. Flooding the pit with boundary water of the Neisse river has been planned. Analyses of the impact of the assumed by the German party volumes of water intakes on the scope of their influence on groundwater were carried out. The analyses were done in order to determine the volumes of water intakes. Taking into account not only the thickness of the aquifer but the characteristic coefficients of filtration as well, the extent of depression of groundwater for three variants of volume of water abstraction from the Neisse river were calculated. The studies have shown that the planned water intakes from the river may affect the location of groundwater's tables up to nearly 1000 m from the river.

3. Benefits of the agreed assessment of the interaction of surface and groundwater

The methodology of examining the relationship between surface water and groundwater based on regular comparative analysis of observational sequences of the studied phenomena (levels of surface and groundwater) is relatively simple to be applied. However, the evaluation of a statistical relationship using Spearman's rank correlation coefficient requires a continuous observation of the amplitude of variation in the studied characteristics. A continuous control of fluctuations and the mutual influence of the level of groundwater and surface water is particularly important in areas where water management is subject to strong pressures (the case of rehabilitation of the pit Berzdorf with surface water of the Neisse river). The use of systematic correlations of observational sequences necessary to analyze the impact of abstraction of surface water on groundwater allows to react quickly enough to protect nearby farms in which groundwater coming from the household wells is intended for everyday use. Permanent analyses of fluctuations in mutual interdependence of surface water and groundwater levels based on the existing observational networks are relatively inexpensive and fast tools which helps to get an overall view about the phenomena examined in the study area. The general view allows to predict the occurrence of smaller zones adversely affected by spatiotemporal variability in the studied characteristics in which additional, often more expensive tools for quantitative evaluation of the studied phenomenon can be applied. Such an approach, from general to specific, allows one to reduce the expenses.

Additionally, many-year observations are an alternative in case of a temporary cessation of observation of one of the phenomena (e.g. in case of a failure of the measuring device or closing down the observation point). On the basis of a long sequence of measurement of a given phenomenon and interdependence which had been acknowledged before, it is possible to reconstruct the course of the phenomenon in which the measuring sequence was lost or the monitoring was finished.

The results of the analysis of surface water and groundwater interaction can be used:

- To fulfill the recommendations of the WFD, due to the fact that one of the required guideline is an assessment of connections between surface water and groundwater. This parameter is an element of hydromorphological assessment which has influence on the results of the surface water evaluation of the

ecological state. Lack of interaction can imply that there is no connection between surface water and groundwater which results in an incorrect assessment of the hydromorphological condition Meanwhile in the area of fluvial valley with undisturbed conditions groundwater and surface water contact could be observed. The contacts results in the existence of typical ecosystems in a natural river valley - riverside forests considered to be priority habitats, endangered not only in Poland but also in other European Union countries.

- To determine the type and intensity of the assessment of anthropogenic impact on aquatic and water dependent ecosystems. Such an analysis of groundwater and surface water interaction, performed for example for environmental assessment, allows to estimate the impact of human activities, as specific undertakings (e.g. startup of coal mine drainage system, construction of water power station etc.), on the potential aquatic and state of water dependent ecosystem particularly concerning the already-mentioned impact area of the undertakings.
- To elaborate the comprehensive water balances for efficient water management. An analysis of surface water and groundwater interaction allows for clarification of certain elements of water balances (e.g. on a specific river mileage), which can contribute to the issue of water-legal permits fall within the size of disposable resources, without their exceeding.
- For elaboration of the water management plans for national and regional water management boards as well as for crisis management. Conducting regular analysis of groundwater and surface water interaction can help to support the control and decision role of above-mentioned state authorities responsible for fulfilling integrated water economy in Poland. Elaborations which concern conducting integrated and sustainable water management for specific river basins included in “Plans of water management’’ are of special interest for some authorities. The ones which include guidelines for proper functioning of aquatic and water dependent ecosystems, which are strictly dependent on the surface water and groundwater are especially appreciated by the following authorities namely: state authorities like the National Water Management Authority, the Regional Water managements Boards, the General Directorate for Environmental Protection or local government units: district and municipal facilities authorities for environmental protection).
- For proper action planning within the maintenance management framework plans for the rivers (basins). Foregoing documents prepared for various sections of a river are intended to determine the specific maintenance actions possible to be taken on the relevant watercourse. They aim to maintain “functionality of flowing water”, taking into consideration realization of legal, national and EU legal status including the Water Framework Directive or Flood Directive. Because of the fact that actions included in the Framework maintenance plans of the river concern a channel and a valley, the results of the analysis of the groundwater and surface water interaction can significantly contribute to the proper assessment of the behavior of groundwater in the stream valley, in which there are valuable habitats of riparian forests or which can potentially be brought by proper actions to the restoration of aquatic and water dependent ecosystems (e.g. riverside forests). What is more?, the assessment of the interaction between surface water and groundwater shall help to identify the most beneficial areas which are worth protection and enable to develop recommendations and actions which are bound to improve the water conditions in a river valley.
- For the assessment of the localization of underground water intake used to supply people in drinking water and protection zone for those water intakes. Proper analysis of the interaction between groundwater and surface water, the above-mentioned facilities for public use so as to simplify the process

of taking appropriate actions aimed at the protection against pollution from surface water, for example during the flood.

- For the assessment of the localization and functioning of agricultural areas located in river valleys. In many valleys in Poland, riverside forests have been cleared and agricultural areas arose in their place. Because of significant fertility and efficiency, the areas are often intensively exploited. Results of the analysis of the interaction between groundwater and surface water can be useful for economic subjects involved in agriculture due to the fact that they will allow to evaluate changes in groundwater table fluctuations - exclude undesirable species in areas rich in water.
- Preparing guidelines for building works in progress in a river valley, carrying out assessment of the conditions for protecting the investemnt against capillary rise. During underground workings, capillary rise of groundwater in excavation is a common problem. Prior recognition of the reaction of groundwater to changes in surface water level shall allow for appropriate plan for building works or undertaking projects which prevent the influence of capillary rise. The information can be useful for economic subjects entering an investment.

4. Opportunities of improvement and action towards the development of the agreed methodology

The development of the methodology is possible both in terms of creating new observation points and the use of statistical methods which are to analyze the correlation between the phenomena. Networks aimed to monitor the change of the location of groundwater can be both extended by new points to monitor a given aquifer horizon. Furthermore, the deeper aquifers can be observed in order to determine the rate of water percolation. Assessment of the existence of interaction between surface water and groundwater and the nature of this relationship, based on an analysis of sequences of observational data is an important element of control and an introduction of the issue of water management in a given area. Sequences of observational data and the correlation with their variability can be used in further studies concerning problematic areas. For instance, the already quantitative relationship between the phenomena can be described or a quantitative evaluation can be performed by numerical modeling.