Subsidence and wetland development in the Ruhr district of Germany

PETER DRECKER
Planungsbüro Drecker, Bottroper Straße 6, D-46244 Bottrop, Germany

DIETER D. GENSKE, KLEMENS HEINRICHS
Delft University of Technology, PO Box 5028, 2600 GA Delft, The Netherlands

HANS-PETER NOLL
Entwicklungagentur Östliches Ruhrgebiet EWA GmbH, Kleiweg 10, D-59192 Bergkamen, Germany

Abstract An overview is given on subsidence in the German Ruhr district. Special attention is paid to wetland development due to the relative rise of the groundwater table. Examples of subsidence lakes and secondary biotopes are introduced.

INTRODUCTION

The Ruhr district in northwest Germany is one of the most densely populated areas in Europe. 5.3 million inhabitants share 4400 km$^2$. In urban regions the population density goes up to 2100 citizens per square kilometre (Jacobi $et$ $al.$, 1992). Traditionally, deep lignite coal mining has been the motor of economic growth in the Ruhr district. In 1988 the total area covered by Ruhr mining was 3044 km$^2$, 64% of which was mined out. The overall volume of coal extracted from 1800 to 1990 is estimated to be 9.54 billion tonnes, i.e. about 5% of the world's production (Meyer, 1993). In 1990, 100 000 miners extracted 54.6 million tonnes of coal from seams of 0.6-4.5 m thickness at an average depth of 920 m. The reserves of first grade coal are estimates to be 20 billion tonnes (Fig. 1) in seams thicker than 0.6 m, 40% of which are minable with today's technology (Jacobi $et$ $al.$, 1992).

The extraction of coal so far has lead to considerable subsidence. The environmental consequences are immense. Today we start thinking about the implications and introduce remediation measures, the benefits of which future generations will appreciate.

HISTORY OF SUBSIDENCE

In the Ruhr, subsidence resulting from mining has been a matter of concern since the middle of the century. Since mining took place at increasing depths mainly in the form of longwall mining, the cause of damage at the surface was no longer restricted to the mined out working. In order to be able to assess the justification to arising claims for damage, altimetry was increasingly conducted from about 1860 on, and measuring lines were laid out over the panels. In particular, these measurements were on behalf of railway companies and home and property owners. At the end of last century subsidence
has caused the reversal of natural drainage in extensive areas. This gave rise to severe sanitary problems and eventually triggered an epidemic increase of typhus and cholera cases. To restore public health the authorities were urged to take action. In 1904 the Emschergenossenschaft (Emscher Cooperative Society) was founded. Their initial task was the design and construction of systems to control and tread the increasing amount of sewage and to rearrange the existing but distorted drainage pattern. The assessment of surface observation lines enabled the Emschergenosschaft to make predictions on future subsiding at the surface. Thus conducting and evaluation of altimetry formed the actual basis for later surface damage research. In the course of time, experience and theoretical findings on subsidence provided the basis for developing the science of surface damage (Niemczyk, 1949; Kratzsch, 1974), which has been a subject at German mining schools since 1931. Not only is the science of surface damage concerned with land movement and strata structure analyses, it also includes mining laws, land laws and also mining technology and engineering. Also covered are aspects of hydrology and hydraulics, agricultural-, town- and traffic-planning.

The extent to which subsidence becomes apparent and possibly leads to damage depends primarily on natural conditions such as the number, thickness and inclination of the mined seams, the tectonics and petrographic state of the hanging wall. Furthermore, the course of mining and stowing are of decisive significance. However, it must be pointed out that even the optimum stowing will not prevent subsidence and consequent damage.

**AMOUNT OF SUBSIDENCE**

The total amount of coal mined allows a back calculation of the voids created (Meyer, 1993). The 9.54 billion tonnes of coal extracted are equivalent to 7 km$^3$. Adding 2.5 km$^3$
of refuse gives a total of up to 9 km$^3$ of extraction mainly from longwall mining. Since stowing is applied only in special cases the overall subsidence ranges from 80 to 90% of the seam thickness, thus resulting in an overall subsidence volume of some 8 km$^3$.

The maximum subsidence observed so far is 24 m. Compression and extension at the subsidence troughs may reach up to 10 mm m$^{-1}$. The inclination of surface structures may be as high as 30 mm m$^{-1}$ (Szelag & Weber, 1993).

**EFFECTS OF MINE SUBSIDENCE**

The extent of damage resulting from mining-related earth movements is strongly dependent upon the way the site is used. For buildings and structures, for instance, damage will result foremost due to subsidence sloping, flexing and displacement at the site. In the case of traffic and supply facilities, it is particularly elevation changes and pressure or tension which are noticed. On the other hand, in the case of agricultural areas only the relative rise of the groundwater table as a consequence of subsidence will lead to damage.

The migration of mining in the Ruhr district which follows the deposits is a foreseeable development which has been taking place for over a century. It is a consequence of the geological situation where the seams of the (hard) coal deposits are exposed in the southern Ruhr area and which are covered northwards by strata of growing thickness. The gradual northward migration of mining has led to many southern areas now being free of mining activities. Subsidence that has strongly affected regions of the lower Emscher plain has now ceased. In this area, drainage conditions had already been extremely unfavourable and strained even before the development of mining activities. Floods often occur when there is a long period of continual rainfall. Additional subsidence has led to a situation where the predominant part of the Emscher regions are "Polderland". To protect these areas from flooding and swamping, they have to be drained with a large number of pumping stations.

Meanwhile similar conditions prevail in the eastern lowlands of the Lippe River so that a belt of subsidence areas stretches from the Rhine trend along the northern Ruhr area to Hamm. Surface subsidence has not ceased in this region but continues to occur or is even increasing.

According to the "Arbeitsgemeinschaft Rahmenkonzept Gewässersystem Emscher" (1990) in 1953 some 147 km$^2$ of the drainage area of the Emscher River were already poldered. In 1989 the Polderland comprised already 340 km$^2$. Together with the drainage area of the Lippe River where 243 km$^2$ are poldered this adds up to about 600 km$^2$ (Meyer, 1993). For every tonne of coal mined today in the Ruhr district 1.6 m$^3$ of water have to be pumped. Figure 2 gives a comparison of the extraction of groundwater in the Ruhr district and the observed precipitation.

**FORMATION OF SECONDARY BIOTOPES**

Should a large area fall below the groundwater level due to mine subsidence, and should this be compatible with the objectives of regional and environmental planning, on the long term, a terrain will be formed which can be led back to human activity. However,
the further development of vegetation and fauna will take a course which is predominantly free of human intervention, at least with the exception of eutrophic influences. Only few waters resulting from mine subsidence are situated in an open area, most are embedded in wooded areas. Water originates primarily from precipitation and flowing groundwater. Only very few lakes and ponds receive water from streams flowing into them.

Particularly in a densely populated region such as the Ruhr area, the number of natural unimpaired waters is extremely low. Thus the bodies of water formed due to mining activities could be of great importance for flora and fauna of the area. In the Ruhr area, a large share of the natural preserves and wildlife areas formed by water are so-called secondary biotopes that can be traced back to former mine subsidence.

Since the retreat of coal and steel industry in the 1970s and 1980s the demand of society for a more natural environment increased. Environmental awareness became a key issue and the Ruhr district was considered to be an ideal one-to-one scale laboratory to experiment with. The formation of secondary biotopes fits perfectly in this main stream of ideas.

THREE EXAMPLES

Lake Lanstrop in Dortmund-Lanstrop

The surface changes resulting from the former mining activities of the Gneisenau colliery in the area of Dortmund-Grevel and Dortmund-Lanstrop are referred to as an example. Here the coal seam is beneath a covering strata that is almost 300 m thick. This strata is composed of marl and chalk layers. Coal was first able to be mined in this area only after steam engines had solved the groundwater problems. In the area of severe mine subsidence, Dortmund-Lanstrop, where mining has largely come to an end, five coal seams at depths between 300 m and 500 m were mined in the past years. Impressive
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Evidence of this are several lakes and ponds formed only some years ago (Fig. 3).

A few were pumped off or filled up (as for No. 3 and 4 in Fig. 3). The largest of these lakes formed by subsidence, the so-called "Lake Lanstrop" (No. 2 in Fig. 3), with a width of 200 m and a length of 450 m, came into being between 1963 and 1967. The coal mining particularly concentrated at this site led to subsidence to the extent of about 9 m. Owing to this extreme subsidence, the ground level fell below the groundwater level thus forming the lake (Fig. 4).

Mine subsidence in the area investigated virtually involves all elements of land use: The formation of "Lake Lanstrop" led to sinking of the old Friedrichshagener Straße (road) and this had to be rerouted around the lake. Haus Wenge — an old moated castle situated directly adjacent to the lake — threatened to collapse and, as cultural-historical monument, had to be preserved at great expense. Some of the population of Lanstrop were also affected directly when sewerage from their homes was no longer able to flow off. Furthermore agricultural operations were strongly affected by the relative groundwater rise.

Besides the impairment to agriculture and structures mine subsidence has had also positive effects: The rapid formation of Lake Lanstrop was certainly of great interest to biologists since the settlement of plants and animals was able to be followed closely as if in a laboratory. After all, this lake represents an enrichment of the landscape and has already become a fishing centre which has been designated a conservation area by the authorities.
Lake Hallerey in Dortmund-Dorstfeld

Marks (1993) reports on the formation of a subsidence lake in Dortmund-Dorstfeld. The formation of wetland was first observed around 1900 as a consequence of ongoing longwall mining. In 1920 the lake covered an area similar to that today, but the lake was drained, later used as a landfill site and finally as a flotation basin for coal refuse. Today, Lake Hallerey has the shape depicted in Fig. 5.

Highways and rail roads that were built over the years lead to a complete isolation of the site. This isolation caused a drastic decrease of fauna. From 1965 to 1991 some species were reduced to 10% of their original population, in some dramatic cases only 1% survived. Hallerey Lake became one of the most intensely studied nature reservation in Germany.

It became clear that a stable ecological balance is not easy to achieve in an area as populated as the Ruhr district. In this particular case a central problem is to harmonize...
Fig. 5 Lake Hallerey, Dortmund-Dorstfeld (from Marks, 1993).
the introduction of shallow water zones to stimulate the development of fauna with the need of a large and deep fresh water body to allow dispersion and biological reduction of the abundant contamination. The research to achieve this goal is still going on. Migrating birds, however, have already accepted this secondary biotope: Hallerey lake has become one of their favourite resting places in northwest Germany.

Renaturation of the Dellwig creek, Dortmund-Lütgendortmund

An example typical for most creeks and rivers of the Ruhr district affected by subsidence is the Dellwig creek in Dortmund-Lütgendortmund (Grote, 1993). As mentioned above subsidence disturbed and reversed the flow direction of rivers, thus causing severe flooding and sanitary problems. Consequently, rivers had to be aligned and channelled, a fate Dellwig creek shared with a large number of Ruhr, Emscher, and Lippe tributaries. Around 1930 an artificial streambed for Dellwig creek was constructed, large enough to hold also the sewage of the surrounding communities.

In 1977 the area was declared a development zone for recreation, an attempt of the City of Dortmund to increase the quality of life in this area. Shortly after this decision the renaturation of Dellwig creek became an ecological pilot project of the State of North Rhine-Westfalia. The renaturation work started in 1982 (Fig. 6), spearheaded by the Emschergenossenschaft that 50 years ago aligned the river and turned it into a sewage canal. The variety of aspects to be considered in this renaturation project made it a complex and challenging task for the interdisciplinary team in charge of the project. The environmental consequence of the removal of the concrete lining of the canal had to be predicted, the hydrogeological effect on the groundwater table had to be discussed, the appropriate flora had to be prepared, all tasks where only little experience had been gained so far. The effort was not in vain: in 1986, after an investment of 5 million Ecu, the area became an officially protected state park.

![Fig. 6 Renaturation of Dellwig creek (from Grote, 1993 and unpublished documentation of Emschergenossenschaft).](image-url)
CONCLUSIONS

The commitment to environmental issues as already formulated in the "Allgemeine Berggesetz für die preußischen Staaten" in 1865 has been finally taken up again. 120 years after the "Allgemeine Berggesetz" the European Community implemented the legal framework to carry out environmental impact studies for every major project connected with mining activities. In the Ruhr district international environmental programmes are utilized such as the European Fund for Regional Development (EFRE) that not only aids the remediation of abandoned industrial sites (Genske & Noll, 1995), but also supported the restoration of natural environments. With the instigation of additional projects such as the "Internationale Bauaustellung IBA Emscherpark" (the International Emscher Building Fair), the "Bundesgartenschau" (the National Garden Fair) the financial resources are now available to turn the Ruhr district into the "Greenest Industry Belt of the World" as postulated by the Government of North Rhine-Westfalia at the beginning of this decade. Already 207 national parks, i.e. 132 km$^2$ of recreation areas (Duckwitz, 1993) have been established.

REFERENCES


