An information system for managing the reclamation of a landscape degraded by opencast mining

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Informační systém pro řízení rekultivace krajiny postižené povrchovou těžbou

V tomto článku jsou popsány výsledky výzkumu v oblasti řízení tvorby a rekultivace krajiny po povrchové hornické činnosti. Popisuji východiska návrhu informačního systému, rozbor jednotlivých nutných informací, jejich návaznosti a vztahy. Dále je popsán návrh informačního systému, jeho technické a programové zabezpečení. Popisuji jednotlivé vrstvy systému.V závěru článku popisuji výstupy systému, návaznosti na prováděné práce při zahlazování následků těžby a další předpokládaný postup ve vývoji systému směrem k systému expertnímu.

Key Words: *opencast mining, modelling, simulation, landscape formation, GIS.*

Introduction

The goal of the described project is the design of a graphic information system for landscape forming in the course of and after mining operations. The task of such a system is the solving of the following problems concerning:

- landscape formation, landscape modification in the course of and after mining operations;
- the purposeful utilisation of spaces created by mining activities;
- the utilisation of materials and raw materials deposited on mine dumps;
- the management of moving large volumes of materials and technologies;
- landscape modelling;
- the observation and modelling of biological reclamation;
- the modelling of ecological points of view.

The first step was to find the goals of systems and requirements as determined by legislation, regulations and usage for the reclamation of a degraded area. From this, demands for outputs and also for information sources followed.

Another step of solving was a design of the detailed conception of needful data collection, holding and maintenance, and mainly the methodology for their utilisation in solving. Potential data sources were examined; a database and connections in it were designed.

Subsequently, software and hardware for the processing of needful data were designed, mathematical methods for solving the problems given above were selected and developed, and these problems were included into the uniform GIS.

The creation of the system for modelling a landscape corresponds to the trend of information system applications in such organisations, within whose competency problems of area administration, area planning, ecology, exploitation and processing of mineral raw materials (including e.g. exploratory and design activities) lie. The base for designing the system is an exhaustive analysis of existing information systems in the mentioned organisations, the extent and mode of computing technique employment, and primarily data models and database implementations in these organisations.

At present some program systems are applied to the processing of underlying data of landscape recovery and its management. However, they are mostly used as individual blocks, e.g. for terrain modelling, calculating the amount of material, slopes, etc.

The objective of the project is the interconnection of individual tasks and the database into one graphic information system.

Requirement for the system

The system must enable the satisfying of requirements following from laws, decrees and demands for the subsequent utilisation of the recovered landscape.

The basic goals that must be pursued by the project are as follows:

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- conceptual – governmental decisions, decisions of the mine company;
- technical – the obeying of provisions of the Mining Act, the elaboration of alternatives and selection of
- the optimum variant of closure, the settlement of reserves of useful raw materials, complying with safety, fire and hygienic regulations, the settlement of commitments in relation to governmental agencies, self-administration, legal entities and physical entities;
- economic – to maintain the calculated costs of coal opencast mine closure, to settle the fixed assets and commitments, to compensate maximally the costs by earnings from closure (sale of real-estates, sale of capital goods, scrap, etc.), to create entrepreneurial activities for the utilisation of the recovered area (small- and medium-sized enterprises, waste dumps, water utilisation, recreational and amusement parks, etc.), costs of investment frustrated by closing the opencast mine (closure costs and foreign frustrated investment);
- social - in cooperation with regional authorities to prepare in advance job opportunities for dismissed workers, on time to prepare and start the retraining of dismissed workers, to ensure prospective subsidiary productions in cooperation with regional authorities (investment participation);
- ecological – to work out the project of removing the impacts of mining activity in relation to development plans;
- legislative – to agree with regional authorities on actions, to create the principles and rules of cooperation with environmental parties and movements, to participate actively and joint in new entrepreneurial ecological activities on the formation of a recovered landscape;
- organizational – to create an optimisation model of the organisational structure of the process of coal opencast mine closure in various time periods of closure.

The content of the project

The project must satisfy the requirements given in the ČBÚ Decree No. 104/1988 Coll. and its amendment according to the ČBÚ Decree No. 242/1993 Coll. on giving the permission for mining activity. A part of the project must also be a plan for closing shafts and related workings according to Annex No. 6 to the Decree. It must cover above all the following points, including graphic documentation:

- reasons for closure;
- results of exploration, opening, development and exploitation;
- reserves management;
- the method of closing the shafts and related workings and opencast mines;
- basic safety measures;
- the fulfilment of requirements following from regulations and agreements;
- the time sequence of closing operations;
- the utilisation of mine workings, equipment, buildings for other purposes;
- mine water management;
- the method of improvement and remediation of lands after mining and the method of complying with requirements following from decisions of authorities and agreements with agencies and organisations being competent to deal with the protection of objects and interests according to special regulations, and further documents on the settlement of conflicts of interests.

Information on the opencast mine

In addition to above mentioned matters, the project should contain, for the purpose of landscape restoration and utilisation, the summary decisive pieces of information usable in the process of closure, property settlement and archiving for the next potential use. It is especially the case of the following:

- the layouts of the allotment and the protected deposit area;
- underground services – transport, electrical connections, heat, water, steam, telecommunication;
- planning permissions and legislation related;
- regional links – power plant, heating power station, sales;
- the deposit description – geological setting, tectonic structure, coal reserves, reserves of accompanying raw materials, qualitative features of coal, qualitative features of accompanying raw materials;
- basic safety conditions – general gradients of slopes of the opencast mine, spoil heaps, spontaneous ignition and fire preventive measures, precautions against flooding the opencast mine, other safety measures according to the specific characteristics of the opencast mine;
- the basic control system for the exploitation in the opencast mine – the number and construction of overburden sections, the number and construction of spoil levels, transport and access roads, the power-supply system, the set of technological units on particular sections, the system of draining the opencast

mine, overburden deposition, the management of mine dumps and their reclamation, the preparation of opencast mine foreland (demolition work, ground shaping, blasting operations, etc.);
- the description of surface buildings – working plants, plants for the treatment and upgrading of useful raw materials, auxiliary plants, social services, etc.;
- technical-economic factors of the opencast mine;
- mining capacity – if possible, to document the development of production during the whole life of the mine, otherwise on the basis of statistical documents, the existing mining capacity, the state of overburden sections, stripping in advance; with the untimely closed opencast mine: designed and achieved mining capacity and the designed life of the opencast mine;
- qualitative coal features – development in the last five years, especially ash, water, sulphur, heating value, carbon content, hydrogen content, ash melting point;
- accompanying raw materials – the description of accompanying raw materials, reserves of accompanying raw materials, qualitative features of accompanying raw materials, industrial utilisation, the evaluation of the deposit of accompanying raw materials (with the opencast mine closed untimely), the assessment (design) of the business plan of their next utilisation, deposits of accompanying raw materials in the spoil heap;
- the documentation of investment construction according to buildings, technological units;
- induced investments;
- labour force;
- economic factors;
- ecological factors;
- biological information.

From the requirements presented above based on legislation and regulations, a need for extensive documentation follows as well. It is especially the case of map documentation, profiles, geological sections, documentation, and calculations. Recommended documentation is given in (Neustupa, 1997), (Štýs, 1981).

The project of the system for forming the landscape after mining activity

On the basis of software research and evaluation, what was used was a mining planning program system enabling the work with the terrain, surfaces, geology, operating planning and opencast mine design, the design of technical reclamation.

When designing, I proceeded from the summarisation of requirements for the system to the design of the system structure. The final output is the creation of groups and layers of the system, including the structures of input data, output data and program modules and their interconnecting. Requirements for the system are given by the following points:
- diagrams (of the allotment, the protected deposit area, the surroundings of the opencast mine, etc.);
- the description of the deposit, geology;
- hydrogeology;
- the description of mine dumps and overburden;
- technical reclamation;
- classification of surfaces;
- technical facilities (communication, underground services, buildings);
- ecological information
- cadastral information.

From the standpoint of data access, the system is structured into five levels. The first level is the program system itself, the nucleus of which makes it possible to start the program interface for another access, further it makes it possible to start also other program modules with the connection of the following project level.

Factually, the project is the first proper data level, on which it is possible to work really. Either it must exist, or it must be, in the case of a new task, created mostly from the program interface. The project is defined by a name, and forms the directory and subdirectories for the subsequent work itself. Automatically at the creation of a new project, basic structures of blocks and surfaces are formed as well.

Groups represented by graphic files and including all information on the work on the problem are another level.

Layers are the next level. It is the case of sets of pieces of information on objects that are callable and displayable individually. The number of layers in the group can be 1024.

Objects are the last level. They are points, lines, closed forms (rectangle, square, polygon), but unfortunately no 3D objects (cuboid, sphere, etc.) in the applied version of the program package. The object is

defined by its ID number and XYZ coordinates. By means of the function of user data it is possible to add other pieces of information to each object. ID is the description itself and the means of communication with the consecutive database.

The following minimum structure of modules and subsidiary means result from the requirements:

Program system:
- system nucleus;
- geological database;
- stratigraphic model;
- opencast mine;
- reserves;
- roads.

Database server:
- Oracle server;
- Oracle Workstation;
- SQL-based server;.
- bridge for the external database;
- mine surveying.

System groups and layers, data, funkcions, outputs

The system is composed of basic groups in one project that ensure the performance of partial functions of the system. Individual groups enable the interconnection of individual pieces of information on the base of IDs of objects and also cooperation in the common part of the database. Another interaction is possible merely in virtue of possibilities of transmitting the information of particular layers in the groups of one project.

Group of surfaces

In principle, this group represents digital models of terrain, concentrates information on the condition of the opencast mine, its map underlying data, foot edges, contour lines, historical reliefs - initial one before the exploitation, and the courses of actions during the mining. Graphic materials are the output; maps are without any symbols so far, because in the system, this function is not built-in.

Layers used:
- the initial topography;
- the existing relief of the opencast mine;
- the existing relief of spoil heaps;
- the boundary of the deposit area;
- the history of the opencast mine.

The sources of data are primarily digitised maps, information from photogrammetry and digital maps from the Zabaget systems.

Data is usually delivered in the ASCII form, or DXF, or it is translated to this form. XYZ coordinates are carrier information. The outputs are the maps of the opencast mine and mine dumps with the final state of overburden and coal sections, levels of internal and external spoil heaps on a scale of 1:2000 to 1:10000 with the outlines of the boundaries of the allotment, the protected deposit area, the outcrop of the coal seam and with the delimitation of area morphology by relevant altitudes, and further maps of the historical relief, maps documenting the advance of mining and maps of mine workings of previous mining activity on an original scale.

Group of geology

This group includes information on the deposit, boreholes, and models of the deposit. It enables the output of information on the deposit, accompanying raw materials, etc. Modules of the geological database and the stratmodel process the information.

Layers used are as follows:
- the original and the existing surface;
- boreholes and dummy boreholes, test pits;
- the geological model of the deposit of the initial locality;
- the geological model of the existing deposit;
- the geological model of overburden;
- the model of the mine dump.

The sources of data are especially boreholes.

In the case of deposits of accompanying raw materials in the spoil heap and the composition of the dump material, the sources of data are dummy boreholes. The dummy boreholes are created on the base of determining the time and location of deposition on the dump. Information on the relief necessary for the deposit delimitation is taken from the group of surfaces. As for coal deposits, data from boreholes is stated, divided into layers, with

information – borehole name (name, number), borehole coordinates XYZ, layer number, layer elevation, ash in dry matter, calorific value in dry matter, sulphur in dry matter, tar in flammable matter, and another needful information.

For the overburden, interlayer and the subsoil of the mine dump, data from boreholes divided into layers is stated, with the following information: borehole name (name, number), borehole coordinates XYZ, layer number, layer elevation, geotechnical zone, lithological type of rock, location, kind of rock, classification, class, consistency, coal content.

With the deposits of accompanying raw materials, data from boreholes is divided into layers, with information as follows: borehole name (name, number), borehole coordinates XYZ, layer number, layer elevation, kind of raw material, composition. With the mine dumps, data from boreholes, test pits and dummy boreholes is stated. Information in the dummy boreholes has been acquired on the basis of knowledge of deposited material, the determining of the time and location of depositing on the mine dump. It is the name of the borehole (name, number), borehole coordinates XYZ, layer number, layer elevation, deposition date, deposition mode, indication of landslide manifestations, mark according to the documentation of bulk materials, JSK classification, relative density, plasticity index, deformation modulus, strength, classification. Pieces of information need not be compulsory; adjustments are possible on the basis of operating needs.

For the deposits of accompanying raw materials in the mine dump, data from dummy boreholes is used. Information is obtained in the dummy boreholes in virtue of the knowledge of material deposited, the determination of the time and location of its deposition on the spoil heap. To the information, the date of deposition, deposition mode, borehole name (name, number), borehole coordinates XYZ, layer number, layer elevation, kind of raw material, and composition belong.

Outputs are logs of the boreholes and test pits, including the complete documentation, the list of boreholes; a map with the layout of all deposits and the occurrence of accompanying raw materials found in the overlying and underlying beds of the deposit; a map of contour lines of the roof and the bottom of the deposit on a scale of 1:2000 to 1:5000; a line of minimally five geological sections; geological sections through the whole extent of the deposit on a scale; the estimation of reserves of the mine under closure; a map of reserves, and others.

Group of hydrogeology and hydrology

In this group, information on the hydrogeology of the deposit, the mine dump, the opencast mine and the close surrounding is collected. Historical information gives an opportunity to see the saturation of mine dumps and the behaviour of water in the landscape after reclamation.

Layers used:

- deposit hydrogeology;
- mine dump hydrogeology;
- surface waters;
- boreholes;
- wells;
- historical hydrogeology;
- historical surface waters;
- drainage.

The source of data is the proper hydrogeological investigation of the opencast mine, information of the Czech Geological Institute, of catchment area agencies, and others. The form of data with underground waters is the underground water level, qualitative parameters, or the vector of flowing, zones of water source protection. With surface waters, it is finding the direction of water streams and perennial water bodies, the name, the flow rate or the quantity, quality.

Hydrogeological maps, drainage maps are the output.

Group of technical reclamation

This group gathers information needed for the performance of technical reclamation, shaft removal, slope formation, etc.

Layers used:

- the existing surface;
- the recovered surface;
- material transport;
- slope conditions.

It is the group of surfaces and the reclamation project that are the source of data. Data is graphic layers, the existing surface, the determination of slope conditions, the limitation of overlapping the areas, the height in metres, the delimitation of coal seam burial in metres, the swell factor, requirements for drainage channels,

inflows, etc. Outputs are maps of final technical reclamation, maps of slope conditions, sections, isometric views.

Group of biological reclamation

This part enables to interconnect the pieces of information on executed works, works being done and planned works on the surface. It provides the information on the surface, slope conditions, surface waters, the method of reclamation performed and on soils.

Layers used:

- the surface;
- inclines;
- soil;
- reclamation executed;
- reclamation in progress;
- planned reclamation;
- surface waters.

The layers of the groups of technical reclamation and hydrogeology, analysis of soils from mine dumps, plans and description of reclamation works are the source of data.

The data is graphic files from other groups; in particular layers the pieces of information are then bound to objects determining their validity. Pieces of information on the surface of the mine dump and soils are bound to the space, therefore their form is the delimitation of the area by means of coordinates of vertices of the area, the class of erosion resistance, the class of soil-forming substrate of spoil heaps, granularity, mineralogy, pH, heavy metal content, calcite, organic content, sorption capacity, nitrogen content, nutrient content, phosphorus, potassium, magnesium, calcium, hydrophysical properties, capillary capacity, wilting point, efficient water capacity, volume density. For reclamation purposes, it is the delimitation of the area by means of coordinates of vertices, the date of reclamation beginning, the date of reclamation completion, reclamation method, stand definition, and another information as given e.g. in (Forman-Gordon, 1993).

Outputs are isometric views, maps of slope conditions, 3D views, reclamation maps.

Group of technical facilities

The group of technical facilities gathers pieces of information on underground services, buildings and communications in the ownership of the mine company.

Layers used:

- belt transport;
- rail transport;
- communications;
- power distribution systems;
- water;
- steam;
- telecommunication.

The documentation of the mine company is the source of data. The data is in the form of graphic presentation of individual items, such as objects, with related information on objects. Belt transport is described by these pieces of information: type, outputs of drive units, specification, date of acquisition, date of building. Communications are described by the date of construction, type, specification. Energy distribution systems are described by the date of building, type, voltage, specification.

Outputs are maps and graphic representations.

Group of cadastral information

In this group, pieces of information are stated concerning the objects that are not in the ownership of the mine company, but that are situated in the described area of interest or in its immediate vicinity.

Layers used:

- built-up areas;
- wooded areas;
- communications;
- railways;
- electrical power distribution systems;
- a land-use plan.

Digitising the relevant plans is the source of data.

The situation and other possibilities of the project

The system designed like that provides the needed information and graphic outputs for the design of landscape utilisation and landscape regeneration after mining activity. The information together with underlying materials is then a guide when making decisions on procedures.

Various possibilities were tested; work on individual layers and groups still proceeds as stated in (Neustupa, 1995) and (Neustupa-Truneček, 1997). The design as well as the system is open, it is possible to add other groups and layers according to user needs and requirements.

Conclusion

The goal of the initial project was to design a total system for forming a landscape after mining activity. The system, as designed and described in this article, is the initial stage of realization of this objective.

The designed system enables interactive reclamation modelling, furnishes information needed for making decisions on the next progress. This makes it possible to model situations for individual steps of advance, and accelerates the working out of documentation. These functions are important especially in case of unscheduled changes in the exploitation progression or in reclamation intentions (e.g. change from the wet variant to the dry one).

When designing, we concentrated on an opencast coal mine. However, the methodology and the design of the system enable, after changes, the utilisation for an underground mine or an opencast mine of useful raw materials.

The system allows another development and can be orientated towards a total expert system by adding other layers and models together with creating knowledge modules and programs making decisions on data.

The work on the system proceeds primarily by supplementing by the layers of ecology and economic evaluation. A final goal defined newly is an expert system for managing the landscape regeneration as a tool for management and planning.

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