Czech University of Life Sciences

Faculty of Environmental Sciences

Department of Land Use and Improvement

Diploma Thesis

Feasibility study of river restoration measures and the patency of migration barriers on the Knovízský stream

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DIPLOMA THESIS ASSIGNMENT

Dvořáková Kateřina

Thesis title
Feasibility study of river restoration measures and the patency of migration barriers on the Knovízský stream

Objectives of thesis
Providing a review of the feasibility study (description of problematic and processing) and the river restoration methods.
Implementing selected feasibility study on the Knovízský stream included the river restoration measures designed for this case study.

Methodology
The first part of the thesis will be about studying available literature and it will be reviewed there. Following is data collection, observation of the study area and proposed design of restoration measures. Finally will be written the outcome of the observation, and it will be discussed and concluded.

Schedule for processing
Reading and studying literature
Outline of the literature review
Preparing methodology for the feasibility study
Realizing the feasibility study on the Knovízský stream
Writing the thesis
Submission of the thesis

The proposed extent of the thesis

40 – 60 pages

Keywords

Feasibility study, River restoration, River restoration measures, Hydromorphology, Hydromorphology assessment, Knovízský stream

Recommended information sources

Darby, S., Sear, D., 2008. River Restoration: Managing the Uncertainty in Restoration Physical Habitat. John Wiley and Sons, 328 pp.

Just, T., et al., 2005. Vodohospodářské revitalizace a jejich uplatnění v ochraně před povodněmi. 3. ZO ČSOP Hořovicko ve spolupráci se společností Ekologické služby s.r.o., Agenturou ochrany přírody a krajiny ČR a Ministerstva životního prostředí ČR, Praha, 360 pp.

O'Hanley, J., R., 2011. Open rivers: Barrier removal planning and the restoration of free-flowing rivers. Journal of Environmental Management 92, 3112-3120.

Perrow, M. ,R., Davy, A., J., 2008. Handbook of Ecological Restoration - Volume 1 – Principles of Restoration, Restoration in Practice. Cambridge University Press, 464 pp.

Rinaldi, M., et al., 2013. A method for the assessment and analysis of the hydromorphological condition of Italian streams: The Morphological Quality Index (MQI). Geomorphology 180 – 181, 96 – 108.

Roni, P., Beechie, T., 2013. Stream and Watershed Restoration: A Guide to Restoring Riverine Processes and Habitats. Wiley – Blackwell, 316 pp.

Rosgen, D. ,1996. Applied river morphology. Wildland Hydrology, Pagosa Spings, Colorado., 390 pp.

Thomas, G., 2013. Improving restoration practice by deriving appropriate techniques from analysing the spatial organization of river network. Limnologica - Ecology and Management of Inland Waters 45, 50 - 60.

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Dean

I hereby declare that this project presents my own work and has not been submitted, in whole or in part by me or other person, for the purpose of obtaining any other credit or grade. I agree that this project may be made available by the University to future students.

Prague, 22nd April

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Finally I would like to thank my family and friends for support, patience and for valuable advice.

Abstract

River restoration has become a very required topic. There are many efforts to improve the quality of environment and river restoration is one of many valuable tools.

Knovízský stream is located north-west from Prague. Stream spring is in village Libušín and in the city Kralupy nad Vltavou stream inlets into the Zákolanský stream. The land use around this stream is mostly due to agriculture and urban areas. Both agriculture and urbanization have significant influence to the streams' state. The stream is straight because of the urbanization and many sections of stream are moderately fouled by eroded sediments from bad management of agricultural lands. The goal of this study is to improve the environmental quality here. There were several proposed measures according to The Documentation and Selection of Water Stream Section from the Morphological-Ecological point of view (MES). This document is the methodology created by the Nature Conservation Agency of the Czech Republic and the Povodí Vltavy, s.p and the basis of it is to return natural conditions to the watercourses in Czech Republic. In accordance to this methodology are proposed measures, both investment and non-investment. Within the entire area of interest, there are many land owners and this can be serious problem for the feasibility of this study.

Key words:

Feasibility study, River restoration, River restoration measures, Hydromorphology, Hydromorphology assessment, Knovízský stream

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1. Introduction

The river restoration is a tool which can help to modify the misconducts from the past. Historically, streams were straightened artificially and modified with the help of concrete blocks and other non nature friendly measures. Not only the reinforcement is the current problem in the streams. The in-stream structures built many years ago, which are not maintained now, are a serious problem as well. They can cause flooding during the high flow rates, they change the environment in the stream from the ecological and biological point of view and last but not least, they are migration barriers. The longitudinal patency of the stream is destroyed by these structures and the whole stream biodiversity is changed.

The behavior of streams, as well as the reinforcement of its banks, is affected by their straightening. These modifications increase the flow velocity in the stream and they are a big threat for the urban areas on the stream. The mass flood waves are created during the high flow rates and thanks to straightening there is nothing to stop them.

This project was created in cooperation with the company Vodohospodářský rozvoj a výstavba, zkráceně VRV, a.s.[1] During this study my project supervisor at the company was Miroslav Pácl. The data for this study were provided by the VRV, a.s.

[1] Vodohospodářský rozvoj a výstavba, zkráceně VRV, a.s., sídlem Nábřežní 4, Praha 5, 150 00

2. Purpose and Aims of the Study

This feasibility study should offer the solution for river restoration of Knovizsky stream. The proposal is to improve the quality of environment and to help the nature affected by man. Modifications done in the history did not only harm the nature but it had influence on people as well. We designed a suitable river restoration that will improve quality of the environment and follow people's needs.

This project was designed according to the methodology created by the Agency of Landscape and Nature protection of Czech Republic. It is the combination of the basics of river restoration on one side and harmony with nature on the other side. The name of this document is The Documentation and Selection of Water Stream Section from the Morphological – Ecological point of view (MES).

My contribution to this work was to do the survey in the area of interest, elaboration of the given documents and designing of the measures which are according to the MES methodology. Mr. Pácl, as my supervisor, controlled all steps I did in the technical report as well as in the designing part.

3. Literature review

3.1. Goals of Feasibility Study

3.1.1. General Description

The feasibility study is the paperwork that requires adequate quality of elaboration. The feasibility study is used not only for evaluation of the project feasibility from the financial perspective but it should also inform us about the meaningfulness of the project. This document is the main one which is used for the project management. It is important to do the study as a description of problems, to give several opportunities of problem solving and to give the optimization and evaluation of project with all other aspects. (Sieber, 2004)

3.1.2. Description of Problems

The feasibility study, sometimes also called the technical-economic study, is the document that makes summary of all relevant implementation aspects of the project. The goal is to valorize all alternatives that could be realized and also to evaluate the feasibility of the given project. It should provide all necessary documents for the investment decision. This document is elaborated in the pre-investment phase of the project itself. (Sieber, 2004)

This feasibility study was made as a part of a big project which was done for the catchment of the Vltava and Labe River. The state companies Povodí Labe and Povodí Vltavy wanted to know if it is possible make some restorations in their catchment. The general task was not only the restoration of the two rivers and its streams, but also the environmental improvement in general. The feasibility study should reveal problems on watercourses. There were studies which focused on stream permeability, the ecological state of streams and the state of floodplains and also it should evaluate the state of in-stream constructions.

3.2. River Hydromorphology

The EU Water Framework Directive (WFD; European Commission, 2000) introduced the term “hydromorphology”, which is defined as a process of consideration of any modifications of flow regime, sediment transport, river morphology and lateral channel mobility. Hydromorphology has increasingly grown as a cross-disciplinary topic nowadays at the interface between hydrology, geomorphology and ecology (Rinaldi, 2013). The aim is to evaluate the ecological status of freshwater ecosystems and to identify the cause of inappropriate river conditions (Langhans, 2013). Tools, such as river monitoring and assessment programs are important for quantifying the condition of river ecosystems, providing documentation of trends, detecting deficits and outlining preliminary steps for improvement of surveyed systems based on indicators highlighting problems or deficits (Langhans, 2013).

Many European countries have a problem with hydromorphological degradation which represents one of the major types of stream bed disruption. It is mainly caused by human activities. A considerable pressure from human world requires channel adjustment (M. Rinaldi, 2013).

The main goal of the EU Water Framework Directive is to create sustainable and high quality landscape function of surface water. Members of EU have a duty monitor feedbacks, as well as to control state of restorations. Norm EN 14614: “Water quality: Guidance standard for assessing the hydromorphological features of rivers” (Smetana, 2008) represents the driving document for this matter.

3.2.1. Situation in Czech Republic

In 2001, the Czech Republic implemented the Water Law from the EU which led to so called Water Act (No. 254/2001 Sb.) This Act describes the duty of assessment and monitoring of watercourses from the point of eco-hydrology and hydromorphology. The monitoring indexes have to be consistent with the EU Water Framework Directive.

The problem in the Czech Republic is the united methodology and an evaluation of given results. Although several efforts were made to create one the best methodologies these are still in discussions without any specific results. (Smetana, 2008).

3.2.2. Rosgen Classification

"This classification system was developed by establishing morphological-process relations at reach specific levels, then, developing methods to extrapolate these findings to other locations at broader levels of injury" (Rosgen, 1996).
Rosgen classification system is currently one of the most used systems all over the world. It is the most complex methodology of streams classification. The reason for its world-wide use and its popularity is its practicality. The division is done by quantitative analysis of characteristics through the table method. It gives the system a wide utilization and people who are involved in the process are not required to possess a detailed technical knowledge. (Smetana, 2008)

Four main leves (levels of specificity) lead to hierarchy of river morpohology:

Level I – describes geomorphic characteristics that result from the integration of basin relief, land form and valley morphology. Many of these criteria can be determined from maps or aerial photographs.
Level II – is a more detailed description which provides information about entrenchment, patterns, profile, etc. It gives the quantitative morphological assessment and provides higher-resolution of information with utility for management applications.
Level III is a description of existing conditions of the stream and relates to with a potential response and function of the stream. In addition, it also describes the field parameters, such as riparian vegetation, sediment supply and flow regime. These analyses are very useful as they form the basis for integrating companion studies.
Level IV – during this level measurements are done to verify process of relationships. Using relationships developed at Level IV, existing data from gage station and research sites can be analyzed and extrapolated (Rosgen, 1996).

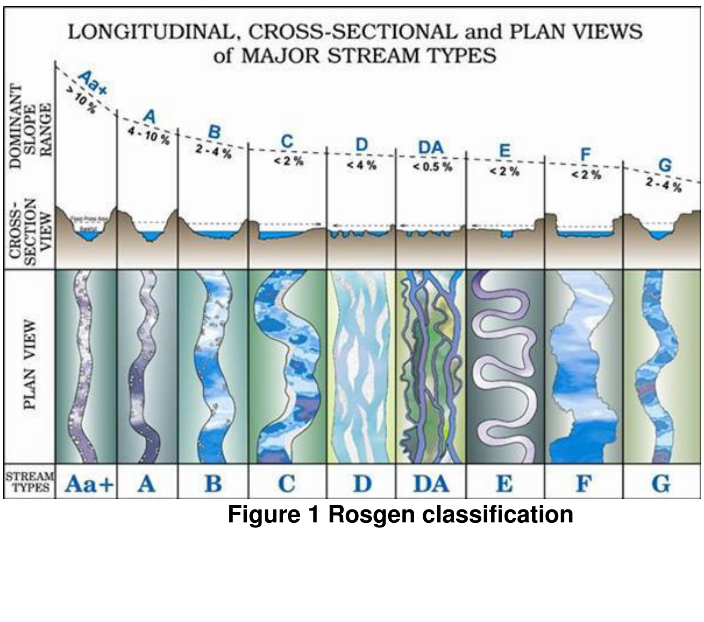

Figure 1 Rosgen classification

The Rosgen's classification system requires a more detailed scale of classification. It should be done on the representative parts of the stream (i.e. where the length is in ratio with width) and are found out mostly the morphological parameters of the stream. The next step of classification is the assessment of the current state of stream and its surroundings. This evaluation is based on the eco-hydromorphological point of view and has different types of classification, e.g. type of land use in stream surroundings, potential risk of bank erosion or the state of the riparian vegetation.

The most detailed step of this classification makes the division of stream parts to stretches according to fluvial processes that take place in each stretch (Smetana, 2008).

Detailed description of parameters and visualization of Rosgen classification is in Appendix 1.

3.2.3. Montgomery and Buffington Classification

The Montgomery and Buffington classification is also well known around the world. According to expert opinions it becomes more and more popular.

This classification is built on dominant fluvial processes and to their corresponding morphological and morphometric attributes. Morphometric attributes are, for example, the slope of a river bed, the index of channel recess, or the distance between riffles and pools.

This classification characterizes the relative response of a river to sediment transport. (Montgomery and Buffington, 1993). Another evaluation is the division between the material of the river bed and the river banks. This is important as it seeks to find the place of potential transport of sediments and contaminants into the stream. The system has eight Alluvial stream classes as shown in figure 9, Appendix 1.

This methodology captures the core of problem without being complicated with use of difficult tables or investigations of a large amount of information. It evaluates both quantitative parameters (evaluation is given by table) and qualitative (subjective evaluation) parameters. The pattern is a concept of hierarchy and it allows for a possibility to evaluate each single stream or the segment of stream in detail according to time scale (Smetana, 2008).

The classification table is in the Appendix 1, figure 9.

3.2.4. Biological Assessment

Biomonitoring, or biological monitoring, is generally defined as "the systematic use of living organisms or their responses to determine the condition or changes of the environment" (Gerhardt, 1999). It is a method of observing the impact of external factors on ecosystems. Bioindication can be an easy and a cost effective tool for monitoring of environmental and ecosystem integrity (both short and long term). This is helpful if the restoration budget is deficient for following monitoring (Pander, 2013). The development over a period of time or ascertaining of differences between one location and another is monitored and results are precisely observed (Li, 20010). This is based on physical, chemical and bacteriological measurements, as these provide a complete range of information for correct water management. Aquatic organisms, such as benthic invertebrates, marcophytes, fishes and algae may serve as good bioindicators (Pander, 2013). Examples of commonly used bioindication assessment tools and indices in stream ecology interpreted by Pander are in Appendix 2. These bioindicators are integrated in their total environment and their responses should complete the view of sets of environmental conditions. They provide us with the way and the possibility of how to obtain an ecological overview of the current status of streams or rivers (Li, 2010).

"Aquatic bioindicators are organisms accumulating toxic substances or responding to environmental stress, such as pollution, nutrient enrichment, habitat loss or overexploitation" (Adams, 2002). The process of investigation requires standardized procedures, including field sampling, sample processing and identification of collected organisms. The results of these observations are usually summarized in biological metrics and gather information on occurring taxa. For gathering of information we can use different processes do it in countless ways. We can be used different equipment, different steps to determine the organisms we can use as the different taxonomic key, etc. However, this bioindicator tool represents a problem with its usage. It is possible to use it only to determine the success of small-scale restoration (Pander, 2013).

In Europe, bio-assessment methods differ based on geography which is an important factor, to be taken into account. Response of organisms to stress may vary by region and the type of ecosystem (Birk, 2012).

In the last ten years, bio-monitoring of European aquatic ecosystems has changed substantially. The EU Water Framework Directive requires assessment methods for different ecosystem types ("water categories": rivers, lakes, transitional waters, coastal waters) and different organism groups ("biological quality elements" = BQEs: phytoplankton, aquatic flora, benthic invertebrates, fish). However, the only quality that the EU Water Framework Directive changed is management objectives from pollution control to ensuring ecosystem integrity (Borja et al., 2008).

3.2.5. Physical Assessment

3.2.5.1. Sediments

Dirt roads, agricultural use, river banks, or pastures disturbed by animals that lie around the stream, are continuous source of fine sediments which are transported by runoff into the river (Thomas, 2014). The sediment regime is closely dependent on the discharge into the stream and its morphology. The most important parameters from morphological point of view are the longitudinal profile and the material of the river bed and the river banks. Places with higher discharges are more inclinable for the sediment denuding and other vise places with lower longitudinal profiles are inclinable for the sedimentation. Places where denuding and sedimentation are in balance are called dynamically stable (Just, 2005). This dynamically stable bed is mainly a theoretical term. In reality, the sedimentation and the water erosion processes go hand in hand and contribute to the natural segmentation of bed and proper water saturation.

From the 50ties of the 19th century the most popular trend in straightening and creating artificial beds was by using concrete blocks. These procedures decrease the natural water environment, increase the velocity in the stream and the result of these restorations was the degradation of stream bed. The water in stream was not appropriately saturated and to improve that it increased the bank erosion around these restorations.

Today, we try to restore rivers and streams to the original state, but it is quite difficult as it is not possible to exactly tell how big the denudation or sedimentation is. The biggest problem is the erosion from surrounding landscape, mostly when the land is used for agricultural purposes, but it is not maintained in properly. To protect the stream which we want to restore back to its natural way, we have to respect the following principles:

- Not to stop the sediments from upper parts of the stream
- Accept that the erosion will continue. We can only design the ideal shape of the bed to protect the stream bed and let erode only longitudinally stream banks.
- Let the water flow its way – let the water to create its own shape of stream bed and erode the banks.
- Do not use reinforcements of stream banks in non urban area (Just, 2005).

3.2.6. Ecological Assessment

The river physical habitat is an important driver of an ecological response. It shows where to develop hydromorphological tools. Although fully integrated ecological approaches are not operational yet and there is an urgent need to generate data to describe the physical template of rivers on which biotic function depends (Orr, 2008).

The goal of ecological assessment is to find a way of how to restore the natural state. It is not important to create the environment for possibly the biggest number of species (Perrow and Darby, 2008). To do this properly, one needs to find the best conditions for these species that are native to the place of interest. In general, the ecological assessment seeks to support the naturalness, not the quantity (Just, 2005).

The ecological assessment dependents on a number of factors, e.g. water quality, character of the stream surroundings, stream morphology and the land which is flooded during higher discharges, and not to forget, the migration throughput. (Just, 2005)

3.2.6.1. Ecological status

One way of ecological assessment is to use the term “ecological status”. This is a type of the identification that helps to show the state of a river and its surroundings.

According to the EU Water Framework Directive, the ecological status of water bodies is divided into five classes (or statuses). The classes according to qualification are high, good, moderate, poor and bad. The goal is to create a complete dataset with spatial and temporal representative environmental information for the entire river basin together with a procedure for a comprehensive and realistic aggregation of information. The EU Water Framework Directive provides a general framework for Ecological Status classification (Perrow and Darby, 2008). It gives the Member States the responsibility for developing appropriate monitoring and assessment methods. This strategy should be the first step to ecological improvements (S. Gottado, 2011).The European Union Member States are required to establish monitoring methods and classification tools for assessing ecological status for each biological quality element (fish, macroinvertebrates, aquatic flora and phytoplankton) within each water body type. The outcome of this requirement is a guidance that will be guarded by state (Kelly, 2012).

The ecological status depends on different requirements which we need to find out (Perrow and Darby, 2008). There are a lot of variables and qualities that could be measured and monitored. It is mostly dependent on the purpose for which the monitoring is done, e.g. monitoring of biological indicators (macrophytes, bentos, etc.), or the chemical point of view. (total organic carbon, total nitrogen, particulate organic carbon, chlorophyll-a, etc.) (Gottado, 2011).

3.2.6.2. Stream Segmentation

The stream segmentation is one of the most important factors in assessment of ecological quality. It includes places where fishes can hide, or where insect larvae can hatch (Roni and Beechie, 2013).Calm parts of river serve as a place for rest. Tree roots are the ideal ecological elements which are rooted into the stream bank. This place also gives protection for animals and aquatic fauna. In general, the more stream segmentation, the more habitat find home in the stream. (Just, 2005).

Elements that creates the stream segmentation:

- <u>Places with different velocity of water flow</u> – in quickly flowing waters there is more oxygen which enhances the chemical properties of water and also improves the ecological properties
  - in slower waters there are more sediments and thus, more nutrients and more animals
- <u>Different depth of stream bed</u>
  - Depth of stream bed influences the composition of species. As each fish lives in a different environment, it gives possibility for more species to live together in one place. A lot of fishes change the depth where they live during their evolution (Roni and Beechie, 2013). The fry lives in very shallow and calm water with enough sunlight. As adults they rather live in deeper parts of stream.
  - Deeper water is indispensable for the winter period of fish life. Even fish species that live in shallow water need to hide not get frozen and ideal place is a deep part of stream bed. This is very important to keep in mind when thinking about the design of stream restoration.
- <u>Sediments</u> – denudation of sediments and organic sediments have also its place in the ecologic state of stream. Small size sediments allow some fish species to hatch and a many invertebrates live there as well. Sediments also create the diversification of the stream. They divide the fast and the slow parts of the flow (Just, 2005). On another hand, fine sediments can be a problem. They can cause turbidity of water. In case of really fine sediments, can clog the river. As a result, the exchange between surface water and ground water can be disturbed. The oxygen exchange can be lower, as well (Thomas, 2014).

3.2.6.3. Shelters

As mentioned above, the shelters are very important for aquatic life. Even better designed stream bed with pure water, would be occupied with small number of fauna without shelters. The most used places to hide are:

- Stones – exact spacing in between the stones is used as shelters for huge spectrum of animals. Here are a few examples: invertebrates (flatworms, annelids or insect fries), crayfishes or some species of fish (loach, bullhead). Stones break the water flow and create places for fish to rest. Another important function is oxygenation of water which takes place in shallow segments of stream. The water falls over them and intakes the air oxygen. A bigger amount of stones can also create natural dams and slow down the water flow.
- Root systems of trees provide for natural reinforcement of stream banks. This is the best reinforcement even a better one that of the artificial concrete blocks. Next function of root systems is the creation of shelters for animals. They can be used by aquatic habitat, as well as semi-aquatic habitat. (invertebrates, amphibians, reptiles, birds or small mammals).
- Undercut slope banks
- Branches and large wooden debris fallen into the stream are a natural instrument for pools creation and slowing of the water flow. They are often the reason for a change of bed shape, successive rise of pools and blind stream branches. These branches serve as the best place for hiding and, also for living of an uncountable number of animals and plants (Just, 2005).

3.2.6.4. Bank Character

The bank enhancement has a considerable value for the proper ecological function. This is caused by several factors, such as subsoil, velocity of water flow, width of the stream bed, etc. From ecological point of view, the best way is to let nature itself give shape to stream banks (Just, 2005). However, there are several mechanisms that may lead to a stream bank failure, and to sediment loading to streams, including, toe erosion, removal of matrix, bank sloughing caused by infiltrated precipitation or stream bank storage (Midgley, 2012).

This is why it is very hard to design bank reinforcement. The character is changing value with time, and, even stone riprap, which seems like a natural type of forcing, is not a good solution.

A lot of animals find home in undercut slope banks or eroded steep banks. Few types' of animals do need these places for their life (Just, 2005). "The importance of bank slope as a predictor of conservation status in river corridors was assessed by means of a survey of the taxonomic richness, taxonomic density and relative abundance of aquatic and terrestrial macro-invertebrates, invertebrates, vascular plants and bryophytes in aquatic" (Learner, 1990).

3.2.5.5. Migration Permeability and Barriers Removal

Another very important factor playing a role in the ecological quality in stream assessment is migration permeability (Just, 2005). Especially, the migratory species can disperse only along the stream and the longitudinal connectivity is vital for them (Thomas, 2014). "River infrastructure, such as dams, road crossings and flood control barriers, while important in providing a range of socioeconomic goods and services, are well known for having considerable negative impacts on freshwater ecosystems and the hydrologic process which sustain them" (O'Hanley, 2011). Migration is one of the unaffected processes in animal's life and its limitation can significantly change the species diversity (Just, 2005). In-stream barriers can lead in other ways to disrupt the natural hydrology and the ecology of systems (O'Hanley, 2011). It is important not to design dams or weirs on the stream if it is not inevitable (Just, 2005). The design estimates usually require the subjective judgment of qualified fisheries biologists, or more systematic statistical modeling using structural and hydrological data collected form in-situ surveys to prevent the good state of the patency (O'Hanley, 2011). In the event that some construction must be designed, it is necessary to design also the bypass for fishes and preserve the permeability of the stream (Just, 2005).

"Migration barriers influence mostly:

- Stream discharge, depth and temperature
- Dissolved oxygen content
- Suspended and load sediment transport
- Nutrients and large woody debris supply
- River morphology" (O'Hanley, 2011)

Today, barriers removal becomes a relevant topic. The reason is the global warming that changes not only global conditions, but also, conditions in river systems. Patency of rivers can help temperature-sensitive taxa of fishes to adapt to environmental changes by moving into parts of river with sufficient conditions (Thomas, 2014).

3.2.6.6. Floodplain Areas

Flooding of stream surroundings (in non urban area) is an integral part of ecological function of watercourses. It is good not only for the ecological stability, but it is also one of the best working elements of flood waves flattering (Havlík, 2014).
In places which are flooded, stable pools or periodical pools rise. They can serve as home for an uncountable number of fauna and flora. Typical species representing flora, can be found there: annual plants, reeds, sedges and a special biotope floodplain forest.
Pools have stable water levels, which can warm very quickly and create ideal environment for animals and plants (Just, 2005).

- Stable pools – are supplied by high ground water level or by leakages from stream. Sometimes the flooding is helpful in regard to the new species (animal or plants), who can find the ideal conditions for life there. These species can build there a very big population and re-flooding can help to increase the variability of stream due to flashing of pool (Just, 2005). Data from ecological outcome of habitat restoration suggest that directly adjacent species pools are an important factor in successful restoration (Thomas, 2014).
- Periodical pools – created in the terrain depressions, flooded during the spring thaw, during higher flow rates and when water level rises. Very specific fauna and flora is connected with this type of pools. Mainly, it is a station for water insects, reproduction place for some species of amphibians or other animals (Roni and Beechie, 2013). Special inhabitants of these pools are sometimes brine shrimps and tad pole shrimps. Their specific lifetime requires periodical flooding and droughts. Their eggs hatch after flooding, but they have to be at least once dried before flooding. (Just, 2005).

3.2.6.7. Riparian Vegetation

Riparian vegetation has several functions. It serves as natural bank reinforcement and can be used as a buffer zone in places with intensive agriculture or rooting systems of trees or bush branches which can provide shelters for river habitat. To achieve its proper function it is important to know the properties of the vegetation used for riparian vegetation. Surrounding landscape has to be taken into account as well (Just, 2005).
In case when riparian vegetation is used as a buffer zone, its purpose is to increase quality of runoff water. The rooting system of correctly chosen trees and bushes can serve as the treatment section. The most caught are nutrients – especially nitrogen and phosphorus, and fine sediments. The buffer function is limited in case of pesticides and it varies between systems (Thomas, 2014).

Another property to increase the water quality is shading. In rivers with low flow it is important for the decreasing amount of algae. Presence of algae on a bigger scale decreases water quality from the view of oxygen supply (Roni and Beechie, 2013).
Falling leaves, litter and woody debris from vegetation are very good source of nutrients and also provide protection for some species (Just, 2005).
The riparian buffer strips are more cost efficient than active in-stream restoration because it of being self-developing. The influence differs for each headwater (Thomas, 2014).

3.2.6.8. Dendritic Structure

"A dendritic ecosystem structure is unique to river networks, with the exception of rare ecosystems, such as caves or artificial hedgerows, which are organized in a similar way" (Campbell Grant et al., 2007). The organization of corridors makes rivers highly sensitive to fragmentation. As a very mobile species, fishes are strongly sensitive to and affected by fragmentation. This quality makes them good indicators of river integrity (Schiemer, 2000). The persistence of diadromous and potamodromous fish species in river networks depends on their ability to migrate freely over long distances. The shift between habitats used for spawning, foraging, or functioning as nursery grounds (Northcote, 1998) is essential for their life history. In landscapes with big slopes, streams are used for hydropower generation and it also increases the likelihood of fragmentation (Thomas, 2014). Another problem represents the artificial connection of natural streams. These connections are problematic due to being ideal places for spreading of invasive species. In the past, invasive species have spread successfully through such waterways and have colonized new river-systems (Thomas, 2014).

3.3. River Restoration

The stream restoration is a tool that has become more popular in the last few years but it still evolves (Darby and Sear, 2008). Despite the evolution, it is a very important mean for improving environmental quality. "To the future, it is important to make this tool more efficient, cost effective and necessary is to break all limits which it is fighting with now" (Thomas, 2014). We need to look back to the past and learn from the history. We can return to historical resemblance of streams. Historical aerial photos may be a good source for designing part of restoration process. It can be a helpful tool due to the fact that aerials show us the original shape of a stream and what was its surroundings (Pospíšil, 2013).
Another possibility of river restoration techniques may be using a computer model. This tool is more favored abroad. The reason is an easy access to data and the data quality. In the Czech Republic, it is not used that much. The general problem is that

models might not appropriately assess the response of nature. These models are based on special algorithms that should assess the spatial resolution. The problem is that the computer resolves reaction of each element, but in reality, the surroundings reaction restoration as one unit. As an error origins, it can dramatically change the result of the model (Thomas, 2014).
Nature can help itself to design cost effective restoration. We need to respect natural processes and allow the stream to change as it needs. Riparian vegetation can change riverbed morphology, and improve the water quality (Just, 2005). “In future, restoration planning must shift from tactical to a strategic emphasis, in which processes and species dispersal are evaluated on a catchment scale (Thomas, 2014).

3.3.1. Used Restoration Techniques

The target of river restoration is highly connected with the purpose of the project. It is possible to design river restoration for ecological purposes or from a socio-economical perspective. Each type of restoration has its own principles and values and it is inevitable to respect these principles (Just, 2005).
Today, river restoration designers try to be more focused on re-establishing the natural resources (Thomas, 2014).
This study proposed mostly non-vegetation measures which are described in 3.1.1. The reason is that the stream has very well developed its surroundings (riparian vegetation). In some cases, it was proposed to maintain vegetation for example, in case of dense bush growth. There was a threat of optional flooding because of blocking by covered branches.

3.3.1.1. Stone Riprap

In our proposals, we used the stone riprap as a non-vegetation technique. It is widely used for the reinforcement of the adjusted parts of river bank. Ripraps differ according to:

1. **A process used for realization:**
    - Simple riprap – material is only scuff and arranged to the natural like state according to designed thickness.
    - Stabilized riprap – part of this riprap is technically or artificially stabilized.

2. **Grain size of used material:**
    - Big – material is usually nature stone (weight up to 200 kg or more); it is more often used in mountainous regions and for streams with high flow rates. In case of channels and common streams, it is used in special cases for stream bed forcing or reinforcement around weirs.

      Small – if it is possible are used natural materials from alluvial plain. It is dependent on the size of the effective grain size of the material. In this case, restoration is more cost – effective and it is possible to save money. If there is no appropriate natural material, crashed natural stone of required fraction is used (Fluvial Geomorphology, Havlík, Just, 2005).

This procedure is used in cases where the bank slope is up to ratio 1:2. In both cases we can provide enhancement by vegetation, e.g. willow, or if necessary, we can make a technical reinforcement, such as sprayed resin, or in problematical sections, an artificial enhancement by concrete (Just, 2005).

Figure 2 Stone riprap

3.3.1.2. Stone Filling

Stone filling is widely used for enhancement of the end part of river bank – heel of slope. It creates the construction that should have stabilizing function. Stones are embedded into the stream bed from one side and into river bank on the other side (Havlík A. 2014). It is filled in by smaller stones for better consistency and higher toughness. It is also used in streams where the stream bed is very deep and the vegetation reinforcement is not possible. It protects the stream bank before changes in trajectory that is often necessary for example in villages or an urban area in general. The disadvantage is the steep slope of banks. Also, it makes it difficult to get into water (Fluvial Geomorphology, Havlík, Just, 2005).

Figure 3 Stone filling

During the restoration, we often put solitary stones. It is a supplement of both, stone riprap as well as stone filling. Their function is primarily to diverse the stream. Flat stones are left in the stream without enhancement for a reason to keep the bigger amount of shelters. In case of using common stones, they are embedded from part to better grounding. (Just, 2005)

3.3.1.3. Pools

The pools are depressions in terrain or stream bed, which are filled with water. Origin of pools is taken from natural streams, which are created from blind stream branches or by the isolated depressions in flood plains after flood events. They can be filled by water all the time; some of them are filled by water only periodically. Pools are highly valuable biotopes as they are created artificially during restoration practices (Thomas, 2014).

The difference between a small water reservoir and a pool is in its construction. Pools do not have any storage dams and water releases. The embankment is done only in special cases, and its character is only complementary (Just, 2005).

The size of a pool depends on the water availability in the stream and the terrain of the flood plain. Pools are cost-effective as there are no constructions. Only technical support is sometimes needed for the excavation (Havlík, 2014).

Pools serve as a natural site for different kind of animals, as sedimentation catchment and help to flatter the flood waves. Pools enhance surface water and groundwater, and also improve the general view of landscape.

There are several types of pools. In this study, the types of pools are the following:

- <u>Micro-pools in the stream bed</u>

These micro-pools are naturally situated in wider and deeper parts of the stream. Micro-pools and direct flow segments always change longitudinal profile. Natural occurrence is in denuding parts of stream and they decrease the scouring process of transversal flow. They are often subject to changes.

- <u>Passable pools in the stream</u>

Passable pools are created by the stream bed enlargement. Water supply can be direct or tangential. Pools with tangential water supply can serve as a centrifugal sediment reservoir. In this case, the pool must be cleaned at least once a year due to fulfillment by sediments.

- <u>Side pools connected with stream</u>

There are two types of pools: side pools supplied by up-stream water, and side pools supplied by downstream water. The former has a problem with sedimentation. The latter has a better possibility for design. It is not as sensitive for sedimentation and is also less sensitive for water erosion.

- <u>Pools supplied by groundwater</u>

This is the most natural imitation of flood pools. The groundwater supply should not be the one supply. The stream should be connected apart. These pools are the best in flood wave flattering (Just, 2005)

3.3.2. Long Term Natural Restoration

Natural restoration is a process used for the stream beds which were modified by a technical restoration in the 60ties of the 20^{th} century. These modifications were reinforcement of banks by concrete blocks or usage of semi natural concrete blocks for forcing of river bed.
The basic rule of the natural restoration is to let the stream develop its way. The principle is simple - to let sediments denudate the bed, let plants and riparian vegetation grow over and support break down of old migration barriers. A part of the natural restoration is a transition of stream trajectory caused by the erosion

processes (Pácl, 2013). Natural restoration is a valuable natural process which improves the stream quality at minimal costs.
In the last few years, disruption of natural restoration became a problem. As a result, stricter rules were implemented during restoration evaluation processes. In the event that someone wants to proceed with the restoration of a stream, one has to substantiate the purpose of restoration with detailed documentation, and also, show designs of implemented technical modifications (Just, 2005).

There are two limits in natural restoration processes:

- Artificially enforced stream banks

As noted before, concrete or semi-concrete reinforcing blocks stop natural scouring. Another problem is the direct flow in stream, as it increases the velocity of flow and makes it impossible to take any sediment. This type of reinforcement was widely used during restorations in the past. The reason for using concrete blocks was to change shape of the stream, specifically to straighten it. As the straight line was not its natural way, the stream would obviously try to gain its shape back, the use of concrete blocks was necessary. This type of a historical restoration had an aftermath in the form of bigger floods. The stream bed was straightened and stream banks were enhanced by concrete blocks, but there was nothing for slowing of water during the higher flow rates. Thus, water in full strength could destroy everything in its path (Just, 2005).

- Extensive countersink of stream bed

The extensive countersink can be caused by unprofessional adjustments of stream. Artificial bank enhancement can be one reason for it or it may be caused by improper dredging of stream bed. If the bed has been once technically adjusted it has tendency for deeper and deeper countersinking. In this case neither natural dams form fell branches, nor tree stems are enough to solve the problem. To halt any further extension, it is better to fill up the stream bed with soil and to create new stream bed next to the original one. (Just, 2005)

A natural restoration represents a very slow process that requires a long period of time to achieve results. Whenever possible, we can help nature to deal with it. One possibility is, for example, to help to remove the artificial bank enhancement instead of waiting for a long time for its breakup. Another possibility is to make small correction steps, such as reforesting of riparian vegetation, or creation of natural dams. Only if it is clear these corrective steps will not work, it is necessary to make a design for the technical restoration (Just, 2005).
In general, the natural restoration is more valuable, but sometimes, it is not possible to wait such a long time for nature to help itself and we have to give it a helping hand.

4. Methodology

4.1. Data Collection

The first step of processing is the data collection. Data collection is made after receiving of the documentation with the intention of the project. Investor gave us only the task, with the rest of data to find out from each organization, such as Cadastral office, ZABAGED, geodetic agency, etc.
For feasibility study of river restoration, the study of river conditions from the biological perspective is required. This study is mostly made in cooperation with an expert company or external experts. The biological study helps with selecting appropriate location of sections and helps with understanding of the water environment. The other data used for this study were provided by the municipalities or data were freely available on the internet.

4.2. Survey of Area of Interest

When all data are obtained and processed, it is important to do the first observation of the area i.e. go to the terrain and do the hydromorphology survey. This survey gives a better view of problematic in area of interest. It is better for the survey to obtain maps from the cadastral office or geodetic agency and to write notes into these maps during the observation. A detailed photo documentation is also very important for later processing and preparing (drafting) proposals.

4.3. Description of Current State.

The end of the observation is necessary to review all notes made. These notes and photo documentation were used for the description of current state of the area of interest. They capture conditions on the stream. The photo documentation is an integral part of the final report, which is given to the company as outcome of the study.

4.4. The Documentation and Selection of Water Stream Section from the Morphological-Ecological point of view (MES)

This methodology was created by the Nature Conservation Agency of the Czech Republic and the Povodí Vltavy, s.p. The basic principles of the methodology are:

1. The preservation of a natural restoration;
2. Ecologically oriented maintenance of the stream;
3. Cancelling of waterworks on the stream; and
4. Point measures – non-regular usage of stone ripraps, stone fillings or individual stones in the stream bottom or embedding of large woody debris into the bottom.

It was tested, during the year 2012, on the watercourses in the catchment of Rakovnický stream. The methodology was used for the purposes of this study as it puts the emphasis on the improvement and it requires nearly no investment character measures.

Within each section of the stream which needs some improvements, there are 4 categories proposed for application of these measures:

A. The section of the stream in non urban area which requires more intensive restoration measures (investment character, mostly);
B. The section of the stream in non urban area or urban area, where the improvement of MES can be attained by less intensive or non-intensive restoration measures (non-investment character); usage of the nature restoration by appropriate ecologically targeted administration;
C. The section of the stream in the urban area or with direct influence on a urban area; which requires the introduction of the natural flood control measures (usually, the investment ones); and
D. Local restoration measures; usually, removal or patency of migration barriers on the stream.

There are two cases when we do not use the measures and we accept the current state:

1. The waterworks which are in a good state and are still in operation for serious reasons (such as, the flooding protection and stability protection of the urban area, roads, water dividers or other constructions); and
2. The traverse dike which is in operation and it is presently used with possible negative ecological impacts which can be mitigated, for example, by a bypass.

4.4.1. Description Categories according to MES

A. The section of the stream in non urban area which requires more intensive restoration measures (investment character, mostly)

The following list of the historical modifications on the stream may help with the classification into the category A:

- The technical reinforcement resisting to the decay, especially, the masonry lining, semi-vegetation blocks and other types of concrete blocks; in the landscape, these constructions are less acceptable than in the urban area;
- The technical reinforcement of the stream bottom (in urban area, could be acceptable);
- The technical bank protection which will represent a foreign element, even after the decay and as a result, it will be necessary to remove it from the stream;
- The stream bed is immoderately excavated – it does not correspond to the natural morphology;
- The presence of the traverse dikes (bottom drops, weirs), badly managed culverts, etc. which create the migration barriers on the stream;
- The slope of the longitudinal profile is so steep that there is no tendency to improvement, even by the sediment enhancement;
- The slope of the longitudinal profile and the character of its bedrock is hazardous from the perspective of a later excavation (clays or sandy soils);
- In the given area, it is necessary to introduce some measures in a short time period due to flood protection, or the nature preservation, and the natural restoration would take much more time;
- The character of stream surroundings (urban area) limits the development of the natural restoration – the improvement of the current state is possible only through the restoration which respects the nature; and
- The river restoration is possible with easily guaranteed results – the land in the area is suitable for restoration, an old stream bed is possible to be reconstructed from the aerial photos, or, if it is still partially preserved, from the period before the modification.

B. The section of the stream in non urban area or urban area, where the improvement of MES can be attained by less intensive or non-intensive restoration measures (non-investment character); usage of the nature restoration by appropriate ecologically targeted administration

The division of the stream section to the category B means, in reality, that in this section, the stream bed can follow the natural restoration. The technical reinforcements are already in decay, the shape of the stream has a more natural appearance, the stream bed is fouled or, it is otherwise scoured. These processes could be supported or streamlined by partial water management operations, but without any investment interventions. The goal of these operations is in the first place, the suppression of unfavorable aspects of the natural restoration. For example, an immoderate excavation of stream bottom or the change of trajectory in areas with the problematic land ownership.

The list of properties which may assist with the classification into the category B:

- The technical reinforcement is in decay by the natural way and it becomes part of the nature like material in the stream, or it is sufficient to collect the decayed material from the stream;
- The stream bed is partially modified, but the quality of the restoration is not as good and makes it impossible to develop the stream, and it is not registered as the investment property with the stream administrator;
- Although the stream line is straightened and the stream banks are partially reinforced, the stream bottom evolved into the natural state;
- The riparian vegetation helps the decay of technical forcing and through introduction of any restoration measures, this vegetation may be destroyed;
- The stream has a tendency to the sedimentation (including sections with a little slope in longitudinal profile where the technical bank protection remains, but it is covered by sediments);
- The stream bed changes the stream line favorably by the denudation of stream banks and this development is not limited by the surrounding land ownerships; and
- The significant improvement of the stream state can be reached only by using of single element, e.g. non-regular stone riprap or large woody debris.

C. The section of the stream in the urban area or with direct influence on a urban area; which requires the introduction of a natural flood control measures (usually, the investment ones)

The character of the stream section was in some way damaged according to MES by technical modifications or by an inappropriate construction of a transverse dike. The improvement of MES is not possible to be reached by consistent renewal of natural state of section due to the requirement for preservation of the big cross section in built up areas. This is necessary for the protection of the built up area for the reason of diversion of water during higher flow rates. Usually, the requirements for the stream bed stability cannot be ignored, so, it is not possible to support the natural development of the stream here, or it can be supported only partially. The strengthening of the flood control measures can be one of the main reasons for the design of the measures. In this case, the proposal is to increase the flow or the retention capacity of the stream bed or the entire stream. These measures must be accompanied, at least, by the basic indicators of favorable morphological-ecological state of the stream.

D. Local restoration measures; usually, removal or patency of migration barriers on the stream

These measures are:

- Removal of unfavorable hydrological facility which is the migration barrier or the obstacle during floods or it can be harmful for the MES for the stream by the backwater storage, etc.;
- Replacement of the facility by another one, much lower and more nature like; and
- Patency of the migration barriers through the construction of a bypass.

4.5. Technical Report

The technical report is the outcome of this study. The first part is a general description of the area of interest. The report have several requirements which have to be studied i.e. the hydrological identification of the stream, description of climate, protected areas or the information about the land use in the area of interest. These information were obtained from collected data in the beginning of the study.
The second part of the technical report is the description of current state in the area. The third and the most important part are proposals of river restoration measures according to the documentation and selection of water stream section from the morphological – ecological point of view (MES). This document defines the sectioning of the stream as well as the proposed restoration measures.

4.6. Designs

Significant number of different designs was required to write up the study, for example designs in which we highlighted ownership of the land in the study area, designs with highlighted use of the land, designs with our proposed measures, or with stream trajectory shape changes.

5. Project

5.1. Project Identification

Name of project:	River restoration of Knovízský stream
Region:	Středočeský
Municipality with extended competence:	Kralupy nad Vltavou, Kladno
Cadastral area:	Kralupy nad Vltavou (river kilometer 0,000-0,183),
	Mikovice (river kilometer 0,183-1,714), Zeměchy (river kilometer 1,714-3,673), Olovnice (river kilometer 2,673-6,423), Neuměřice (river kilometer 6,423-7,422), Kamenný Most (river kilometer 7,422-8,796), Zvoleněves (river kilometer 8,796-10,774), Podlešín (river kilometer 10,774-12,918), Knovíz (river kilometer 12,918-14,884), Jemníky (river kilometer 14,884-16,600), Pchery (river kilometer 16,600-16,924),
	Saky (river kilometer 16,924-18,675),km, Třebichovice (river kilometer 18,675-19,380)
Client:	Povodí Vltavy, státní podnik
	Holečkova 8, Praha 5, 150 56
Level of Project:	Feasibility study
Processed by:	Vodohospodářský rozvoj a výstavba, a.s.,
	Nábřežní 4, 150 56 Praha 5

5.2. List of Documents Used in the Study

1) Technical documents of Knovízský stream, SVIP – Asociance projektantů a geodetů, 2007
2) The database of AOPK ČR, AOPK ČR, 11/2012
3) Actualized planning analytical documents for the municipality with extended competence Kralupy nad Vltavou, Institut regionálních informací, s.r.o., 11/2010
4) Planning analytical documents of municipality with extended competence Slaný, Georeal, s.r.o., 2010
5) Kralupy nad Vltavou, Common measures plan, Atelier pro urbanismus a územní planování, 2002
6) Neuměřice, Common measures plan, Agrourbanistický ateliér, 1/2011
7) Kamenný most, Common measures plan, Agrourbanistický ateliér, 2002
8) Zvoleněves, Common measures plan, PAFF, 2002
9) Podlešín, Common measures plan, Agrourbanistický ateliér, 2006
10) Knovíz, Common measures plan, Ing. Arch. Merunková, 2005
11) Pchery, Common measures plan, KA*KA projektový ateliér, 2009
12) Třebichovice, Common measures plan, Ing. Arch. J. Mejsnarová, 2007
13) Analytical planning l documents
14) The biological study

5.3. Description of the Area of Interest

5.3.1. Description of Current State

The area of interest is defined by the Knovízský stream which is a part of the catchment of Zákolanský stream. Extent of the study is determined by the length of the stream – from the 0,000 to 19,380 river kilometer. The area belongs to Středočeský region and the municipality with extended competence is Kralupy nad Vltavou and Slaný. The goal of this project is the feasibility study of river restoration measures and the patency of migration barriers on this stream.

The stream flows in the north-east direction. The spring of Knovízský stream is in the south from the village Libušín. In the beginning the stream flows in the forest and the stream bed is not very well distinguishable. The first village on the stream is Libušín. In the village the stream flows through the urban area and its bed is technically reinforced by concrete blocks. The stream is canalized in some parts of the village. The next part of the stream flows through the non urban area. There are several tributaries that are unmarked. The next village is Třebichovice and in this village there starts our area of interest. The area of interest is limited by the railway corridor on one side and the road on the other side. In the area of interest there are several villages affecting the stream - Saky, Jemníky, Knovíz , Podlešín, Zvoleněves, Kamenný Most, Neuměřice, Olovnice, Zeměchy, Mikovice and Kralupy nad Vltavou. In the city Kralupy nad Vltavou is the confluence of Knovízský stream and Zákolanský stream. The biggest tributaries of Knovízský stream are

Svinařovský stream, its confluence is in the village Třebichovice and the stream Slatina who's confluence is beyond the village Olovnice.
The stream character is mostly agricultural in this area– there are changes in between the meadows and urban areas. In the past this stream was largely technically modified. The straightening and bank reinforcement were applied there. A detailed description follows in the next point of this chapter 5.4.

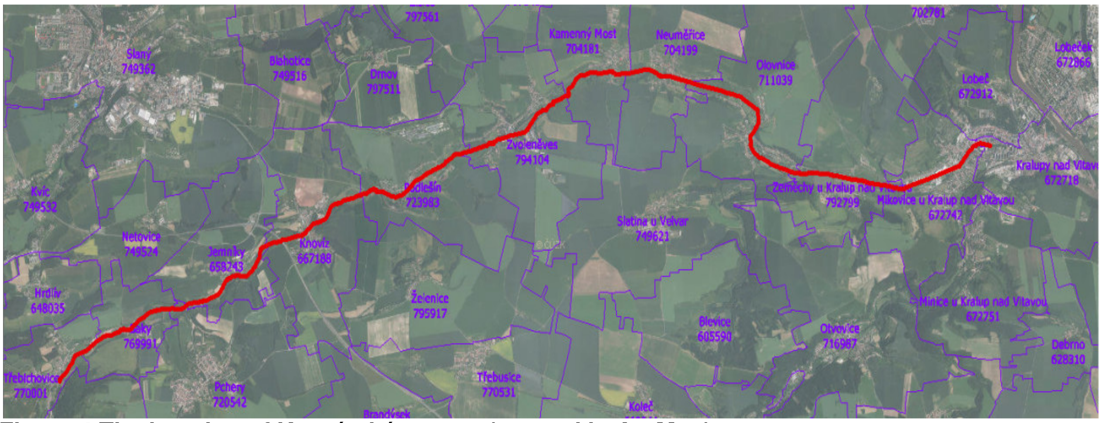

Figure 4 The location of Knovízský stream (created in ArcMap)

Legend

stream route

The water stream flow through these cadastral areas:

Kralupy nad Vltavou (river kilometer 0,000-0,183),
Mikovice u Kralup nad Vltavou (river kilometer 0,183-1,714),
Zeměchy u Kralup nad Vltavou (river kilometer 1,714-3,673),
Olovnice (river kilometer 2,673-6,423),
Neuměřice (river kilometer 6,423-7,422),
Kamenný Most (river kilometer 7,422-8,796),
Zvoleněves (river kilometer 8,796-10,774),
Podlešín (river kilometer 10,774-12,918),
Knovíz (river kilometer 12,918-14,884),
Jemníky (river kilometer 14,884-16,600),
Pchery (river kilometer 16,600-16,924),
Saky (river kilometer 16,924-18,675),
Třebichovice (river kilometer 18,675-19,380)

5.3.2. Hydrological Identification

Knovízský stream together with Zákolanský stream are part of the catchment of river Vltava.
The stream spring is a few kilometers south-west from the village Libušín. The flow direction of the stream is to the east. The area of the catchment of Knovízský stream is 92,231 km^2.

The Knovízský stream belongs to the list of significant watercourses according to the **267/2005 Sb.**,

Serial number	*Water stream*	*The identification of the stream according to the notice nr. 391/2004*	*The hydrological number according to the notice nr. 391/2004*	*The length of the stream (km)*	*The stream administrator*
310	Knovízský stream	10100219	1-12-02-041	25,0	PVl

Table 1 Stream identification (eAgri.cz)

5.3.3. Climate

The climate of the stream is influenced by Krušné and Doupovské mountains. There is a low amount of precipitation caused by these mountains. The average precipitation is from 450 mm to 550 mm per year. The lowest amount of precipitation (442 mm per year) was measured in the village Neuměřice.

5.3.4. Hydrological – Geological Conditions

In the area of Knovízský stream it is possible to find dominantly fissure groundwater with small yield. It is caused by the lower soil layers - the maternal rocks are covered by rubble with smaller permeability.
The occurrence of alluvial waters is around the city Kralupy nad Vltavou. The soil layer has higher permeability.
The groundwater table is directly dependent on the water level in the stream in the whole area of interest.

5.3.5. Protected Deposit Areas

In our area of interest there are no protected deposit areas.

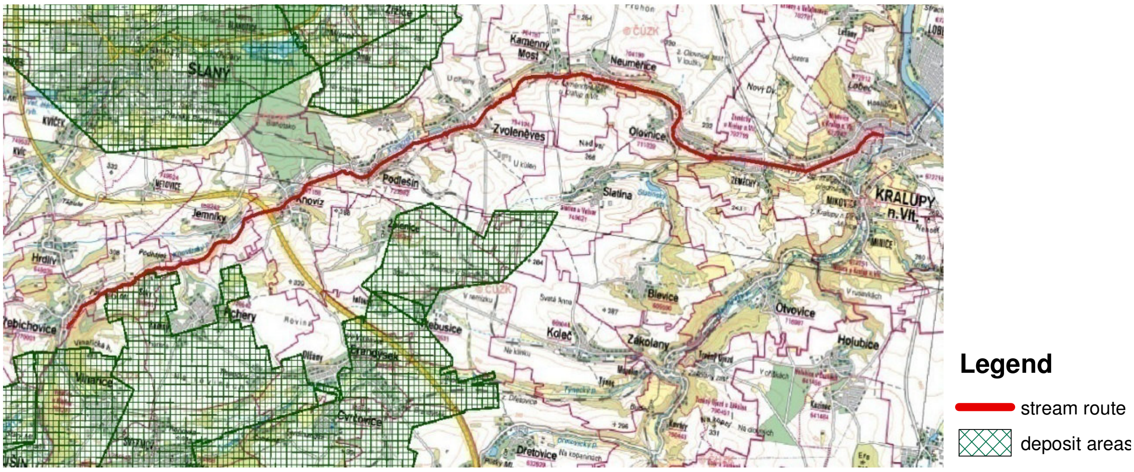

Figure 5 Protected deposit areas (created in ArcMap) (geoportal.cz)

5.3.6. Soil types

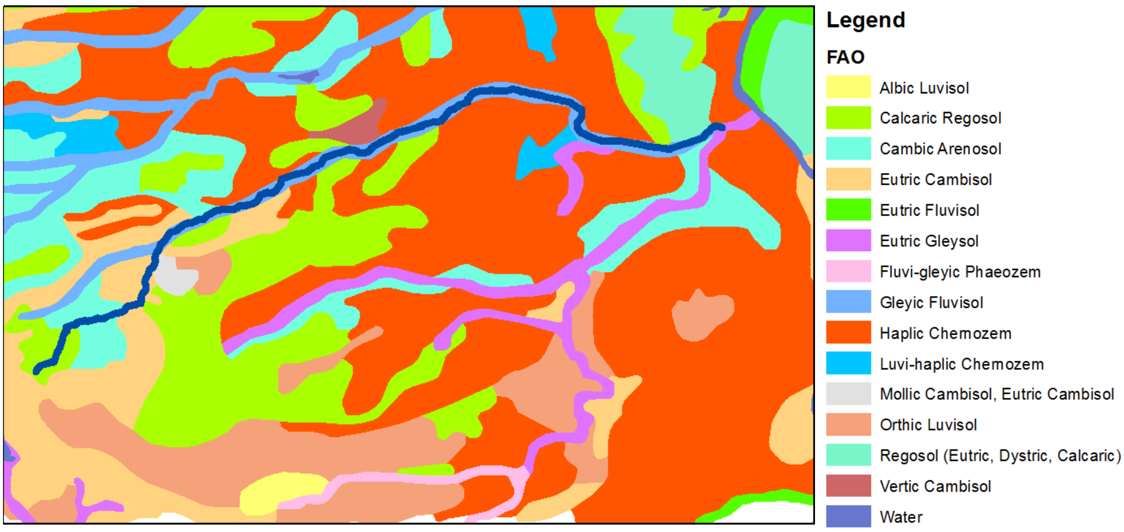

Figure 6 Soil types (created in AcrMap)

5.3.7. The Land Use according to CORINE Land Cover 2000

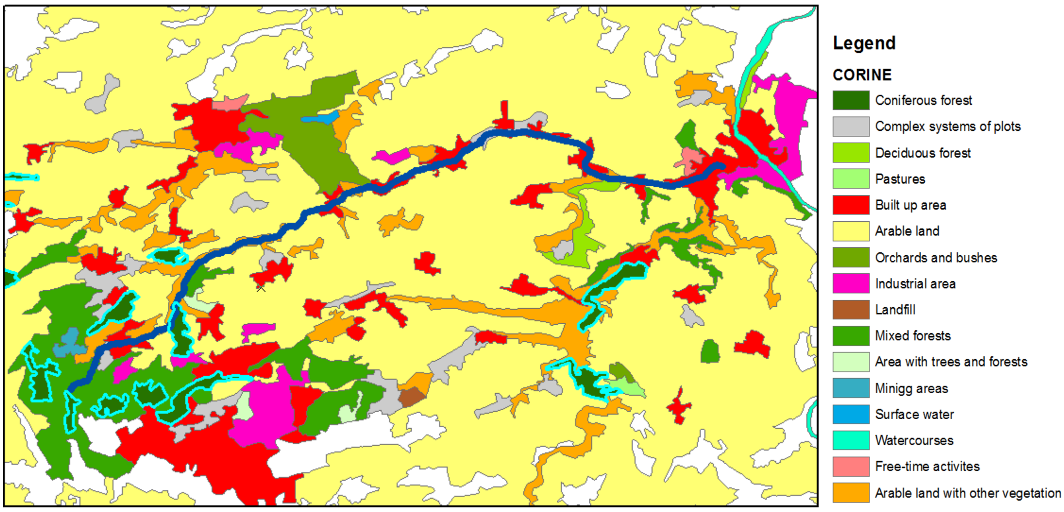

Figure 7 Corine Land Cover (created in AcrMap)

The arable land is a dominant land cover in the area of interest. The other important components of the land use are the urban areas on the stream.

5.3.8. Limitations in the Land Use

5.3.8.1. Protected Areas

In the area of interest are no protected areas according to Act 114/1992.

5.3.8.2. The Natura 2000

In the area of interest there are no localities of European significance not even a bird area.

5.3.8.3. Territorial systems of ecological stability

The goal of the territorial system of ecological stability (TSES) is the interconnection of the natural and modified ecosystems. It should keep the natural balance. The main goals are:

- The creation of the net of the ecologically stable areas which have positive influence on the less ecologically stable landscape
- Preservation or the restoration of the natural geofond
- Preservation or support of the biodiversity

We can find the regional or local biocoridors or biocentres (nowadays functionless) in entire area of interest. The restoration should improve the interconnection of these elements of ecological stability. The role of the stream is a significant element in the landscape. The improvement of morphological and biological parameters of the stream bed and surrounding flood plains is very important.

5.3.8.4. Protected Areas of Natural Accumulation of Water

The area of interest does not belong to the protected area of natural accumulation of water.

5.3.8.5. Undermined Areas

Historically this area was used for the black coal mining. The most undermined areas are in the cadastral areas Neuměřice, Kamenný Most and Podlešín.

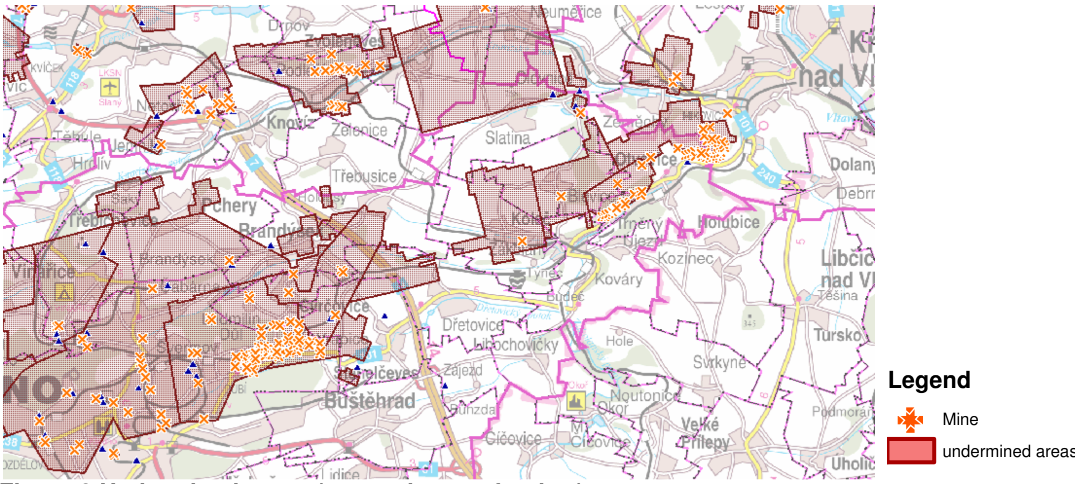

Figure 8 Undermined areas (mapmaker.geofond.cz)

5.3.9. Water management structure

The water management structure of this area was compiled from the Plan of the development of water supply and sewage system for the Středočeský region. The technical documentation of each village assisted to fulfill the proper area description.

5.3.10. Urban Planning Documentation

A big number of affected land owners were found out from accessible urban planning documentation. Affected are networks of technical infrastructures and other infrastructure as electricity and water supply, sewage networks, roads and railway, etc. One of the other affected areas, are drinking water protection zones or undermined areas.

5.3.11. Historical Research according to Maps

One of the reasons for river restoration can be the stream modification made in the past. The most common modification was the change of the stream trajectory (straightening). The stream modifications were used in accordance to the increase of population. The historical maps are a very important source for the river restoration survey. These maps can help to find out the original shape and the location of the stream in past.
For the assessment of these maps can be used historical development of the stream:

- Cadastral maps
- Land cadastral maps
- The Imperial imprints of the stable cadastre
- Military maps
- Aerial photos

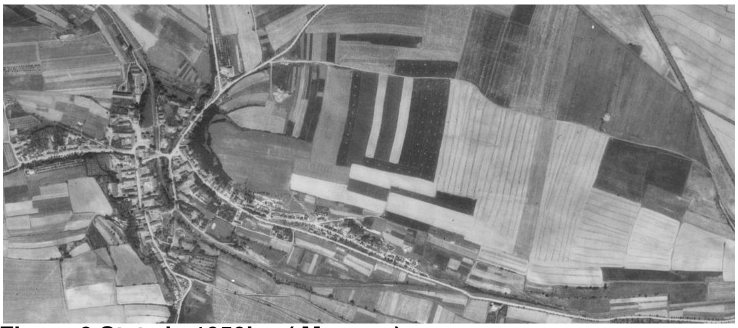

Figure 9 State in 1950ies (Mapy.cz)

Figure 10 Current state (Mapy.cz)

5.3.12. Melioration interventions

In the area of interest are melioration interventions according to the Urban planning documentation. In this stage of study this problem was not solved. The problem solution is the part of the technical documentation during the next stages of the project.

5.3.13. Flood plains

The Knovízský stream does not belong to streams inclinable to floods. In accordance to this fact there is inappropriate awareness of people in terms of the flash floods and it can be also the reason for the insufficient resolving of the river restoration. The situation is deteriorated by the improper maintenance and in-stream structures (bridges, weirs...).

5.4. Division of Area of Interest and Detailed Description of Sections

Area of interest was divided into seven sections for the purposes of this study.

Section number	Section definition	Section definition – river kilometer
1	Inflow to the Zákolanský stream – The road bridge in upper part of city Kralupy nad Vltavou	0,00 – 1,723
2	The road bridge in upper part of city Kralupy nad Vltavou – The road brigde in Olovnice village (street Kralupská)	1,723 – 4,678
3	The road brigde in Olovnice village (street Kralupská)- The road bridge in Kamenný most village	4,678 – 7,778
4	The road bridge in Kamenný most village – The road bridge in Zvoleněves village	7,778 – 9,956
5	The road bridge in Zvoleněves village – The railway viaduct in Podlešín village	9,956– 12,512
6	The railway viaduct in Podlešín village – The road bridge in Jemníky village	12,511- 15,445
7	The road bridge in Jemníky village – The bridge near the football ground in Třebichovice village	15,445– 19,380

Table 2 Division of area of interest

Figure 11 Division of area of interest (created in ArcMap)

Legend

section1 section3 section5 section7
section2 section4 section6

5.4.1. Description of Current State of Section Nr. 1

Inflow to the Zákolanský stream – The road bridge in upper part of city Kralupy nad Vltavou,
River kilometer 0,00 – 1,723

Figure 12 Section nr. 1 (created in ArcMap)

Cadastral area:	Kralupy nad Vltavou, Mikovice u Kralup nad Vltavou
Section length:	1723 m
Elevation in the beginning:	173,58 m n.m.
Elevation in the end:	181,69 m n.m.
The bottom slope:	4,73‰

This section begins where Knovízský stream inflows into the Zákolanský stream. It is in the urban area of the city of Kralupy nad Vltavou, near the school. Knovízský stream is a significant element here because it flows through it. The Masner path is situated on the left side of river bank and it is used by people for free time activities.
In the beginning (i.e. in the lower part of stream near the school), the flow area has reinforced trapezoidal cross-section. The slope of banks is 1:1,5 and the width of bottom is from 3 to 3,5 meters. The stream bank reinforcement is approximately 1 meter high, and it is made from concrete masonry lining. However, this bank protection is not constructed regularly in whole length of the first section. The stream bed is filled with gravel. From river kilometer 0,300 to 0,700 (crossing with Přemyslova Street), the stream is without any significant reinforcement. The right side of the stream bank is very badly accessible due to dense riparian vegetation

which is not maintained. The stream is led through a canal in river kilometer 1,100 – 1,175. The reasons are: the industrial area on the right bank side and a soil dump on the left bank side. After the end of canalization, the stream banks are reinforced, and from the river kilometer 1,330, a heel of slope is reinforced by concrete panels. The first section ends by the road bridge, on the upper part of the built up area of the city of Kralupy nad Vltavou.

Figure 13 Confluence with Zákolanský stream. Left side: Zákolanský stream, Right side: directly flowing stream bed of Knovízský stream

Figure 14 Stones in the stream bed increase the diversity of flow

Figure 15: Banks have a steep slope character

Figure 16: Part of stream surroundings have a park character so enables design of restoration and flood control measures

5.4.2. Description of Current State of Section Nr. 2

The road bridge in upper part of city Kralupy nad Vltavou – The Road bridge in Olovnice village (street Kralupská)
River kilometer 1,723 – 4,678

Figure 17 Section nr. 2 (created in ArcMap)

Cadastral area:	Mikovice u Kralup nad Vltavou, Zeměchy, Olovnice
Section length:	2951 m
Elevation in the beginning:	181,69 m n.m.
Elevation in the end:	190,09 m n.m.
The bottom slope:	2,85 ‰

This section begins in river kilometer 1,723, at the outlet of the road bridge. Here, the stream is straightened, it has trapezoidal cross-section with slopes of banks 1:1,5 and a bottom width of 3 meters. In the inflow into the city, the stream bed is protected by permanent grassland, which is filled by riparian vegetation. The stream bottom is immoderately excavated in non urban area and it causes drainage of the flood plain. Next village on the stream is Zeměchy village, with a summer house area located there, as well, the Water Treatment Plant and the outlet of drainage system from the village.

Knovízský stream flows only through the summer house area, but not through the village itself. There are artificial man-made dams constructed on the stream creating migration barriers. The other construction in the area is a concrete wall. At the end of village, the stream has a natural appearance with stream bank slope1:1,5 and a bottom width 3 meters. There are 3 big ponds on the right side of the stream. The stream Slatina is a right sided inflow and the confluence is on river kilometer 3,467.

On the left side, the stream is bound by the railway. In the village Olovnice, which is the following one, there is a crossing of the stream and the railway. Where the village begins, there are huge swamps located on the left side.
At the beginning of the village Olovnice, the stream bed changes its shape into a concrete channel. The channel has a rectangular cross-section made by concrete blocks. In this way, the stream is reinforced until the end of the section, i.e. the road bridge on river kilometer 4,678.

Figure 18: Artificial man-made dam in summer house area

Figure 19: The concrete wall in summer house area

Figure 20: The stream on inflow into village Zeměchy

Figure 21: A concrete channel in Olovnice village

5.4.3. Description of Current State in Section Nr. 3

The road bridge in Olovnice village (street Kralupská) – The road bridge in Kamenný most village
River kilometer 4,678 – 7,778

Figure 22 Section nr. 3 (created in ArcMap)

Cadastral area:	Olovnice, Neuměřice, Kamenný Most
Length of section:	3100 m
Elevation in the beginning:	190,09 m n.m.
Elevation in the end:	200,95 m n.m.
The bottom slope:	3,50‰

The stream channel is reinforced only at the beginning of the section in Olovnice village (river kilometer 4,570 - 4,900). On the inflow to the village, the stream bed returns back to a semi-natural appearance. It has the trapezoidal cross-section with slopes of banks 1:1,5 – 1:2 and the width of 3 meters in the bottom. After the village, there are swamps on the left side of the stream. These swamps are spacious and are accompanied with typical swampy vegetation. The next village on the stream is Neuměřice. The stream flows only on the boarder of this village, so the stream is only partially protected. The reinforcement is made by masonry lining and stone riprap with height of 0,5 to 1 meter. In this part of the stream, it is possible to see a gradual natural restoration.

The stream continues to non urban area where it is reinforced with lattice fence. Then, the stream flows out into the urban area of the village Kamenný most. In this village, there is a pond on the left stream bank side. The Knovízský stream is in the village reinforced by stone riprap and masonry lining. The character of the stream bed is very similar to the previous sections. From the left side, the stream is limited by the railway.

Figure 23: Concrete channel in Olovnice village

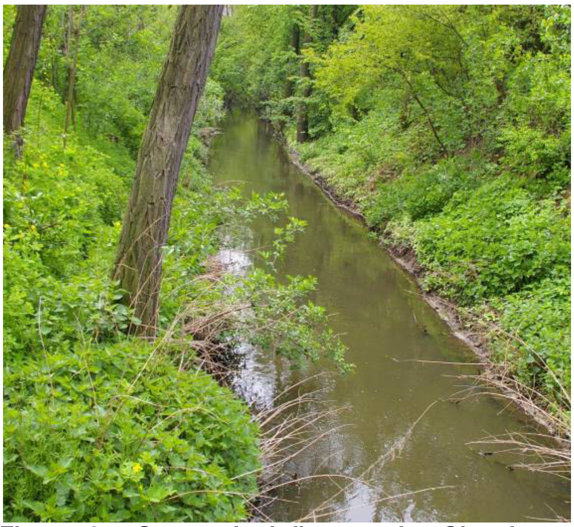

Figure 24: Stream in inflow to the Olovnice village

Figure 25: Knovízský stream is limited by the railway

Figure 26: Lattice fence enforces the banks in between village Neuměřice and Kamenný most

5.4.4. Description of Current State of Section Nr. 4

The road bridge in Kamenný most village – The road bridge in Zvoleněves village, River kilometer 7,774 – 9,951

Figure 27 Section nr. 4 (created in ArcMap)

Cadastral area:	Kamenný Most, Zvoleněves
Length of section:	2177 m
Elevation in the beginning:	200,95 m n.m.
Elevation in the end:	211,42 m n.m.
The bottom slope:	4,81‰

The stream character is very similar to the previous one. Similarly, as in the third section, there is a stream restriction by the railway, on the right side, and another restriction by the road, on the left side. This limitation continues until the 9,047 river kilometer at the crossing of the railway and the stream.

In the inflow of the Kamenný most village, there is quite dense riparian vegetation which makes the access to the stream difficult. It can also be a threat, in the event of higher flow rates. The riparian vegetation may jam the stream bed by catching wooden debris and may cause spillage of the stream. Before the inflow to the village, there are wide swamps along the stream. The land with the swamps belongs to the village, so we may assume that this area can be used for the restoration (stream curvature or pool construction with corresponding vegetation).

In the non urban area, the stream bed has a natural appearance with occurrences of large wooden debris. These debris could be evaluated as a temporal migration barriers. In the stream surroundings, there are several swamps with corresponding vegetation. In the 8,762 river kilometer, there is an old concrete and damaged weir. It is a significant migration barrier and it may be the reason for flooding, in the event of higher flow rates. A few meters after the weir, on the left bank, there are sedimentation tanks which were used in past. The lower retention tank has an area 1,7 ha, the middle retention tank has an area 0,8 ha and the upper retention tank has an area 0,5 ha. Presently, these tanks are overgrown with permanent grassland and trees.

The stream is overgrown with dense riparian vegetation and the river bed shows the natural character. Up the stream, the stream line is curved and the bank line has also a more natural shape.

In the outflow of the village Zvoleněves, which is next village on the stream, we can see again the bank protection by concrete blocks which are constructed in the trapezoidal shape. In the river kilometer 9,406 - 9,689, there is an industrial area. In this area, the stream is canalized. The area is fenced, so it was not possible to go there and to see the canal, not even to evaluate the state it is in.

Figure 28: Pond in the village Kamenný Most is on the left side of the Knovízský stream

Figure 29: Dense riparian vegetation

Figure 30: Concrete enhancement in outflow of Zvoleněves village

Figure 31: Retention tanks used in past – nowadays overgrown by vegetation

5.4.5. Description of Current State of Section Nr. 5

The road bridge in Zvoleněves village – The railway viaduct in Podlešín village
River kilometer 9,956– 12,512

Figure 31 Section nr. 5 (created in ArcMap)

Cadastral area:	Zvoleněves, Podlešín
Length of section	2560 m
Elevation in the beginning:	211,42 m n.m.
Elevation in the end:	220,33 m n.m.
Slope of bottom	3,48‰

The fifth section begins right next to the road bridge in the village Zvoleněves. A few meters after the location of this bridge, there is a small concrete weir with a water gate. The water gate is in operation, but the construction of the entire weir is damaged. Then, the stream flows through the village to the next concrete weir. This weir is placed on the stream due to the pond Otrok which is on the left side of it. The stream bed continues in a natural character with very dense riparian vegetation. This vegetation makes it impossible to access the stream.
In the non urban area, there are visible traces of water erosion from the agricultural land. It also has influence on the bottom of the stream – as there is significant sedimentation in this area.
Further, the stream flows around the Waste Water Treatment Plant in Podlešín village, then, it flows through urban area of the village and continues to non urban area. In the village, the character of the stream bed is artificially reiforced trapezoid,

with the bottom width of 2 meters and bank slopes 1:1,5. The bottom of the stream and the heel of the slope are artificially reinforced, as well, for that protection, masonry lining was used. The stream banks are very well maintained in the village, but the stream is mostly overgrown by permanent grassland. As the riparian vegetation is in appropriate distance, it does not block the flow in the stream.
A few meters from the road bridge, in village Podlešín, there is a concrete wall with hiking trails leading to it which are used for free time activities. Then, the stream inflows into the village and again, it has a more natural character.

Figure 32: Weir with water gate after the canalization

Figure 33: Pond Otrok is supplied by the Knovízský stream

Figure 34: Water divider of pond Otrok

Figure 35: The hiking trail in village Podlešín

5.4.6. Description of Current state of Section Nr. 6

Railway viaduct in Podlešín village – Road Bridge in Jemníky village
River kilometer 12,512- 15,445

Figure 36 Section nr. 6 (created in ArcMap)

Cadastral area:	Podlešín, Knovíz, Jemníky
Length of section	2923 m
Elevation in the beginning:	220,33 m n.m.
Elevation in the end:	236,08 m n.m.
Slope of bottom	5,39‰

The section number six begins from the viaduct which is located after the village Podlešín. The stream flows through non urban area with agricultural character to the village Knovíz. There, it continues around the Water Treatment Plant, garden colony and an urban area. This section ends under the road bridge in village Jemníky. The stream bed is approximately 2 meters wide and the bank slope is 1:1,5.

In the urban area of the village Knovíz, there are two types of shapes of the stream bed. In its first part, the stream has a rectangular shape, it is made from the concrete wall and it is filled with stones. At the end of the village, the shape of the stream has changed to the trapezoidal one. The width of the stream is 1,5 – 2 meters.

Before the inflow to the village, the stream returns to a semi-natural character. In the beginning of non urban area, there are remnants of stone reinforcement and there is also very dense riparian vegetation. This vegetation makes it impossible to access the stream. In some places, it may even cause serious problems during higher flow rates. The sedimentation here represents the same problem as in the previous section. In the stream surroundings, there are many agricultural areas which are not utilized according to the erosion principles. Then, the stream crosses the highway from Praha to Slaný. The next village on the stream is Jemníky. A few kilometers before the village, there is an old stony weir with a water gate. This water gate is out of order (there is only the iron structure), but it blocks the stream and it is a migration barrier. It can be also the reason for the spillage of the stream.

Figure 37: Stream enhancement in the the village Knovíz

Figure 38: Viaduct away the village Podlešín

Figure 39: Bank enhancement in the non urban area after the village Jemníky

Figure 40: Old weir with water gate – the iron structure

5.4.7. Description of Current State of Section Nr. 7

The road bridge in the Jemníky village – The bridge near the football ground in Třebichovice village
River kilometer 15,445 – 19,380

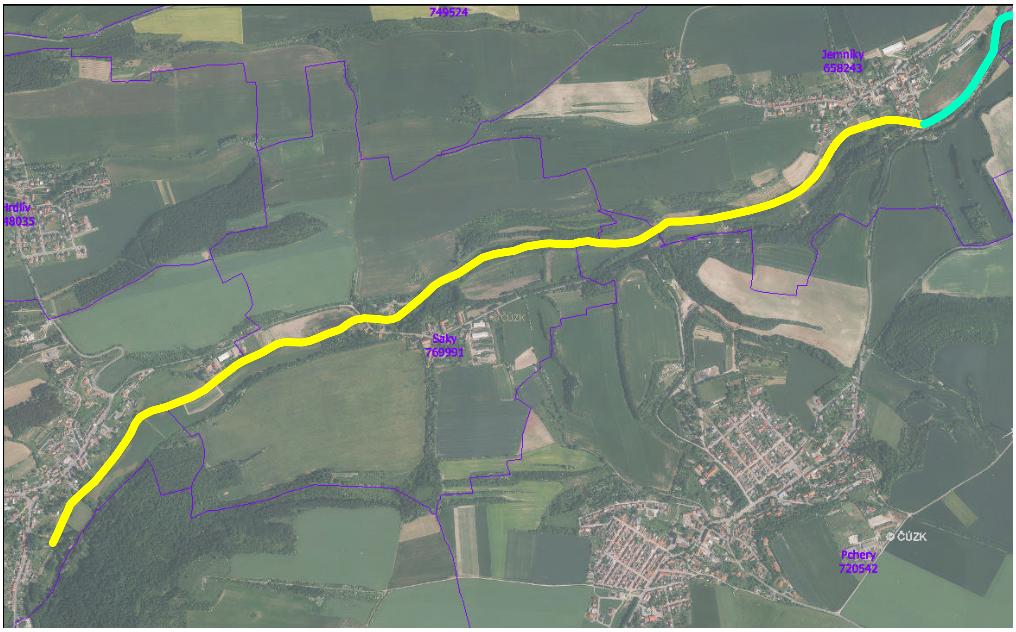

Figure 41 Section nr. 7 (created in ArcMap)

Cadastral area:	Jemníky, Saky, Třebichovice
Length of section:	3946 m
Elevation in the beginning:	236,08 m n.m.
Elevation in the end:	263,30 m n.m.
Slope of bottom:	6,90‰

In the village Jemníky, where our section starts, the stream bed is reinforced by concrete panels. It has a trapezoidal shape. In the inflow to the village, the stream has again a relatively natural character with the stream bottom width of 1,5 meters and the slopes of banks in ration of 1:2. Then, the stream continues to the next village Saky and it flows through the urban area. In this village, it flows around an old mill called Panínský. The stream flow has natural character with smaller width, around 1 – 1,5 meters and the slope ration is 1:2.
The village Třebichovice is the last village of our area of interest. At the beginning of the village, the vegetation quite often fell into the stream bed and created a migration barrier which can also cause flooding. The stream bed is very well maintained, the riparian vegetation was eliminated before we did our observation. The stream has several tributaries in the village - Svinařovský stream, and many

others which names are not known. In the village, the stream is straightened and it does not have the appropriate flow capacity.

Figure 42: Natural character in village Třebichovice-Saky

Figure 43: Tributary of Knovízský stream

Figure 44: The stream bed with small capacity

Figure 45: Fell vegetation – migration barriers on stream

5.5. Proposed River Restoration Measures

5.5.1. River Restoration Proposals for the Section Nr. 1

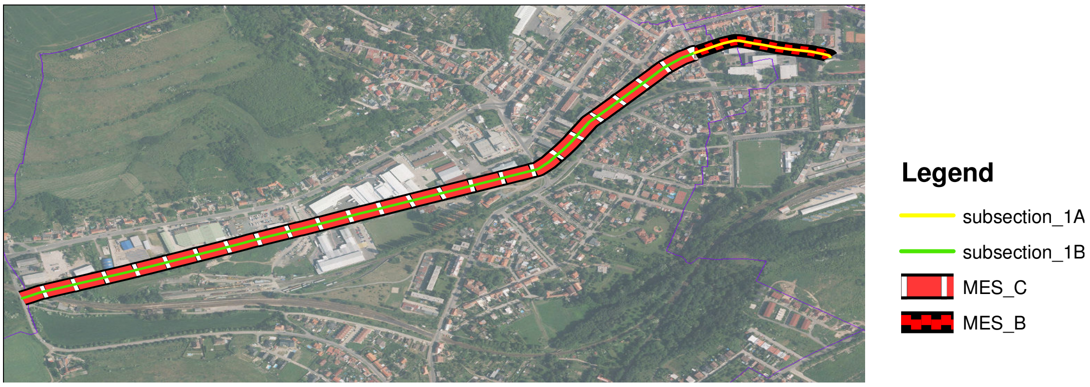

Figure 46 Proposals for the section 1 (created in ArcMap)

5.5.1.1.Subsection 1A

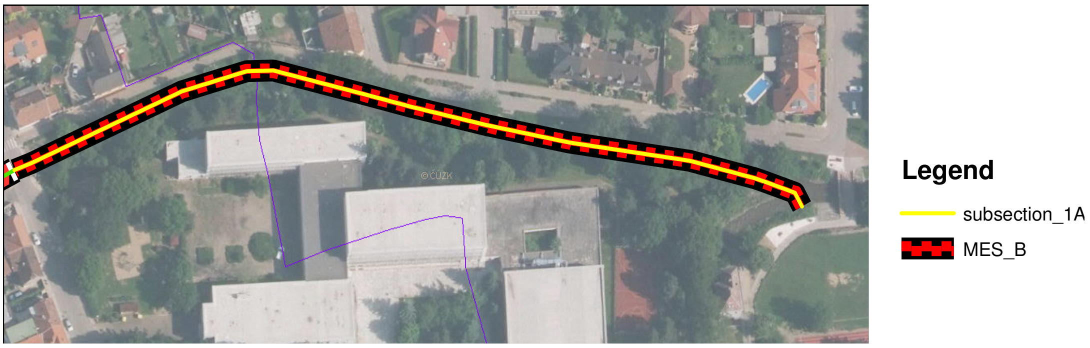

Figure 47 Subsection 1A (created in ArcMap)

The subsection 1A is located in the urban area of the city Kralupy nad Vltavou. Around the stream, there leads the Masner path which is widely used by people for free time activities. To improve the environmental quality of this urban subsection, we propose to use local stone ripraps for the diversification of the stream line. Another proposal is to remove all barriers which are located in the stream bed.

5.5.1.2. Subsection 1B

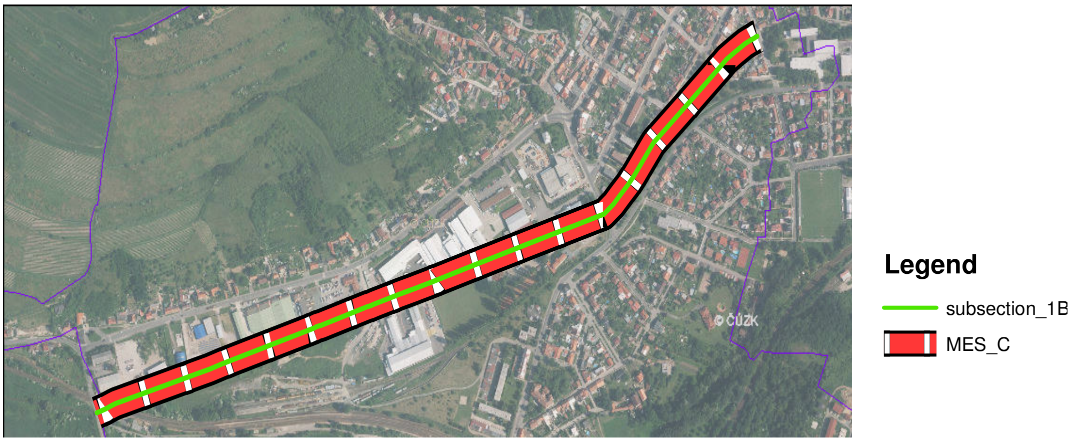

Figure 48 Subsection 1B (created in ArcMap)

This subsection flows by urban area as well. The proposal is to enlarge the stream bed with irregular use of stone ripraps. The enlargement should include the curvature of the stream line in sections without the stone ripraps. This measure should slow down the flow velocity in the stream. The stream banks should be reinforced with permanent grassland.

5.5.2. River Restoration Proposals for the Section Nr. 2

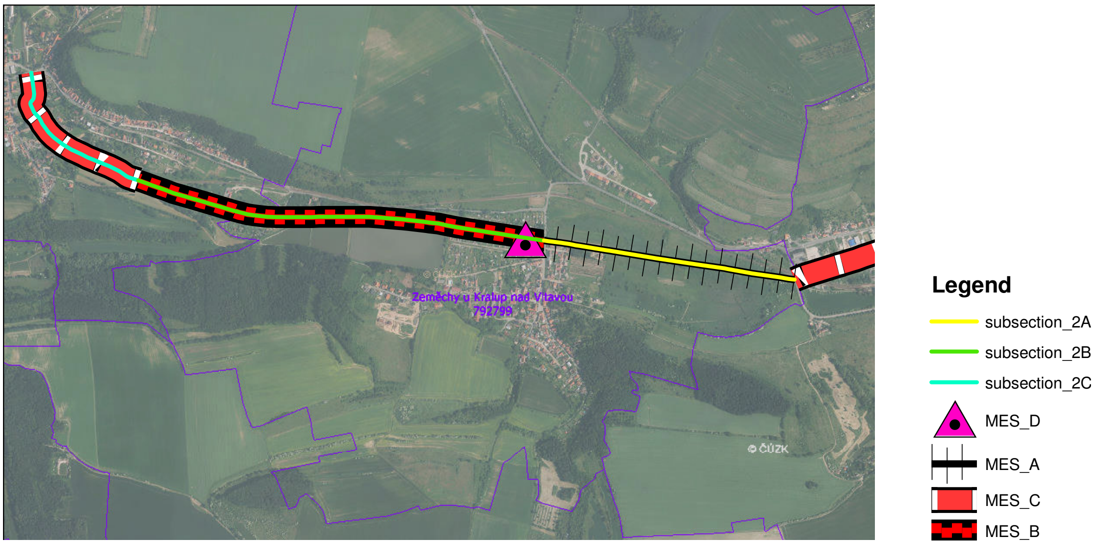

Figure 49 Proposals for the section nr. 3 (created in ArcMap)

5.5.2.1. Subsection 2A

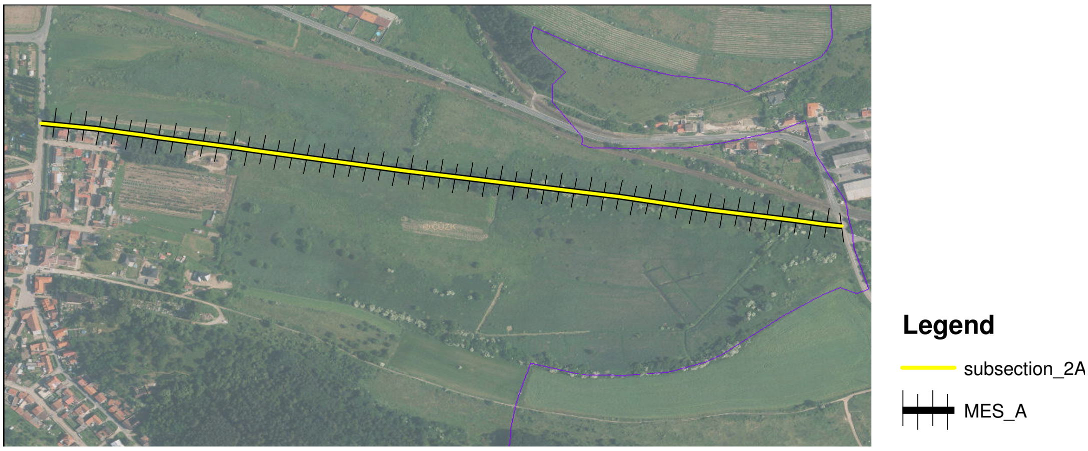

Figure 50 Subsection 2A (created in ArcMap)

This subsection begins after the city Kralupy nad Vltavou (river kilometer 1,75 – 2,617). In the past, the stream bed was straightened, so it is proposed to apply here the MES category A – to change the trajectory of flow and to curve the stream line. Around the stream, there are huge swamps which are presently extremely drained due to the stream straightening. The stream curvature should repair this and restore the stream to its natural appearance. The proposal includes the design of passable pools in the stream. They should be the source of water during the re-irrigation of swamps. According to the proposal, the stream bed is designed in a natural way and should end in front of the village Zeměchy.

5.5.2.2. Subsection 2B

Figure 51 Subsection 2B (created in ArcMap)

This subsection flows through the summer house area. Approximately, in 2,750 river kilometer, there is an artificial dam constructed in the stream. According to the patency of the stream, it is proposed to remove this dam pursuant to MES category D. This migration barrier deteriorates the flow rates during the flood events, as well.

After the through flow by the summer area, there is not enough space for designing any special measures because of the pond (river kilometer 2,70 – 2,95). For this reason, the proposal is to use figures from the stone riprap and the maintenance of the stream banks. Around the pond, it is proposed to use the reinforcement by the stone riprap or the stone filling to preserve the current flow rates.

After the pond, the stream bed is very well restored by nature, so we propose to use only smaller measures from the category B.

In the river kilometer 4,743, there is a bottom drop. The Proposal is to remove this drop according to the MES category D.

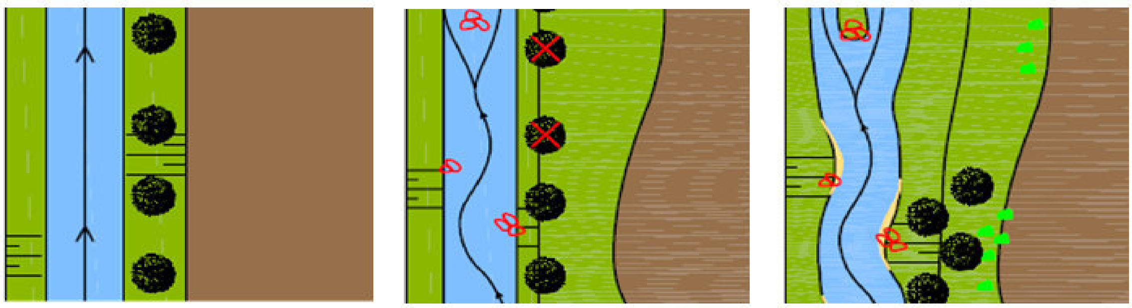

Figure 52 Scheme of the measure type B - the stream diversification

5.5.2.3. Subsection 2C

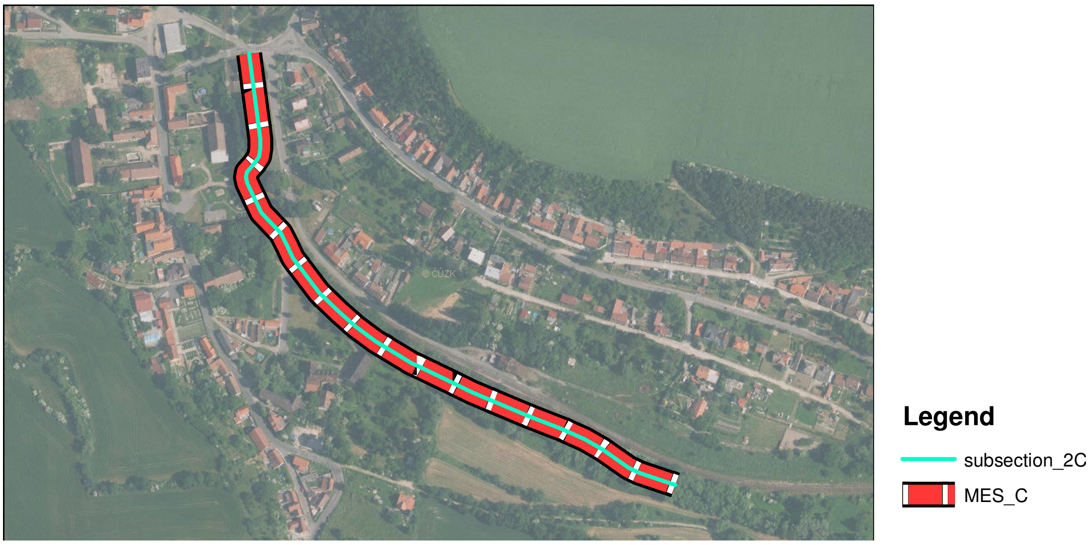

Figure 53 Subsection 2C (created in ArcMap)

In the village Olovnice, the stream bed is reinforced by concrete blocks. The stream cross section has a rectangular shape up to the road bridge. After the road bridge, the shape is changed to the trapezoidal one. The proposal for this subsection is to remove the concrete blocks from the stream and to replace them with the stone filling. This measure is more natural and it is more flexible during the high flow rates. It is proposed to enhance the flow rates in the stream using stone fraction to the stream bottom. All these proposals are designed according to the MES category C.

5.5.3. River Restoration Proposals for the Section Nr. 3

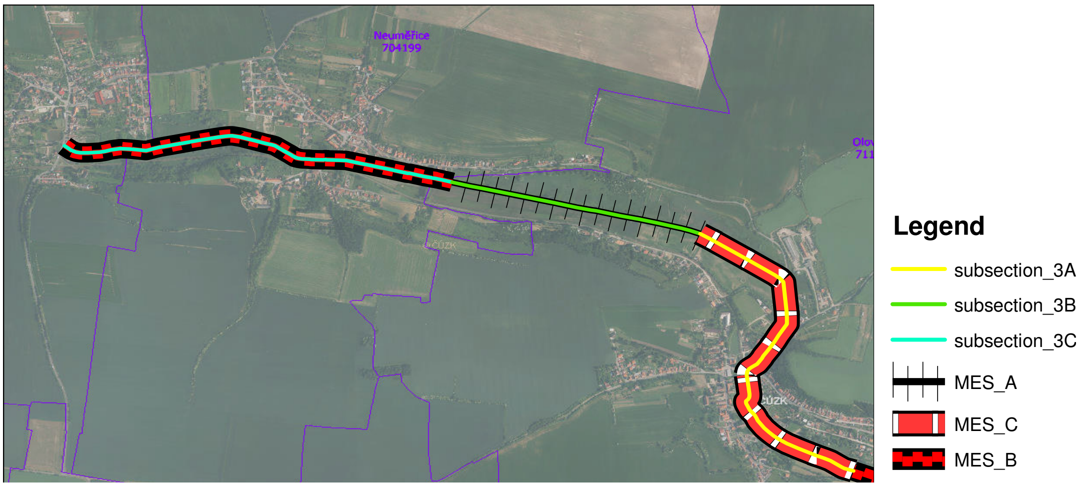

Figure 54 Proposals for the section nr. 3 (created in ArcMap)

5.5.3.1. Subsection nr. 3A

Figure 55 Subsection 3A (created in ArcMap)

This subsection begins after the road bridge in the village Olovnice. The stream has a trapezoidal shape and it is protected by the concrete blocks, similarly to the previous subsection. The proposal for the centre of the urban area is to remove the concrete blocks and to replace them with the stone filling. On the suburb of the village, the proposal is to replace concrete blocks with the stone riprap according to MES category C. The stream banks can be protected by permanent grassland. In case it is needed, the stream bottom can be reinforced by the stone of high fraction.

5.5.3.2. Subsection 3B

Figure 56 Subsection 3B (created in ArcMap)

In the river kilometer 5,50 – 6,60, the restoration is designed with an investment character, thus applying measures from the MES category A. The stream is straightened in this subsection, the stream banks are reinforced by the concrete blocks and the biological value of the stream here is really low. The design is based on the change of the stream line. The present state of the stream bed is very bad. As the flood plain area is not used for any agricultural purposes, it may be used for the intentions of flood wave flattering. The proposal for this place is to construct the furrow with migratory cynette.

5.5.3.3. Subsection 3C

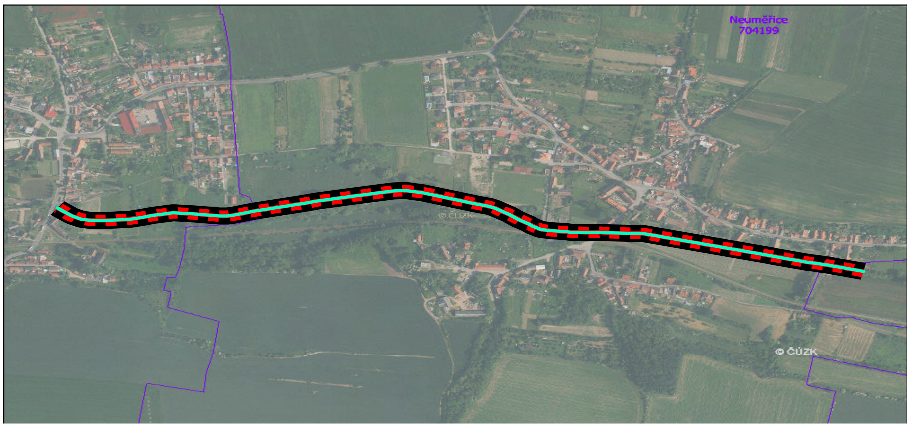

Figure 57 Subsection 3C (created in ArcMap)

The stream banks in the village Neuměřice are reinforced with lattice fences, so we propose to remove them. Their removal and the curvature of the stream line by irregular stone ripraps may result in better ecological quality of the stream and its surroundings. In the village, it is possible to use the stone filling for the bank reinforcement to protect the urban area.

In the river kilometer 7,657 and 7,761, there are concrete bottom drops. It is proposed to remove these drops and to replace them with a more preferable rough boulder ramp which is better for the patency of the stream. This is proposed according to the MES category D.

5.5.4. River Restoration Proposals for the Section Nr. 4

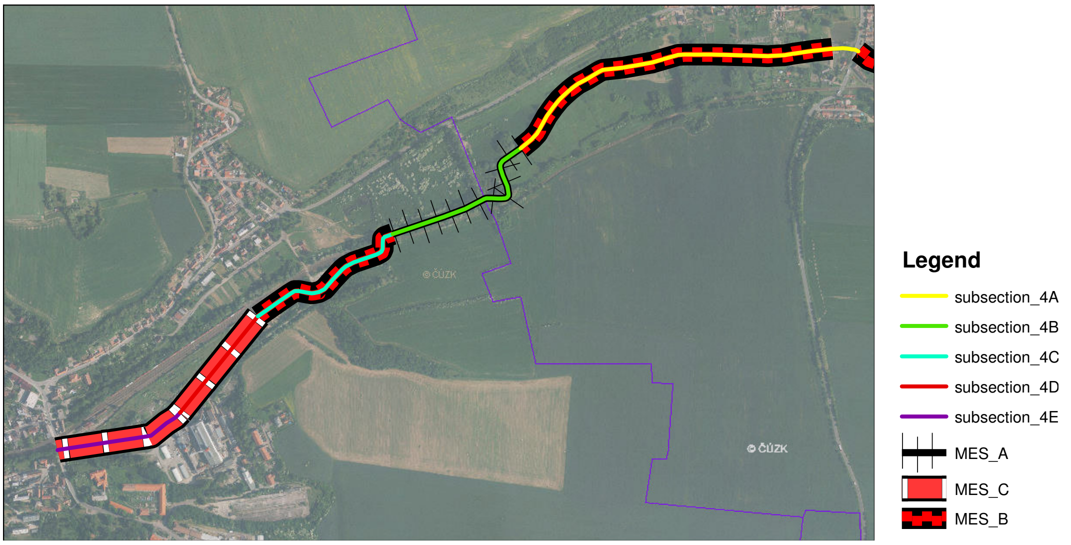

Figure 58 Proposals for the section nr. 4 (created in ArcMap)

5.5.4.1. Subsection 4A

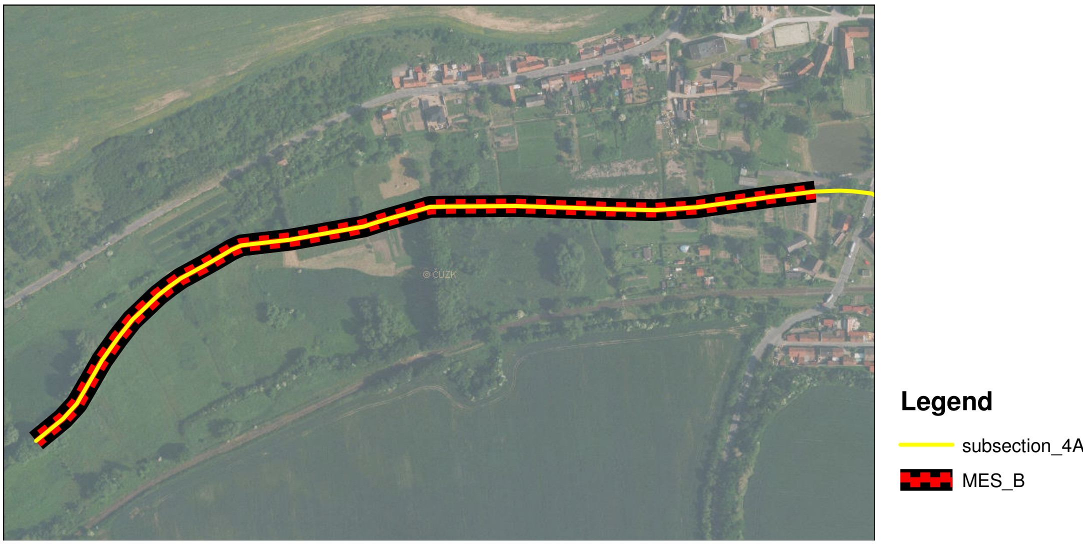

Figure 59 Subsection 4A (created in ArcMap)

In the village Kamenný most, on the left stream bank, there is a new pond (river kilometer 8,05 – 8,55). After the pond ends, the dense riparian vegetation begins. It is proposed to maintain this vegetation according to the MES category B – partial thinning of the vegetation which is intervening into the stream bed. Another proposal is to reach the diversification of the stream line by the irregular use of stones in the stream bottom.

5.5.4.2. Subsection 4B

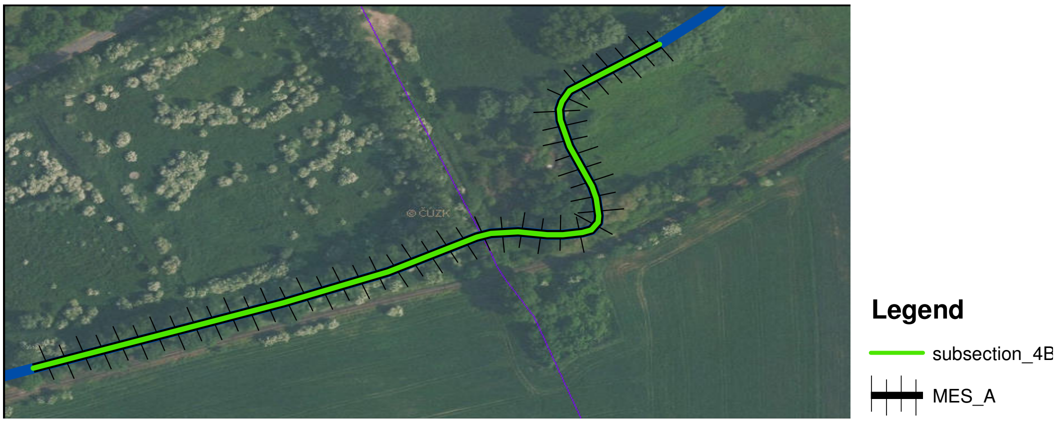

Figure 60 Subsection 4B (created in ArcMap)

In between the river kilometer 8,90 and 9,05,the stream is straightened and there are huge swamps located there. These are ideal conditions for the reversion of the stream to the natural conditions. To reflect these conditions, there are designed measures according to the MES category A – the stream restoration out of the current stream bed. It is proposed to curve the stream line and the flood plain can be used as the place for the flood wave flattering.

5.5.4.3. Subsection 4C

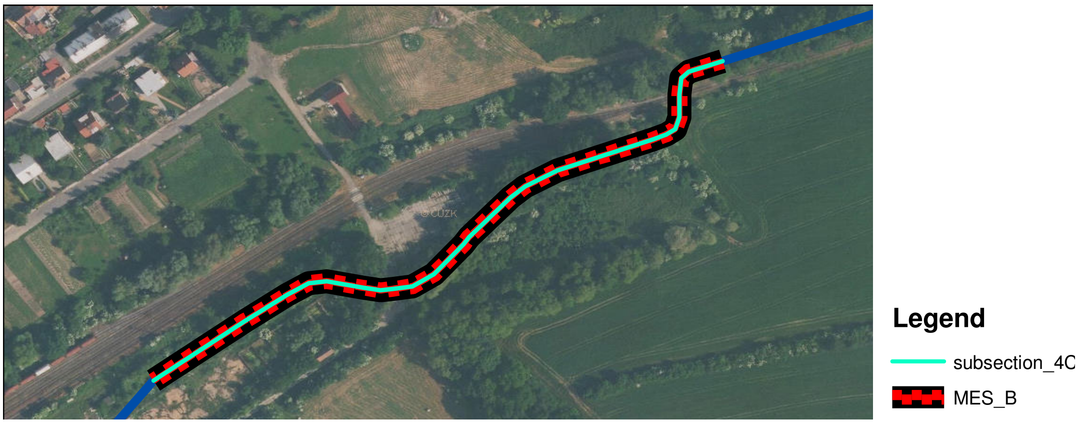

Figure 61 Subsection 4C (created in ArcMap)

At the end of the village Zvoleněves, the stream bed is technically modified (river kilometer 9,2- 9,3). Due to the concrete blocks which were used for the modification, it is proposed to remove these blocks and to replace them with the stone filling in accordance to the MES category A.

In the river kilometer 9,944, there is a concrete drop which is propose to be removed according to the MES category D. The drop should be replaced with the rough boulder ramp.

5.5.4.4. Subsection 4D

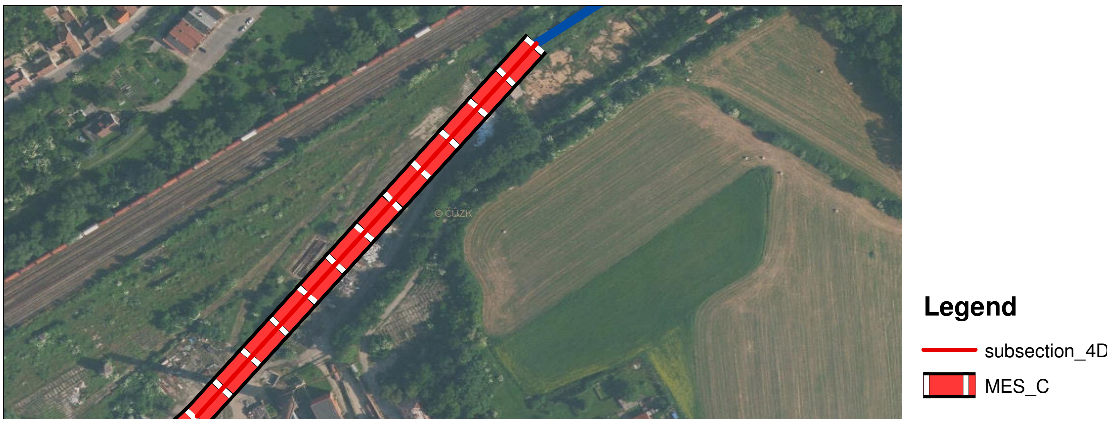

Figure 62 Subsection 4D (created in ArcMap)

In the village Zvoleněves, the stream is canalized due to a sugar factory which is directly located on it. According to the MES category C, it is proposed to remove this canal and to create a more natural stream bed in its place instead. Due to its location in the urban area, it is proposed to reinforce the stream banks by stone filling, and for the reinforcement of the bottom of the stream, to use a stone of high fraction.

5.5.4.5. Subsection 4E

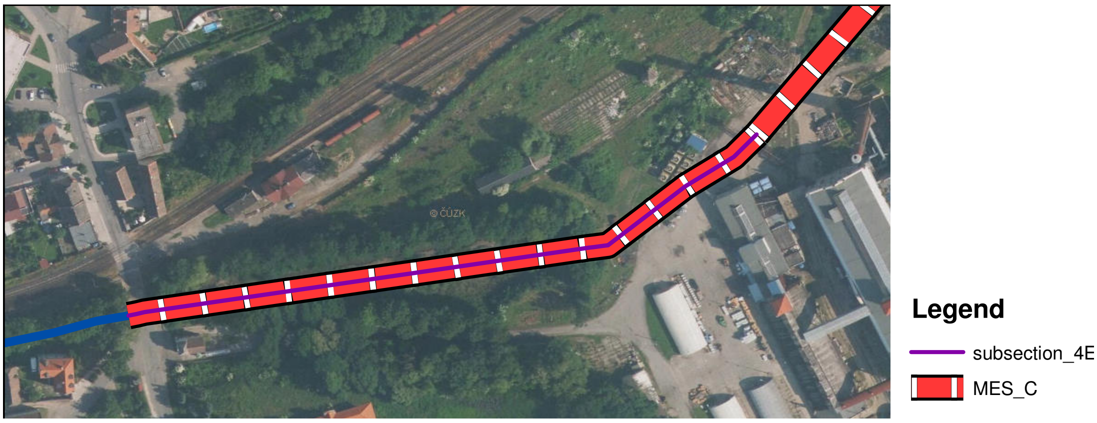

Figure 63 Subsection 4E (created in ArcMap)

The canalization ends at the beginning of this subsection. The stream bed is in the natural state with no artificial reinforcement. Due to the stream flow through the urban area, it is proposed to reinforce the banks by the stone filling, to reinforce the stream bottom by a stone of high fraction, and thus, applying the MES category C.

5.5.5. River Restoration Proposals for the Section Nr. 5

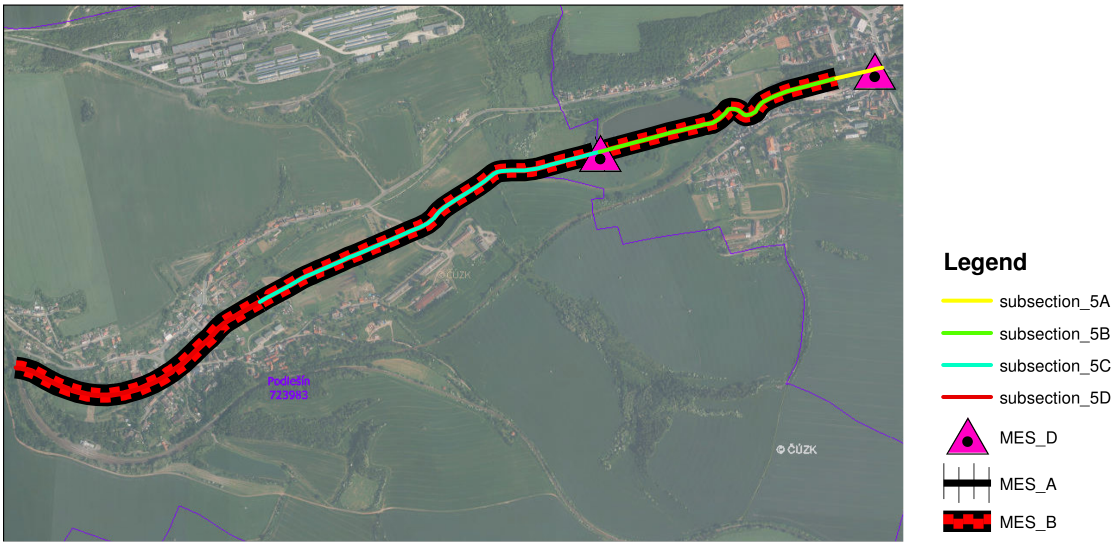

Figure 64 Proposal for the section nr. 5 (created in ArcMap)

5.5.5.1. Subsection 5A

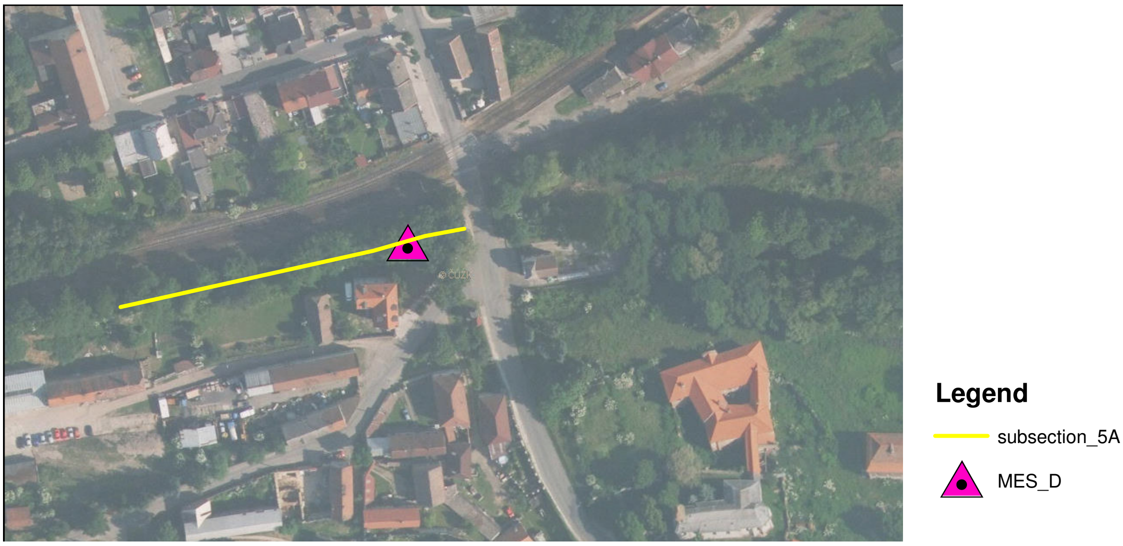

Figure 65 Subsection 5A (created in ArcMap)

At the beginning of this subsection (river kilometer 9,976), there is a weir with a water gate located there. Despite the fact that the weir is operational, it does not correspond to the technical regulations. Therefore, a removal of the object is required according to the MES category D.

5.5.5.2. Subsection 5B

Figure 66 Subsection 5B (created in ArcMap)

The subsection 5B is defined by a concrete weir in the village Zvoleněves on one side, and by a water divider of the pond Otrok, on the other side. The state of the stream bed is being restored in a natural way, therefore, it is proposed to reinforce the bank by the stone filling, or the stone riprap along the pond.

5.5.5.3. Subsection 5C

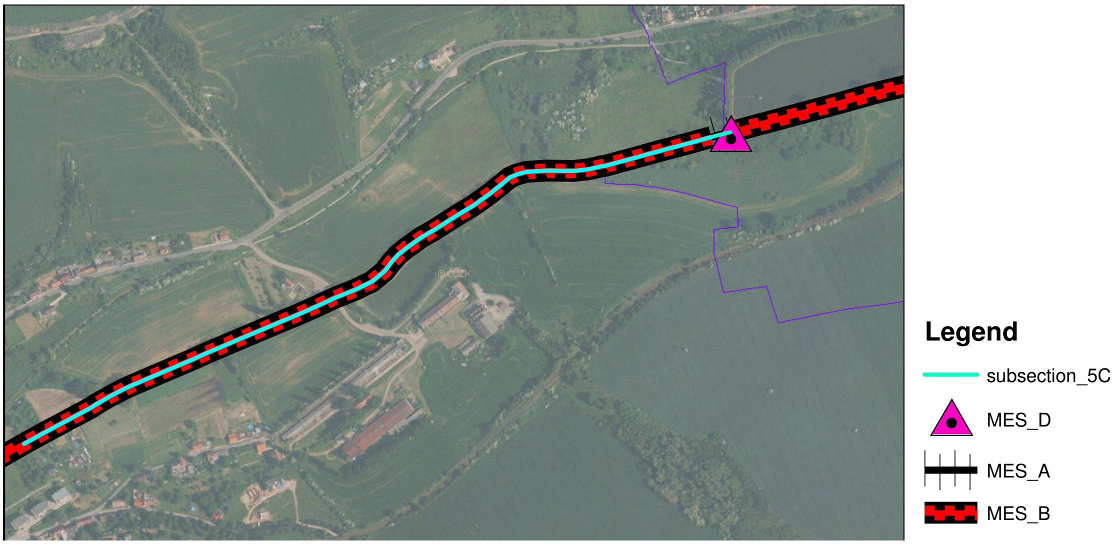

Figure 67 Subsection 5C (created in ArcMap)

In the river kilometer 10,768, there is a water divider as mentioned above. This object provides the water supply for the pond Otrok, so it is not possible to remove it. At the present time, the divider is a migration barrier on the stream which disrupts the patency of the stream. The proposal is to construct the bypass around the water divider to preserve the migration ability of the stream according the MES category A.

After the water divider, the stream section (river kilometer 10,80 – 11,10) is very overgrown by dense riparian vegetation. This vegetation may cause flooding of the surrounding area during bigger flow rates, and it also causes the impermeability of the stream for fishes and creates a migration barrier. It is designed to maintain the vegetation according to the MES category B – the saw through of vegetation and the removal of migration barriers.

5.5.5.4. Subsection 5D

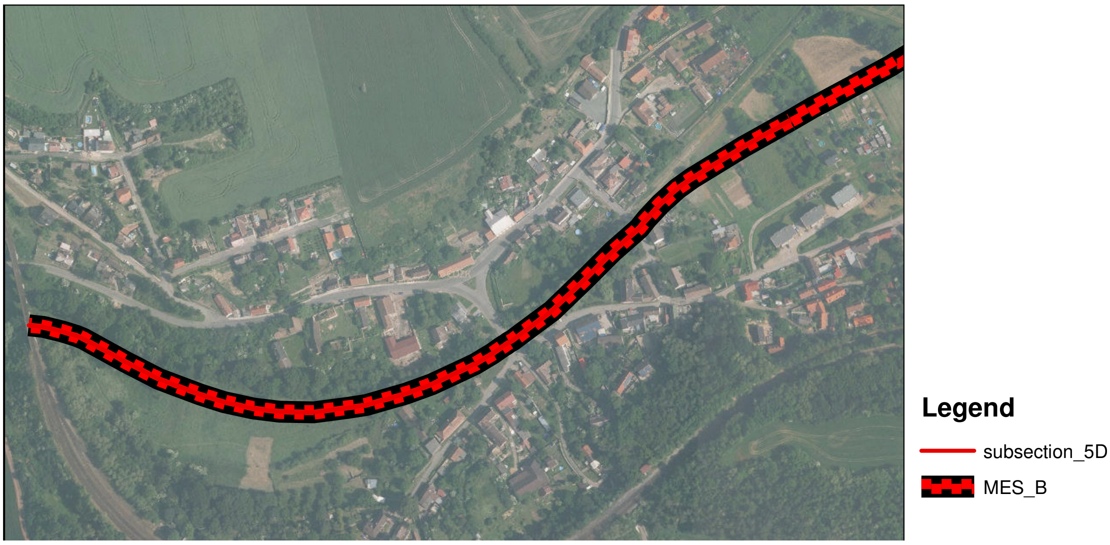

Figure 68 Subsection 5D (created in ArcMap)

The stream in this subsection (river kilometer 11,10 – 11,80) is in a very good state. The natural restoration takes place here. The proposal is to apply only a few measures according to the MES category B – to use the stone riprap to improve the curvature of the stream and to increase the natural appearance.

5.5.6. River Restoration Proposals for the Section Nr. 6

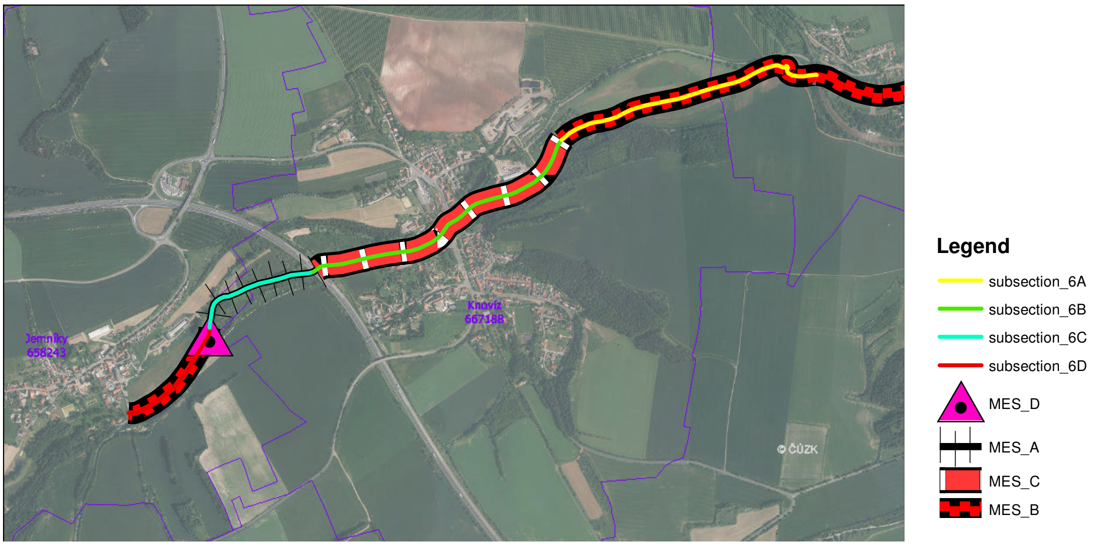

Figure 69 Proposals for the section nr. 6 (created in ArcMap)

5.5.6.1. Subsection 6A

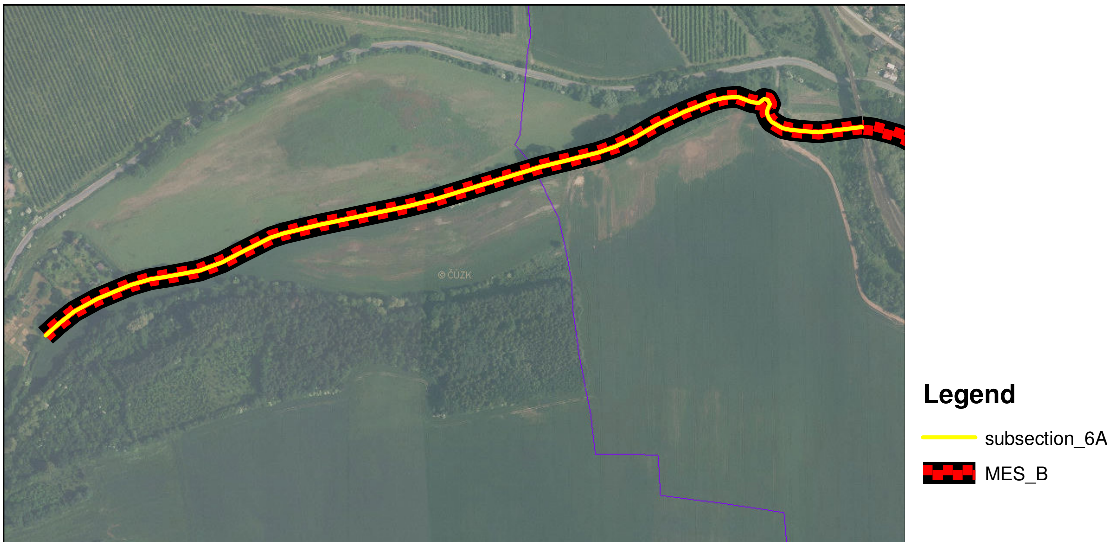

Figure 70 Subsection 6A (created in ArcMap)

The subsection is defined by a viaduct after the village Podlešín and by the beginning of the village Knovíz. It is possible to see the natural appearance at this subsection, as well. The bank protection lining is almost decomposed. It is proposed to enhance the natural restoration by irregular figures of the stone riprap (measures according to the MES category B). These measures will increase the scouring of the banks and it will support the restoration. The flood plain represents a very small scale here, especially, in the lower part of the subsection, so it is proposed to plant new trees around the stream to improve the quality of its environment.

5.5.6.2. Subsection 6B

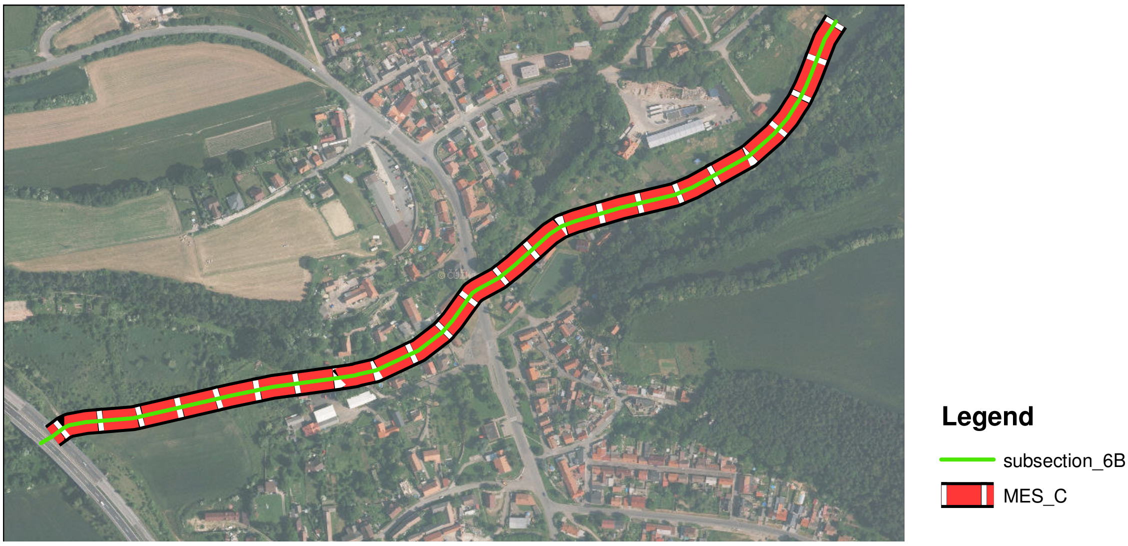

Figure 71 Subsection 6B (created in ArcMap)

The stream flows through the urban area and the stream bed is protected by the concrete blocks with rectangular shape. The proposal is to remove the blocks, to change the shape of the stream bed to the trapezoidal one and to replace blocks by the stone filling according to the MES category C. The stream banks can be protected by permanent grassland. For the reinforcement of the stream bottom, the stone of high fraction can be used. At the end of the village, the stream bed has the trapezoidal shape, so here, it is proposed to remove the concrete blocks only and to replace them with stone filling. After the village, the stream has a more natural appearance. It is possible to enhance this natural restoration by the irregular stone riprap (to increase the bank scouring and thus, to change the stream line according to its curvature).

5.5.6.3. Subsection 6C

Figure 72 Subsection 6C (created in ArcMap)

The stream was straightened in the river kilometer 14,6 – 14,86,but in its surroundings, there are swamps, so it is proposed to use this area for the curvature of the stream bed. Part of the design is the construction of pools. One pool should be passable and the second one should be a side pool. This design counts on the stream enlargement and a creation of an approximately 12 meters wide stream bed. It should be a furrow with free cynette and a capacity of the discharge Q_2. The area for the new proposal represents the strip of width of 15 - 30 meters. It includes the place for the new stream bed, pools, a place for riparian vegetation and as a buffer zone, the permanent grassland. In the river kilometer 14,65, a pool is designed to be supplied with ground water. An obstacle in its realization may be the land ownership of this area – as there are many land owners here according to the cadastral maps.
In the event that the above mentioned designed measures according to the MES category A cannot be realized, it is proposed to apply instead, the point measures according to the MES category B only – the micro pools construction and the usage of the irregular stone riprap for the diversification of the stream bed.

In the river kilometer 14,909, there is an old weir with a water gate which is no longer in operation. The proposal is to remove this weir according to the MES category D.

5.5.6.4. Subsection 6D

Figure 73 Subsection 6D (created in ArcMap)

The steam bed is reinforced by masonry lining in the heel of the slope, but the current state of this reinforcement is very bad and it is in decay. The proposal is to apply only the local measures according the MES category B – a removal of migration barriers caused by vegetation or the usage of the stone riprap in locations with no reinforcement of stream banks.

5.5.7. River Restoration Proposals for the Section Nr. 7

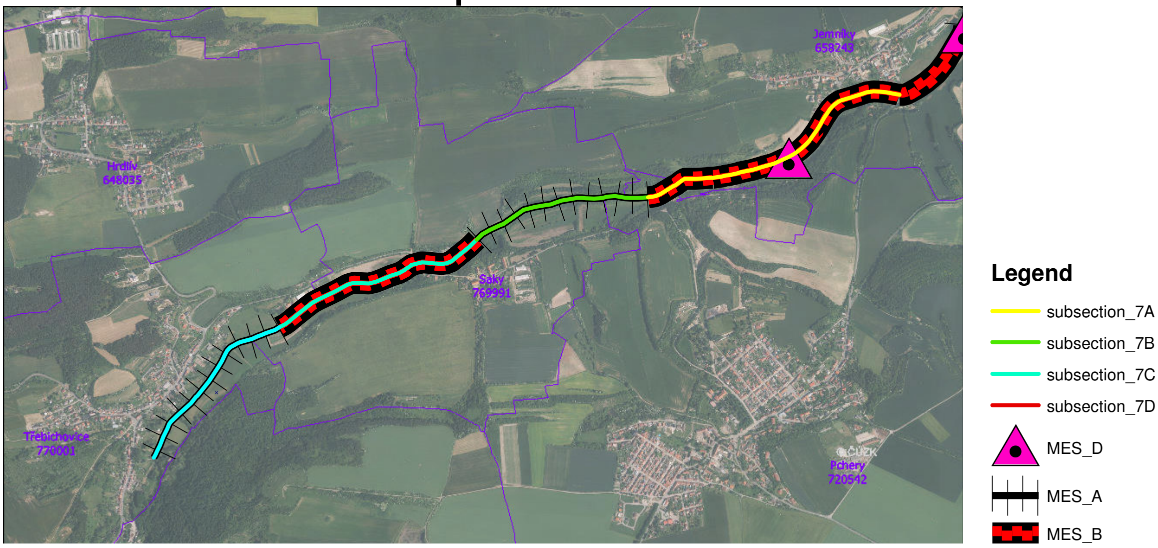

Figure 74 Proposals for the section 7 (created in ArcMap)

5.5.7.1. Subsection 7A

Figure 75 Subsection 7A (created in ArcMap)

The stream in this subsection is in a good state, so it is proposed to use only the local measures (according to MES category B). These measures should be only smaller ones to preserve the flow rate capacity. It means irregular figures of stone ripraps and a removal of the decayed parts of the reinforcement. This will lead to an improved state of the stream. Taking into account the though flow in the summer house area, it is necessary to maintain the stream bed in relation to the vegetation. In this case, the patency of the stream is very important. A removal of the wooden

debris and other subjects from the stream will protect the summer house area against floods.
In the 16,342 river kilometer, there is a concrete weir with a water gate. The weir is still in operation, nevertheless, it does not comply with the regulations. The proposal is to remove this object according to the MES category D.

5.5.7.2. Subsection 7B

Figure 76 Subsection 7B (created in ArcMap)

The stream flows from 16,9 to 17,6 river kilometer through an agricultural area and the stream in this part does not have the required capacity. Therefore, it is proposed to apply the measures according to the MES category A – the enlargement of the stream. In the design, we propose a furrow with free cynette. Riparian vegetation is designed around it with permanent grassland, as well. The stone ripraps can be used for the diversification of the stream bed and the stream bottom.

5.5.7.3. Subsection 7C

Figure 77 Subsection 7C (created in ArcMap)

The section is defined by the 17,82 and 18,84 river kilometer. Here, the stream flows through the village Saky. The stream bed is in a very good condition. Therefore, we propose only a local usage of the stone riprap for better diversification of the stream trajectory to be followed with curvature of the stream bed.

5.5.7.4. Subsection 7D

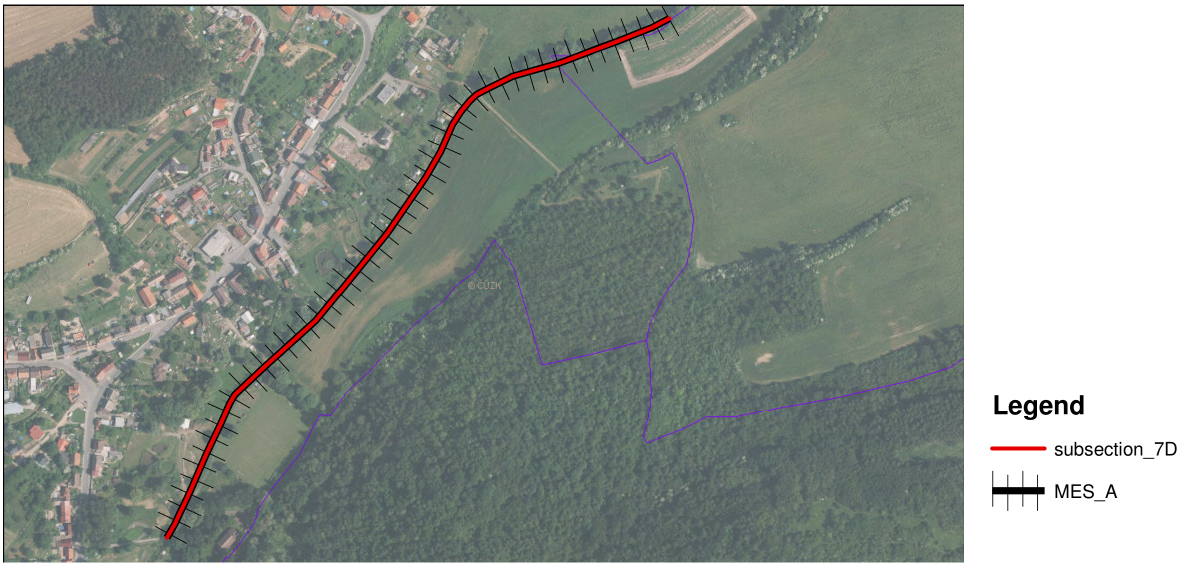

Figure 78 Subsection 7D (created in ArcMap)

In the last subsection of our project flows the stream around the village Třebichovice. (river kilometer 17,8 – 19,380). The stream bed has not got the required capacity so it is proposed apply the measures according to MES category A. It means that in here is designed the enlargement of the stream bed and possible introduction of meanders in the stream. During the realization of this proposal will be removed migration barriers caused by vegetation and loads situated in the stream nowadays.

6. Results

The result of this feasibility study is the Technical report and set of several Designs which are in Appendix 4. This work gives overview of the area of interest, especially informs about the stream conditions as well as about the environment around it.

The stream is from the bigger part technically modified. We applied here several measures to return the current state of Knovízský stream to more natural. The most proposed measures were non-investment ones, for better feasibility of this project. There are also several subsections where we have to propose the investment measures to reach our task. These modifications are in the non-urban area as well as in urban area. In urban area there is the most important replacement of a concrete reinforcement and introduction of more natural like measures (stone riprap, stone filling, etc.). In non urban areas proposal were targeted especially to streamline diversification and re-irrigation of flood plain. The removal of 5 traverse dikes from the stream is proposed for better patency and longitudinal re-connection.

7. Discussion

Knovízský stream is on the list of significant streams of the Czech Republic, but it is in a very poor condition. One of the reasons is that this stream does not suffer by the flood extremes, that is why people do not care about its maintenance. Most of the people are not affected by the stream and they have no interest in this topic. This situation is quite disturbing and it should be resolved. One part of this study was to inform people, predominantly the owners of affected land, about the state of the stream and planned changes. A lot of affected owners have no idea how unsuitable the state of steam is. There is relatively big number of owners who does not care and they do not agree with intended restorations. Their reason is, that their land was not affected in the past and nowadays, they are not in danger. They have no interest in the ecological conditions of the stream. The proposals were changed, according to these responses and new propositions were made to fit these limited conditions.

The biggest problems were with the proposals from a category A, especially the streamline changes in landscape. Changes were designed in a smaller scale. Instead of a stream with meanders and side pools, only micro pools will be created directly in the stream bed as well as implying proposals from the category B according to MES. The introduction of individual stones into the stream bed will provide sufficient modification of the streamline and it will enhance diversification and partially fulfill the requirements of MES.

8. Conclusion

The land ownership is the biggest problem during this project. As it was mentioned before, this feasibility study was overworked according to responses of the affected subjects and according their requirements or given possibilities.
After this reprocessing the study was sent to the client - Povodí Vltavy, s.p. Nowadays it is processed by the company and their decision is expected.

9. Sources

1. Adams S., Greeley M., 2000: Ecotoxical indicators of water quality: Using multi-response indicators to assess the health of aquatic ecosystems, Environmental Sciences 123: 103-115
2. Adams S., 2002: Biological Indicators of Aquatic ecosystems, American Fisheries Society, 656p.
3. Birk S., Bonne W., Bojra A., Brucet S., Courrat A., Poikane S., Solimini A., Van De Bund W., Zampoukas N., Henrik D., 2012: Three hundred ways to assess Europe's surface waters: An almost complete overview of biological method to implement The Water Framework Directive, Ecological Indicators 18: 31-41
4. Campbel Grant E., Lowe W., Fagan W., 2007: Living in the branches: population dynamics and ecological processes in dendritic networks, Ecology letters 10, 165-175
5. Darby S., Sear, D., 2008: River Restoration: Managing the Uncertainty in Restoration Physical Habitat, John Wiley and Sons., United Kingdom, 328 p.
6. Fluvial Geomorphology, Montgomery and Buffington Classification Table, online: http://www.fgmorph.com/fg_4_11.php, 15.2.2014
7. Gerhardt A., 1999: Biomonitoring of Polluted Water - Reviews on Actual Topics, Environmental Research Forum: 9, 120-131
8. Gottado S., Semenzin E., Giove S., et al, 2011: Integrated risk assessment for WFD ecological status classification applied to Llobregat river basin (Spain). Part I - Fuzzy approach to integrate biological indicators, The Science of the total environment 409: 4701-12
9. Havlík A., Vodní toky, online: http://hydraulika.fsv.cvut.cz/Vin/ke_stazeni/Vodni_toky.pdf, 30.3.2014
10. Henshaw A., Thorne C., Clofford N., 2013: Identifying causes and controls of river bank erosion in a British upland catchment, Catena 100: 107-119
11. Just T., et al., 2005: Vodohospodářské revitalizace a jejich uplatnění v ochraně před povodněmi, 3. ZO ČSOP Hořovicko ve spolupráci se společností Ekologické služby s.r.o., Agenturou ochrany přírody a krajiny ČR a Ministerstva životního prostředí ČR, Praha, 359 p.
12. Kelly F., Harrison A., Allen M., Connor L., Rosell R., 2012: Development and application of an ecological classification of an ecological classification tool for fish in lakes in Ireland, Ecologic Indicators 18: 608-619
13. Kessler A., Gupta S., Brown M., 2013: Assessment of river bank erosion in Southern Minesota rivers post European settlement, Geomorphology 201: 312-322
14. Langhans S., Lienert J., SchuwirthN, et al., 2013: How to make river assessment comparable: A demonstration for hydromorphology

15. Learner M., Bowker D., Halewood J., 1990: An assessment of bank slope as a predictor of conservation status in River Corridors, Biological Conservation 54: 1-13

16. Li L., Zheng B., Liu L.2010: Biomonitoring and bioindicators used for river ecosystem: Definitions approaches and trends, Procedia Environmental Sciences 2:1510-1524

17. Midgley T. L., Fox A. G., Heeren D.M., 2012: Evaluation of the bank stability and toe erosion model (BSTEM) for predicting lateral retreat on composite banks, Geomorphology 145-146: 107-114

18. O'Hanley J.R., 2011: Open barriers: Barrier removal planning and the restoration of free/flowing rivers, Journal of Environmental Management 92: 3112-3120

19. Orr H., Large A., Newson M.D., Walsh C.L., 2008: A predictive typology for characterizing hydromorphology, Geomorphology 100: 32-40

20. Pander J., Geist J, 2013: Ecological indicators for stream restoration success, Ecological indicators 30: 106-118

21. Pácl M., 2013, verbal information, Area survey

22. Pospíšil L., 2013, verbal information, Summer Workshop II

23. Perrow M. R., Davy A. J., 2008: Handbook of Ecological Restoration (Volume 1 – Principles of restoration, Restoration in Practice), Cambridge University Press. 464 p.

24. Rinaldi M., Surian N., Comiti F, et al., 2013: A method for the assessment and analysis of the hydromorphological condition of Italian streams: The Morphological Quality Index (MQI), Geomorphology 180-181: 96-108

25. Roni, P., Beechie, T., 2012: Stream and Watershed Restoration: A Guide to Restoring Riverine Processes and Habitats, Wiley-Blackwell, United States, 316 p.

26. Rosgen, D. (1996) Applied river morphology, Woodland Hydrology, Pagosa Spings, Colorado. 390 p.

27. Smetana M., 2008, Mapování koryto-nivních jednotek řeky Svratky v CHKO Žďárské vrchy, online: http://is.muni.cz/th/106738/prif_m/, 4.2.2014

28. Thomas G., 2014: Improving restoration practice by deriving appropriate techniques from analyzing the spatial organization of river network, Limnologica - Ecology and Management of Inland Waters 45: 50-60

29. Thorne C., 1981: Field measurement of rates of bank erosion and bank material strength, Erosion and Sediment Transport Measurement 133: 503-512

30. Gerhardt, A. (Ed), 1999. Biomonitoring of Polluted Water - Reviews on Actual Topics. Environmental Research Forum, Vol. 9.

10. The List of Figures and Tables

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10.2. Tables

11. Appendix

11.1. Appendix 1- River morphology classification

11.2. Appendix 2 - Table of biological indicators

11.3. Appendix 3 - List of affected owners

11.4. Appendix 4 - Designs