Problems of mineral deposit protection in spatial development in Poland

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Abstract

This paper presents problems of restrained possibility to exploit economic resources of mineral deposits due to inappropriate spatial management. Minerals as non-renewable natural resources are under protection involving rational management of resources and their comprehensive exploitation. Occurrence of a deposit, depending on the type of the mineral, gives the opportunity of sustainable development based on its use at a local or even regional scale. However, instead of rational management of the deposit, spatial development is quite frequently commenced over the deposit which hinders further exploitation. Basing on the examples of selected mineral deposits from Małopolska Voivodeship, the cases of irrational, in terms of sustainable development, obstruction of the access to mineral deposits caused by spatial development have been presented.

Keywords: mineral deposit, spatial development, accessibility, planning documents

Introduction

Nowadays, spatial development is understood as a process of deliberate, conscious and rational managing of space in a comprehensive approach. The purpose of the process is to obtain spatial order - the state allowing the society and the economy to function optimally, with the least possible number of environmental conflicts, which does not lead to degradation of the natural environment.

Mineral deposits are defined by the Act of Geological and Mining Law (Ustawa, 2011) as a natural accumulation of minerals and rocks or other substances, which exploitation can bring economic profits. The amount, size and nature of the deposits depend on the type, dynamics and duration of the geological processes that occurred in the given area. Available mineral resources have been significantly reduced for the last decades. Such state is caused by several reasons (Koncepcja, 2011):

- depletion of the best accessible stocks of mineral deposits,
- rising costs of their exploitation,
- collision of mineral deposits with other elements of the environment and spatial development,
- or the lack of public acceptance of mining activity.

The problem concerns many European countries and therefore it was included in “The European Parliament Resolution of 13th September 2011 on successful European natural resources strategy”. One of the elements of the strategy was supporting preparation of strategic plans of land use in all Member States in order to balance exploitation of mineral resources and other types of needs related to land use as well as protection of the environment and biodiversity. It is worth noting that unlike other industrial branches, mining is strictly connected with the place of exploitation, hence, the location of documented mineral deposits. The need to build new mines to replace mines whose resources have been depleted leads - especially in Europe – to many conflicts with other land users (www.europarl.europa.eu).

Articles 71.1 and 72.1 of the Environmental Protection Law (Ustawa, 2001) states that the principles of sustainable development and environmental protection are the basis for preparation and updating of planning documents. The study of conditions and directions of the spatial management (SUiKZP) and the local spatial management plans (MPZP) should include conditions necessary to maintain balance in nature and rational management of environmental resources, among others by means of:

- establishing programs of rational land use (including the areas where mineral deposits are exploited) and rational land management,
- taking into account the areas where mineral deposits occur and also the current and potential future needs of exploitation of the deposits.

However in practice, protection of mineral resources in the aforementioned planning documents is not sufficiently implemented, and not at the same level as other elements of the space: water resources, soils, forests, living nature and landscape. Mineral deposits are often disregarded or they are considered erroneously (either in improper boundaries or location).

The article presents preliminary results of investigations carried out within the statutory research scheme at the Department of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology in Krakow. Their goal is to estimate availability of documented deposits in Małopolska Voivodeship pointed out as the ones to be protected in the valid Plan of Spatial Management of Małopolska Voivodeship of the year 2003 (Plan, 2003).

Area of the research

The Małopolska Voivodeship is one of 16 Polish provinces. As far as the area is concerned it is on of the smaller provinces, but with the highest population density in the country (217 people per km^2). It is located in the south of Poland and includes a part of Polish-Slovakian border. Considering the economy, it is one of the most varied regions in Poland. Its strong position in the country economy results from its large share in the total value of sold production of industry and building industry.

The Małopolska Voivodeship region comprises 22 counties, which are divided into 182 communes. Regional spatial planning is regulated by the Plan of Spatial Management of Małopolska Voivodeship of the year 2003. Currently about 63% of the voivodeship area is covered by the local spatial management plans. However, there are still some communes with no local plans or plans covering only a small area. It mostly applies to the areas located in the north-east part of the voivodeship, in mountain areas and a few communes in the west part of Małopolska (Raport, 2010).

There are four major geological units: the Carpathians, Carpathian Foredeep Basin, Upper Silesian Coal Basin and the Silesia-Cracow Monocline within Małopolska Voivodeship. Rich and varied mineral deposits result from such a varied geological structure. However, their economic use often remains in conflict with other natural resources, as well as generates conflicting interests with existing and/or planned land management and land use in the areas where the deposits are located.

The majority of the deposits located in Małopolska Voivodeship, included in the national balance of resources are currently exploited and it is assessed that common mineral resources are sufficient to meet the current and nearest future needs of the voivodeship. According to the state of 2009, the total number of documented mineral deposits is 571, including 209 currently exploited ones. Considering the quantity, the highest number of documented deposits appears in the group of natural aggregates (274) and clay materials for construction ceramics (74). The largest number of resources have been identified with hard coal, backfilling sands, natural aggregates, sandstones and limestones. The highest number of documented resources occur in the following counties (poviats): Brzesko, Wieliczka, Bochnia, Oświęcim (Auschwitz) and Chrzanów, and the lowest number in Miechów county. According to the Report on the state of spatial development in Małopolska Voivodeship 2010 (Raport, 2010) in the period of 2005-2008, despite the increase of the number of documented and exploited mineral deposits, there was a decline in the size of resources in most of the types of minerals.

Research methodology

The intended investigations on the availability of documented resources will include:

- verifying the approach to protection of the areas with prospective and economically undeveloped deposits presented in the planning documents of communes (SUiKZP and MPZP).
- estimation of the methods applied to include such spatial management of the areas in the local spatial management plan which will not collide with future exploitation of the deposits, for example farming or temporary use (e.g. tourism and recreation).

The conducted verifications and estimations will be based on the systems of spatial information and data bases of mineral resources provided by Polish Geological Institute – National Research Institute (Infogeoskarb, Midas) and the planning documents from particular communes as well as information layers will be provided by geoportal.gov.pl. The desk research will be supported by field investigations.

Discussion of results

The results of preliminary studies conducted in Stary Sącz and Niepołomice communes prove real and urgent need to solve the discussed issue.

The first example concerns the problem of protection of documented resources of high quality natural aggregate deposits - "Podmajerz" located within the town limits of Stary Sącz after changes of records in the planning documents. The study of conditions and directions of the spatial management of 2000 and the local spatial management plan of the town of Stary Sącz, plan No. 2 of 2004 have been changed in recent years due to planned and ongoing investments (SUiKZP, 2000, MPZP, 2004).

The deposit "Podmajerz" was documented in 1967 with the resources of 6.455 thousand tons (Turza, 1961) and it was properly recorded in the spatial management planning documents (SUiKZP, 2000 and in the local spatial management plan Stary Sącz - Plan No. 2, 2004). The area above the deposit, covering the area of 61.10 ha, was intended for agricultural use with building prohibition, which enabled its protection for prospective exploitation. Two years later, in Appendix no. 1 (Filo, 2006), the resources of the geological deposits were verified and decreased to 4.786 thousand tons due to the changes of the surface development over the deposit (including road construction). It resulted in reduction of the deposit area by 10.75 ha (Fig. 1) in the changed MPZP Stary Sącz - Plan No. 2 (Zmiana MPZP, 2009).

Fig. 1. The borders of the documented deposit "Podmajerz," the state of:
a) LOCAL SPATIAL MANAGEMENT PLAN STARY SĄCZ - PLAN NO. 2, 2004 (MPZP, 2004),
b) CHANGE OF LOCAL SPATIAL MANAGEMENT PLAN STARY SĄCZ - PLAN NO. 2, 2009 (MPZP, 2009).

The second example shows the state of a documented but unexploited deposit of sands and gravels "Węgrzce Wielkie" - field B, which is located in north-east part of Niepołomice commune. It was recorded in the Resolution No. LXIII/629/10 of Niepołomice City Council (SUiKZP, 2010) that the deposit, together with other deposits documented within the area of the community, were under protection. However, despite the fact that the boundaries of the deposit covering the area of 161.3 ha (Midas, 2011) remained the same, they were incorrectly marked in the graphic annex to SUiKZP of the town and community of Niepołomice (SUiKZP, 2010) concerning natural conditions. Location of the deposit is incompatible with the contour lines of the deposit provided by the system Infogeoskarb (Infogeoskarb, 2011). Moreover, in some of the documents determining directions of development of the community, the area over the deposit was included into Niepołomice Industrial Zone and it was planned for service-production development (MPZP, 2007). Future exploitation of the deposit is difficult due to environmental reasons and according to the sozological classification the deposit belongs to conflict ones, because the area is permanently built-up (factories, roads, municipal and residential areas) (Fig. 2). In accordance with the directions of the commune development (SUiKZP, 2010) further building development in the area will be possible only after deleting the deposit from the balance of natural resources.

Fig. 2. The existing land use of the documented deposit of sands and gravels "Węgrzce Wielkie" - field B in Niepołomice commune based on an orthophoto map from www.geoportal.gov.pl.

Due to a planned change of the spatial development plan (the first example) and the existence of buildings over the mineral resources deposit (the second example) there is partial or even complete loss of the non-renewable resources of natural aggregates. This fact is inconsistent with the record of the Act on spatial planning and development of 2003 (Ustawa, 2003) concerning inclusion of occurrence of documented mineral deposits into SUiKZP and obligatory determination of their limits and ways of land use and premises to be protected in MPZP, as determined on the basis of separate provisions (articles 10, 15). This obligation results from Article 95 Geological and Mining Law (Ustawa, 2011) which purpose is to protect mineral resources and to protect the possibility of comprehensive use of the natural wealth of the country, which is also stated in the article 125 of the Act of 27 April 2001 Environmental Protection Law (Ustawa, 2001).

Summary

Mineral resources occurring within the area of a commune form its functional and spatial structure and determine the local economic development. Access to mineral resources determines the correct development of key sectors of the economy, including construction, chemical and automotive industries.

Exploitation of the mineral resources base mostly depends on spatial management in the commune and obeying constraints of the spatial management related to protection of the mineral deposits. The mineral resources are non-renewable ones, except the groundwater resources, including thermal ones, therefore, their potential loss by restraining access to them is an irreparable loss, which may cause or increase the risk of danger connected with energy and raw materials policy in future. Hence, protection of mineral resources deposits is especially important. Irrationally conducted spatial policy at the commune level may restrain exploitation of mineral deposits occurring there for many years.

The article has been prepared within the statutory research scheme AGH 11.11.140.560.

Bibliography

Filo A. (2006). *Dodatek nr 1 do dokumentacji geologicznej złoża kruszywa naturalnego "Podmajerz" w kat. C1 w miejsc. Stary Sącz*, Zakład Geologiczno-Górniczy.
Infogeoskarb (2011) - baza.pgi.gov.pl/igs
Koncepcja (2011). *Koncepcja Przestrzennego Zagospodarowania Kraju 2030* - www.mrr.gov.pl
MPZP (2004). *Miejscowy plan zagospodarowania przestrzennego MIASTO STARY SĄCZ - PLAN NR 2*. Uchwała Nr XXX/324/04 Rady Miejskiej w Starym Sączu z dnia 30 grudnia 2004 r.
SUiKZP (2000). *Studium Uwarunkowań i Kierunków Zagospodarowania Przestrzennego Miasta i Gminy Stary Sącz*. Uchwała Nr XXVIII/73/2000 Rady Miejskiej w Starym Sączu z dnia 11 września 2000 r.
MPZP (2007). *Miejscowy plan zagospodarowania przestrzennego Gminy Niepołomice na terenie Niepołomickiej Strefy Przemysłowej*. Uchwała nr V/37/07 z dnia 16.01.2007.
Plan (2003): *Plan zagospodarowania przestrzennego województwa małopolskiego*. Kraków, 2003.
Raport (2010). *Raport o stanie zagospodarowania przestrzennego województwa małopolskiego 2010.* Urząd Marszałkowski Województwa Małopolskiego Departament Polityki Regionalnej, Kraków, 2010.
SUiKZP (2010). *Studium uwarunkowań i kierunków zagospodarowania przestrzennego miasta i Gminy Niepołomice*. Uchwałą nr LXIII/629/10 Rady Miejskiej w Niepołomicach z dnia 27 kwietnia 2010 roku.
Zmiana MPZP (2009). *Zmiana Miejscowego planu zagospodarowania przestrzennego MIASTO STARY SĄCZ – PLAN NR 2.* Uchwała Nr XXXVII / 490 / 09 Rady Miejskiej w Starym Sączu z dnia 30 marca 2009 r.
Midas (2011) - http://geoportal.pgi.gov.pl
Turza M. (1961). *Dokumentacja geologiczna złoża kruszywa naturalnego „Podmajerz”,* Przeds. Geol. S.A., Kraków.
Ustawa (2011). *z dnia 9 czerwca 2011 r. Prawo geologiczne i górnicze*, Dz.U. 2011 nr 163 poz. 981
Ustawa (2001). *Ustawa z dnia 27 kwietnia 2001 roku Prawo ochrony środowiska*, Dz.U. 2006. 129. 902 z późn. zm.
Ustawa (2003). *Ustawa z dnia 27 marca 2003 r. o planowaniu i zagospodarowaniu przestrzennym*, Dz.U.2003.80.717 z późn. zm.
www.europarl.europa.eu
www.geoportal.gov.pl

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Models and software for environmental impact assessment

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Abstract
Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. Modeling attempts to replicate a real-world situation, so as to allow experimentation with the replica in order to gain insight into the expected behaviour of the real system. Models, implemented on computers, are extremely powerful tools of analysis, though they are often demanding and complex. There are many environmental softwares for modeling and analysis which are used in environmental impact assessment. The paper presents some of these – software for noise pollution modelling, for electromagnetic pollution, software for air pollution and for water pollution modelling.
Keywords: models, software, pollution, environment.

Introduction
Environmental Impact Assessment (EIA) is a systematic process to identify, predict and evaluate the environmental effects of proposed actions in order to aid decision making regarding the significant environmental consequences of projects, developments and programmes. Modeling systems analysis and modeling are among the few techniques that allow consideration of multi-dimensional problems that involve multiple (and usually conflicting) objectives, multiple criteria, multiple purposes and users, as well as interest groups. Modeling has been used extensively in developed countries, but its use for impact assessment in developing countries has been rather limited because of constraints on resources, especially in expertise and data (Fedra, 1991). Modeling is a step by step process by which models are developed and/or applied.

Material and Methods
This paper was conducted using an inductive research approach, which aimed to establish knowledge by objective, theory-free observations. To achieve the aims there have been applied review of environmental softwares for modeling and analysis which are used in environmental impact assessment.
The three most common types of models used in EIA are physical models, experimental models, and mathematical models.

- Physical Models: Physical models are small-scale models of the environmental system under investigation on which experiments can be carried out to predict future changes. Illustrative or visual models depict changes to an environmental system caused by a proposed development activity using pictorial images developed from photographs, three-dimensional scale models, and by digital terrain models or digital image processing systems. Working physical models, on the other hand, simulate the processes occurring in the environment using reduced scale models so that resulting changes can be observed and measured in the model. Such models, however, cannot satisfactorily model all real-life situations; faults may occasionally arise as a result of the scaling process.
- Experimental Models: Scientific data from laboratory or field experiments provide basic information on the relationships between environmental components and human activities. Research results are used to construct empirical models that can infer the likely effects of an activity on an environmental component. Examples of experiments in which the environmental system is modeled and tested in the laboratory include toxicological tests on living organisms using polluted air, water, food, etc.. Examples of experiments in which tests are carried out in the actual environment include in situ tracer experiments to monitor the movement of releases into the environment.
- Mathematical Models: Mathematical models use mathematical equations to represent the functional relationships between variables. In general, sets of equations are combined to simulate the behaviour of environmental systems. The number of variables in a model and the nature of the relationships between them are determined by the complexity of the environmental system being modeled. Mathematical modeling aims to limit, as much as possible, the number of variables and thus keep the relationships between variables as simple as possible without compromising the accuracy of representation of the environmental system (Lohani, 1997).

Software applications in general imply tools of collecting data from sensors and analyzers through their processing into the desired shape and size and archiving and mediation for the user and the general public.
Basic characteristics of the software:

- processing the input data of the measurement points or stations,

- communication with the measuring nodes automatically or manually through the universal communication software,
- detecting immediate values and conditions of measurement locations,
- graphic display of concentration in different types of averages,
- comparison of data from several measurement points,
- ability to communicate with other external devices.

The article will then report on the specific softwares.

Results and Discussion

Canarina CUSTIC software - noise pollution modelling

CUSTIC is software for noise pollution modelling. The program calculates the noise level in each point of the space considering each one of the sources and the conditions of the atmosphere. The system of simulation of processes of dispersion that CUSTIC has, offers to the beginner and the expert programmer, a quick and practical system to evaluate noise pollution. The program is based on the operating system Microsoft WINDOWS where one works intensively with the mouse and the graphic windows (Canarina environmental software, 2012).

Canarina DISPER software - air pollution modeling

DISPER is software for air pollution dispersion analysis. The program calculates the pollutant concentration in each point of the air considering each one of the pollutant sources and the conditions of the atmosphere. The system of simulation of processes of dispersion that DISPER has, offers to the beginner and the expert programmer, a quick and practical system to evaluate the dispersion of pollutants in the air. We can say, with a certain security that the software DISPER is one of the best tools, to carry out numeric simulations of air pollution processes (Canarina environmental software, 2012).

Canarina DESCAR software - water pollution modeling

DESCAR is a software for wastewater dispersion analysis. The program calculates the pollutant concentration in each point of the water considering each one of the pollutant sources and the conditions of the water. The system of simulation of processes of dispersion that DESCAR has, offers to the beginner and the expert programmer, a quick and practical system to evaluate the dispersion of pollutants in the water (Canarina environmental software, 2012).

Canarina RADIA software - electromagnetic pollution

It is software for analysis of electromagnetic pollution in environment: for the purposes of environmental modeling, environmental impact assessment, environmental engineering, and environmental consultancy service and environment simulation. The program calculates the electromagnetic pollution in each point of the air considering each one of the antennas in mobile phone towers. The system of simulation of processes of pollution that RADIA has, offers to the beginner and the expert programmer, a quick and practical system to evaluate the pollution in the air (Canarina environmental software, 2012).

Conclusion

This paper has given an overview of trends of environmental software's for modeling and analysis. In this paper we have tried to present the basic knowledge about modelling and models which are used in environmental impact assessment. The importance of environmental softwares will continue because EIA has become of ever increasing importance as a tool for development decision-making.

Acknowledgements

The Centre was supported by the Slovak Research and Development Agency under the contract No. SUSPP-0007-09.

References

Fedra, K. (1991). *Environmental Impact Assessment Methods* [online]. [cit. 2012-01-10]. Retrieved from http://www.ess.co.at/EIA/

Lohani, B. (1997). *Environmental Impact Assessment for Develoing Countries in Asia* [online]. [cit. 2012-01-11]. Retrieved from http://www.adb.org/documents/books/environment_impact/env_impact.pdf

Envitech [online]. [cit. 2012-01-10]. Retrieved from http://mail.envitech.sk/software.html

Canarina Environmental Software [online]. [cit. 2012-01-10]. Retrieved from http://www.environmental-expert.com/companies/canarina-environmental-software-28409

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Using analytic hierarchy process in flood risk assessment

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Abstract
The Analytic hierarchy process (AHP) has been developed by T. Saaty and is one of the best known and most widely used multicriteria analysis (MCA) approaches. The analytic hierarchy process is a mathematical method for analysing complex decision problems under multiple criteria. It aims at quantifying relative priorites for given set of alternatives on a ratio scale, based on the judgement of the decision-marker as well as the consistency of the comparison of alternatives in the decision-making process.
The aims of this papier is to present analytic hierarchy process and its application in the flood risk assessment.
Keywords: flood risk, analytic hierarchy process, causative factor, geographical information system

Introduction
In the late 1960's, Thomas Saaty, one of the pioneers of Operations Research, and author of the first Mathematical Methods of Operations Research textbook and the first queueing textbook, was directing research projects for the Arms Control and Disarmament Agency at the U.S. Department of State.
AHP was developed by Dr. Thomas Saaty in 1980 as a tool to help with solving technical and managerial problems (Palcic et al., 2009). AHP has been very successful in gaining the acceptance of practitioners, possibly owing to the helpfulness of the hierarchical problem presentation and the appeal of pairwise comparisons in preference elicitation. The range of reported practical applications is extensive and includes Resource Allocation, Strategic Planning and Project/Risk Management (Kasperczyk et al., 2005; Saaty, 1990).

Material and methods
The hierarchy of AHP can have as many levels as needed to fully characterize a particular decision situation. AHP methodology has the ability to handle decision making situations involving subjective judgments among multiple decision possibilities and the ability to provide measures of consistency in preference (Mangalathu et al., 2011). The management options for a particular decision problem are characterised by their attributes with respect to a set of detailed criteria. Criteria or objectives can be divided into sub- or sub-sub-criteria (objectives) for additional information and for clarification and refinement. Criteria can be subjective (such as impact of trees on recreational values) or objective (such as tree planting cost), depending on the means used in evaluating the contribution of those criteria below them in the hierarchy. Criteria are regarded as mutually exclusive and do not depend on the elements below them in the hierarchy (Quershi et al., 2003).
The AHP consists of three main operations, including hierarchy construction, priority analysis, and consistency verification. First of all, the decision makers need to break down complex multiple criteria decision problems into its component parts of which every possible attributes are arranged into multiple hierarchical levels. After that, the decision makers have to compare each cluster in the same level in a pairwise fashion based on their own experience and knowledge. For instance, every two criteria in the second level are compared at each time with respect to the goal, whereas every two attributes if the same criteria in the third level are compared at a time with respect to the corresponding criterion. Since the comparisons are carried out through personal or subjective judgments, some degree of inconsistency may be occurred. To guarantee the judgments are consistent, the final operation called consistency verification, which is regarded as one of the most advantages of the AHP, is incorporated in order to measure the degree of consistency among the pairwise comparisons by computing the consistency ratio. If it is found that the consistency ratio exceeds the limit, the decision makers should review and revise the pairwise comparisons. Once all pairwise comparisons are carried out at every level, and are proved to be consistent, the judgments can then be synthesized to find out the priority ranking of each criterion and its attributes. The overall procedure of the AHP is shown in figure 1 (Ho, 2008).
Any complex situation that requires structuring, measurement, and and/or synthesis is a good candidate for AHP. However, AHP is rarely used in isolation. Rather, it is used along with, or in support of other methodologies. For example to synthesize the results of other methodologies such as in deciding how many servers to employ in a queueing situation taking into account waiting times, costs, and human frustrations, or to derive probabilities for a decision tree. Broad areas where AHP has been successfully employed include: selection of one alternative from many; resource allocation; forecasting; total quality management; business process re-

engineering; quality function deployment, and the balanced scorecard (Froman et al., 2001).

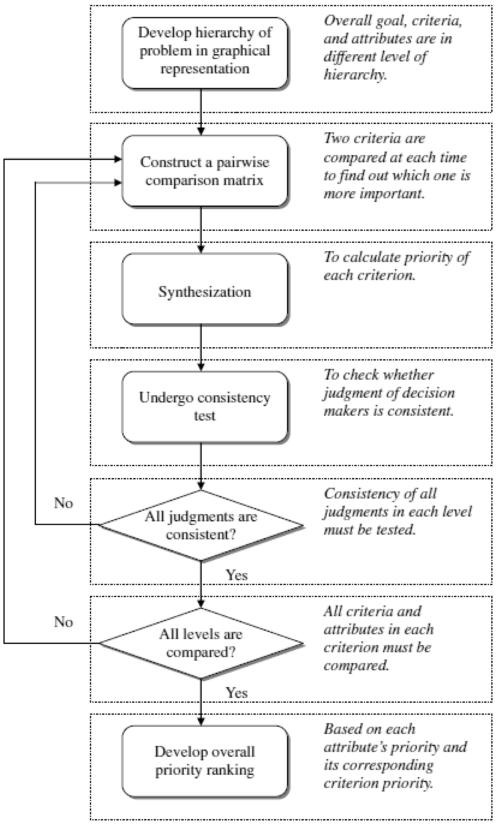

Fig. 1 The flowchart of the analytic hierarchy process (Ho, 2008)

The areas in which AHP is applied are diverse and numerous. Examples applications of AHP are listed below:

- Evaluation of product features,
- Cost-Benefit Analysis,
- Strategy development,
- Selection of Key Performance Indicators,
- Deriving weights for a combined performance index,
- Deriving a consolidated scale of importance from different inputs,
- etc.

The next chapter describes the use of AHP for flood risk assessment in the selected river basins.

Case study

Flood risk assessment is an essential part of flood risk management, a concept that is becoming more and more popular in European flood policy and is part of the new European Union Flood directive. In contrast, flood risk management does not only consider the hazard but also the possible consequences. Therefore, flood risk management measures not only aim to control flood waters but also consider possibilities to reduce the vulnerability for flooding; for example, by reducing the number of elements at risk and/or their susceptibility (Meyer et al., 2009).

The paper presents the evaluation of flood vulnerable areas in eastern Slovakia, particularly in Bodrog and Hornád river basins (fig. 2).

Fig. 2 River stations in Bodrog and Hornad river basins

The first step in assessing the flood vulnerability is to determine the factors affecting floods on the basis of an analysis of existing studies and knowledge. We have considered the following factors:

- Soil type
- Rainfall
- Land use
- Size of watershed
- Slope

The inverse ranking was applied to dividing these factors into classes (the least important = 1, the next least important = 2, etc. (table 1)).

There are many different types of software that help with the use of AHP process, but they are mostly commercial and quite expensive. Therefore, we have developed a simple computer application in widely popular Microsoft Excel 2007. This application enables help with simple AHP procedures. AHP was programmed in Microsoft Excel by RNDr. Pavol Purcz, PhD..

The nineteen river stations in the Latorica, Laborec, Cirocha, Topľa, Ondava, Bodrog, Hornád and Torysa streams were assessed. For each river station was established matrix 5 x 5 – factors x class (1 - 5).

This matrix was completed with values from 1 to 5, depending to what class the factor in river station is located in the following way: e.g. when river station is located in the area where rainfall belong to class one, so to the line "rainfall" and column "1" was written number 1, other values in this line are zero. In this way the whole matrix was completed for all factors (figure 3).

Tab. 1 The significance of the impact of flooding causative factors

Classes	Causative factors				
	Rainfall [mm]	**Slope [%]**	**Content of clay particles [%] (Soil type)**	**Land use**	**Size of watershed [km^2]**
1	0 - 1.8	0 - 15	0 - 10	forest	0 -100
2	1.8 - 2.0	15 - 30	10 - 30	-	100 - 500
3	2.0 - 2.2	30 - 45	30 - 45	agricultural	500 - 1000
4	2.2 - more	45 - 80	45 - 60	-	1000 - more
5	-	80 - more	60 - more	urbanized	-

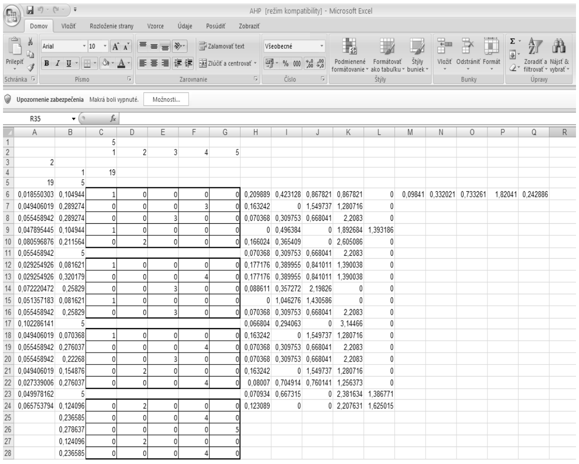

Fig. 3 The calculation of weight for each river station

Tab. 2 Risk acceptability

Risk acceptability	Scale of risk
acceptable	0 – 0,025
moderate	0,026 – 0,050
undesirable	0,051 - 0,075
unacceptable	0,076 and more

The flood risk in the study area has been divided in to four classes (acceptable, moderate, undesirable, unacceptable). The resulting scale (table 2) according the computed weight was established on the basis of professional judgment.

Results

The obtained results of flood risk assessment are shown in table 3.

The flood risk assessment results with the use of AHP process showed, that Bodrog and Hornád watershed is mainly in moderate and undesirable flood risk.

Tab. 3 Resultant weights for river stations

River station	Weight	Acceptability
Krásny Brod	0,102286	unacceptable
Stropkov	0,080597	unacceptable
Michalovce	0,07222	undesirable
Spišská Nová Ves	0,065754	undesirable
Snina	0,055459	undesirable
Hanušovce	0,055459	undesirable
Prešov	0,055459	undesirable
Sabinov	0,055459	undesirable
Svidník	0,055459	undesirable
Humenné	0,051357	undesirable
Spišské Vlachy	0,049978	moderate
Horovce	0,049406	moderate
Košické Olšany	0,049406	moderate
Ždaňa	0,049406	moderate
Bardejov	0,047895	moderate
Ižkovce	0,029255	moderate
Veľké Kapušany	0,029255	moderate
Kysak	0,027339	moderate
Streda nad Bodrogom	0,01855	acceptable

Areas with unacceptable risk have been identified, only in two river stations – Krásny Brod and Stropkov. Undesirable risk have been indentified in eight river stations – Michalovce, Spišská Nová Ves, Snina, Hanušovce, Prešov, Sabinov, Svidník and Humenné. Moderate risk was found in of the surroundings of Spišské Vlachy, Horovce, Košické Olšany, Ždaňa, Bardejov, Ižkovce, Veľké Kapušany and Kysak. The area of acceptable risk has been detected around Streda nad Bodrogom.

Conclusion

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools. Many outstanding works have been published based on AHP: they include applications of AHP in different fields such as planning, selecting a best alternative, resource allocations, resolving conflict, optimization, etc., and numerical extensions of AHP (Vaidya, 2006).

Decisions that need support methods are difficult by definition and therefore complex to model. A trade-off between prefect modelling and usability of the model should be achieved.

It is our belief that AHP has reached this compromise and will be useful for many other cases as it has been in the past. In particular, AHP has broken through the academic community to be widely used by practitioners. This widespread use is certainly due to its ease of applicability and the structure of AHP which follows the intuitive way in which managers solve problems. The hierarchical modelling of the problem, the possibility to adopt verbal judgements and the verification of the consistency are its major assets (Ishizaka at al., 2009; Saaty, 2008).

The AHP process is nowaday used in various decision-making situations. We have decided to present its use for evaluating flood risk in river stations. The flood risk in the study area were evaluated in four classes: acceptable, moderate, undesirable and unacceptable. A table 2 showing resultant weights depicting the level of flood vulnerability of the study area for nineteen river stations in Bodrog and Hornad river basins in the eastern Slovakia. Resultant weights can be used as valuable tool for assessing flood risk.

Acknowledgement

Authors are grateful for financial support of project HUSK/1001/2.1.2/0058.

References

Quershi, M. E., Harrison, S. R. (2003). Application of the Analytic Hierarchy Process to Riparioan Revegatation Policy Options. Small-scale Forest Economics, Management and Policy, 441- 458.

Palcic, I., Lalic, B. (2009). Analytic hierarchy process as a tool for selecting and evaluating projects. Int j simul model 8, 16-26.

Ho, W. (2008). Integrated analytic hierarchy process and its applications – A literature review. In: *European journal of operational research*. Volume 186, Issue 1, 211-228.

Froman, E. H., Gass, S. I. (2001). The Analytic Hierarchy Process: An Exposition. In: *Operations Research*. Volume 49, No. 4, 469-489.

Kasperczyk, N., Knickel, K. (2005). The Analytic Hierarchy Process. [online]. Retrieved from http://www.johnsaunders.com/papers/ahpexpo.pdf

Saaty, T. L. (1990) How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research 48*. Pp. 9-26

Mangalathu, S. G., at al.: Decision Making in Risk Assessment of Producer Gas Furnaces: An Integrated Approach with AHP & Promethee Techniques. *Journal Manufacturing Engineering*, Volume 10, Number 1, 49-54.

Meyer, V. et al. (2009). Flood risk assessment in European river basins - concept, methods, and challenges exemplified at the Mulde River. Integrated Environmental Assessment and Management. Volume 5, Issue 1, p. 17-26.

Vaidya, O. S., Kumar, S. (2006). Analytic hierarchy process: An overview of applications. In: *European Journal of Operational Research*. Volume 169, Issue 1, 1-29.

Ishizaka, A., Labib, A. (2009). Analytic hierarchy process and expert choice: benefits and limitations. OR Insight 22, 201-220.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. In: *International Journal of Services Sciences*. Volume 1, Number 1, 83-98.

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Remoulding of Water Reservoir Banks Caused by Abrasion Process

Petr Pelikán, Miloslav Šlezingr

Abstract
The phenomenon of bank deformations appears as the problem of the most of water reservoirs in both the Czech Republic and the world. The banks are transformed by the effect of wind water waves whereas this process consists in scouring, bank destruction and forming of accumulations on foreshores. Many scientists have been interested in the problems of bank transformations on water reservoirs since the beginning of their building-up. The paper is focused on the shore abrasion and prognostic methods for determination of shoreline retreat on water reservoirs.

Keywords:
Abrasion terminal point, geodynamic processes, shore abrasion, water wave

Introduction

The building-up of water dam reservoirs have been known since antiquity, although the rapid development was registered in the 20th century when the water management systems were built-up for water supply. The attention has been paid to the effect of water structure on its closest vicinity, respectively wave regime. A lot of hydrological changes tending to bank transformations could happen after fulfilling the reservoir. The phenomenon of bank deformations appears as the problem of the most of water reservoirs in both the Czech Republic and the world. The origin and abrasion progress is caused by many factors, however the results are the same – serious reservoir bank failures, origin of abrasion caves and the washing out of tens or hundreds cubic meters of soil. Consequential landslides are not uncommon and adjacent structures and communications could fall to danger. The bank abrasion represents the surface grinding of bottom and banks caused by water movement (wave motion) involving the transport and sedimentation of loose material.

Materials and methods

Prognosis of bank transformation can be worked out on the basis of analysis of factors undermining and implicating the abrasion origin. The methods could be divided into three groups:

1. Analytic methods (derived from the observations of bank deformations on existing reservoirs)
2. Computational methods
3. Laboratory simulation

The research results of American and Russian engineers belong to the oldest publications attended to the impact of waving on new water reservoir banks. They persuaded the principle of bank transformations lies in reciprocal activity between banks and water. The banks are transformed by influence of water regime modification and waves originated by mechanical force of wind on the water level. The process can approve oneself by both bank scouring and destruction and formation of accumulations below the water level or at foreshore.

Method by E. G. Kačugin

Kačugin´s original prognostic computational method of shoreline transformations (1949) was derived from calculation of the finite width of bank alternation zone. In 1953 author worked out new prognostic method involving the effect of wave energy. He introduced the term of efficient (operational) wave, i.e. wave with height of the highest occurrence probability, which scours the bank. There is paid attention to the height and grade of bank in this method.

Kačugin illustrated on his results that we can suppose small bank transformations on gentle slopes (3 – 4°) as well as on the banks consisting of minerals seemed to be resistant to water scouring.

Kačugin drew up graphically his observations and he established three characteristic water levels in the water reservoir for the computation of bank transformation prognosis. These are the operational water level (water level of steady storage), maximum water level (probability of occurrence n = 2 – 4%) and minimal water level (n = 96 – 98%). The upper limit of transformation caused by waves was given by adding 1/3 of operational wave height to the maximum water level. The lower limit was given by subtraction of wave height from the minimum water level. The future abrasion platform angle was derived from the diagram of relation among abrasion platform grade, wave height and kind of rock. The upper limit was linked with the lower limit by line drawn under the found angle. Consequently the line was elongated to the surface under the angle corresponding with maximum grade for minerals forming the bank (angle of repose).

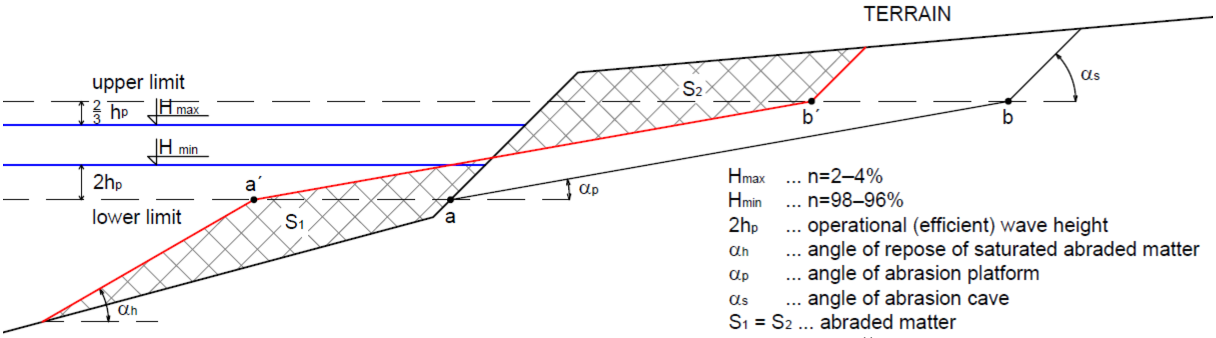

Fig. 1 Scheme for the shoreline retreat determination by Kačugin

Method by G. S. Zolotarev

The method worked up on the basis of observations on the Rybinsk reservoir and others (G. S. Zolotarev, 1953) involves the geological and hydrological factors, rock character, stability and generic types of banks where the transformation is in progress. The author tabulated data about various rock resistance to water scouring in antequarternary and recent alluvial, deluvial and sliding soil inside the water reservoirs in Volga basin. Consequently he emphasizes the importance of abrasion platform angle computation for the depiction of cross sections and bank transformation prognosis.

The Zolotarev´s method was applied in bank transformation computations for Kujbysev, Ceboksary and Stalingrad water reservoirs. Bank transformation fastness was assessed in accordance to transformation zones for two stages – the first decade of dam operation and final stadium of transformation. The first one was usually worked out graphically. The presented method insists on geological conditions during the genesis of new bank shapes.

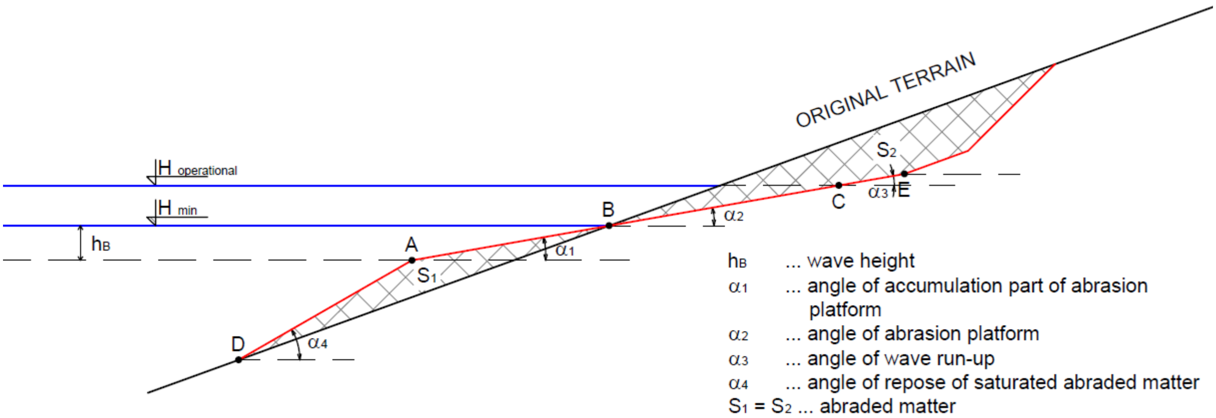

Fig. 2 Scheme for the shoreline retreat determination by Zolotarev

Method by M. Šlezingr (modified Linhart´s method)

The procedure called the method of abrasion terminal point determination appears applicable very well when dealing with questions of shoreline retreat prognosis. The original method was proposed and worked out in the 50´s of 20th century by Dr. J. Linhart. That one is semi-graphical method used for determination of abrasion terminal point as extreme limit where the progress of abrasion will stop spontaneously. The method was designed and partially verified on Brno dam reservoir (Linhart 1954, 1958). Only a few bank cross sections were geodetic surveyed (Sokolské koupaliště area) in the framework of finding out amount of abraded material during 16 years of the dam operation (Linhart, 1958). Unfortunately the observations had not been held on and the method had not been applied up to the 80´s. At that time the original method was reworked because of computation specification.

The modified method of shoreline retreat prognosis is based on the abrasion terminal point determination A_T (Fig. 3). This one is uniquely determined by intersection of elongated line representing the abrasion platform with angle α´ and horizontal line representing the maximum water level with the highest occurrence probability (Mn_{max}) leveled up by the drift of water level by wind (ΔH), wave midline elevation above the calm water level Mn_{max} (h_0) and one-half of the significant wave height ($h_n/2$). The potential altitude of abrasion cave toe (V_a) is determined by instituting numerical values into the computation. The obtained value is important for bank stability providing because determines the zone where the antiabrasion measures should be made. The point of extreme shoreline retreat (B_T) is given by intersection of the terrain and the line depicted from A_T under the angle of repose φ related to the bank material. The point B_T represents the potential bank edge caused by cooperation of abrasion and erosion process.

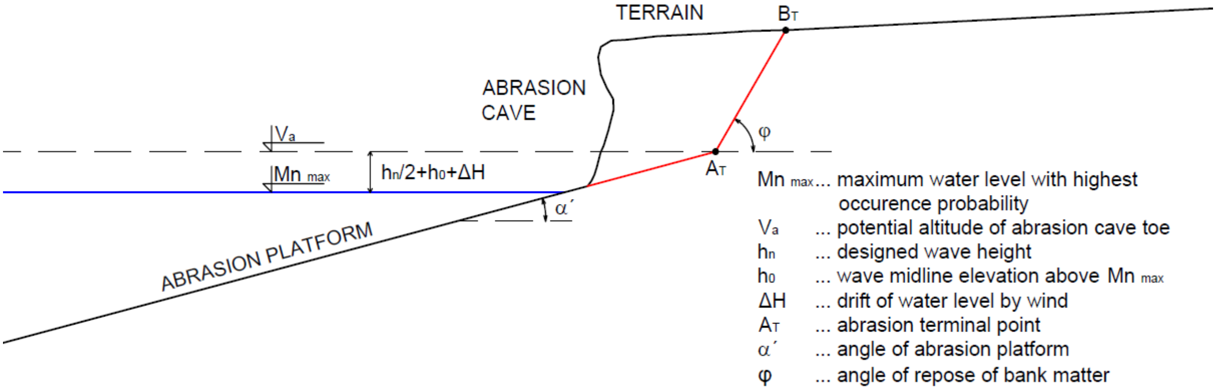

Fig. 3 Scheme for the shoreline retreat determination by Šlezingr

Results and discussion

Today the findings about application of modified method of shoreline retreat prognosis are available for selected localities along the Brno dam reservoir. The problem treatment is focused on sanitation of deformed banks inside localities with the developed abrasion features. However the method is applicable well for the prognosis for banks where abrasion distortion have not already appeared.

Figure 4 shows the volume of abraded bank matter derived from the relation between the significant wave height (h_n) and the angle of undisturbed bank (α). The drift of water level by wind (ΔH) is neglected in the presented example for simplification because its value ranges in millimeters. When dealing with the simple linear wave theory wave midline elevation over the calm water level $h_0 = 0$. The angle of abrasion platform equals 5° and the angle of repose for bank matter is $\varphi = 30°$. We can see certain relation between the bank matter angle of repose and the abrasion platform angle because we consider the same material. The matter is initially set inside bank but consequently scoured and settled in the conditions of full saturation below the water level. The prognosis of shoreline retreat and estimation of abraded material volume for specified soils, bank slopes and various wave heights is available on the basis of geological survey and soil determination.

It can be deduced from the results comparison that the differences are minimal between short term and long term prognosis. The larger dissimilarities are known alongside transformation zones, e.g. overall transformation zone is always higher by Zolotarev. The difference is explained as the method is based on analysis of geological conditions, saturated rocks and recent and probable landslides. These premises are valid mainly for clay soil.

Quantitative result variation between mentioned methods can be confirmed through detailed problems insight. All methods are not fully suitable for all various situations hence considering the geological conditions of locality and the other factors affecting bank transformation is critical to choose the best one.

Today the universal computation method for the bank transformations on water reservoirs does not exist. In our conditions approved the methods presented above.

The best form of prognosis demonstration is the map of water reservoir banks in which the potential transformations and the finite shoreline retreat are projected.

The prognosis of bank transformation caused by landslides has to contain recognition whether the reservoir is not threatened with catastrophic reduction of accumulation capacity.

Conclusion

The shore abrasion is the result of the activity of many factors and natural conditions from whom only few of them is possible to determine exactly. Application of exact method for the determination of abrasion progress celerity (shoreline retreat) is very problematic. Simplification of input conditions and neglecting of hardly definable factors leads to the distortion of final results.

Many scientists have been interested in problems of banks transformation on water reservoirs since the beginning of their building-up. Several bank transformation prognostic methods were selected for the detailed insight.

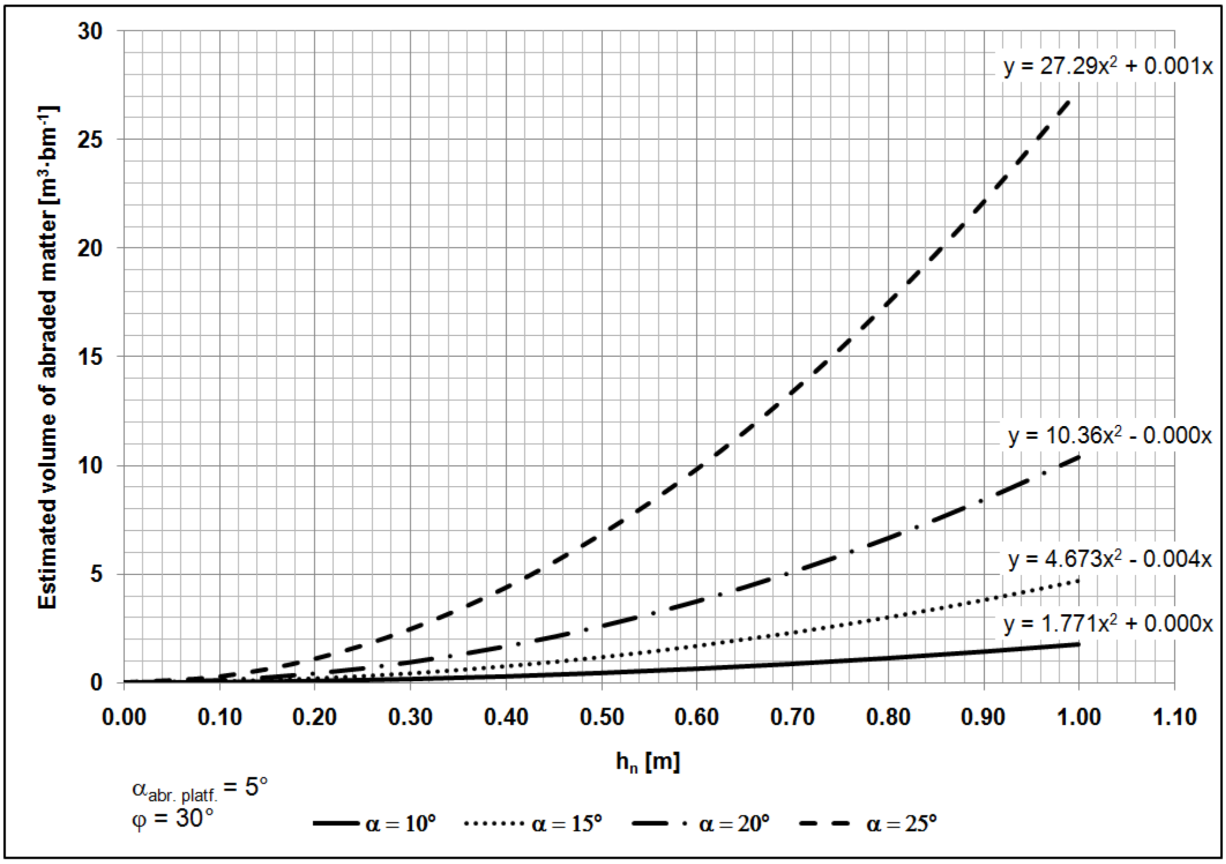

Fig 4 Abraded material volume as a function of bank slope and wave height

The relation between volume of the abraded bank matter, significant wave height and the angle of undisturbed bank was demonstrated on the example of application of the modified prognostic method of abrasion terminal point determination.

References

KAČUGIN, E. G., 1959: Inženerno-geologičeskije issledovania i prognozy pererabotki beregov vodochranilišč, Gosgeoltechnizdat, 3–90, Moskva.

KAČUGIN, E. G., 1961: Nekotorye zakonomernosti processov pererabotki beregov vodochranilišč, Voprosy ustojč. sklonov 35, Moskva, AN SSSR.

KÁLAL, I., 1955: Rozměry větrových vln na jezerech a nádržích, Vodní hospodářství, 5, Praha.

KRATOCHVIL, S., 1970: Stanovení parametrů větrových vln gravitačních vln v hlubokých přehradních nádržích a jezerech, Vodohospodársky časopis, ročník XVIII, č. 3.

LINHART, J., 1957: Ustupování břehů nádrží, Voda a život II., Praha.

LUKÁČ, M., 1972: Vlnenie na nádrži a jeho účinky na brehy nádrže, Bratislava, MS Katedra Geotechniky SVŠT.

MARHOUN K., KUTÍLEK P., 1988: Ochrana břehů nádrží proti abrazi, Hydroprojekt Brno.

SAVARENSKIJ, F. P., 1940: Vlijanie podpornych gidrotechničeskich sooruženij na rekach na pererabotku beregov, DAN SSSR, 27, 9.

ŠIRJAMOV, V. A., 1940: Kmetodike izučenija pererabotki beregovych sklonov vodochranilišč, Trudy in–ta geol. nauk AN SSSR, vyp. 43.

ŠLEZINGR, M., 2004: Břehová abraze, CERM, Brno, ISBN 80-7204-342-0.

ŠLEZINGR, M., 2007: Stabilisation of reservoir banks using an "armoured earth structure", *Journal of Hydrology and Hydromechanics*, 55 (1), pp. 64 – 69.

WOZNICA, L., 1967: přetváření břehů zátopných oblastí přehrad, MS IGHP Žilina, Brno.

ZÁRUBA, Q., MENCL, V., 1987: Sesuvy a zabezpečování svahů, Academia Praha.

ZOLOTAREV, G. S., 1953: Metodika i primerypostroenija a profilej prognoza pererabotki beregov, Inform. soobščenie č. 5128, Moskva, Gidroenergoprojekt.

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Rainwater management worldwide

Martina Zeleňáková, Radovan Kret

Abstract
Harvesting rainwater for saving drinking water has gained enormously in significance as a modern water saving sanitary technique. This can be used for private and public buildings as well as for many industrial areas. Beyond that rainwater harvesting plays an important role for the rainwater (stormwater) management of housing estates. Due to the storage (retention) and the usage of rainwater the water flowing off housing estates in both reduced and delayed. The paper presents approaches to rainwater harvesting in the countries worldwide.
Key words: rainwater, rainwater harvesting, retention, drinking water

Introduction
The English term “Rainwater harvesting” has been internationally widely accepted. Interestingly enough, the emphasis has not been on the utilisation of rainwater but on its harvesting. Harvesting means “crop” or “yield” and is a synonym for “gift of nature”. Therefore, it goes without saying that the harvested should be also utilised and every yield is preceded by its own activities. Mankind will have to deal more carefully in the future with the world-wide available and utilisable freshwater reserves. This is primarily a question of awareness and education.The approaches to rainwater management are various worldwide as presents the paper. Althought the main aim – water saving are common for all the countries.

Asia
Pacific Islands
Asia has a special tradition and culture when it comes to rainwater. On Jeju-Island south of Korea and on Miyake (volcano Island), rainwater is harvested from trees. For this purpose, many strings with interwoven ends hang down from trees. Water trickles over this meshwork into a gutter which is directed into a cistern or a jar (König and Sperfeld, 2007).
The indigenous people of Miyake use the tap water of the newly installed centralised drinking water supply system only to conserve their cistern reserves. With the hygienically clean municipal tap water which smells strongly of chlorine, they only flush their toilets, irrigate their garden or use it for the washing machine (König and Sperfeld, 2007).

Japan
In the Rainwater Museum of Sumida, national and international projects are presented and products exhibited which come partly from Germany. In the past few years, the number of urban buildings in Tokyo utilising rainwater has increased considerably from 3 plants in 1970 to about 1000 in 2003. The city advises and supports residents and firms in the planning and installation of rainwater plants. New constructed buildings must collect and use rainwater and other cities in Japan are also following their steps (König and Sperfeld, 2007).
China
Gansu is one of the driest provinces in China. The annual precipitation is about 300 mm, while potential evaporation amounts to 1500-2000 mm. Surface water and groundwater is limited, thus agriculture in the province relies on rainfall and people generally suffer from inadequate supplies of drinking water (UNEP, 2011).
Since the 1980s, research, demonstration and extension projects on rainwater harvesting have been carried out with very positive results. In 1995/96, the “121” Rainwater Catchment Project implemented by the Gansu Provincial Government supported farmers by building one rainwater collection field, two water storage tanks and providing one piece of land to grow cash crops. This project has proven successful in supplying drinking water for 1.3 million people and developing irrigated land for a courtyard economy. As of 2000, a total of 2,183,000 rainwater tanks had been built with a total capacity of 73.1 million m^3 in Gansu Province, supplying drinking water for 1.97 million people and supplementary irrigation for 236,400 ha of land (UNEP, 2011).

Fig. 1 Rainwater tanks in China (UNEP, 2011)

Rainwater harvesting has become an important option for Gansu Province to supply drinking water, develop rain-fed agriculture and improve the ecosystem in dry areas.

Seventeen provinces in China have since adopted the rainwater utilization technique, building 5.6 million tanks with a total capacity of 1.8 billion m^3, supplying drinking water for approximately 15 million people and supplemental irrigation for 1.2 million ha of land (UNEP, 2011).

South Korea

South Korea is rated by the United Nations Organization (UNO) as a country with water shortage. Measures which conserve drinking water resources are especially important. Flood protection in this country also enjoys the same priority. Strong precipitations within very short time periods always result in heavy floods. Public institutions and universities are developing suitable measures. In addition, rainwater utilisation in buildings plays an important role as part of the rainwater retention measures.

Currently a government programme is being developed which will accommodate in future construction projects the installation of retention reservoirs. Due to the uneven distribution of rainfall with long dry periods, water recycling measures such as greywater recycling, are becoming a part of a sustainable water management. The current low water price and flat rates which do not follow the polluter-pays-principle, are still a hindrance for an effective implementation (König and Sperfeld, 2007).

India

Traditionally, rainwater has been the basic provision of the population in India before the colonial power England supplied the country with a centralised drinking water supply system. In the meantime, local community initiatives grasp back on the well established decentralised concepts. The Centre for Science and Environment (CSE), an independent organisation, which supports and promotes rainwater utilisation in India through several measures, offers courses continuously in the different regions of India (König and Sperfeld, 2007).

Rainwater distribution varies from 100 mm in the Northwest deserts to 15,000 mm in the mountains of the Northeast. Rainwater harvesting supports agriculture in India since a long time. In addition to that, there is a demand for novel methods for decentralised water supply systems in urban areas. Large investments in residential construction programmes for the coming years in Mumbai (Bombay) are an answer to the continuing migration into the cities. Due to the strong population growth, urbanisation as well as increasing commercial activities, India has been ranked by the Food and Agriculture Organisation of the United Nations (FAO) as one of six countries with a significant future water shortage (König and Sperfeld, 2007).

Thailand

Many water programmes, combined with economies of scale, government subsidies and fierce private sector competition helped to push the price of a 2 m^3 household jar down to about US$ 20,-. Since the mid-1980s, millions of these 2 m^3 wire-reinforced cement rainwater storage jars have been constructed for household roof catchment supplies. Households were able to purchase the jars for immediate delivery. By using some of their savings, some households managed to increase their storage capacity further by buying a second or third jar (Toolkit, 2011).

Fig. 2 Rainwater storage jars in Thailand

(Toolkit, 2011)

Singapore

Singapore, which has limited land resources and a rising demand for water, is on the lookout for alternative sources and innovative methods of harvesting water. Almost 86% of Singapore's population lives in high-rise buildings. A light roofing is placed on the roofs to act as catchment. Collected roof water is kept in separate cisterns on the roofs for non-potable uses (UNEP, 2011).

A marginally larger rainwater harvesting and utilisation system exists in the Changi Airport. Rainfall from the runways and the surrounding green areas is diverted to two impounding reservoirs. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The water is used primarily for non-potable functions such fire-fighting drills and toilet flushing. Such collected and treated water accounts for 28 to 33% of the total water used, resulting in savings of approximately US$ 390,000 per annum (UNEP, 2011).

Australia

In Australia, a considerable expansion in the service water and rainwater utilisation is

anticipated for the next years. In Sydney, private households consume about 70 % of the total drinking water requirement. The government of New South Wales began action by enacting ordinances and propagating massive water-saving campaigns in order to reduce the water consumption. A part of these measures is the Building Sustainability Index (BASIX), a programme which incorporates rainwater utilisation among other issues. Since October 1, 2005 all new buildings have to be constructed according to the BASIX-Standard. This implies that rainwater utilisation plants are becoming a must (König and Sperfeld, 2007).
Rainwater has been used since long as a drinking water resource in Southern Australia. Likewise, it is common to use rainwater in the "hot water systems" (building services systems for hot water processing) for the personal hygiene. Long-term, scientific investigations on the impact of rainwater used as drinking water are available in Australia since 2001. The risk for intestinal diseases has been rated as very low (UNEP, 2011).

South America

Brazil

The Brazilian Semi-Arid Tropics or the so-called drought-stricken polygon in the Northeastern part of the country is a region extending over almost one million square kilometers and peopled by about 15 million inhabitants. NGOs and grass-root organisations have especially focused on rainwater catchment systems during the past decade, as these can make an essential contribution to people's survival. The organisations which teach appropriate technologies usually first try to generate an appropriate understanding of the semiarid climate and only then do they introduce rainwater catchment systems.They take into consideration the socio-economic and cultural conditions of the people involved (Toolkit, 2011).
To radically change the situation of rural water supply in Northeastern Brazil, some NGOs have formulated a project to construct 1 million cisterns. This has been approved by the government and receives funding from them (Toolkit, 2011).

North America

Increasing interest in rainwater utilisation can be also identified in the USA and Canada. Storage technology is so far available, however, other remaining components do not confirm with the German standards and are still in the initial stages of development. Lacking environmental awareness and across-the-board billing methods during consumption measurement in buildings are the causes for about three to four-fold higher water consumption than in Germany. Other reasons are partly the lower construction standards in the house services and sanitary engineering (König and Sperfeld, 2007).

United states of America

Special engagement in rainwater management is known from the US States of Maine, California, Oregon and Washington. Rainwater utilisation for irrigation is popular in Texas. The American Rainwater Catchment Systems association (ARCSA) is based there as well as a commercial filling station for rainwater for use as drinking water. The bottle labels have been humorously designated with "fresh squeezed cloud juice". The source of origin is the Dripping Springs (König and Sperfeld, 2007).

Canada

In Canada, the wood shingle roofs which are being treated with fire resistant materials in compliance with guidelines of the insurance companies, influence the quality of the draining rainwater. The same influence from fungicides can be seen in asphalt shingle roofs. Under the aspect of environmental protection and improvement of the water quality for rainwater utilisation, a rethinking is urgently required. In the coastal regions of the Atlantic and the Pacific, rainwater is often utilised as a drinking water substitute although these roof materials are widely spread (König and Sperfeld, 2007).

Africa

African countries suffering or facing water shortages as a result of climate change have a massive potential in rainwater harvesting, with nations like Ethiopia and Kenya capable of meeting the needs of six to seven times their current populations, according to a United Nations report released today (UN, 2011).

Fig. 3 Cistern for rainwater in Kenya (UN, 2011)

Overall the quantity of rain falling across the continent is equivalent to the needs of 9 billion people, one and half times the current global population. About a third of Africa is deemed suitable for rainwater harvesting if a threshold of 200 millimetres of arrival rainfall, considered to be at the lower end of the scale, is used (UN, 2011).

Kenya

Kenya, with a population of somewhere under 40 million people, has enough rainfall to supply the needs of six to seven times its current population, according to the study. In Kenya the women are responsible for the community infrastructure. They construct cisterns (fig. 3) above the ground made from local concrete with the help of church organisations from Germany and with governmental aid from New Zealand (König and Sperfeld, 2007).

Ethiopia

Ethiopia, where just over a fifth of the population is covered by domestic water supply and an estimated 46 per cent of the population suffer hunger, has a potential rainwater harvest equivalent to the needs of over 520 million people (UN, 2011).

West Europe

Due to the extensive market development and about 80,000 plants produced yearly, Germany is as before the leading country in Europe playing a significant role in the development of service and rainwater utilisation.

Developments in the field are also found in Austria, Switzerland, Belgium and Denmark.

The official attitude in France is determined by the water suppliers, who for reasons of economical self-interest similar to Germany, look with criticism at rainwater utilisation.

Interest in rainwater utilisation is present among the local authorities, planners and architects. However, the state of knowledge and recognition for rainwater utilisation is very low at the present time (König and Sperfeld, 2007).

East Europe

The East European neighbours, the Czech Republic, Slovakia, Poland and Hungary in the first place are forced to raise the technical and environmental standards to the EU level. The interest in rainwater utilisation is constantly increasing. Some commercial and public large projects have been already realised. Because of the low water price and low income of private households, the investments in own homes is still restrained. Wage differentials and governmental subsidies lead to the foundation of production facilities and branch offices of German rainwater firms in these countries.

South Europe

The development of a rainwater market in South European countries such as Greece, Italy, Spain and Portugal which are partly afflicted with massive dry periods, is still currently at very low level and is influenced by region.

Conclusion

It is quite clear that service water and rainwater utilisation have won internationally on significance. Germany is leading in this field and gives impulse for technical standards, public relations, advanced training and system dissemination.

Acknowledgements

The Centre was supported by the Slovak Research and Development Agency under the contract No. SUSPP-0007-09.

References

Heyworth, J.S., Glonek, G., Maynard, E.J., Baghurst, P.A., Finlay-Jones J. *Consumption of untreated tank rainwater and gastroenteritis among young children in South Australia* [online]. [cit. 2011-12-15]. Retrieved from http://ije.oxfordjournals.org/content/35/4/1051.full.pdf

Examples of Rainwater Harvesting and Utilisation Around the World. [online]. [cit. 2011-12-15]. Retrieved from http://www.unep.or.jp/ietc/publications/urban/urbanenv-2/9.asp

König, K.W., Sperfeld, D. (2007) Rainwater harvesting. *Sustainable water management 1-2007*. p. 31-35

Rainwater harvesting could end much of Africa's water shortage. UN reports [online]. [cit. 2011-12-15]. Retrieved from http://www.un.org/apps/news/story.asp?NewsID=20581&Cr=unep&Cr1=water

Thailand – Jar revolution: Boosting the local economy. [online]. [cit. 2011-12-15]. Retrieved from http://www.rainwater-toolkit.net/index.php?id=20

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Forest Road Network and Parameters for its Assessment

Petr Hruza, Alice Kozumplíková, Petr Pelikán

Abstract

Forest roads are an integral part of a forest environment and an essential means of forest management. The density and quality of a forest road network is an indicator used for the level of development of forest management. While some countries have not started with a systematic forest road network construction, developed countries are facing the need to optimize or partially reduced its excessive density. However, the density of a forest road network does not imply its efficiency concerning access to the transport area. If the road network has an unsuitable layout – roads are concentrated in a part of the area – their efficiency regarding the entire area is often very low. We tried to verify this hypothesis in a selected area of the National Park Šumava. The conducted study comparing the density of hauling roads in the area and their efficiency concerning access to the area has confirmed the hypothesis. For this reason, we suggest that the parameter of forest road network density should be supplemented or replaced by the parameter of forest road network efficiency.

Key words: forest road network density, density of hauling roads, forest road network efficiency, forest road network parameter

Introduction

The most globally used parameter of the forest road network assessment is the density of hauling roads. The density of hauling roads is a proportion of the length of forest hauling roads to the area to be accessed. The hauling roads taken into account are the roads of the first and second classes. Some authors use the length of the entire forest road network, including skid roads and public roads. In that case, the data are misleading. However, the parameter of the density of hauling roads is also misleading for the assessment of the efficiency of the forest road network as the efficiency often does not correspond to the density of hauling roads.

The issues of forest roads and forest road network optimization in the Czech Republic was mainly dealt with by Beneš (1973, 1982, 1986a, 1986b). He discussed the factors that affect the layout of a forest road network and divided them into natural and economic factors. Particular factors and their effect on the forest road network construction plans are described in detail in his studies where he introduced principles of forest road network optimization. In his studies "Forest Roads in Mountain Forests" and "Forest Roads in Uplands", Beneš (1989,1991) proposes a conception of the distribution of a forest road network in these areas. He uses a new criterion - the efficiency of forest hauling roads expressed as a proportion of the theoretical skidding distance to the mean geometrical skidding distance. This is a value independent of the road density and expresses the economy of their distribution in the area. Eastaugh and Molina (2011) argue the topological aspects of forest roads are most commonly quantified only by length and road density, which are poor indicators of many aspects of the network relevant to forest managers. Their paper presents three new metrics – coverage, efficiency and convenience – and uses a case study to demonstrate their utility in assisting road network decision-making.

According to Ryan et al. (2004) for any given site there is an optimum road density that minimises the combined cost of construction, maintenance and timber extraction. In calculating the optimum density, it is essential to have reliable estimates for: volume and quality of timber to be harvested over the rotation; cost of road construction; cost of road maintenance; and extraction method and off-road movement cost. He adds that the optimum density is only used as a guide to the appropriate roading for an area. There are many factors which may cause deviation from the optimum. Also, optimum road density does not take account of all the costs and benefits, e.g. recreation, hunting, access for fires etc., so it may be necessary in some circumstances to undertake a more complete cost benefit analysis before proceeding with road construction. The road density factor is completed by so-called an efficiency factor in this guide. It is not always possible to haul timber in a direct line to the road. Also there will be areas in the vicinity of sharp bends and junctions that are over served (they can be hauled in different directions). Furthermore, it will not always be possible to haul to a road equally from both sides. The recommended efficiency factors (e) are: 0.44 for two way haulage (timber can be hauled from either side of the road) and 0.91 for one way haulage (timber can be hauled onto the road from one side only).

The efficiency of a forest road network is used in Pentek's study (Pentek et al., 2005), where he analyses the current forest road network and emphasizes the significance of this parameter for the distribution of a forest road network. In contrast, Demir (2006) uses the parameter of road spacing in his study focusing on the criteria for forest road network plans. Heinimann investigated the optimal road spacing on slopes for transportation technology in the Swiss Alps (Heinimann, 1998). He analyzed transportation and road geometry to specify the relationship between road density, slope gradient and road spacing. He introduced a computer model to differentiate skidder and cable-yarder based road network concepts on steep slopes as a result of the research with the implementation of a total cost model. Brink adopts a similar approach. He considers many factors that influence the layout and spacing of forest roads. Some of these factors are terrain conditions, stand density or volume to be removed per hectare, primary transport costs, secondary transport costs and demands, road construction and maintenance costs, forest area removed from production, type of forest management practiced, needs of other road and forest users and environmental factors (Brink et al., 2005). He emphasizes the roads should be spaced so that the minimum total cost is achieved. Many of the above mentioned factors are difficult to quantify. To simplify the problem, the author only applies primary transport costs, road construction costs and the volume removed per hectare to the optimum road spacing equation. Some researchers deal with the average skidding distance for forest stands as an important parameter for determination of the optimum road density and spacing (e.g. Lotfalian, Zadeh, Hosseini, 2011). In their research the real mean skidding distance and theoretical mean skidding distance were measured to calculate the correction factor of the skidding distance for a selected forest complex. The results indicate that the road density and road spacing are important factors in logging planning to help minimize the total cost of harvesting and roading. The optimum road spacing (ORS) of forwarding operations in Styria in Southern Austria was studied by Ghaffarian, Stampfer and Sessions (2009). The research focused on the comparison of three methods to determine the optimal road spacing for forwarder-type logging operations. In a harvesting operation it is important to compute the ORS to minimize the total cost of harvesting and roading. The three methods used were Matthew's formula (1942), Sundberg's method (1976), and two statistical models for predicting the cycle time. The analysis of forwarding data indicated that the speed was related to a distance which contributed to the difference between models and that the loading and unloading time may be related to one or several other study variables. Road spacing equations based on the forwarding and travelling costs derived by the research team are presented using several project outputs. Tan (1999). developed a spatial and heuristic road locating procedure which has been improved and integrated using microcomputers. The optimal road spacing is calculated as the break-even point between the road construction cost and wood transport cost. Tan demonstrates via his results that the improved procedure proved to be beneficial in helping forest road planning managers evaluate alternatives and hence select the optimal location for a road network. It contains a heuristic algorithm capable of locating forest roads so as to minimize the total costs and impacts of road construction, wood extraction, and wood transport. Geographic information systems (GIS) are a powerful modern automated tool in forest road network and location analysis. Musa and Mohamed explored possibilities of GIS technology for planning process of routing and alignment of the forest road network (Musa, Mohamed, 2002). The authors introduced locating forest road network model as a tool to help forest managers judge the efficiency and determine an optimal location for a forest road network, while considering and determining the technological criteria, gradient and other topographical features of the area. Their results show that the best-path analysis design is one of the best solutions to forest road network placement and provides sensitivity to rule base and input features.

The issue of forest road network density and its distribution in the stand in relation to a forest environment is dealt with by Miller (Miller et al., 1996), who investigated the dependence of the forest road network density on the landscape structure. They concluded that when forest stands were delineated on the basis of several stages and covertypes, no relationship was evident between road density and average stand size. He added that because roads in forested landscapes influence a variety of biotic and abiotic processes, they should be considered as an inherent component of the landscape structure. Furthermore, plans involving both the routing of new roads and the closure of existing ones should be designed so as to optimize the structure of landscape mosaics, given a set of conservation goals. Other authors emphasize the need to deal with the distribution of a forest road network with respect to the increasing demands of multifunctional use of forest roads; e.g. McGarigal (McGarigal et al.,2001) notes that there is increasing concern that forest management activities related mainly to timber harvest and the extensive network of roads constructed to support timber harvest, fire control, and recreation can lead to cumulative effects of roads and logging on landscape structure.

Area Specification

The assessment of the suitability of the forest road network density parameter was carried out in the National Park Šumava (Fig.1), forest district Stožec, the catchment area of the Hučina stream. The size of the assessed transport area is 1061 ha (Fig.2). The western part of the area has a character of Hercynian highlands; the eastern part has marked slopes and rocks of a mountain ridge. The geological subgrade is granite. The plots of forests are located in the 6th forest altitudinal zone – the spruce and beech zone – and they consist of coniferous and mixed stands. This is a transport the optimum density of forest road network is established to be equal to or over 17.5 m/ha.

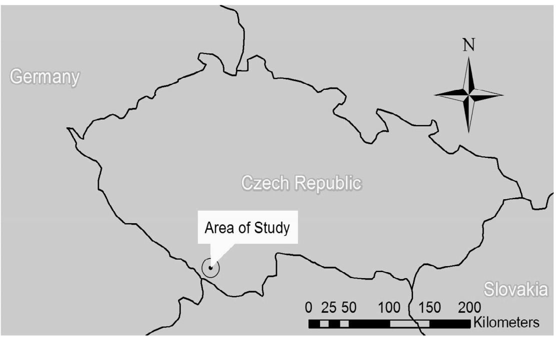

Fig. 1 The study area

Objectives and Methodology

Our study uses the results of prof. Beneš's research activities and his methodology (Beneš, 1986) to evaluate a road network in the transport area within the Hučina catchment area. A transport area is an area from which timber is hauled into one place.

The aim of the study was to establish whether the value of the parameter of hauling roads density corresponds to the parameter of forest access efficiency. The real conditions of forest road network as evaluated by the parameter of the density of hauling roads was compared with the recommended optimum density of the type of transport segment in compliance with Regional Forest Development Plans (ÚHUL,2001).

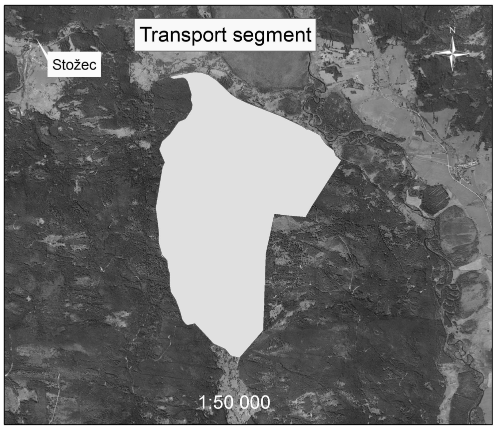

Fig. 2 Transport segment

The assessed parameters were:

Density of hauling roads (H_S) – the proportion of the length of hauling roads in metres to the accessed area in hectares.

Skidding distance (D_S) – the length of the journey of a skidding means transporting timber to a hauling road in meters. The mean skidding distance ($D_{SØ}$) is an arithmetic mean of skidding distances in the accessed area.

Geometrical skidding distance (DG) – the shortest distance in meters from the stump of a transported trunk to the hauling road. The mean geometrical skidding distance ($D_{GØ}$) is an arithmetic mean of geometric skidding distances. Its length depends on the layout of hauling roads, mainly their even distribution along the accessed area. For example, if roads are in the edge of forest, they often cross, they are located on both sides of a watercourse, the value of the mean geometric skidding distance increases. Optimally, it is between 140 and 180 m.

Theoretical skidding distance (DT) – the skidding distance in meters at an optimum distribution of forest roads in the accessed area. It depends on the density of roads and is expressed as $D_T = 10\,000/(4H_S)$ [m].

Efficiency of transport area accessing (U) – the economy of the distribution of hauling roads in the accessed area – one of the most important criteria when proposing a road network in uplands/plateaus/pahorkatin. It is a relative value, independent of the density of roads. It is the proportion of the theoretical skidding distance to the mean geometric skidding distance and is expressed in per cents: $U = (Dt / Dg) \cdot 100$ [%].

Theoretically, there is a direct proportion – the closer is the real density of hauling roads to the recommended optimum, the closer is the efficiency of forest road network to the ideal 100%. This study tried to assess whether this theory is valid or not.

Results

The length of all hauling roads in the examined transport segment was derived from digital maps of the Regional Forest Development Plan and it was 32678 m. The same map also gave us the area of the segment, which was 1061 ha. Based on these data, the density of hauling roads was calculated (as a proportion of the length of all hauling roads in the transport segment to its area) $H_S = 30.8$ *m/ha*.

The skidding distances in the transport segment were also established based on the digital maps of the Regional Forest Development Plan using the following procedure. We marked the spots of concentrated harvesting. These spots were put in a regular raster using a 10 ha grid and we measured the skid trails perpendicular to the contour and skid roads to a hauling road. The total length of used skid trails from the spots of concentrated logging to the existing hauling roads was measured. The total length of skid trails was 32,780 m and the mean skidding distance was calculated as $D_S = 312$ *m*.

The theoretical skidding distance was calculated to be $D_t = 81$ *m*.

The geometrical skidding distance, ascertained by measuring the shortest distance from spots of concentrated logging to hauling roads, was $Dg = 236$ *m*.

The efficiency of the forest road network in the transport area, the theoretical quantity expressing the efficiency and the layout of hauling roads in the accessed area, reached the value $U = 34$ *%*.

The calculated results show that there is a high density of hauling roads in the area – 30.8 m/ha when compared with the recommended density for the examined transport segment – 17.5 m/ha; however, the efficiency of the forest road network is very low due to a bad distribution of the hauling roads. There is a high concentration of forest roads in the western part of the area, whereas the eastern part lacks a large amount of roads. Therefore, the geometrical skidding distance ranges around 236 m, yet the optimum is 140–180 m. This confirms that a high density of hauling roads is not a very suitable parameter for assessing the quality of the forest road network. The parameter of density of hauling roads needs to be supplemented by a parameter of forest road network efficiency.

Conclusion

The parameter of density of hauling roads does not always provide valuable information about the quality of the forest road network and in the future it needs to be supplemented or replaced by a parameter of forest road network efficiency.

The forest road network efficiency is a basic parameter when selecting the most suitable plan of hauling roads in an accessed transport area. It expresses the efficiency of the routing of hauling roads in the terrain. When the distribution is regular, the efficiency is maximized with respect to the density of roads. The presented example of the National Park Šumava calls for the forest road network optimization. Selected roads in the places with their high concentration should be reforested and new roads should be planned in the eastern part based on the presented criteria so that the new forest road network with a higher overall efficiency reduces the skidding distances.

References:

Beneš, J. (1973). Vliv tvaru terénu na dopravní zpřístupnění lesa. Lesnictví, 19(6), 479-492.

Beneš, J. (1982). Eroze způsobená výstavbou lesních cest a dopravou po nich. Lesnictví, 28(7),539-554.

Beneš, J. (1986a). Optimalizace lesní dopravní sítě. Lesnictví, 32(12),1089-1114.

Beneš, J. (1986b). Předpoklady zpřístupnění lesa. FOLIA VŠZ v Brně, 66.

Beneš, J. (1989). Zpřístupnění horských lesů. Lesnictví, 35(2), 153-172.

Beneš, J. (1991). Zpřístupnění lesů v pahorkatinách. Lesnictví, 37(3), 245-266.

Brink, M., Slate, J., Ackermann, P. A., 2005: South African Forest Road Handbook, Forest Engineering Southern Africa, Pietermaritzburg, 212 pp., ISBN 9780620349031.

Demir, M. Impacts, management and functional planning criterion of forest road network system in Turkey. Transportation research part A – policy and practise, 41(1), 56-68.

Eastaugh, C., S., Molina, D., Forest road networks: metrics for coverage, efficiency and konvenience. Australian Forestry, 74(1), 54-61.

Ghaffarian, M. R., Stampfer, K., Sessions, J., 2009: Comparison of three methods to determine optimal road spacing for forwarder-type logging operations, Journal of Forest Science, 55, 2009 (9): 423–431, ISSN 1212-4834.

Heinimann, H. R., 1998: A Computer Model to Differentiate Skidder and Cable-Yarder Based Road Network Concepts on Steep Slopes, Journal of Forest Research 3: 1–9, ISSN 13416979.

Lotfalian, M., Zadeh, E. H., Hosseini, S. A., 2011: Calculating the correction factor of skidding distance based on forest road network, Journal of Forest Science, 57, 2011 (11): 467–471, ISSN 1212-4834.

McGarigal, K., Romme, W., H., Crist, M., Roworth, E. (2001) Cumulative effects of roads and logging on landscape structure in the San Juan Mountains, Colorado (USA). Landscape Ecology, 16(4), 327-349.

Miller, JR, Joyce, LA, Knight, RL, King, RM. (1996). Forest roads and landscape structure in the southern Rocky Mountains. Landscape Ecology, 11 (2), 115-127.

Musa, M. K., Mohamed, A., 2002: Alignment and Locating Forest Road Network by Best-Path Modeling Method, Asian Conference on Remote Sensing 2002, Kathmandu, Nepal.

Oblastní plán rozvoje lesa pro PLO 13
Šumavu. [CD-ROM]. Plzeň: ÚHUL, 2001-.
Retrieved 2007-05-05 from
<http://212.158.143.149/index.php>

Pentek, T., Pičman, D., Potočnok, I., Dvoršćak, P., Nevečeřel, H. (2005) Analysis of an existing forest road network. Croatian Journal of Forest Engineering, 26(1), 39-50.

Tan, J., 1999: Locating Forest Roads by a Spatial and Heuristic Procedure Using Microcomputers, International Journal of Forest Engineering, vol. 10, no. 2, ISSN 1913-2220.

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The Effect of Providing the Ancillary Reserve the on the Balance of a Reservoir's Storage Volume

Martin Orfánus, Peter Šulek

Abstract

A considerable attention has been paid to the optimal utilization of the dynamic characteristics of the hydropower plants in electric power system of Slovakia. For more than 20 years, simplified optimization solutions have been used for the operation planning as well as the real time operative control. The issue of the assuring the support services in the field of the primary, secondary and tertiary reserve of power output has been increasingly occurring by the operation of the hydropower plants in the last years. The article describes suitable methods for the solutions of the problems of the hydropower plant control related to the new tendencies in the planning and the market with electrical energy, while primary taking into account their generality in the aspect of the planning and providing the ancillary reserve.

Key words:
hydropower plant, ancillary reserve, generation scheduling, electric power system, hydro-thermal coordination.

Introduction

To generate and to supply the electrical power system (EPS) with as much power as is being demanded at the same moment (including transmission losses) is important mainly because the electric power can not be stored in a larger scale and subsequently used in the time of increased power demand. The sources, which are assuring the balance of the energy system between the power generation and the power demand, provide the so-called ancillary reserve (AR) to the electric power system.

The support services can be divided into:

- the primary reserve (PRV),
- the secondary reserve (SRV),
- the tertiary reserve (TRV),
- the quick and the cold dispatch backup.

The power in the EPS which is reserved for the ancillary reserve assuring is called the regulation (power) backup.

Materials and methods

Whether at the production of the base power or the assuring of the AR, the objective of the power producer should be to maintain the maximum operational effectiveness of the power system. The simplest and the most common criterion for the optimal allocation of the load between the power sources of the system is the achievement of the minimal production costs with the respect to the limiting conditions, which are linked to this criterion in the specific time and space (Kolcun, 2001; Seewald, 1997). Based on the previous, for a hydrothermal system, which consists of m thermal and n hydropower plants, can be the total fuel costs N_c in a regulation period T expressed as following:

$$N_c = \sum_{j=1}^{T}\sum_{i=1}^{m}\begin{pmatrix} {}^{s}N_{i,j}({}^{s}P_{i,j}) \\ +{}^{AR}N_{i,j}({}^{s}P_{i,j}, {}^{AR+}P_{i,j}, {}^{AR-}P_{i,j}) \end{pmatrix} \tag{1}$$

where j is the index of the time interval of the solution within the total regulation time T (j=1 2, .., T), i is the index of the thermal power plant (i=1, 2, .., m), ${}^{s}N_{i,j}$ is the fuel costs of the i thermal power plant during the j hour at the base power generation, ${}^{s}P_{i,j}$ is the power output (base power) of the i thermal power plant (TPP) during the j hour [MW], ${}^{AR}N_{i,j}$ is the fuel costs of the i thermal power plant during the j hour, related to the providing of the AR [costs/hour], ${}^{AR+}P_{i,j}$ is positive regulation power output of the i thermal power plant during the j hour [MW] and ${}^{AR-}P_{i,j}$ is negative regulation power output of the i thermal power plant during the j hour [MW].

For the balance of the power outputs (base power) in the j hour of the regulation period T can be written:

$${}^{s}P_j = \sum_{i=1}^{m} {}^{s}P_{i,j} + \sum_{k=1}^{n} {}^{s}P_{k,j} \tag{2}$$

where k is the index of the hydropower plant (HPP) (k=1, 2, .., n), ${}^{s}P_j$ is the total required base power during the j hour [MW] and ${}^{s}P_{k,j}$ is the base power of the k hydropower plant during the j hour [MW].

For the balance of the power backup during the j hour stands in the positive or negative course of the deviation following:

$${}^{AR+}P_j = \sum_{i=1}^{m} {}^{AR+}P_{i,j} + \sum_{k=1}^{n} {}^{AR+}P_{k,j} \quad \text{or}$$

$${}^{AR-}P_j = \sum_{i=1}^{m} {}^{AR-}P_{i,j} + \sum_{k=1}^{n} {}^{AR-}P_{k,j} \tag{3}$$

where ${}^{AR+}P_j$ is the total required positive regulation backup during the j hour [MW], ${}^{AR+}P_{k,j}$ is the positive regulation backup of the k hydropower plant during the j hour [MW], ${}^{AR-}P_{j,}$ the total required negative regulation backup during the j hour [MW] and ${}^{AR-}P_{k,j}$ is the negative regulation backup of the k hydropower plant during the j hour [MW].

The diversion of the load between thermal and hydropower plants with the respect to all of the boundary water management and energetic conditions and fulfilling the criterion (2) will be optimal and the total fuel costs in the energetic system will be minimal.

The system of the energetic sources of the Slovenské elektrárne company, which operates 2 nuclear, 2 thermal and 34 hydropower plants, can also be considered as a hydrothermal system. Apart from the complicated analytic expression of the costs related to the providing of the ancillary reserve, the complexity of the optimal distribution of the load between the TPPs and the HPPs is caused mostly by the operation of the hydropower plants in the cascade (the Váh Cascade), where the hydropower plants are interconnected between themselves by complicated hydraulic links.

The complexity of the support services distribution is also caused by the fact that the ability of providing ancillary reserve for the EPS depends on the type of the hydropower plant, as well. To express the suitability of the particular types of the hydropower plants for the AR providing is a very complex and complicated task.

In the real process of the planning of the energetic system's operation, the distribution of the ancillary reserve between particular sources is rather based on the experience of the dispatch operators (Nedorost, 2004).

In the first step, the percentage of the generation unit's ability to provide power backup with taking into account the backup's use for the providing of the ancillary reserve of a higher rank is specified (e.g., for estimating the ability of the unit to provide the power backup for the tertiary reserve, the backup for the primary and the secondary reserve is taken into account). In the next step, the base power load distribution between the HPP and the TPP is based on the regime efficiency criterion expressed as follows:

$$F = \sum_{j=1}^{T} \sum_{k=1}^{n} b_j \left({}^{s}P_j - \sum_{k=1}^{k-1} {}^{s}P_{k,j} \right) . {}^{s}P_{k,j} \tag{4}$$

$$\overset{min}{P}_{k,j} + {}^{AR-}P_{k,j} \leq {}^{s}P_{k,j} \leq \overset{max}{P}_{k,j} - {}^{AR+}P_{k,j} \tag{5}$$

$$\overset{min}{HN}_{k,j} \leq HN_{k,j} \leq \overset{max}{HN}_{k,j} \tag{6}$$

$$HN_{k,T} = {}^{req}HN_{k,T} \tag{7}$$

$$V_{k,j} = V_{k,j-1} + {}^{inf\,low}V_{k,j} - {}^{outflow}V_{k,j} \tag{8}$$

where $\overset{min}{P}_{k,j}$, $\overset{max}{P}_{k,j}$ are the minimal and the maximal attainable power output of the k HPP during the *j* hour [MW], $\overset{min}{HN}_{k,j}$, $\overset{max}{HN}_{k,j}$ are the minimal and the maximal operational water level in the reservoir of the *k* HPP during the *j* hour [m a.s.l.], $HN_{k,j}$ is the water level in the reservoir of the *k* HPP in the end of the *j* hour [m a.s.l.], $HN_{k,T}$ is the water level in the reservoir of the *k* HPP in the end of the *T* [m a.s.l.], ${}^{req}HN_{k,T}$ is the required water level in the reservoir of the *k* HPP in the end of the *T* [m a.s.l.], $V_{k,j}$ is the storage volume of the reservoir of the *k* HPP in the end of the *j* hour [m^3], ${}^{inflow}V_{k,j}$ is the total volume of inflow into the reservoir of the *k* HPP in the *j* hour reduced by the evaporation losses, leakage and other not energetic withdrawals [m^3] and ${}^{outflow}V_{k,j}$ is the total volume of water withdrawn for energetic purposes from the reservoir of the *k* HPP during the *j* hour [m^3].

Results and Discussion

The scheme in the fig.1 shows that the value of the ${}^{outflowr}V_{k,j}$ is based on the nature of the provided AR (Šulek, Dušička, 2006). Based on its nature, for the *primary reserve* is the PRV+ or the PRV- volume equivalent neglected. For its planning, only the assigning of the required power backup is taken into account.

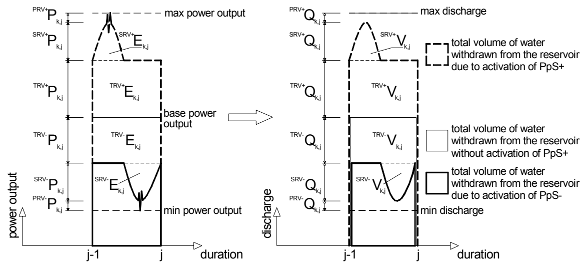

Fig.1 The estimation of the water volume withdrawn for the energetic purposes of the k HPP's reservoir during the *j* hour

For the *secondary reserve*, the volume of water required for the SRV+ or SRV- can be expressed as follows:

$${}^{SRV+(-)}V_{k,j} = \int_{j-1}^{j} {}^{SRV+(-)}Q_k(t).dt \tag{9}$$

where ${}^{SRV+(-)}Q_k$ is the actual discharge equivalent of the SRV+(-) of the k HPP [m^3.s^{-1}]

For the providing of the *tertiary reserve* is also necessary to take into account the volume change of the water withdrawn from the reservoir. The expression for the TRV+ or TRV- volume equivalent is as follows:

$${}^{TRV+(-)}V_{k,j} = \int_{j-1}^{j} {}^{TRV+(-)}k . {}^{TRV+(-)}Q_k(t).dt \tag{10}$$

where ${}^{TRV+(-)}Q_k$ is the actual TRV+(-) discharge equivalent of the *k* HPP [m^3.s^{-1}], ${}^{TRV+(-)}k$ is the TRV's utilization coefficient, expressing the uncertainity rate of the moment of the tertiary reserve load in the total regulation period *T*. It can acquire values in the range <0~1>. If the ${}^{TRV+(-)}k$ value equals 1, it means that the TRV is assumed to be activated in every hour of the *T* [-].

Then, for the computation of the ${}^{outflow}V_{k,j}$ stand following:

$${}^{outflow}V_{k,j} = {}^{0}V_{k,j} + {}^{SRV+}V_{k,j} - {}^{SRV-}V_{k,j} + {}^{TRV+}V_{k,j}$$

or

$${}^{outflow}V_{k,j} = {}^{0}V_{k,j} + {}^{SRV+}V_{k,j} - {}^{SRV-}V_{k,j} - {}^{TRV-}V_{k,j} \quad (11)$$

The effect of providing the ancillary reserve on a reservoir's operation water level is shown on the scheme in Fig.2. Meeting the (13) and (14) boundary conditions for both limiting water level regimes should maintain a "safety pillow" for providing the planned support services in a range of the total regulation period *T*.

$$\overset{min}{HN}_{k,j} \leq {}^{AR+}HN_{k,j} \leq \overset{max}{HN}_{k,j} \quad (12)$$

$$\overset{min}{HN}_{k,j} \leq {}^{AR-}HN_{k,j} \leq \overset{max}{HN}_{k,j} \quad (13)$$

where ${}^{AR+}HN_{k,j}$ is the water level inf the reservoir of the *k* HPP at the end of the *j* hour when the AR+ is activated [m a.s.l.], ${}^{AR-}HN_{k,j}$ is the water level inf the reservoir of the *k* HPP at the end of the *j* hour when the AR-.

The above shows that an important factor for assessment of the AR planning is the real estimation of the water levels when activating the particular AR. This estimation depends on determination of the ${}^{SRV+(-)}k$ and ${}^{TRV+(-)}k$ coefficients. These have to be determined so that they describe as precisely as possible the share of the particular AR on the changes of the reservoir's available storage volume, guarantee providing the AR during the whole regulation period and at the same time do not restrain the regulation abilitiy of the reservoir.

According to the operators of the Dispatch centre of the hydropower plants in Trenčín, for the estimations of the limiting operational water levels, the values of the ${}^{SRV+(-)}k$ between 0~0,1 and ${}^{TRV+(-)}k$ between 0,2~0,25 give the most real results.

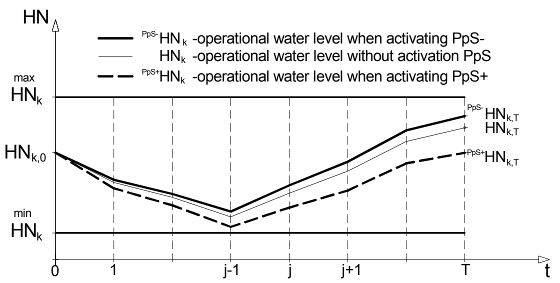

Fig. 2 The effect of activating the ancillary reserve on the operation water level regime in a reservoir

Conclusion

The described methodology of the planning of the ancillary resreve on the hydropower plants has been implemented into the model of the planning and operative control of the operations of the hydropower plants since 2007. The model is a part of the complex information system of the operations planning of the energetic sources of the Slovenské elektrárne, Co.

In the model, the solution of the optimization objective, which is described by the criterion function (4), is based on the modified simplex method with the corrective algorithm enabling a quick convergence to the optimal result. Although the behaviour of the criterion function is nonlinear, for the selection of this method has been the determining criterion the request of the shortest computational time of the optimization as possible.

The methodology of the optimal load allocation between the thermal and the hydropower plants with the reserving of power backup for the ancillary reserve assuring, which is based on the energy producer so called regime efficiency, is universal only in the case that the EPS operator is identical to the power producer or the case that the power producer's capacity totally covers the demands of the whole ES. In other cases, the conditions of the optimal load allocation much more complicated. It is caused mostly by the fact that the base power and the support services have a substitute character. It means that the increased production of the one product requires the decrease of the production of the second product. Thus a situation may occur that some sources with low marginal costs (e.g. hydropower plants) will be allocated from the base power generation to the providing of the AR. This will decrease the system operator's costs but at the same time it will lead to the increase the prices in the energy market, because these sources will be replaced by the ones with higher costs. The decrease of the AR costs of the system operator would be at the expense of the consumers in the energy market. The situation is complicated also by the facts that the price for the particular types of the ancillary reserve is not defined and the support services market, which would generate their prizes, is not created. The prize for particular types of the ancillary reserve is defied by a temporary apparatus, which is based on the amount of the finances available to the supplier of the AR- the operator of the electric supply system after the confirmation from the regulatory office.

References

Kolcun, M. et al. (2001). *Operational Control of an Electric System*. Bratislava

Seewald, V. (1997). *Control of the hydropower system of the SE*, Co. - Hydropower Plants

Trenčín. EE Journal of Electrical and Power Engineering, No. 1, Volume III, Bratislava.
Nedorost, J. (2004). *Cooperation of Generation Sources of the ESS SR by the Load Covering*. Research Report., VUPEX Bratislava, Bratislava.
Šulek, P., Dušička, P. (2006). *Characterization of Hydro-modeling Algorithms Designed for SW Model of Hydropower Plant Operation Planning*, Technical Documentation. STU Bratislava

Acknowledgements
This paper was supported by the Grant agency VEGA under contract No.1/0578/11 and the Slovak Research and Development Agency under contract No.APVV-0680-10.

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The hydropower plant Sereď
in field of liberation electricity market

Stanislav Kelčík, Peter Šulek

Abstract

The Sereď water structure on river Váh supposes also hydro energetic use of river Váh by hydropower plant. The goal of this work will be assess the possibility of regulation operation of hydropower plant Sereď given to the possibilities provided in the hydropower plants of Váh cascade placed above it.

Key words:
hydropower plant, regulate operation, Sereď

Introduction

The stretch of the Váh river between the water structure Drahovce and Kráľová is just used for energy production in the upper part by the hydropower plant Madunice. It is not still used for energy production from Madunice to Kraľová. The water structure Sereď was proposed to use it. The purpose of the water structure Sereď is energy use, the possibility of waterway and use for agriculture and recreation. Hydropower plant Sereď is proposed for the peak load operation. It requires storage reservoir or it can operated in tandem with the hydropower plant Madunice. The operator of the hydropower plant Madunice is Slovenské elektrárne, a.s.. The hydropower plant Sereď will most likely have another operator (Dušička, 2007). In this case the possibility of a tandem operation would be very difficult. The paper describes ability of this hydropower plant in field of liberation electricity market.

Material and Methods

As recommended variant of construction water works Sereď has been chosen derivative variant with channel on the left side of the river Váh. Water works requires the construction of the main objects as:

- reservoir Siladice
- weir Siladice
- treatment of the riverbed under the weir Siladice
- approach channel to hydropower plant Sereď
- hydropower plant Sereď and lock chamber
- gutter from hydropower plant Sereď
- deepened riverbed level under the hydropower plant Sereď

The volume of the reservoir Siladice which is used to accumulate water for hydropower plant Sereď, and inlets to the reservoir from hydropower plant Madunice and old riverbed of the Vah river are limiting elements for peak load operation of hydropower plant Sereď. Total volume of Siladice reservoir is 23,3 mil. m^3 from which approximately 3,5 mil. m^3 can be used for hydropower plant Sereď. The average annual flow of the river Váh here is 149,7 $m^3.s^{-1}$ (Šulek, 1997).

The water works Sereď will be located on the left side of the river Váh, northeast of the town Sereď. It consists of two key objects – hydropower plant and lock chamber. Hydropower plant is located right of the lock chambers and it was originally designed to work in tandem operation with hydropower plant Madunice. Hydropower plant is designed for peak load operation and will have these parameters:

- maximum discharge – 300 $m^3.s^{-1}$
- the type of turbine - vertical Kaplan
- number of turbines – 3 x 100 $m^3.s^{-1}$
- max. performance - P_{max} = 51,39 MW
- average annual production –

E = 182,95 GWh

Now we proceed to calculate the blocks of peak load operation. The balance sheet of volume based on system hydropower plant Madunice - hydropower plant Sereď was made with hourly time step. The scheme of the model is shown in Fig. 1 (Kelčík, 2011).

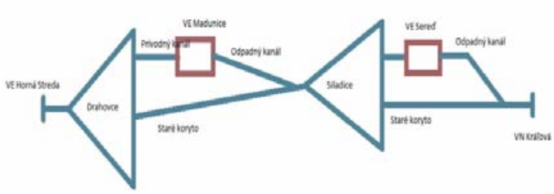

Fig. 1 The scheme of system Madunice – Sereď

A storage volume in the reservoir Siladice at the end of the i-th hour V_i [m^3] is controlled by balance equations:

$$V_i = V_{i-1} - 3600.Q_{š,i} + I_i$$

Where:

V_i - a storage volume of the Siladice reservoir at the end of the i-th hour [m^3]

$Q_{š,i}$ – peak flow through the hydropower plant Sereď in the i-th hour [$m^3.s^{-1}$]

I_i – the amount of inflow into the Siladice reservoir in the i-th hour [$m^3.s^{-1}$]

while must be met:

$V_{min} <= V_i <= V_{max}$

where:

V_{min} – a minimum storage volume of the reservoir Siladice , V_{min}=0

V_{max} – a maximum storage capacity of the reservoir Siladice, V_{max}=3,5 mil. m^3

Calculations were made with hour step for the period from January to December 2010. We had available hourly average flows from the hydropower plant Madunice and old riverbed of Váh. We consider the average monthly flow rates for parameter I_i. We assumed that the flow through the hydropower plant is constant over the period of peak load operation ($Q_š$) and is equal to 300 (250) $m^3.s^{-1}$. Lengths of the blocks were considered in period of 6-12 hours. Start of blocks was always from 6.00 am each day across the interval of solution (ie 2010).

Results

The results of calculations for $Qš,i$ = 250 $m^3.s^{-1}$ are in Fig. 2.

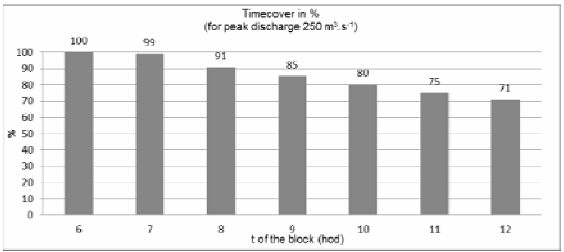

Fig. 2 Timecover in % for peak discharge 250 $m^3.s^{-1}$

The results of calculations for $Q_{š,i}$ = 350 $m^3.s^{-1}$ are in Fig. 3.

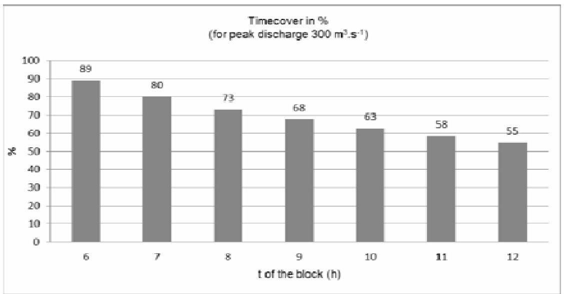

Fig. 3 Timecover in % for peak discharge 300 $m^3.s^{-1}$

Conclusion

The hydropower plant Sereď is proposed for the peak load operation therefore requires accumulation reservoir or it can work in tandem with Madunice hydropower plant. Operator of hydropower plant Madunice are ENEL Slovenské elektrárne, a.s. but Sered hydropower plant will most likely have another operator. In this case the possibility of a tandem operation would be very difficult. The capacity of a storage volume of weir Siladice, which is used for water storage for hydropower plant Sereď, inflow to reservoir Siladice from hydropower plant Madunice and from old riverbed of Váh, are therefore limiting elements for peak load operation of hydropower plant Sereď. Balance sheet of the constructed model can be used for further processing of measured data and with the help of other necessary documents can be achieved the most economical operation of the hydropower plant Sereď.

References

Dušička, P. et. al. (2007). *Vodná stavba Sereď – poradenská služba. SvF Stu Bratislava.*

Kelčík, S. (2011). *Možnosti regulačnej prevádzky VE Sereď.* Diplomová práca. *SvF STU Bratislava.*

Šulek, P. (1997). *Možnosti špičkovej prevádzky VE Sereď.* Diplomová práca. *SvF STU Bratislava*.

Acknowledgement

This paper was supported by the Grant agency VEGA under contract No.1/0578/11.

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Environmental criteria for site selection of hydroelectric power plants

Lenka Zvijáková, Martina Zeleňáková

Abstract
Before a project can be developed, it must go through a rigorous process that examines the impact the project would have on the environment and on local communities. Water flow, water quality, water shed, management, fish passage, habitat protection, as well as the welfare and lifestyle of the local communities are taken into consideration. Hydroelectric power plants - project have many environmental impacts. These impacts will of course vary from case to case. This paper presents the main aspects regarding the impact of hydroelectric power plants on the environment.
Keywords: hydroelectric power plants, environmental impact assessment (EIA), indicators.

Introduction
Few types of development projects arouse as much controversy as hydroelectric dams. Their often serious environmental damage has been amply documented within the past decade. Nonetheless, many countries, in Latin America and worldwide, rely upon hydroelectric dams for a major portion of their electric power. Electricity remains a key ingredient for improving the lives of poor people almost everywhere. In developing countries, rapid urbanization and continued population growth will ensure increased demand for electric power for decades to come, even with the most successful of demand management and energy efficiency measures. Energy planners in many developing countries are thus likely to continue seeing hydroelectric dams as a promising source of renewable electric power (Ladec and Quintero, 2003).
This paper provides a simple, yet robust, methodology for comparing proposed hydroelectric project sites in terms of their expected negative environmental impacts, and relating these to power generation benefits.
Large dams and hydroelectric power plants vary considerably in their adverse environmental impacts. While some large dams are relatively benign, others have caused major environmental damage. The severity of environmental impacts from a hydroelectric project is largely determined by the dam site. While dams at good sites can be very defensible from an environmental standpoint, those proposed at bad sites will inherently be highly problematic, even if all feasible mitigation measures are properly implemented (Ladec, Quintero, 2003).
The paper presents quantitative indicators (using data that are relatively easy to obtain) for rating and ranking proposed new hydroelectric projects in terms of their likely adverse environmental impacts.

Material and Methods
Before a hydroelectric project site is chosen (with a project-specific environmental impact assessment), sector-level environmental analysis can rank potential sites according to their degree of environmental is desirability. There exist various quantitative, easily calculated indicators that can be used to estimate the extent of adverse environmental impacts for any proposed hydroelectric project.
A matrix, the most common method in environmental impact assessment, is a grid-like table for identifying the interaction between project activities (displayed on one axis) and environmental characteristics (displayed on the other axis).
Universal Matrix of Risk Analysis (UMRA) method has two phases (Tichý, 2006):
1. Verbal phase focuses on the identification of the UMRA
    - segments of projects, which are exposed to danger,
    - sources of danger, which threaten the segments.

The result of this phase is the form of initial matrix which is used in the numerical phase.

2. Numerical phase includes:
    - the seriousness of the danger (with using matrix UMRA),
    - quantification of risk by estimation of the severity.

Environment-activity interactions can be noted in the appropriate cells or intersecting points in the grid. Matrices organize and quantify the interactions between stressors and their impact in different field. A simple matrix of interactions of “stressors” and environmental “impact to...” is show in Tab. 1. It presents impact of stressors to compounds of the environment (marked as o).
Prerequisite for effective assessment of the potential impact of water construction on the environment is a set of indicators. Selection, arrangement and evaluation of the indicators in the final assessment are complex and time demanding process. Important prerequisite for the creation of purpose-oriented set of indicators is the correct classification of each indicator.

Tab. 1 Hydroelectric project impact matrix

Stressor \ Impact	population	rock environment, minerals, geodynamic phenomena	climatic conditions	atmosphere	water ratios	land	fauna, flora and their habitats	country - the structure and land use, landscape	protected areas and their buffer zones	territorial system of ecological stability	urban complex and use of land	cultural and historical monuments	archaeological sites	paleontological sites and important geological sites	cultural values of incorporeal character	other
Flooding	RF		o	o	o	o	o	o	o	o	o	o	o	o	o	
Earthworks	o	o		o	o	o	o			o		o	o	o		
Transport	o		o	o	o	o	o	o			o					
Waste water	o			o	o	o		o	o							
Noise	RF						o	o								
Eutrophication	o				RF											
Sedimenta-tion		o			RF	o	o	o	o	o						
Erosion	o	o			o	o	o	o		o	o	o				
Water Flow		o			o	RF	RF	o	o	o	o					
Other																

Note: RF – Risk factor

Results and Discussion

This paper presents quantitative, easily calculated risk factors that we consider especially useful for hydropower power plants site selection from an environmental standpoint. These indicators have high predictive value for likely adverse environmental impacts.

The numerical phase focuses on the risk factors, which are identified in UMRA. Risk factor (RF) is a function of two key parameters: likelihood (L) and consequence (C),

$$RF = L \times C \qquad (1)$$

It is necessary to establish the parameters of the likelihood and consequences of stressors for the determination of the risk factor (Tab. 2). Determination of these values is based on the standards, laws or literature, as well as subjective suggestions. All categories of consequences and likelihood at Table 2 and their characteristics were determined after reviewing scientific resources (Castaldi et al. 2003); (Baird, 2004); (Coface, 2003); (Fairfull and Witheridge, 2003); (Fisheries and oceans Canada, 2007).

There is defined Risk Index (RI) for each identifying interaction between stressor and impact to each stressor, for each variant, which is assessed in environmental impact assessment (EIA) process, according the equation:

$$RI = \frac{\sum RF}{n} \qquad (2)$$

where

RF is calculated risk factor for each stressor impact;

n is number of evaluated *RF*;

RI is the risk index calculated for each assessed variant of planned water construction or activity in water management.

Then, according to the value of RI is chosen the best variant of construction with acceptable risks to the environment. For classification the probability has been chosen the point method with four stages (Tab. 3) Interval of RI is determined for all risk factors. The lower is the risk of the variant; the more acceptable is the choice in terms of the EIA process.

Tab. 2 Indicators used to assess the negative impacts of a hydroelectric power

Stressor	Level of Likelihood „L“	Indicator	Category of Consequence „C“	Indicator
Stressor: Flooding	Impact to population			
	Level of Likelihood „L“	Hectares flooded / MW (ha/MW)	Category of Consequence „C“	People displaced / MW (n/MW)
	1	< 1	1	< 1
	2	1 – 50	2	1 – 25
	3	51 – 100	3	25 – 50
	4	> 100	4	> 50
Stressor: Eutrophication	Impact to water ratios			
	Level of Likelihood „L“	Depth of the reservoir (m)	Category of Consequence „C“	Water Retention Time in Reservoir (number of days)
	1	≤ 5	1	0 – 40
	2	6 – 30	2	41 – 60
	3	31 – 55	3	61 – 80
	4	≥ 56	4	≥ 81
Stressor: Noise	Impact to population			
	Level of Likelihood „L“	Sound power of turbine (W)	Category of Consequence „C“	Distance from the populated part of the sound source (m)
	1	0 – 100 kW	1	> 1900
	2	101 – 500 kW	2	1001 - 1900
	3	501 – 5 000 kW	3	101 - 1000
	4	> 5 000 kW	4	< 100
Stressor: Sedimentation	Impact to water ratios			
	Level of Likelihood „L“	Densimetric Froude Number (-)	Category of Consequence „C“	Amount of sediment collected in the reservoirs (m^3)
	1	> 1	1	0 – 100
	2	0,9 – 0,8	2	101 – 500
	3	0,7 – 0,6	3	501 – 1000
	4	< 0,6	4	≥ 1001
Stressor: Water flow	Impact to fauna, flora and their habitats			
	Level of Likelihood „L“	Water velocity (m/s)	Category of Consequence „C“	Fish passage (-)
	1	0 – 4	1	natural migration paths
	2	5 – 8	2	diversions
	3	9 – 12	3	natural fish passage
	4	> 12	4	technical fish passage
Stressor: Water flow	Impact to land			
	Level of Likelihood „L“	Water depth (cm)	Category of Consequence „C“	Fish habitat (-)
	1	40	1	Major (threatened fish species is observed)
	2	30	2	Moderate (fish habitat is present)
	3	20	3	Minimal (known fish habitat is observed)
	4	10	4	Unlikely (no permanent fish habitat is present)

Tab. 3 Risk classification and acceptability

Class of risk	Interval of RI	Acceptability of risk to the environment
I.	1 – 24	acceptable
II.	25 – 48	moderate
III.	49 – 72	undesirable
IV.	73 – 96	unacceptable

Conclusion

For projects that require the construction of hydropower plants, an environmental impact assessment is required.

After investigating the various impacts of a hydroelectric plant, we are able to determine the feasibility of implementing a hydroelectric plant. Since most environmental concerns stem from construction of the dam, this location would not be greatly affected by the installation of a hydropower generating facility.

This paper is aimed at clarifying the criteria used in the environmental review of major projects. They identify the main impact indicators – stressors of a project within a given sector on the environment and, for each of these factors, define three impact indicators - stressors.

As such, the primary stressors of a large dam project are the following: sedimentation, eutrophication and flooding.

The amount of possible environmental damage from a proposed hydroelectric project is largely determined by the dam site. In general, the most environmentally benign hydroelectric dam sites are on upper tributaries, while the most problematic ones are on the large main stems of rivers.

This paper provides important advice for substantially reducing the environmental damage from future hydroelectric dams through good project site selection. It is innovative methodology for dam site selection - based on robust environmental criteria and straightforward, quantitative indicators - should prove useful worldwide. The relatively simple, quantitative indicators proposed in this paper should be used for preliminary rating and ranking of proposed new hydroprojects in terms of their expected adverse environmental impacts, until more complete information is provided by sectoral environmental assessments or other detailed studies.

Acknowledgement

Authors are grateful for financial support of project HUSK/1001/2.1.2/0009.

References

Baird, S. (2004). *Hydro-electric power* [online]. [cit. 2011-12-15]. Retrieved from http://www.groept.be/www/dam/HYDROpower.htm

Castaldi, D., Chastain, E., Windram, M., Ziatyk, L. (2003). *A Study of Hydroelectric Power: From a Global Perspective to a Local Application* [online]. [cit. 2011-12-15]. Retrieved from http://www.ems.psu.edu/~elsworth/courses/cause2003/finalprojects/vikingpaper.pdf

Coface (2003). *Hydroelectric power stations and large dams* [online]. [cit. 2012-01-15]. Retrieved from http://www.adb.org/water/topics/dams/pdf/barragesgb.pdf

Fairfull, S. and Witheridge, G. (2003). *Why do fish need to cross the road? Fish passage requirements for waterway crossings* [online]. [cit. 2012-01-15]. Retrieved from http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/202693/Why-do-fish-need-to-cross-the-road_booklet.pdf

Fisheries and oceans Canada. (2007). *Practitioners Guide to Fish Passage* [online]. [cit. 2012-01-15]. Retrieved from http://www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/passage/page01-eng.asp

Ladec, G., Quintero, J. D. (2003). *Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects* [online]. [cit. 2012-01-30]. Retrieved from http://siteresources.worldbank.org/LACEXT/Resources/258553-1123250606139/Good_and_Bad_Dams_WP16.pdf

Tichý, M. (2006). *Risk control: analysis and management*, (in Czech). Prague, C. H. Beck.

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Modelling of groundwater level regime during flood periods.

Tatiana Pindjaková, Andrej Šoltész, Dana Baroková

Abstract
The contribution deals with groundwater model creation for methodology of developing flood hazard maps caused by groundwater flooding. The methodology consists of groundwater level regime simulation (GWL) in the period of extreme hydrological conditions. The problem was solved using numerical modelling by means of TRIWACO simulation software(Royal Haskoning, 2002).

Key words:
Flood, Groundwater, TRIWACO

Introduction

The Flood Protection Law No 7/2010 in Slovakia defines a flood as a "temporary flooded area which is usually not covered by water". This law, inter alia, also defines a flood caused by increased groundwater (GW) above the surface, what is the consequence of long-lasting high water level conditions in the river. Ministry of Environment of the Slovak Republic in the area of the flood prevention may impose the obligation to the Slovak Hydro-meteorological Institute to ensure the elaboration of „flood hazard maps caused by groundwater excess" up to the June 22, 2012 and thenafter every 6 years.

Material and methods

For demonstration an area in lower part of rivers Nitra and Žitava was chosen. During the flood situation in 2010 such a problem appeared. The area was not flooded by water surface water surplus (Korytárová et. al, 2007) but by increased GW over the surface http://novezam ky.sme.sk, http://hnonline.sk

It is important during creation of the model (Šoltész, Baroková, 2010) to select boundary conditions properly. Determination of the boundary was based on the map of the quaternary sediments (Bodiš et. al., 2004), which is shown in the Fig. 1. The boundary was marked by territory of the quaternary sediments from the west, east and northern parts. The polygon is completed by curve from the north, which passes just over the village Komjatice, Černík and Kmeťovo as it is shown in Fig. 2. Polygon was completed by line from the south, which passes through the Nitriansky Hrádok village.

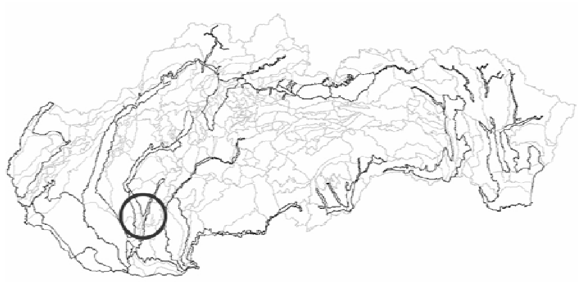

Fig. 1 Part of quaternary map of Slovakia

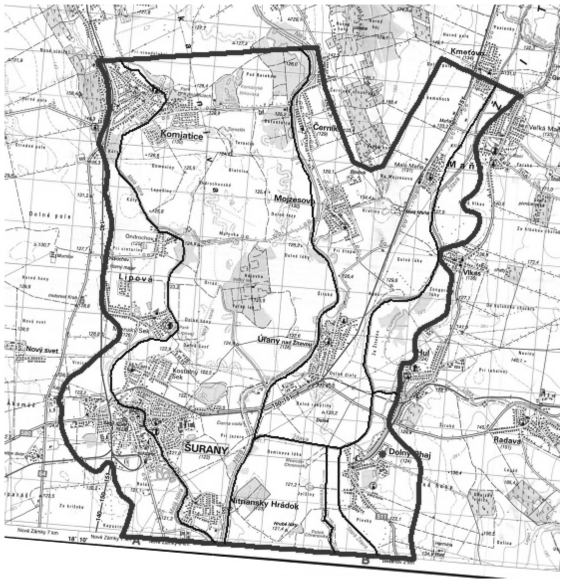

Fig. 2 The area of interest illustrated in tourist map.

It was also necessary during model creation to specify additional parameters to create a final element mesh. It includes rivers (Nitra, Malá Nitra, Žitava, Stará Žitava, Liska and Chrenovka) which flow in the area and set up the polygons to size value of triangle shape element. (Program system TRIWACO works using finite element method).

The groundwater values as boundary conditions in specified area were known from SHMI (Slovak Hydrometeorological Institute) (SHMI, 2000-2010) groundwater observation bore-holes. On that part of boundary, where the GWL was known the Dirichlet boundary condition was set up. On that part of boundary where then GWL was unknown the Neumann boundary condition was used with no-flow value condition. It was considered that a bad estimate of boundary condition value significantly may not affect modelling results, because of area of interest (Fig. 3) being far from the boundary.

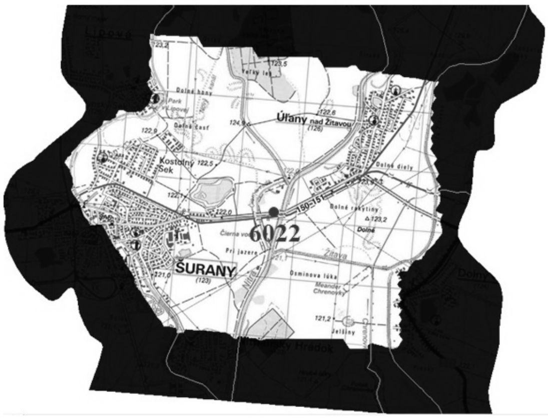

Fig. 3 Area of interest with location of the observation well 6022

Calibration of model in steady state conditions consisted of setting the parameters of the model so that the model is the best copy of reality and between average values (which were measured) and calculated values were not so great differences. When the finite element mesh was made and boundary conditions were set it was necessary to enter other general parameters. They consisted of digital terrain model, precipitation excess, top of the aquifer bottom of the aquifer and its hydraulic conductivity (or transmissivity) (Burger, 2011), river water levels, width of the river and its resistance (e. i. drainage and infiltration resistance of the clogging thickness of the river bottom). Drainage and infiltration resistance (Zaadnoordijk, 2009) were considered as calibration parameters, which influenced the quality of model (Dulovičová, Velísková, 2011), (Šebová, Velísková, 2011). Calculations were started for steady state simulation and free surface conditions.
Results of simulation, e. i. piezometric head or GWL is shown in Fig. 4.

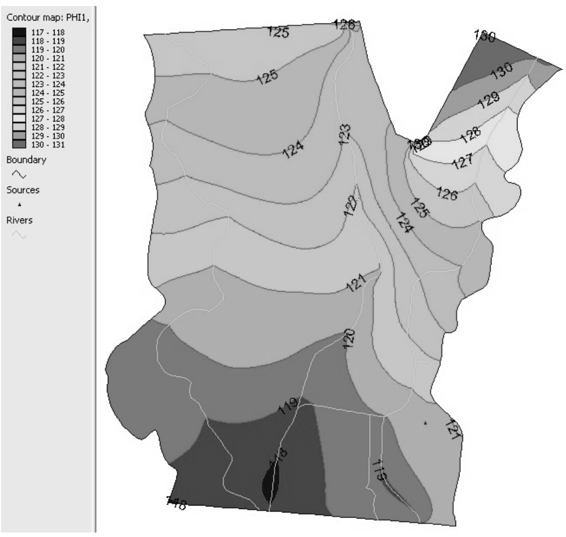

Fig. 4 Contours of the groundwater level.

The sum of the differences between measured and calculated values of GWL in the whole observation SHMI wells was not more than 0,1 m, it means that model reflects the reality sufficiently. The time period for unsteady simulation was set from December 21, 2005 to July 5, 2006. It was a period of extreme rainfalls occurred (Várallyay, 2008). Setting up other parameters as the specific storativity, effective porosity as well as repairing the drainage and infiltration resistance (Šlezingr, Pelikán 2011), which were set in steady flow calculation affecting the quality of the transient model and on its calibration process. For the calculation following data were available: daily precipitation, daily mean water levels in the Nitra River (rkm 22) and change of water level in meters in this reach. Our assumption was that water level in river fluctuated steadily in the whole section. We recommend this simplification in implementing the methodology in practice to replace the model of river flow in open channels in transient flow. Comparing calculated and measured groundwater regime we concentrated on observation well 6022 illustrated in the Fig. 3 and groundwater regime should not be influenced by boundary conditions. Match of measured values of SHMI and calculated model in observation well 6022 was sufficient for the verification of the model.

Calibration of transient simulation, verification of the model and results of simulation
The aim of verification is to show the credibility of model by using calibrated values of porous media (Pařílková, et. al. 2011) parameter for reproduction of a new independent set of terrain measurement (Baroková, 2006). Another time period (from 1.1.2009 to 27.10.2010) was set for verification of unsteady flow model. Measured values of GW in observation well 6022 are the results of simulation and parameters which were defined in calibration of calculation were confirmed. Evaluation of model was focused on the first half of year 2010 (from January 1, 2010 to August 8, 2010), because exactly during this period in the area of lower Nitra water levels occurred floods (Pekárová et. al. 2011), which were caused by groundwater surplus. http://novezam ky.sme.sk, http://hnonline.sk, (Pindjaková, 2011). The result of simulation is the time period of groundwater regime under the terrain, e. i. "map of flood caused by groundwater" for the model area. This map is figured in the Fig. 5 for day June 6, 2010, which shows maximum groundwater level in model time. Based on such a map areas flooded by groundwater can be determined (Šlezingr, Korytárová, 2007).. The area, which

is illustrated in the map (fig. 5) with dark colour will be submerged or flooded by ground water during the flood.

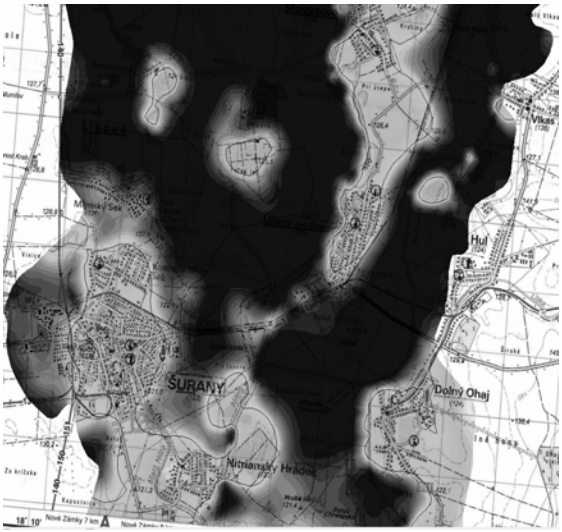
Fig. 5 “Map of flood caused by groundwater“

Results and discussion
The aim of this article was to determine the methodology of a "map of a flood caused by groundwater ". Programming system used for preparation of such maps was Triwaco modelling program used mostly for solving unsteady groundwater flow. Lower parts of the Nitra and Žitava rivers were chosen for verifying the possibilities of using the model of flooding by groundwater surplus.. This article describes a model that results in a „map of flood caused by groundwater. Using this model it can be decided if the flood is caused by groundwater or not. The model was calibrated for both steady and unsteady flow. Calibration of the model consisted of setting following parameters: specific storativity, effective porosity as well as drainage and infiltration resistance so that the model faithfully replicated the fact that differences between calculated and measured values of groundwater level in observation well were minimal. Calibrated model was used to develop a „map of flood caused by groundwater“. After considering the hydrological and meteorological data and having an exact digital terrain map as well as simulated flow of extreme precipitation excess and water flow in river available (if water will no overflow the levees) this method can be used as methodology for creating „maps of flood caused by groundwater”. This means it can be used for solving map of arbitrary area by the rivers which is temporary covered by water. These maps can be used also in conclusion of insurance contracts because of flooding.

References

Baroková, D. (2006). *Určenie vplyvu vodnej stavby na hladinový režim podzemných vôd a možnosti jeho regulácie*. Bratislava. Edícia vedeckých prác STU, 154 p.

Bodiš, D., Kullman, E., Malik, P., Hornáčková - Patschová, A. (2004). *Vymedzenie útvarov podzemných vôd na Slovensku. Národná správa 2004 – časť podzemné vody*, Bratislava, SHMÚ.

Burger, F. (2011). *Change of Groundwater Flow Characteristics After Construction of the Waterworks System Protective Measures on the Danube River – A Case Study in Slovakia.* Studies on Water Management Issues, Edited by: Muthukri-shnavellaisamy Kumarasamy, InTech, Croatia, 53-76

Dulovičová, R., Velísková, Y. (2011). *Sediment Impact on Surface Water and Groundwater Interaction at Gabčíkovo-Topoľníky Channel (Žitný ostrov).* XXVth Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management, Budapest, VITUKI, 1-14

Gomboš, M., Pavelková, D. (2011) *Estimation and planar presentation of forecasted changes of soil water storage caused by the climate changes*. Növénytermelés, vol. 60, supplement, 353-356.

Korytárová, J., Šlezingr, M., Uhmanová, H. (2007) *Determination of potential damage to representatives of real estate property in areas afflicted by flooding*. Journal of Hydrology and Hydromechanic, roč. 2007, č. 4, 282-285.

Možiešiková, K., Sopková, M., Švasta,J. (2007) *Povodie Nitry a Žitavy – modelovanie režimu podzemných vôd* (TRIWACO), 14. Slovenská hydrogeo- logická konferencia, SAH, Btratislava

Pařílková, J., Gomboš, M.; Tall, A.; Pařílek, L.; Kandra, B., Pavelková, D. (2011). *Soil moisture impakt on electrical impedance of porous environment.* In Transport vody, chemikálií a energie v systéme pôda - rastlina - atmosféra. neuv. Bratislava: Institute of Hydrology SAV, 127-139.

Pekárová, P., Škoda, P., Majerčáková, O., Miklánek, P. (2011). *Významné povodne na území Slovenska v minulosti*. Acta Hydrologica Slovaca, roč. 12, č. 1, 65-73

Pindjaková, T. (2011). Vplyv povodňovej vlny v povrchovom toku na režim podzemných *vôd*, Diplomová práca, Bratislava, SvF STU v Bratislave.

Royal Haskoning (2002). *Triwaco a simulation package for groundwater*, Version 3.0 internal release RH, Royal Haskoning division water, Rotterdam, Netherlands.

SHMI – Slovak Hydrometeorological Institute in Bratislava (SHMÚ) teplota, denný úhrn zrážok, vodný stavy hladiny v rieke Nitra, hladiny podzemnej vody - režimové merania pre roky 2000 - 2010 (v digitálnej podobe)

Šebová, E., Velísková, Y. (2011). *Faktory ovplyvňujúce interakciu povrchových a podzemných vôd - doterajšie skúsenosti a výsledky.* Physics of Soil Water - 18th slovak - czech - polish scientific seminar. Influence of Anthropogenic Activities of Water Regime of Lowland Territory - 8th International Conference, ÚH SAV, Michalovce, 453-466

Šlezingr, M., Korytárová, J. (2007). *Practical Using of Methodology of the Potential Flood Loss Assesment*. Wasserbau kolloquium 2007. TU Dresden, Dresden, 235-240.

Šlezingr, M., Pelikán, P. (2011). *Methology for the establishment of physical and geometric properties of a drainage basin*. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* roč. LIX, č. 6, 265-270.

Šoltész, A., Baroková, D. (2010) *Hydro informatika 2. čast*, *Simulácia prúdenia podzemnej vody v pórovitom prostredí*. Bratislava, STU, 161p.

Tall, A. (2010) *Impact of predicted climatic changes to the groundwater level in lowland territory.* Növénytermelés. Vol.59, suppl. 3, 239-242.

Várallyay, G. (2008). *Extreme soil moisture regime as limiting factor of the plants' water uptake*. Cereal Research Communications, VOL. 36, no. 1, s. 3-6

Zaadnoordijk, W. J. (2009) *Simulating Piecewise - Linear Surface Water and Ground Water Interactions with MODFLOW*, Ground Water, Vol 47, No. 5, 723-726

http://hnonline.sk/slovensko/c1-44050360-ulanu-nad-zitavou-zaplavuje-spodna-voda-hrozi-uz-aj-rieka-nitra

http://novezamky.sme.sk/c/5411205/zitava-klesla-domy-nadalej-zaplavuje-*spodna-voda*.html

Zákon o ochrane pred povodňami Z. z. č. 7/20 10. www.zbierka.sk

Acknowledgement

This article was elaborated on base of financial support of the VEGA agency project No. 1/1011/12.

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3D modelling of flow for design and optimisation of flood protecting hydraulic objects operation

Martin Orfánus, Andrej Šoltész

Abstract
The article deals with application ability of three dimensional mathematical CFD (Computational Fluid Dynamics) model. The analyses were carried out for functional object of Holombek 1 polder in frame of the „Creation and development of environmental technologies at flood protection of urban areas in Small Carpathian region - Modra case study“ (ITMS project code 26240220019) supported by the Research & Development Operational Programme funded by the ERDF. Polder is situated in the area above the Modra city. The steps of pre-processing, processing and post-processing of CFD simulation is described in (Orfánus, 2011).

Keywords:
Computational fluid dynamics, flood protection, polder, hydraulic structure

Introduction

The aim of article is to describe the utilization of CFD software for three-dimensional simulation of water flow for functional objects of the Holombek 1 polder situated in the area above the Modra city (Fig. 1)

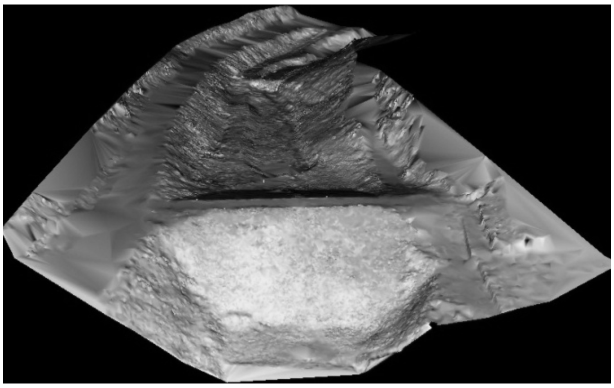

Fig. 1 The Holombek1 polder visualization

CFD („Computational fluid Dynamics), a 3D modelling program, is modern tool of the computational simulating program group well known as the Computer-aided Engineering (CAE). The Computational fluid Dynamics is based on theoretical fluid mechanics. The laws such as the momentum conservation law and the energy conservation law are formulized as the continuum equation, the energy equation and the motion equations also known as the Navier – Stokes partial differential equations. Using simplification of these equations on so called Euler CFD equations for the non-viscous flow and by the space discretisation it is possible to solve the fluid flow on the field of computation technologies by iterative methods. The solution scheme for the hydraulic object Holombek 1 polder was selected as explicit with finite element method.

Material and Methods

The model geometry is copying the geometry of the physical model. The precision of the geometry is specially aimed on hydraulic object's interior. The geometry corresponds to the reality in terms of dimensions and disposition (Fig. 2). The basic geometry model was created by using the CAD application (Rumann, Orfánus, 2011).

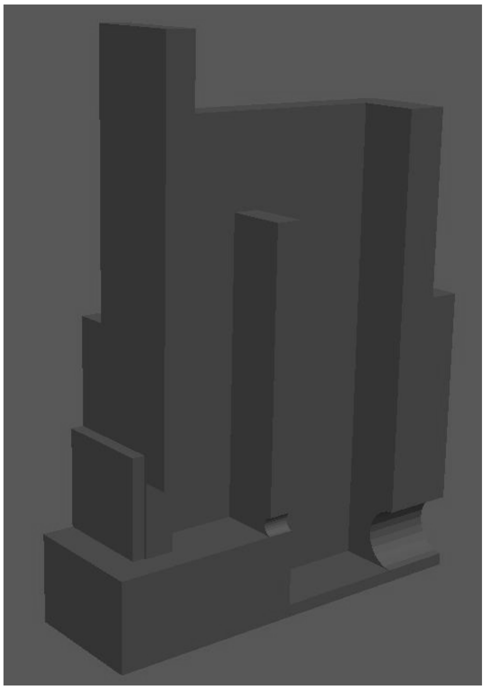

Fig. 2 Functional object geometry of the Holombek 1 polder

The discretisation of model was created by unstructured tetrahedral mesh generation with the cell size approximately of 0.15m (Fig. 3) and total number of 272 337 cells. Tetrahedral cells were than transformed to polyhedral mesh (Fig. 4).
Boundary conditions for this model were set as velocity inlet on the upper side of model and pressure outlet on the lower side of model. Turbulent flows are characterized by fluctuating velocity fields. These fluctuations mix transported quantities such as momentum, energy, and species concentration, and cause the transported quantities to fluctuate as well. Since these fluctuations can be of small scale and high frequency, they are too computationally expensive to simulate directly in practical engineering calculations. Instead of

the instantaneous (exact) governing equations can be time-averaged, ensemble-averaged, or otherwise manipulated to remove the resolution of small scales, resulting in a modified set of equations that are computationally less problematic to solve. However, the modified equations contain additional unknown variables, and turbulence models are needed to determine these variables in terms of known quantities (Ansys Inc, 2009). For this case the turbulence was set as shear-stress transport k-ω model.

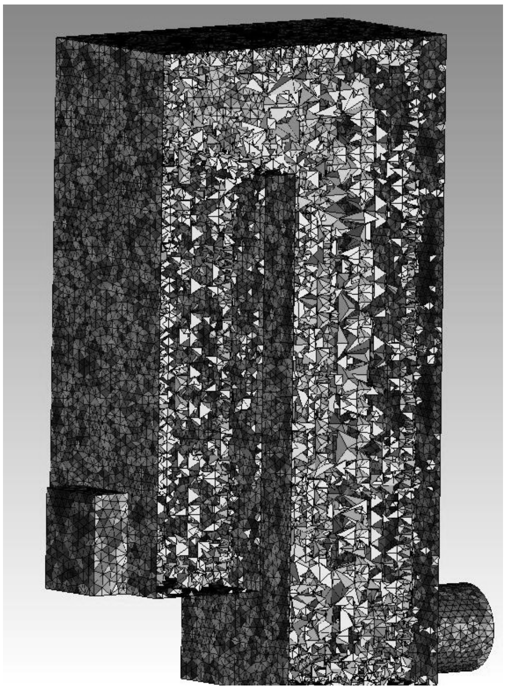

Fig. 3 Tetrahedral mesh

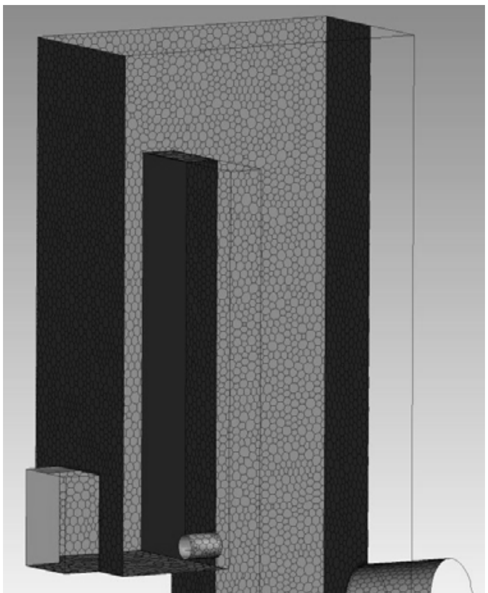

Fig. 4 Polyhedral mesh

The shear-stress transport (SST) k-ω model was developed to effectively blend the robust and accurate formulation of the k-ω model in the near-wall region with the free-stream independence of the k-ε model in the far field (Fig.5). To achieve this, the k-ε model is converted into a k-ω formulation (Ansys Inc, 2009).

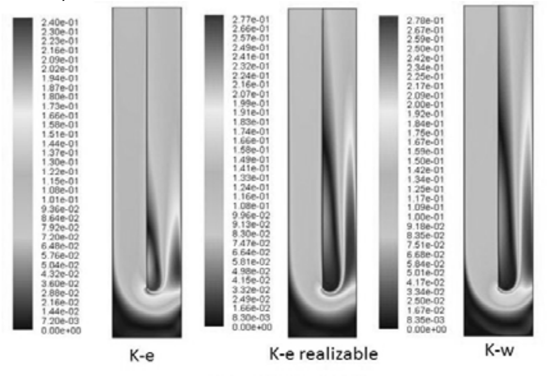

Fig. 5 Difference between turbulence models

The necessity of such a simulation is to deliberate the influence of the water free surface level. A volume of fluid model was used to implement this influence to the simulation. The volume of fluid (VOF) model can simulate two or more immiscible fluids by solving a single set of momentum equations and tracking the volume fraction of each of the fluids throughout the domain. Typical applications include the prediction of jet breakup, the motion of large bubbles in a liquid, motion of liquid after a dam break, and the steady or transient tracking of any liquid-gas interface (Ansys Inc, 2009).

Results and Discussion

The CFD model simulation results are showing a detailed overview on water dynamics flowing through the functional hydraulic object of the Holombek 1 polder above the Modra city (Fig. 6, 7, 8). The possible exploitation of these results is large and capable for analyses of such objects. Nowadays the cutover calculations are made to validate the simulation results as well as the measurement of discharge and velocity field in situ are about to made during the flood in service area.

Conclusion

The aim of this article was to describe the example of CFD software utilisation by simulating the water flow through the functional object of the Holombek 1 detention dam. It should be alleged that three-dimensional mathematical model CFD is applicable tool for water flow dynamics analyses of polder functional objects as well as for other hydraulic problems.

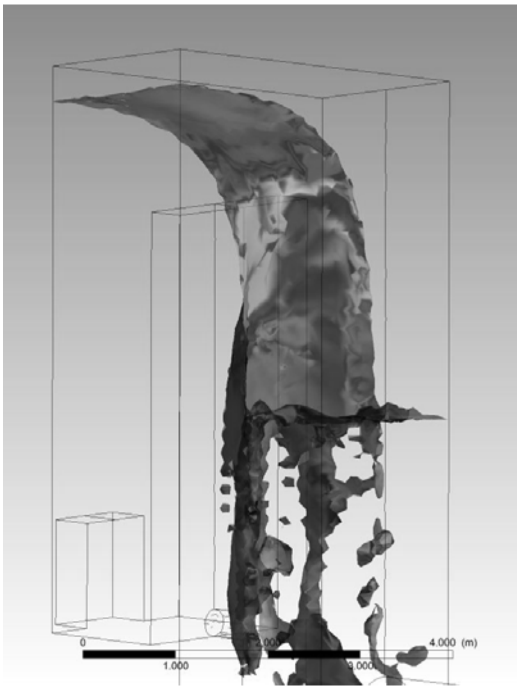

Fig. 6 The water level position

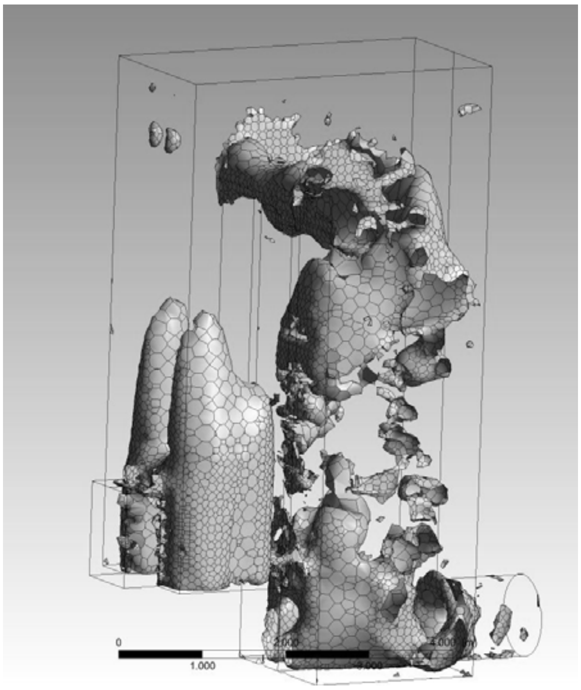

Fig. 8 Swirling strength in the object

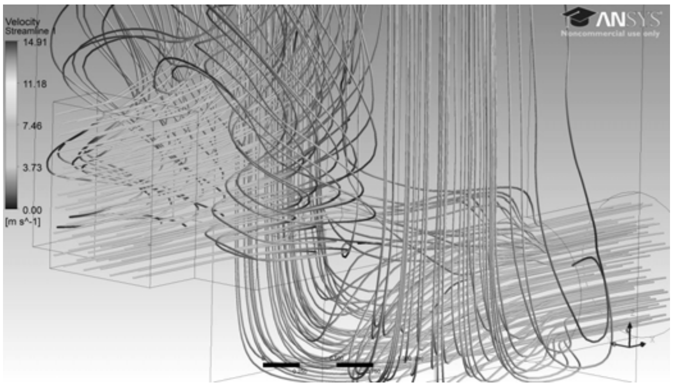

Fig. 7 Streamlines detailed view at the inlet

References

Ansys Inc (2009). *ANSYS FLUENT 12.0 User's Guide*.

Orfánus, M. (2011). *3D modelovanie prúdenia pre návrh a optimalizáciu prevádzky hydrotechnických objektov protipovodňovej ochrany.* Súťaž doktorandov Svf. Bratislava

Rumann, J., Orfánus, M. (2011). *Assessment of the floating barrage on the flow in the intake structure at Dobrohošť.* WMHE 2011.Gdansk.

Acknowledgement

Creation and development of environmental technologies at flood protection of urban areas in Small Carpathian region - Modra case study, (ITMS project code 26240220019) supported by the Research & Development Operational Programme funded by the ERDF.

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Multi-Dimensional Mathematical Modelling of Water Flow in Water Management Facilities

Ivan Valachovič, Radomil Květon

Abstract

The purpose of this study was to assess the impact and use of 2D and 3D modelling of real objects in the water management practices for building small hydropower Dobrohošť sampling. For this purpose, in order to address this issue following questions:

- Effect on the submersible walls MVE Dobrohošť object
- The possibility of biological facilities flow
- The resulting speed fields
- Performance 2D model
- The question of the possibility of using 3D model

The work was designed 2D and 3D model on a finite differences method and the derivation of the shallow water equations.

Keywords:
Mathematical, modelling, water flow

Introduction

Multivariate mathematical 2D and 3D modelling of flow of water in buildings is an appropriate tool for the preparation of projects and optimize the VH already implemented VH objects. (DHI. 1994) Other benefits can include:

- significant reduction in preparation time and financial costs for implementing the physical model
- training and support supervisory control WM object
- simulate emergencies WM objects - a breakthrough wave
- Simulation of flooding and the associated mapping of risk areas, design of flood protection measures

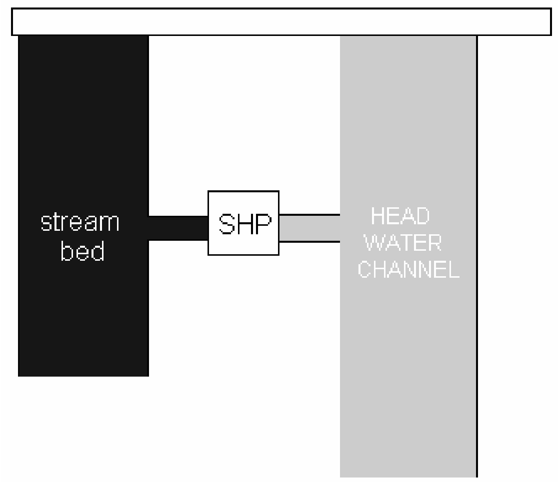

Fig. 1 The scheme links the supply channel and the riverbed through the SHP

Mathematical modelling can not completely replace physical modelling in laboratory conditions, but significantly reduces the number of simulated variants of technical solutions and thus significantly reduces the time needed for laboratory research that is needed especially for the implementation of costly buildings.

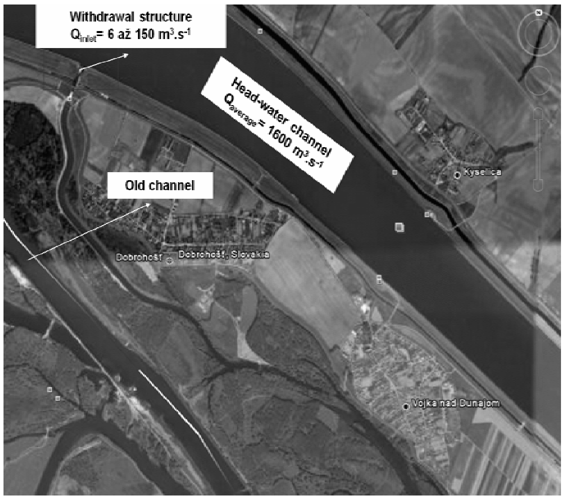

Fig. 2 Supply of water withdrawal structure Dobrohošť the Danube branch system

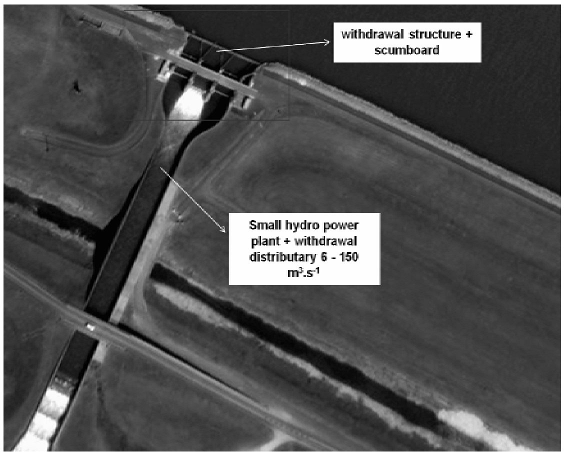

Fig. 3 Orthophoto map Dobrohošť withdrawal structure - details

Materials and methods

The theoretical basis for providing fluid dynamic equations for a constant density. System of differential equations, shallow water can not be solved analytically, it is therefore necessary to use approximate solutions based on numerical methods. These equations are used in the numerical solution based on finite elements. Contain dissipative elements, which are replaced in the calculation so. artificial disipation. The most common methods of this type are finite-difference method (Stelling, 1984) and finite element (Květon, 2006).

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}-fV+g\frac{\partial \zeta}{\partial x}- \tag{1}$$
$$-\frac{KW^2}{H}cos\,\psi+\frac{gU\left(U^2+V^2\right)^{1/2}}{HC^2}=0$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+fU+g\frac{\partial \zeta}{\partial y}- \tag{2}$$
$$-\frac{KW^2}{H}sin\,\psi+\frac{gV\left(U^2+V^2\right)^{1/2}}{HC^2}=0$$

The initial conditions $Q(x,y,t_0)$ and h $h(x,y,t_0)$ are the values corresponding to steady flow in the canal overflow with Q = 1600 $m^3.s^{-1}$ and the water level in modelling object h = 4,8 m. Boundary conditions of the model can be given on the modelled area of the building Dobrohošť divided into:

- upper boundary conditions of type Q(t)
- lower boundary conditions of type Q(h)

The upper and lower boundary conditions varied depending on the flow-through scenario. Given that they can compare the results obtained with the MM measurement of physical research. Another parameter is the absolute roughness, which is not dependent on modelled scenarios and consistently awarded for the entire model area with the value Δ = 0,025. These values have been successively used as inputs for the mathematical model.

Results and discussion

The actual model outputs show the logical sequence of processes in the course of modelling object. Results of mathematical modelling are also derived for two types of scenarios already mentioned and the flow-through and immeability scenario. Achievements can be compared either with the measured values or values derived on the basis of physical research. The benefits are not just 2D modelling data to determine the boundary conditions for the 3D model, but also the basis for selection of an appropriate 3D model. Based on the results obtained, which were compared to show the setting up of the 3D model to be justified. It is also an important conclusion, namely that due to tolerable levels the difference is the possibility of application of the 3D model with a constant 3D computer network. As is mentioned in the following sentence. For example, applications of 3D models based on artificial compressible fluid assumes negligible differences in kótach level - a constant enables the use of network computing.

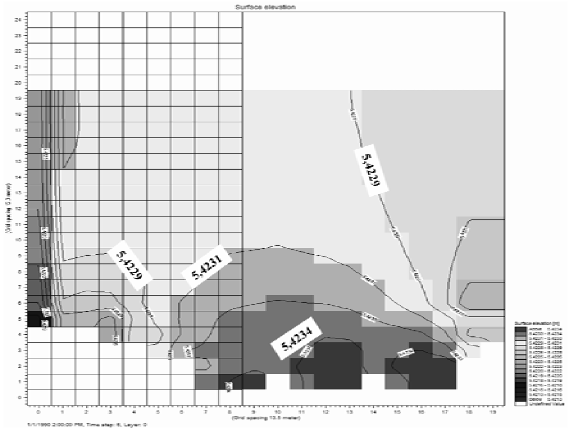

Fig. 4 Graphical output modelling using MIKE 21

Conclusion

Based on the achievements of mathematical modelling and subsequent comparison with the results of physical modelling to arrive at these conclusions:

- efficient use of 2D model has proven to be acceptable in terms of outputs using a 3D model
- achieved by comparing the differences between 2D model and measurements need only be able applications of 3D model
- difference levels of output-based 2D model has proved acceptable to build a 3D model with constant computer network

The ideal would be to link data obtained from measurements of the field for calibration and verification of mathematical models.

References

Květon, R. (2006) *Matematické modelovanie prúdenia vody v otvorených korytách*, Habilitačná práca. Bratislava : STU SvF. 106 s.

DHI. (1994) *Sand Transport Processes* User Guide, Denmark: DHI Water & Environment. 95 s.

Stelling, G.S. (1984). *On the Construction of Computational Methods for Shallow Water Flow Problems*. Rijskwaterstaat Communications, (No. 35/1984)

Acknowledgement

This article was elaborated on base of financial support of the VEGA agency project No. 1/1011/12.

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Innovation in determining saturated hydraulic conductivity in porous soils (substrates).

Michal Henek, Radek Dymák,
Miroslav Kinc, Miroslav Kravka

INTRODUCTION

Saturated hydraulic conductivity is a parameter commonly determined to evaluate the physical characteristics of soil. It is a state of soil saturation - all pores are filled with water, which moves through the gradient in the sense of Darcy's law. From the point of hydrology and water management, saturated hydraulic conductivity is significant in the processes of rainwater infiltration and water movement in soil.

A number of authors have already described the narrow relation between hydraulic conductivity and infiltration rate. Some of them emphasize the high time and spatial variability of these physical characteristics (e.g. Corradini et al., 1998; Van Dam et Feddes, 2000; Diskin et Nazimov, 1995 and 1996; Meng et al., 2006). These parameters are obviously affected by the amount of soil organic matter, which influences occurrence of macropores and soil aggregates (Langhans et al., 2011). The parameters of soil organic matter, particularly its volumes in topsoil, are sometimes considered the basic indicators of soil quality (e.g. Franzluebbens, 2002a,b).

Mathematical models also report high variability of these physical soil characteristics in natural conditions (Buczko et al., 2006, Cerda, 1997; Meng et al., 2006; Moret-Fernández et Gonzáles-Cebollada, 2009). Very limited data have been acquired by direct field measurement and measurements on large areas provide even less information – Gvirzman et al. (2008) bring interesting conclusions in this respect.

The aim of the present work was to determine saturated hydraulic conductivity in materials which represent substrates potentially suitable for growing plants and/or land reclamation. Based on the published results, movement of water in saturated soil may be considered as a limit condition for water infiltration in soil. While infiltration itself is relatively difficult to determine (due to complicated repetition, i.e. creation of equal initial conditions), saturated hydraulic conductivity may easily be measured, which is important in practice.

METHODS

Fig. 1 depicts the principle of determining saturated hydraulic conductivity. The difference in water levels (levels A and B) creates a hydraulic gradient in the measured sample. If level A is kept constant (by adding water) and the difference between the levels is sufficiently high, the water in the sample begins to move. The rate of this movement is determined as the volume of water flowing per time unit. Saturated hydraulic conductivity has a dimension of rate, which we determine by a simple calculation according to Darcy's law. As stated above, the test to determine the hydraulic conductivity may be used to define the basic hydrological and pedological characteristics of soils and substrates, and the obtained data may further be used for a wide range of outputs – from modelling infiltration to quality control in substrate production.

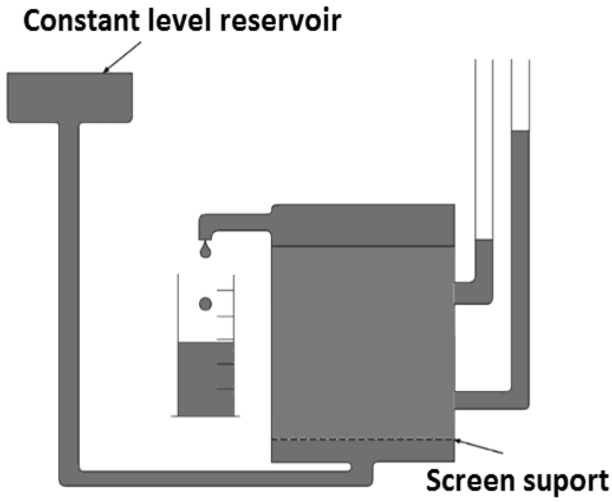

Fig. 1: Principle of determining hydraulic conductivity. The reservoir on the left is designed to hold a constant water level, i.e. a necessary gradient is created and transported to the soil sample (illustrated in orange). If the gradient is sufficiently high, the water begins to move through the soil sample (saturated). We may calculate the hydraulic conductivity of the sample by measuring the volume of flowing water per time unit.

Appliances commonly used in soil physics to determine hydraulic conductivity are not suitable for materials showing high contents of organic matter. In such cases, the gradient of water levels has to be relatively small (substrates are significantly more pervious than common soils). In order to evaluate the synergy effect with soil organic matter, root systems, etc., a maximum size of an undisturbed soil sample has to be used. Taking such samples is complicated though. For this reason, we have developed an innovated appliance Henek 2 – type WC/200mm (Garate et al., 2011). Its main advantage is that its sample cylinder (Fig. 2– 4) is large enough to be planted with vegetation. To conduct standard determination of hydraulic conductivity, the soil samples must be undisturbed. This further complicates the practical use of this method. Based on our experience, the same effect (i.e. an undisturbed sample) may be acquired using our innovated appliance. The soil is left in the cylinder for a period of approximately 2 ½– 3 months under controlled conditions (moisture, temperature) and possibly planted with vegetation. Thus, it may be considered as an undisturbed sample (this does not apply to heavy soils, which are not subject to the present research, though).

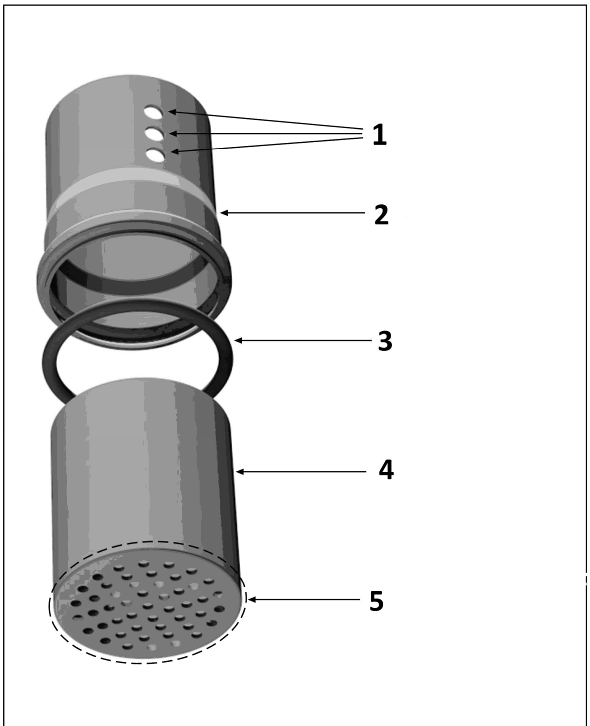

Fig. 2: Design of appliance 1) water excess outlets, 2) pressure cylinder, 3) rubber, 4) sample cylinder, 5) outflow for water to measure

Four types of substrates were selected for testing (Chart 1): to control the influence of organic matter, substrate No. 1 was prepared of highly homogenous and pure (no loam or gley particles) fine sand of fraction 0.0–0.15mm. Substrates No. 2–4 always contained 50% of peat.

Chart. 1: Composition of tested substrates.

Sample No.	Mineral Contents		Organic Contents	
	Description	% Vol.	Description	% Vol.
1	sand fraction 0 – 0,15 mm	100	--	0
2	fire clay, fraction 1 – 3 mm	25	peat	75
3	rubble, fraction 0 – 4 mm	25	peat	75
4	construction sand, fraction 0 – 0,75 mm	25	peat	75

As a control sample, sample No. 1 was neither mixed with organic matter (peat) nor sown and thus represented a homogenous sample with presumed constant hydraulic conditions. Substrates No. 2–4 were planted with vegetation (*Medicago sativa*) and left outside to consolidate during the period of 8 weeks. The final sample represented a model theoretically resembling undisturbed conditions. The sample was sown for two reasons: (1) to model the natural conditions to a maximum extent, i.e. to include the effects of a root system, (2) the plants served as indicators of a suitable water regime.

Fig. 3: Filling up the appliance with the tested substrate. From left to right: empty cylinder (apparent drainage holes at the bottom); geotextile as a separation layer; filling up with substrate (height approx. 30cm, diameter 20cm, i.e. volume approx. 9.5 litres); sowing, covering seeds with a thin layer of substrate.

The samples exposed to outside conditions (with plants and irrigated) were transported to the laboratory. The above ground parts of the plants were carefully removed, including all affected (dead) leaves that might block the flow profile, which were removed using tweezers. This was immediately followed by the actual measurement (to avoid any desiccation of the samples).

The following parameters were set for the appliance: difference in levels = 830mm, sample height = 300mm, diameter = 200mm. Along with the flow rate, these data serve to calculate the filtration coefficient.

RESULTS AND DISCUSSION

Fig. 4 shows the measured data and Chart 2 illustrates their assessment.

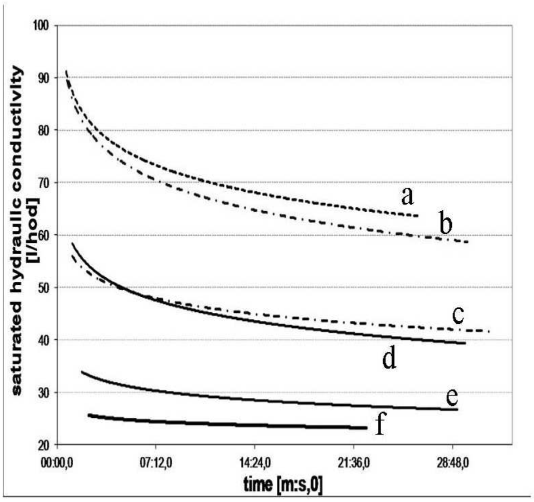

Fig. 4.: Acquired values of saturated hydraulic conductivity in time. Description of individual curves: a = sample No. 3. (rubble); b = sample No. 4 (construction sand + peat) first measurement; c = sample No. 4 (construction sand + peat) second measurement; d = sample No. 2 (fire clay + peat) first measurement; e = sample (fire clay + peat) second measurement; f = control (fine sand).

The acquired data prove that the intensity of infiltration (saturated hydraulic conductivity) depends on granularity of the mineral component. Compared to the control sample, the individual variants of substrates show a significantly higher diversity with the given volume. This explains the changes in the flow rate in time (the initially high flow rate gradually slows down), which further decreases during repeated measurement.

Chart 2: Assessment of acquired data for individual substrates and sequence of measurements. The second measurement was conducted approximately 20 minutes after the end of the first measurement. The trend equation determines the logarithmic equation of dependence and a coefficient of R2 determination. Letters a–f conform with the curves in the graph, Fig. 4.

Variant	Trend equation	R^2	Curve
Rubble	y = -7,502ln(x) + 33,524	0,968	a
Construction sand + peat, first measurement	y = -8,264ln(x) + 26,665	0,934	b
Construction sand + peat, second measurement	y = -4,278ln(x) + 25,218	0,968	c
Fire clay + peat, first measurement	y = -5,802ln(x) + 16,767	0,920	d
Fire clay + peat, second measurement	y = -2,578ln(x) + 16,584	0,973	e
Fine sand	y = -1,04ln(x) + 18,861	0,788	f

A number of authors have recorded a similar diversity in the infiltration rate, particularly in field conditions. For example, Cerda (1997) noted changes in infiltration in individual seasons, and Dunne et al. describe a notable impact of vegetation (e.g. the infiltration rate in the zones of individual turfs significantly varies from the soil without turf. Mocropores represent another important influence.

REFERENCES

BUCZKO, U., O. BENS and R. F. HÜTTL. Water infiltration and hydrophobicity in forest soils of a pine-beech transformation chronosequence. *Journal of Hydrology*. 2006, n. 331, p. 383-395. ISSN 0022-1694.

CERDÀ, A. Seasonal changes of the infiltration rates in a Mediterranean scrumbland on limestone. *Journal of Hydrology*. 1997, n. 198, p. 209-225. ISSN 0022-1694.

CORRADINI, C., R. MORBIDELLI and F. MELONE. On the interaction between infiltration and Hortonian runoff. *Journal of ydrology*. 1998, n. 204, p. 52-67. ISSN 0022-1694.

DISKIN, M. H. and N. NAZIMOV. Linear reservoir with feedback regulated intel as a model for the infiltration process. *Journal of Hydrology*. 1995, p. 313-330. ISSN 0022-1694.

DISKIN, M. H. and N. NAZIMOV. Ponding time and infiltration capacity variation during steady rainfall. *Journal of Hydrology*. 1996, n. 178, p. 369-380. ISSN 0022-1694.

FRANZLUEBBERS, A. J. Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research*. 2002a, p. 95-106. ISSN 0167-1987.

FRANZLUEBBERS, A. J. Water infiltration and soil structure related to organic matter and its stratification with depth. *Soil and Tillage Research*. 2002b, n. 66, p. 197-205. ISSN 0167-1987.

Garate A., R. Dymák, M. Henek and M. Kravka. Assessment of impacts of soil organic matter on the physical properties of soils by testing consolidated container samples. Colloquium on landscape management 2011. 2011, p. 19-23. ISBN 978-80-7375-518-8.

GVIRTZMAN, H., E. SHALEV, O. DAHAN and Y. H. HATZOR. Large-scale infiltration experiments into unsaturated stratified loess sediments: Monitoring and modeling. *Journal of Hydrology*. 2008, n. 349, p. 214-229. ISSN 0022-1694.

LANGHANS, Ch., G. GOVERS, J. DIELS, A. LEYS, W. CLYMANS, A. VAN DEN PUTTE and J. VALCKX. Experimental rainfall-runoff data: Reconsidering the concept of infiltration capacity. *Journal of Hydrology*. 2011, n. 399, p. 255-262. ISSN 0022-1694.

MENG, H., J. D. SALAS, T. R. GREEN and L. R. AHUJA. Scaling analysis of space-time infiltration based on the universal multifractal model. *Journal of Hydrology*. 2006, n. 322, p. 220-235. ISSN 0022-1694.

MORET-FERNÁNDEZ, D. and C. GONZÁLEZ-CEBOLLADA. New method for monitoring soil water infiltration rates applied to a disc infiltrometer. *Journal of Hydrology*. 2009, n. 379, p. 315-322. ISSN 0022-1694.

VAN DAM, J. C. and R. A. FEDDES. Numerical simulation of infiltration, evaporation and shallow groundwater levels with the Richards equation. *Journal of Hydrology*. 2000, n. 233, p. 72-85. ISSN 0022-1694.

ACKNOWLEDGEMENT

Mendel University supported the research presented in this paper under IGA project no. 45/2012.

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New span for microhydropower systems (low flow – high heats)

Štefan Tkáč, Zuzana Vranayová

Abstract

There are several major water resources with great hydro-power potential within the Slovak Republic. To create a huge natural water flow there is always couple of small streams and little rivers joining together. The question that emerged is: are they not sufficiently equivalent hydro-power sources? As many villages, especially those in the mountain regions, posses at least one river flow. In many cases this flow is the annual cause of floods that negatively influence any of the micro-urban regions. The question that emerged is: can be this erratic natural force turned into an advantage for this kind of region by applying suitable device?

Keywords

Micro-urban energy sources, Small hydroelectric power plants, Water turbine

Introduction

Turbine is one of the effective mechanical devices (in case of correct constructional design and emplacement it might reach efficiency close to 70-75%, some sources also refers to 96% [1]) for change of the natural element (water) into usable form without producing any fumes or otherwise devastating the environment. Names like Kaplan, Francis, Pelton, Bánki [2], and others´ works are basic knowledge when we studying the step by step development of man's desire to use water power from the very beginning (e.g. water wheel) up to the present. To make water turbine working, a fundamental requirement needs to be fulfilled - the exploitable source of hydroelectric power.

In the nature the exploitable sources can be usually found in two boundary forms. There are abundant, stable year-round water sources with high flow and low heads and on the other hand unstable sources of low flow with high heads. Understandably, the best water energy source to be used would be the ideal flow of Amazon river with the heads of Alpine mountain streams. However before-mentioned situation does not really occurs in real natural conditions.

There are exactly huge amount of small water sources within the Slovak Republic (the country the device is intended to be applied in), the flow volume of most of them changing according to the season, so that they are relatively unattractive from the energetic (short term economical policy) point of view. But is it really so? The project considering the idea that even small water sources are useful for the needs of everyday life and their use can contribute to unload the electricity network, as heating of water, houses or power the less efficient household appliances like iron, electric cooker, vacuum cleaner, drinking water pump and so on. Micro-hydro systems can be an invaluable means, of bringing power to rural areas. In this way mechanical power for milling and electrical power for lighting, refrigeration and small industry can be generated to improve the quality of life and boost the economy in villages, which are not connected to the national grid [3]. Settlements and villages could cover local consumption of sewage plants too. It is like that famous 'drop' creating seas and oceans. Regional coverage of local energy sources would not need long distance high voltage electric wiring, transformer stations and the costs of the facilities associated with their maintenance and service. The utilization of water sources, even seemingly uneconomic in the case of short-term investments in micro-urban sector might significantly affect the energy policy in long term macro-urban sphere [4].

Description of experimental device

Energy cannot be produce or destroyed; only it changes its form. To achieve this transformation by using water turbine with as smallest losses as possible depends on the suitability of applied device. If it comes to the small sources, currently there are not exactly a large variety of forms. By summarizing knowledge from the field of study and setting the critical points of current practice, the inspiration search for the solution in real life took place.

The causes of unused small water sources were discussed and the opinion that this is due to the long - term return of entry investments was taken as a general idea. As a matter of fact on the other hand almost all the renewable and sustainable systems initially required high entry founds, but the returns are very slow processes [5].

The solution could be simple, efficient, reliable and affordable design of water turbine that would literally give a performance tailored to the specific water source [6]. This theoretical assumption was discussed with everyone who shows interest in this case, getting the most satisfactory outcomes and assurance in the areas that were unclean or in doubts. In addition, in collaboration with specialists mostly from engineer/mechanical designer's practice, many study drawings and final models with real dimensions were accomplished.

At the moment the ongoing laboratory works on research with a demonstration model at a scale of 1:2 shown in *Fig. 1* (on left), are in progress. This issue that has been solved for several months consists of proposing a new type of water turbine, especially tailored to the dimensions of small flow volumes and high heads. As the turbine could be made to fulfill the specific dimensions, matching the needs of concrete brook or local river, precise research for this kind of area must be done first. But in general basic information about local flow volumes, maximum as well as minimum height of water level could be usually found in written attachment of urban study of each county as it is prescribed by EU, that each village, town or city needs to have recent urban conditions mapped.

So if talking about villages in Slovakia, which have constant annual problems closely connected with floods, the water regulation is one of the mainly updated information [7].

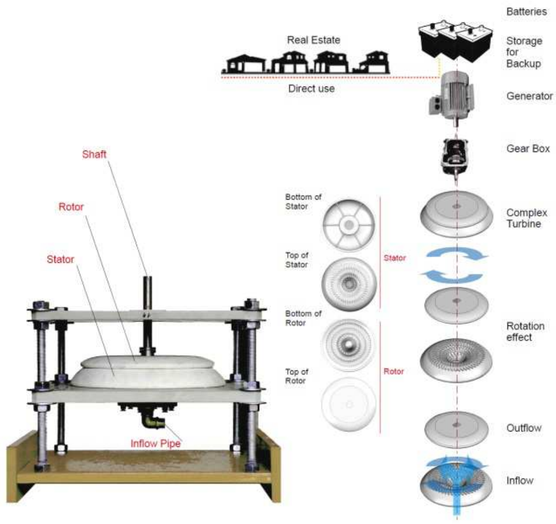

Fig. 1. The 'UFO' Micro-urban multipurpose turbine, composition and basic working principle

As mentioned above the water turbine is device that promotes sustainable, renewable and alternative resource using a rotary machine that creates electrical power by converting potential energy of water into mechanical one. According to the operation modes, turbines are divided into reaction, impulse and kinetic turbines. If talking about structures of current turbines in use, the most complicated, exposed and also expensive part is (except the wheel itself) the imposition of rotary axis, protection and lubrication of bearings, which often operates under the water surface [8]. Bearings have its limited circular speed, needs frequent checking and in many cases argued risk of lubricant leaking into the water environment makes turbine not as suitable ecological device. Proposed construction design does not have any of the rotor roller bearings, high pressure and low flow volume stream enters turbine where it is continually divided into several curved channels creating smaller streamlines, which force water to go in opposite directions, as shown in *Fig. 1* (right). Referring to the drawing in *Fig. 2* the rotor (1) is mounted directly to the stator (2). The working surface (an envelope curve of torus) of rotor fits the torus - like surface of stator. Rotor is constantly pushed into the stator by buffer spring (4) that means rotor is stabilized inside the stator without any additional bearings equipment of rotary axis. In both working surfaces of stator and rotor there are small curved channels directed clockwise (on stator surface) and anticlockwise (on rotor surface). Channels are protruding to each other and they are designed as a centric circle like. Water stream coming from the bottom of the stator through the pipe (3) will be directed into the channels as a multiple streamlines and during passing between stator and rotor it will constantly changing its orientation which results into transmission of the kinetic energy to rotor. During the rotation, rotor is floating on the water film created between the both working surfaces, water flows on curved plane applies Bernoulli principles for fluids. Rotor is permanently sucked to the stator, which increases its stability. Rotor can be connected to the generator (6) directly or through the transmission. According to circumstances of this constructional solution, this kind of water turbine device could work as a pressurized, vacuum pressure or even under the constant pressure.

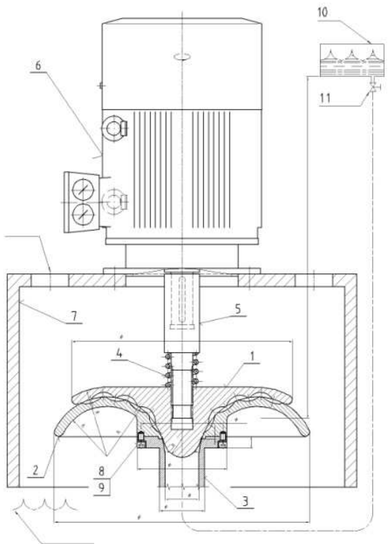

Fig. 2. The ‘UFO’ micro-urban multipurpose turbine, cross section

The proposed water turbine design should ensure greater and more economical hydro-power usability also for smaller water resources (mountain village brooks), which on the other hand have higher pressure heads. The project is focused on using small water resources through a new structural design of water turbine, to improve its qualities for economy as well as for the environment. In the proposed design the importance of solution, which includes a proposal consideration that leads to reduction in maintenance and operation costs, in regard to the small-scale source using? From the analysis of the initial data obtained the solution that emerged applies continual division of the water stream into the streamlines, uses self - stabilized floating rotor and constant turning of the stream flow.

Implementation

It is expected that after several tests including CFD (Computer Fluid Dynamics) test, appropriate balance methods and model laboratory/real conditions tests, the channels modifications might result, that the proposed ‘UFO’ Micro-urban multipurpose turbine will be able to work in all three modes (one gas and two water modes) presented in *Fig. 3.*

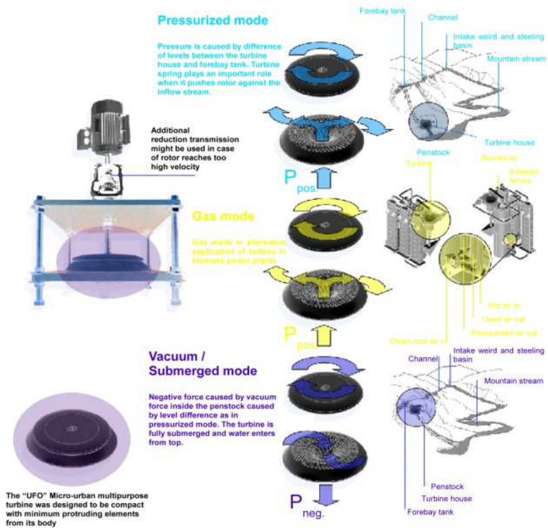

Fig. 3. The ‘UFO’ micro-urban multipurpose turbine, all working modes

Referring to *Fig. 3*, the gas mode might be applied in biomass power stations as a full-value replacement of combustion piston engines. If applied in micro-urban sphere including villages and small towns, biomass power plant equipped with suitable gas turbine might be a useful additional source of energy and also possible urban renewal project idea for all the old, mostly unused farms, which are located almost in each larger village across the whole Slovak Republic as a vestige of uniform agricultural cooperatives.

The two water modes presented in the mentioned *Fig. 3* are dealing with the water element located in Slovak micro-urban sphere as well. The proposal of the 'UFO' Micro-urban multipurpose turbine takes into a count the idea of local water streams that are located in most of the villages and are also the main cause of annual floods, because of unregulated water corridors. Slovakia is generally a mountainous country with sufficient volume of water supplies, so water energy is considerably important issue to develop even on the micro-hydro solutions level [9].

The pressurized mode shown in the *Fig. 3* is an ordinary application of impulse water turbine with high head where so called turbine house is located underneath the fore-bay tank and turbine uses advantage of positive pressure in penstock caused by the head.

In case of the 'UFO' Micro-urban multipurpose turbine the water that enters is not 'cut' by blades, but it is continually divided into several streamlines avoiding 'splash' looses and full water energy is used to create kinetic energy. Then the turbine operates as being in the reaction mode. The buffer spring acts as a presser that presses floating rotor ((1) in *Fig. 2*) into stator ((2) in *Fig. 2*) as the water enters turbine from bottom and gently lifts rotor ((1) in *Fig. 2*) creating water film.

The vacuum/submerged mode also shown in the *Fig. 3* is a kind of water turbine application that calculates with 'negative' pressure in penstock, caused also by head. In this example of application, turbine is submerged under the water directly in the fore-bay tank and the water surface must be above the rotor ((1) in *Fig. 2*) level at minimum. The water enters turbine from top and spring acts as a pulling force that pulls rotor ((2) in *Fig. 2*) and creating a suitable distance for water film between the rotor ((1) in *Fig. 2*) and stator ((2) in *Fig. 2*). Tail of the penstock must be submerged too because of the water pressure creation. It is expected that once this mode is finished, it might be more effective than the pressurized one explained above.

In micro-urban scale, this kind of applications might markedly contribute to the energy independence of micro-urban region in Slovak Republic.

Conclusion

The project deals with using seemingly energy uninteresting water sources by applying the new structural design of water turbine.

As the important solution was considered the one that includes a proposal, which leads to reduction of acquisition and operation costs, given the low efficiency of concrete resource. The solution that was created as a result of the analysis, divides the current into the streamlines, using self-stabilized floating rotor and turning flow direction.

Acknowledgements

Author´s grateful thanks go to doc. Ing. Zuzana Vranayová PhD. and prof. Ron Chen PhD. for constant encouragement, support and advisement as well as to all the members of Technical University of Košice, Faculty of Civil Enrineering and partner university Chung Hua University, Taiwan R.O.C., Department of Architecture and Urban Planning. The presented paper is component of the project VEGA 1/0450/12. Results are currently in theoretical phase and their strengths and weaknesses will be demonstrable in the subsequent period of research including realization, individual laboratory tests and final practical applications.

References

[1] Hydroenergia, *http://www.hydroenergia.sk/vodna-energia/*, (browsed on Sept. 14th, 2011)

[2] Top - Alternative energy-sources, *http://www.top-alternative-energy-sources.com/water -turbine.html,* (browsed on April 4th, 2011)

[3] Harvey A., Brown A. Micro-hydro design manual, A Guide to Small-Scale Water Power Schemes, Practical Action, 1993.

[4] Hodák T., Dušička P. Small Hydropowerstations, Jaga, 1998.

[5] International Hydro-power Association, http://www.hydropower.org/, (browsed on Sept. 14th, 2011)
[6] Davis S., Laschuk C. Microhydro, Clean power from water, New Society Publishers, 2003.
[7] Slovak hydrometeorological institute, *http://www.shmu.sk/en/page=1&id=hydro_stpa&PAtab=PAtab,* (browsed on March 30th, 2011)
[8] Boyle G. Renewable Energy, Oxford University Press, 2004.
[9] The concept of using hydropower potential of rivers in Slovakia until the year 2030, *http://www.minzp.sk/sekcie/temy-oblasti/voda/koncepcne-aplanovaciedokumenty/ koncepcia-vyuzitia-hydroenergetickeho-potencialu-vodnych-tokov-sr-do-roku-2030/*, (browsed on March 30th, 2011)

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Natural regeneration as a way of restoration

Kamila Botková

Abstract

Ecological restoration is a practical approach to a proccess of restoring disturbed sites based on science of restoration ecology. Wide definition from SER Primer (2002) states that „Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.“ The paper summarizes some basic information about use of natural proccesses as a succession in a restoration and states some principles of using this way of restoration on different sites.

Key words: ecological restoration, natural regeneration, succession

Introduction

Traditional restoration methods are agricultural, forestry, hydric and others (recreational use, sports grounds, natural) according to a target state. Every method is generally based on two subsequent steps – technical measures and biological measures. In last decades natural regeneration became in importance equal to a traditional technical view of reclamation possibilities. Not in a legislation where technical approaches are still preferred, however scientific results clearly states high potential of using natural succession. In Czech Republic for example Prach K. & Pyšek P. (2001), Tichý L. (ed.) (2005), Řehounková K. & Prach K. (2008), Konvalinková P.& Prach K. (2010). The effectivity of spontaneous succession or technical measures differs on different sites. Prach and Hobbs (2008) define some basic implications for practise use of natural regeneration in disturbed sites restoration:

- spontaneous succession may be useful, low-cost restoration tool in many situations
- recognizing where spontaneous succession may be possible a priori requires an assessment of the level of environmental stress and productivity in a site to be restored
- technical reclamation is required where environmental stress or productivity is high and where clear abiotic thresholds are apparent, otherwise spontaneous succession is preferred

General aims of restoration ecology, which gives theoretical basement for ecological-natural restoration, are according to Hobbs & Norton (1996):

- To restore highly degraded sites such as mine sites
- To improve productive capability in degraded production landscapes
- To enhance conservation values in protected landscapes
- To enhance conservation values in productive landscapes

Material and Methods

Use of natural regeneration in restoration depends on a target ecosystem – target communities and species. What the need „to restore“ is about. Natural regeneration leads to a relatively high value natural sites with high biodiversity – depends on donor sites quality and availability.

Natural regeneration can be under way on different disturbed sites:

- stone quarries
- spoil heaps from coal mining
- disused sand and gravel pits
- mined peatlands
- clay minerals pits

Basic method for studying succession is carring out phytosociological reléves and other characteristics in representative parts of a site and in different successional stages with site history knowledge. The aim is to determine a population sequence change over time and to define conditions when the process of succession leads to our target ecosystem.

Results

Particular conclusions for stone quarries (Řehounkova K., Řehounek J., Prach K. (eds.), 2011) say that spontaneous succession is very effective. In the deciduous woodland zone of temperate Europe, stone quarries provided refugia for many species typical of open woodland and dry grassland if they occurred in the surroundings. The statistically significant distance is 50m for the successful

establishment of the species. The same distance is critical for some invasive alien plants which are recommended to be eliminated at least inside this distance. Macroclimate and species pool are the most important environmental factors driving succession.
One of the very good examples of stone quarry natural restoration is a Růženin lom (Růžena´s Quarry). The project is described by Tichý L. (ed.) (2005) as a „It is a typical pit quarry of the 1st half of 20th century created in an extensive deposit of Paleozoic limestone on southern slope of Hady hill near Brno. After the quarrying was ended, its bottom was partially filled in with cement dust waste and abandoned. In the rock face quite a strong water spring emerged feeding small crystal clear pools on the bottom. Eroded faces of the quarry and wet spots around the pools have been gradually colonized by vegetation, which continued spreading further leaving bare only deposits of the cement dust and loose gravel slopes. Růžena's quarry is surrounded by nature of great botanical and zoological value. The proposed reclamation thus had to take nature conservation as a core of the project design and implementation. The project proposed modification of the bottom, enlargement of the pools, elimination of invasive plant species and sowing, planting and transfers of steppe species from the immediate vicinity of the site. The overall reclamation thus enhanced the main strength of the site – environment with a large concentration of completely different habitats and wildlife. Wet marshes and pools lie next to arid gravel and stony slopes, southern rocks merge into fine gravel deposits and boulder debris."
Particular conclusions for spoil heaps from coal mining (Řehounkova K., Řehounek J., Prach K. (eds.), 2011) say that spontaneous succession leads to open woodland in about 20 years in various sites across central Europe, with participation of rare species. Spontaneous succession lead to more diverse vegetation, except toxic or acidic sites and soil structure, pH, and species pool appear to be the most important environmental factors. Koutecká V.& Koutecký T. (2006) reached similar results in Ostravá-Karvina black coal minig district: „It is evident that spontaneous vegetation succession is very effective in the restoration of waste dumps."
Particular conclusions for disused sand and gravel pits based on a field research (Řehounkova K., Řehounek J., Prach K. (eds.), 2011) determined spontaneous succession led to target grassland, wetland, or woodland in about 20 years, nearly three quarters of target species, which occurred in the surroundings (up to 100m), were able to colonise the disused pits. The higher proportion of (semi)natural vegetation in the surroundings, the higher probability for target species to establish in a pit. Macroclimate, site moisture, and species pool appeared as the most important environmental factors.
As an example of good practise can be mentioned Dračice sand pit described in Řehounkova K., Řehounek J., Prach K. (eds.) (2011). „Sand was mined in the location from the 1980´s to the beginning of 1990´s. Because of the intervention of the nature conservation authority (Třeboňsko Landscape Protected Area) the planned deposition of building wastes and forest reclamation were not realized. Instead, three small water bodies were created to increase habitat heterogenity."

Conclusion

Řehounkova K., Řehounek J., Prach K. (eds.) (2011) summarize that mining provides nutrient-poor sites where competitively week species, retreating from the surrounding eutrophicated landscape, have a chance to establish. During mining, remnants of (semi)natural vegetation should be preserved in the close surroundings to facilitate colonization. Invasive aliens should be erradicated in the close surroundings. If mining does not disturbed a locality of high natural, historical or aesthetic value it can be profitable from ecological point of view, but only if the site is not technically reclaimed.

References

Konvalinková P.& Prach K. (2010): Spontaneous succession of vegetation in mined peatlands: a multi-site study. Preslia 82: 423-435.

Koutecká V.& Koutecký T. (2006): Plant succession on the anthropogenic habitats of mining landcape of Ostrava-Karviná coal mining district. Zprávy Čes. Bot. Společ. 41 (Mater. 21): 117-124.

Prach K. & Hobbs R.J. (2008): Spontaneous succession versus technical reclamation in the restoration of disturbed sites. – Restoration Ecology 16: 363-366

Prach K. & Pyšek P. (2001):Using spontaneous succession for restoration of human-disturbed habitats: Experience from Central Europe. Ecological Engineering 17: 55-62.

Řehounková K. & Prach K. (2008): Spontaneous vegetation succession in gravel-sand pits: a potential for restoration. Restoration Ecology 16: 305-312.

Řehounkova K., Řehounek J., Prach K. (eds.) (2011): Near-natural restoration vs. technical reclamation of mining sites in the Czech Republic, University of South Bohemia in České Budějovice, České Budějovice, 112 pp.

SER (2002): The SER Primer on Ecological Restoration. Society for Ecological Restoration Science & Policy Working Group. www.ser.org

Tichý L. (ed.) (2005): Rekultivace blízké přírodě. ZO ČSOP Pozemkový spolek Hády, Brno.

Walker L.R., J. Walker & R.J. Hobbs (eds.) (2007): Linking restoration and ecological succession. Springer, New York.

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Contemporary state and management evaluation of protected areas as indicator of landscape preservation

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Abstract
State and management were evaluated in selected small protected areas in the Nymburk region according to the methodology by Svátek (2004). Four territories of diversified habitats with a total area of 201.14 hectares were evaluated. Obtained results show that protected areas in the Nymburk region are on average in a high state. Evaluation of the management showed that protected areas are evaluated medium degree. Measures, which should lead to the development of protected areas, to optimization of the state and management, and also to maintain the object of protection, were suggested in the areas of interest. Results of the evaluation provide up-to-date overview about the state and level of management in chosen protected areas in the Nymburk region.

Keywords

small protected areas, landscape preservation, Nymburk

Introduction

Specially protected areas are an element of the landscape with high naturalist or aesthetical value. This area is used to protect biodiversity in situ (Sklenička, 2003). The need for ongoing monitoring and regulation of their development are essential for maintaining the landscape character and the most valuable fragments of the landscape. Current approaches in the evaluation of the landscape, or its components, record various trends and directions. The paper deals with evaluation of protected areas from the perspective of their condition and management provided. Application and the basic principles of Svátek's methodology (2004) are demonstrated on selected small-scale protected areas of Nymburk region (Natural Monument Chotuc, Mydlovarský luh Nature Reserve, Natural Monument Písečný přesyp u Píst and the National Natural Monument Slatinná louka u Velenky) with a total area of 201.14 hectares (see fig. 1). Results of state and management evaluation of individual protected areas highlight the key problems of particular areas and also give clear, current information on the state of the management in local and regional networks of protected areas.

Material and methods

The contemporary state and management of 4 special protected areas (PA) of the Nymburk region have been evaluated from different points of view, applying the classification method (Svátek, 2004) devised with the aim of simple and fast assessing and allowing easy comparison between protected areas. The basis of evaluation is a quick field research in a particular area which provides current information about the real state and results of management. The methodology can be applied for evaluation of small-scale areas with special status of protection (such as bio-centers, bio-corridors and interaction elements that create compositional components of the territorial systems of landscape's ecological stability) and registered significant landscape elements. Classification method separately assesses contemporary state and management, each of them in eight different categories. A scale used for evaluation comprises six degrees, including degree 0 (null) as the lowest (the worst) and degree 5 (very high) as the highest (the best) degree.

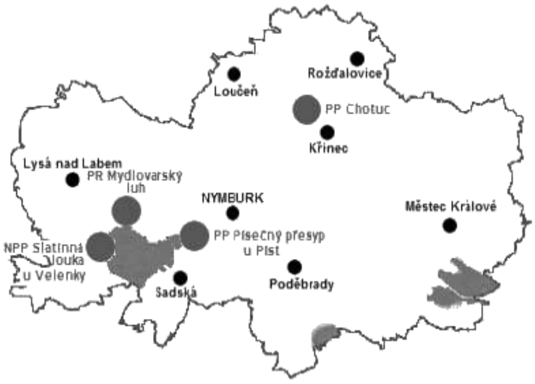

Fig.1. Protected areas in Nymburk region

Contemporary state of PA has been evaluated in following categories:
• species composition (in comparison with species composition of natural (potential) community)
• age and spatial structure (in comparison with structure of natural community)
• specially protected species (occurrence of species specially protected according to the Regulation No. 395/1992 of the Ministry of the Environment of the Czech Republic)
• natural regeneration (self-reproduction capability of protected community)
• damage to natural regeneration (significance and extent of damage)
• invasive and ruderal species (aimed mainly at invasive neophytes)
• dumps and litter (considering their extent and impact on the PA contemporary state)

• other negative impacts (other possible negative influences).

Management of PA has been evaluated in next categories:
• quality of signs (lucidity and distinctness of border signs, presence of state sign tables, accordance with Regulation No. 395/1992 of the Ministry of the Environment of the Czech Republic)
• dump management (clearance of possible dumps and litter)
• impacts of roads (damage or contamination of PA by vehicles or by roads themselves; erosion; PA fragmentation)
• cuttings (all cuttings and silvicultural operations influencing PA contemporary state)
• respecting of the protection zone (evaluation of a protection zone functionality (a protection zone generally should protect PA against negative disturbances from the surroundings) as well as all other activities and phenomena in the protection zone)
• negative impacts from the neighbourhood (all other distinct negative influences from the PA vicinity)
• game management (evaluation of a regeneration protection, i.e. in the forest reserves game management - numbers of game, presence of feeding places (undesirable) and effective regeneration protection (desirable) - all considering to a damage extent)
• fulfilment of declaration principles (general evaluation of protection objectives fulfilment).
Because of different importance of individual categories each category has got its own multiplicative coefficient. In each category an obtained degree multiplied by a multiplicative coefficient makes a number of points.
Final evaluation of PA contemporary state has been gained by sum of points from all eight categories of contemporary state (see Table 1); similarly final evaluation of PA management comprises points from all eight categories of management (see Table 2)(Svátek, 2004).

T a b l e 1 . Classification method – contemporary state

Categories of PA contemporary state	Degree		Multiplicative coefficient		Number of points
Species composition	0–5	multiplied by	3	=	……
Age and spatial structure	0–5		2.5	=	……
Specially protected species	0–5		2	=	……
Natural regeneration	0–5		1.5	=	……
Damage to natural regeneration	0–5		1.5	=	……
Invasive and ruderal species	0–5		1	=	……
Dumps and litter	0–5		1	=	……
Other negative impacts	0–5		1.5	=	……
Final evaluation of PA contemporary state:					sum of points

T a b l e 2 . Classification method – management

Categories of PA management	Degree		Multiplicative coefficient		Number of points
Quality of signs	0–5	multiplied by	0.5	=	……
Dump management	0–5		1.5	=	……
Impacts of roads	0–5		1	=	……
Cuttings	0–5		2.5	=	……
Respecting of the protection zone	0–5		2	=	……
Negative impacts from the neighbourhood	0–5		1.5	=	……
Game management	0–5		2	=	……
Fulfilment of declaration principles	0–5		3	=	……
Final evaluation of PA management:					sum of points

Results and discussion

Four small protected areas with the total area of 201.14 hectares were evaluated within the Nymburk region. The aggregate average rating of the status of protected areas indicates grade 4, which means that they are currently in good condition. Most critically evaluated was the incidence of invasive and expansive species. Significant effect of species that are expansive in such habitats was observed on the majority of protected areas.
Woodyplants of such nature are the most serious problem in natural protected area Písečný přesyp u Píst, where raid of *Robinia pseudoacacia* and *Betula pendula* must be

eliminated due to a small area of the site, because otherwise they would be overgrown in the dune area, which is an important geological monument, and cause slow weakening of psamofilous species (Karlík et al., 2005). The least significant impact of invasive species was recorded in the NPP Slatinná louka u Velenky, where only a small development of *Coryllus avellana* and *Euonymus europaeus* shrubs was monitored (see Table 3).

The most significant disruption of recovery occurs in PP Písečný přesyp u Píst. At this location there is a partial disruption of recovery due to human activity. Undisciplined visitors violate the entry ban on sand dune. Vitality of interest species is suppressed by other growing species in the dune *(Avenella flexuosa*, *Calamagrostis epigejos*). In terms of preservation, the territory Mydlovarský luh nature reserve was rated below average. The main reason is the state of phytocenosis, which have the character of indigenous communities and the abundance of various habitats typical for the floodplain forests throughout all territory. There are, however, also communities of introduced trees (*Phellodendron amurense, Pinus strobus*) and other species (*Robinia pseudoacacia*, *Picea abies*), which substantially alter the composition of natural communities (Míchal, Petříček, 1999).

T a b l e 3. Contemporary state evaluation

Category and name of protected area		Species composition	Age and spatial structure	Specially protected species	Natural regeneration	Damage to natural regeneration	Invasive and ruderal species	Dumps and litter	Other negative impacts	Final evaluation	
NPP	Slatinná louka u Velenky	4	4	4	4	4	4	5	4	55.5	high
PP	Chotuc	4	4	n	4	4	3	4	4	47	high
PR	Mydlovarský luh	3	3	5	4	4	3	4	3	50	high
PP	Písečný přesyp u Píst	4	3	n	n	3	3	4	4	37	medium
Arithmetical mean of degrees										45	high

Note: *n* represents not evaluated criteria

Effects of external influences, recorded in the protected areas, were evaluated as good. Reduced level was assigned to Chotuc natural monument. Nowadays, agricultural use of surrounding land is a major negative influence here. Visitors, who do not respect the road marking, create artificial complex of paths on the territory, thus the movement of persons within the territory is not sufficiently limited (see Table 4). A significant part of the nature reserve Mydlovarský luh with its land is included in the area recognized by the peasantry in the Hunting Act 449/2001 Coll.

T a b l e 4. Management evaluation

Category and name of protected area		Quality of signs	Dump management	Impacts of roads	Cuttings	Respectnig of the protection zone	Negative impacts from the neighbourhood	Game management	Fulfilment of declaration principles	Final evaluation	
NPP	Slatinná louka u Velenky	5	3	4	4	4	4	4	4	55	high
PP	Chotuc	4	3	4	4	3	4	4	4	30	medium
PR	Mydlovarský luh	4	5	4	3	4	4	4	3	31	medium
PP	Písečný přesyp u Píst	4	3	3	3	3	3	3	4	26	low
Arithmetical mean of degrees										36	medium

Not indigenous species that are present on areas of interest are often considered as negative. Ložek et al. 2005 presents that Amur Corktree (*Phellodendron amurense*) occurs in the nature reserve Mydlovarský luh as an interesting exotic wood. Planner of the management plan (Lesprojekt, 2005) for the Mydlovarský luh considers such exotic species as a potential threat, which changes the species composition to against the natural composition of the protected area. Phellodendron amurense was introduced in the reserve planted in 1956, thus 33 years earlier than the existing nature reserve Mydlovarský luh was officially established. Vegetation od Amur Corktree intervenes to the area of Natura 2000, which was established to protect *Rhodeus sericeus* and it is also a part of regional bio-center. Danzer (2007) indicates that the woodyplant can be utilized in the flooded forest biocenoses, without negatively affecting the original composition of these communities. Concerning the extent to which this species can offer its usage, it is possible to support the extension of *Phellodendron amurense* on suitable habitats.

Conclusions

Field research revealed that small-scale areas with special protection in Nymburk region are on average are in high degree state. In terms of the final evaluation of the state, the worst natural landmark evaluation reached Písečný přesyp u Píst. The main cause is a significant disruption of recovery, which is partly caused by human activity. On the contrary, national natural monument in Slatinná louka u Velenky was rated the best with a state almost undisturbed. For the overall evaluation of management for all protected areas the management was found to be in medium degree state. In terms of management evaluation, marking of boundaries is the weakest and all locations rated below- average grade at this criterion. The most significant deficiencies were detected on marking of boundaries in the field, which are represented by the red stripes. The documentation for all locations had the best quality, this criterion obtained in all cases the highest rating. Obtained results provide up to date overview on the state and level of management in protected areas. Based on the identified deficiencies, optimization measures were determined to give direction to the development and to management of protected areas to move them closer to achieving the aims and objectives of protection.

References

Danzer, M. (2007). Hodnocení růstu korkovníku amurského (Phellodendron amurense Rupr.) v LHC Mydlovarský luh. In Čermák, P., Bodejčková, I., Žid, T. *Krajina - les - dřevo*. Brno: Lesnická a dřevařská fakulta MZLU v Brně. 85–95.

Karlík, P., Šmídová, I., Řezáč, M. (2005). Přírodovědný průzkum chráněných lokalit polabských vátých písků, 18 s.- Ms. Depon in Rezervační kniha PP Písečný přesyp u Píst

Lesprojekt, 2005. Plán péče Přírodní rezervace Mydlovarský luh, Stará Boleslav, 29 s. Dep: Rezervační kniha PR Mydlovarský luh.

Ložek, V., Kubíková, J., Spyňar, P. et al. (2005). Střední Čechy, Chráněná území ČR. Svazek XIII., Praha, Agentura ochrany přírody a krajiny ČR a Ekocentrum, 904 s. ISBN 80-86064-87-5.

Sklenička, P. (2003). *Základy krajinného plánování*. Vyd. 2. Praha: Naděžda Skleničková, 321 s. ISBN 80-903206-1-9(brož.).

Svátek, M. (2004). Landscape-ecological approach to the contemporary state and management evaluation of protected areas. In Krnáčová & Hrnčiarová (eds.): Proceedings of the 13th International Symposium on Problems of Landscape Ecological Research, 30 September – 3 October 2003, Mojmírovce, Slovak Republic. Ekológia (Bratislava), Vol. 23, Supplement 1/2004, p. 340–350.

Míchal, I., Petříček, V. (1999). Péče o chráněná území II. Lesní společenstva. AOPK Praha, 713 s., ISBN 80-86064-14-X.

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