1. Introduction

The Sokolov brown coal basin (West Bohemia, Czech Republic) is located near the frontier between the Czech Republic and Germany (Figure 1). The total area of the basin is about 220 km² and the total mining area is 89 km². An area of 2444 ha (27.6%) has now been completely rehabilitated, 983 ha (11.1%) is a post-mining area under recent recultivation, and an area of 5437 ha (61.3%) is planned for future rehabilitation (Sokolovska uhelna, 2002). It is not intended to open up new mines in this region. This situation poses a great challenge for successive rehabilitation of the post-mining landscape.

Restoration of a landscape destroyed by open-cast mining is very often understood as a technical or economic problem only (Bradshaw, 1987). Formerly, only forestry and agricultural forms of recultivation were regarded as being in the public interest. Recently, nature conservation and recreation have also been considered as land-use options (Pietsch, 1998; Schulz and Wiegleb, 2000). Successful rehabilitation of post-mining landscapes requires a holistic approach involving, among others, the ecological and aesthetic context. All parts of the projects must lead toward an integrated proposal to restore ecological, hydrological, aesthetic, production, recreational and other functions of the post-mining area, co-ordinated into a sustainable land-use development plan.

Landscape is perceived as a visual resource. The holistic image of a landscape comprises not only its spatial and structural aspects but also the formal visual and cultural aesthetic expression of the landscape (Krause, 2001). The aesthetic value of landscape is one of the threatened attributes of the human environment. This threat is particularly dramatic in post-mining landscapes. The aesthetic function of landscape is much more difficult to define, evaluate and protect than its ecological function. The motivation for protection is not only

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Restoration of visual values in a post-mining landscape

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Abstract

The aesthetic value of landscape is one of the most threatened attributes of the human environment. This threat is particularly dramatic in post-mining landscapes. The rehabilitation of post-mining landscapes requires an interdisciplinary planning approach. Aesthetic value is a major criterion when evaluating the success of landscape restoration. This paper presents restoration of landscape aesthetics on two levels of scale. On a large scale, the guiding principles are presented by two methods of visual classification of the Sokolov brown coal basin (220 km², Czech Republic). On a small scale, the case study illustrates the key principles by their implementation in the Litov – Chlum (2 km²) study area. The final design is supported by GIS and 3D visualisation.

Key words: Post-mining landscape; Rehabilitation; Restoration; Aesthetic value; Visualisation; Czech Republic
the visual value of the landscape but also the preservation of its recreational potential, and protection of the cultural heritage (Schmid, 2000).

It is the visual quality and character rather than its productive function that attracts people to live or relax in the countryside (Brabec and Smith, 2002). The key aesthetic problem of post-mining areas is the negative visual impact of the mining sites on the surrounding landscape. This means that the aesthetic value of the adjacent landscape is degraded mainly by the negative visual impact of the unreclaimed sites. An evaluation of the former aesthetic characteristics of the area and a prediction of their future development should form the basis for all forms of post-mining landscape planning (e.g., land-use planning, physical planning). Visual improvements brought about by reclamation changes can be simulated to show how visible the recovered landscape structures will be, and how much of the visually degraded territory has vanished from the viewshed. Hehl-Lange and Lange (1999) accent the role of GIS-based virtual landscape models facilitating formulation of several different variants in the process of decision.
2. Methods

The context of restoring aesthetic values was integrated into the approach defined by the project “Rehabilitation of post-mining landscapes” (RPML), supported by the Czech Ministry of Environment (Prikryl et al., 2002). The basic principles of this integrated approach (Figure 2) were inspired by general methods of landscape assessment (Countryside Commission, 1993), of landscape ecological planning (Ruzicka and Miklos, 1982; Wang et al., 2001), by the process scheme of Schulz and Wiegleb (2000), and also by the Visual Impact Analysis (Emmelin, 1995) method for analysing the landscape impacts of policy scenarios and for presenting them in visual terms.

The aesthetic values and the whole RPML were assessed on two different scale levels:

- on a large scale, the relevant attributes were investigated for the whole area of the Sokolov brown coal basin. The received data and experience were used to define large-scale guiding principles for restoring aesthetic values, which were then implemented in the General Plan for the restoration of the Sokolov brown coal basin. Some of the large-scale guiding principles were also used in the small-scale methodology:

2.1. Large-scale principles for assessing aesthetic values

Two basic methods were used to classify the landscape of the Sokolov brown coal basin in terms of its aesthetic values.

a) Landscape typology method

The landscape typology method (Muransky and Naumann, 1970-1980) is based on classifying the landscape types and landscape values (Figure 3). The landscape was classified by interpreting aerial photographs, complemented by terrain reconnaissance.

The basic landscape types (objective typological units) are:

- landscape type A – landscape considerably modified by man,
- landscape type B – landscape partially modified by man,
- landscape type C – relatively natural landscape (predominance of natural elements).

The basic scenic (aesthetic) values are:

- high scenic value (+),
- average scenic value (0),
- low scenic value (-).

By combining these types we obtain a total of nine basic landscape typological units that characterise the internal qualities of each landscape unit. The method also involves selecting the visually important landscape points (views), visual corridors, horizons, etc.
b) Visibility analysis

Unlike the previous method, this landscape classification provides a tool that reflects not only the internal aesthetic attributes of the landscape units but also the external negative visual characteristics of the neighbouring mined areas. The recent situation (in 2001) was analysed, and the future state (in 2025) was predicted. The prediction is based on the official plan for successive rehabilitation of the post-mining landscape provided by the Sokolovska uhelna mining company. This method assumes that rehabilitated post-mining areas do not have a negative visual effect on the surrounding landscapes.

Visual improvements brought about by the performed reclamation changes were simulated and presented by calculating the visibility of the recovered landscape structures. The visibility map will show how much of the visually degraded territory will vanish from the viewshed. The unchanged structures, e.g., dumps and mine pits, are identified by a definite set of observed points representing contours, and the visibility of these points is calculated. The visual quality of the landscape will improve when the ugly landscape structures are replaced by natural-looking or at least visually more pleasant formations (forests, lakes, parks, etc.).

The process of simulating visual improvements pursued the following steps, using ArcView 3.1 tools and its Spatial Analyst extension:

- manual digitisation of the contours of unchanged structures,
- merging the contour map of the territory layer, with 10m elevation step and digitised contours,
- generation of two 3D terrain models from the contour lines (before and after reclamation) with a pixel size of 50 m,
- addition of a forest raster layer to the 3D models (of 20 m in height),
- identification of observed points representing the unchanged landscape structures (201 points before reclamation, 138 after),
- visibility calculation for the observed points,
We classified the landscape into 6 categories according to the number of points seen from the area, as follows:

I. area without negative visual impact (no point)
II. area with very low negative visual impact (1-20 points)
III. area with low negative visual impact (21-40 points)
IV. area with medium-level negative visual impact (41-60 points)
V. area with high negative visual impact (61-80 points)
VI. area with very high negative visual impact (>80 points)

2.2. Small scale case study

The Litov - Chlum model area is located in the Sokolov brown coal basin (Figure 1). The total area is 2 km². It is a spoil bank shaped like an amphitheatre completely without any vegetation cover. The centre of the site consists of an open pit surrounded by man-made slopes. The study area is characterized by the extreme acidity of the geological substrate and of the water in the pit (pH=2.0-2.5). The slopes of the “amphitheatre” are threatened by water erosion, because they are still not covered by vegetation.

The study area is adjacent to the monastery of St. Mary (Church of the Assumption of the Virgin at Chlum), which is a historical monument. This positive landscape feature of regional importance is a very significant place of pilgrimage for Czechs and Germans. The monastery is the main contributor to the very intensive genius loci of this place. A number of small sacral artefacts were buried under the mighty layers of the spoil bank. In recent times, this monastery has been degraded by the negative visual impact of the adjacent unrecovered spoil bank. The key aspect of the rehabilitation of this post-mining site should be to restore the landscape around the monastery from the recent degradations. The views are threatened by irrational afforestation of parts of the background of the monastery. For this reason, we constructed a visual diagram centred round the positive dominant feature of the landscape. The land-use plan and the design of the model area were proposed on the basis of the RPML integrated approach. The final design is determined mainly by the following factors: geo-botanical restoration principles, erosion control measures, neutralisation of extreme soil and water quality, revitalisation of the pit, and the economic feasibility of the proposed variant. The final design must also be based on the landscape ecological characteristics of the surrounding area (Sklenicka and Lhota, 2002a). The changes in the visual landscape reflect the relevant spatial processes. For this reason, landscape heterogeneity was used as a quantitative criterion for landscape restoration (Sklenicka and Lhota, 2002b). The proposed design reflects the context of the historical development of the region, but it also creates quite new aesthetic values. The tourism function is concentrated in those parts of the model areas that are easily accessible and that do not have great potential for nature conservation. The model area is designed in a harmonious relationship with the main tourist resource of the region (St. Mary’s monastery).

The final steps of the design proposal were its visualization and presentation for the mining company, the local authorities, the Ministry of the Environment, independent specialists, and the public.

3. Results

3.1. Assessment of large-scale aesthetic values

The Sokolov brown coal basin, together with its near surroundings (251 km²), was classified by the landscape typology method (Figure 4). The percentage of individual typological landscape units is shown in Table 1. Table 2 gives the values for the total area of the Czech Republic (Michal, 1997). In terms of aesthetic qualities, the Sokolov brown coal basin can be generally classified as very contrasting and unbalanced. The dominant landscape type is man-modified landscape (A – 63.3%), the percentage of harmonic landscape type B is 27.4%, and the percentage of relatively natural type C is 9.3%. The aesthetic qualities are represented mainly by average (47.7%) and low-
level landscape value (48.0%). The percentage of high landscape value is only 4.3%.
In comparison with the total area of the Czech Republic, the Sokolov brown coal basin is characterised by a high percentage of landscape type A (+100%) and also by a high percentage of low-level landscape value (+742%). These high proportions are compensated by a significantly low proportion of landscape type B (-54%), and of high-level landscape value (-86%).

Generally, the landscape of the Sokolov brown coal basin is characterised by a high degree of man-made modification and by dramatically lower aesthetic value than the “average Czech landscape”.

Apart from the landscape typology assessment, visibility analysis were constructed for 7 mining sites still not quite rehabilitated (Figure 5). Figure 6 presents the total exposure by negative visual impacts of these mining sites in 2001. A prediction

### Table 1 Percentage of individual typological landscape units in the Sokolov brown coal basin.

<table>
<thead>
<tr>
<th>Landscape values</th>
<th>Total area</th>
<th>A</th>
<th>Landscape types</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ha]</td>
<td>[%]</td>
<td>[ha]</td>
<td>[%]</td>
<td>[ha]</td>
</tr>
<tr>
<td>High (+)</td>
<td>1110</td>
<td>4.4</td>
<td>24</td>
<td>0.1</td>
<td>532</td>
</tr>
<tr>
<td>Average (0)</td>
<td>11948</td>
<td>47.5</td>
<td>3810</td>
<td>15.2</td>
<td>6347</td>
</tr>
<tr>
<td>Low (-)</td>
<td>12088</td>
<td>48.1</td>
<td>12069</td>
<td>48.0</td>
<td>19</td>
</tr>
<tr>
<td>Total area</td>
<td>25146</td>
<td>100</td>
<td>15903</td>
<td>63.3</td>
<td>6898</td>
</tr>
</tbody>
</table>

Figure 5. Negative visual effect of individual mining sites on the surrounding landscape (in 2001) – an example.
Figure 6. Total exposure by negative visual impacts of unrehabilitated mining sites (in 2001).

Figure 7. Prediction of total exposure by negative visual impacts of unrehabilitated mining sites in 2025.
of future changes (year 2025) is shown in Figure 7. The intensity of the negative visual perception of the mining sites from the surrounding landscape is divided into 6 categories. Table 3 provides a quantitative (spatial) expression of the present and future intensity of negative visual impacts. In contrast to the recent situation (46.2%), it is predicted that 75.5% will be without negative visual impact in 2025. Generally, the whole affected area will be characterised by a lower intensity of negative visual impact in 2025.

3.2. Small scale case study

Figure 8 shows the visual diagram for the monastery buildings and grounds. The visual diagram determines the main places and directions of visual correction of the model area design. This visual correction is aimed mainly at facilitating decisions on the final topology arrangement (modelling of the spoil bank ridges) and on the distribution of trees on the ridges. With the aid of optimum parameters for the final definition of the shape and land cover of the spoil bank we can conserve or even enlarge the surrounding area from which the monastery can be seen. Implementation of this principle will increase the visual values of the rehabilitated and adjacent landscape. The guiding principles for restoration of the Litov – Chlum model area were defined as follows:

- Rescuing important views of St. Mary’s monastery. In practice, this involves slight altitude reduction and maintaining the ridges of the spoil bank without tree vegetation.
- The model area remains visually open to St. Mary’s monastery. This principle expresses the major motivation for restoring the post-mining site.
- The general character of the vegetation will be forest steppe.
- Taking into account the relatively low heterogeneity of the surrounding land-use pattern, high landscape micro-heterogeneity will be an important feature of the site design for the model area.
- The species composition will respect extreme site factors. However, species diversity is one of the key criteria in post-mining area restoration.
- Both of the water elements (the pit and the stream) will remain in their natural state.
- The proposed design makes use of the recent field roads built along the amphitheatre ridges.
- The pit will not be suitable for fish management or for swimming due to mistakes in construction. For this reason, an ecological function is preferred in this case.

Table 2 Percentage of individual typological landscape units in the Czech Republic.

<table>
<thead>
<tr>
<th>Landscape values</th>
<th>Total area [%]</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (+)</td>
<td>30.4</td>
<td>0.4</td>
<td>23.2</td>
<td>6.8</td>
</tr>
<tr>
<td>Average (0)</td>
<td>63.9</td>
<td>27.8</td>
<td>35.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Low (-)</td>
<td>5.7</td>
<td>3.3</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Total area</td>
<td>100.0</td>
<td>31.5</td>
<td>59.9</td>
<td>8.6</td>
</tr>
</tbody>
</table>
Table 3 Analysis of the present situation, and a prediction of the future intensity of negative visual impacts of the mining sites on the surrounding landscape.

<table>
<thead>
<tr>
<th>Year</th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>II.-VI.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>46.2</td>
<td>35.8</td>
<td>12.3</td>
<td>4.4</td>
<td>1.1</td>
<td>0.2</td>
<td>53.8</td>
</tr>
<tr>
<td>2025</td>
<td>75.5</td>
<td>24.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24.5</td>
</tr>
<tr>
<td>Difference</td>
<td>+29.3</td>
<td>-11.3</td>
<td>-12.3</td>
<td>-4.4</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-29.3</td>
</tr>
</tbody>
</table>

- The final design will be supplemented by a number of small sacral artefacts (crucifixes, village chapels, etc.)

The final design of the model area was proposed on the basis of the guiding principles described above. The proposed design was visualised to simplify consultation with the local authorities, the mining company management authorities, the mining company management and the public.

4. Conclusions

Restoration of visual and aesthetic values should be a key criterion in post-mining landscape rehabilitation. The severe damage done to the Sokolov brown coal basin took place under a political regime in which decisions were imposed by technical experts and bureaucrats. An effective solution to the problems should include consultation with a well-informed local community, and the formation of a broad consensus on the changes that are needed. The visual diagrams method and the 3D visualisation present information about landscape restoration in a form that will enable the public to participate intelligently in the restoration decisions.

The guiding principles and method of evaluation and restoration of aesthetic values are different on large-scale and small-scale levels. The two large-scale methods presented in this paper are very useful for land-use or physical planning. In particular, a prediction of the exposure of the landscape to negative visual impacts is a very significant tool for urban development planning and for prognosis of the future recreation potential of a region. In the case of the Sokolov brown coal basin this method predicts the relevant increase in the areas without negative visual impact, and shows where there will be such locations in 2025. Another major task is to define and manage some areas in accordance with their high nature conservation interest. The high scenic value of the cultural landscape is a precondition for this purpose.

A small-scale case study was presented showing the guiding principles for the final proposal. The visual analysis of the model area and surrounding landscape presented here by the visual diagram method formed one of principle bases for defining the design of a post-mining area that will improve its aesthetic values, and also its other values. In addition, this method respects the present cultural and aesthetic values of the surrounding landscape, which could otherwise be impaired by unsuitable shape and land cover of the post-mining site. Post-mining landscape rehabilitation should not reduce the visual impact of existing important cultural or natural features. The final design is the result of many professional activities co-ordinated between 2000-2001. Landscape rehabilitation is undertaken above all by landscape architects, but successful rehabilitation must involve an integrated approach and consensus building.

Post-mining areas can be called “landscapes without a memory”. They provide one of the few chances for landscape architects to create quite a new landscape that will rapidly improve the visual quality of a region.

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