Modern methods of surveyor observations in opencast mining under complex hydrogeological conditions.

L A Usoltseva, V P Lushpei, VA Mursin
Far Eastern Federal University, 8, Sukhanova St., Vladivostok, 690950, Russia
E-mail: Usoltseva.la@dvfu.ru

Abstract. The article considers the possibility of linking the modern methods of surveying security of open mining works to improve industrial safety in the Primorsky Territory, as well as their use in the educational process. Industrial Safety in the management of Surface Mining depends largely on the applied assessment methods and methods of stability of pit walls and slopes of dumps in the complex mining and hydro-geological conditions.

1. Introduction
Structurally, the brown coal deposits of Primorye Territory have a synclinal form. The angles of incidence of coal seams vary from 0° in the central part of the troughs to 20-30° at the outputs of reservoirs under the sediments, in some areas up to 40-50° (section Luchegorsky 2 - Bikin deposit). Overburden is presented by interbedded with clay and sand-clay weak formations. Hydrogeologically developed brown coal deposits of Primorye are complex; if Pavlovsk field food percarbonic upper horizon is due to river water and precipitation, the waters of the lower horizons (coal and subcoal) are artesian. The hydrogeological conditions of Bikin deposit complicated by the large number of synclinal lying aquifers, their uneven watery (see Table 1) in plan and section, and a weak natural discharge with significant groundwater recharge as a result of the infiltration of a large amount of precipitations. Inadequate attention to such problems complicates opencast mining operations, reduces the level of their security, necessitates additional engineering and geological research and development of new solutions for the correction of the project, which ultimately leads to the rise in prices of overburden removal and to occurrence of emergencies (landslides, collapses of massif).

Table 1. Comparative evaluation of water content of brown coal deposits of Primorye

| Cross-section   | The length of the work front, m | The annual volume of production, thous. tons | Water inflow into the cross-section, m³/year | The coefficient of water-abundance, m³/t |
|-----------------|---------------------------------|---------------------------------------------|---------------------------------------------|----------------------------------------|
| Luchegorsky -1 | 6900                            | 3500                                        | 14107                                       | 4.03                                   |
| Luchegorsky-2  | 2300                            | 2000                                        | 4850                                        | 2.42                                   |
| Pavlovsky      | 5200                            | 3500                                        | 7985                                        | 2.28                                   |

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd
In these circumstances, surveyor works, allowing one to quickly visualize and assess the situation, prevailing at the quarry, are needed. So, the arrangement of high precision instrumental observations, using electronic total stations and laser scanner, the formation of a geographic information system on the basis of mining and graphic documentation and the results of field observations, as well as a retrospective analysis and three-dimensional visualization of the results, can also be supplemented by the results of deciphering satellite images and photos on the site of operating quarries. Currently, many surveying services in mining enterprises operate, using obsolete technology, which greatly reduces their competitiveness over the similar foreign companies and, ultimately, exacerbates the problems of industrial safety of the Surface Mining. An important point is also backwardness of the regulatory framework of modern surveying techniques and tools used. Therefore, there is a need to both combine modern technological solutions and minimize costs. This article discusses how to optimize the surveyor monitoring of Surface Mining that improve industrial safety in Surface Mining and in complex hydrogeological conditions of the Primorsky Territory of the Russian Federation.

2. **Practical application of «GNSS»**
First, during any types of geodetic and surveying works the problem of determining the rectangular coordinates and elevation points of plan-height study arises. As a rule, these works are carried out with the use of satellite positioning systems [1-4]. The method consists in the fact that the receivers simultaneously measure the code ranges and the phase of the carrier to the same satellites, thereby eliminated the error introduced by the Earth's ionosphere. Thus, positioning accuracy reaches 0.6 cm horizontally and 0.9 cm in height. Accuracy can be improved by using a greater number of receivers as base stations. An important link in the chain determination of rectangular coordinates and elevations, using GNSS, is software. This is the software, owing to which the final processing of "raw" data from receivers take place, and, as a result, one obtains the equation in rectangular coordinates of the local coordinate system. At the moment, there are many different. The specialized software modules that are most often used at the enterprises of the region are the following: TrimbleGeomatics Office, Trimble Business Center, Leica Geo Office, JUSTIN (company JAVAD), Spectra Precision, etc.

3. **Using high resolution satellite images**
Another possibility is the use of high resolution satellite images for surveying work in the open-cut mining of mineral deposits [5].
Raster satellite images can be downloaded to various load vector editors. A loaded bitmap and can be scaled and superimposed on the survey. As a result, it is possible to control the taken picture or supplement it. Figure 1 shows an example of the superimposed satellite imagery in AutoCAD (the picture was made in winter time) on the performed survey of the pit in the vector form. It is clearly seen that the contours of the top and bottom of slopes (highlighted in orange) coincide with the characteristic lines on the images.
Figure 1. Satellite image of pit, andesites, working of Pushkarevskoe field, superimposed on topographical survey.

It is important to remember that these companies provide static information, i.e. satellite imagery is shown not in real time. To work with the historical data, there are many specialized programs. For the region of Primorsky Krai, optical submeter resolution images from satellites KOMSAT-3, supplied by the Russian company "Perspective", and supporting data processing digital photogrammetric station PHOTOMOD, using RPC-coefficients, are actual. The use of radar satellite KOMPSAT-5, carrying out shooting in the X-band in three modes, which provides high-quality data in all weather conditions, is also possible. The system PHOTOMOD Radar, designed for processing remote sensing data, obtained by the synthetic aperture radar antenna, allows one to process sensor data to produce the whole spectrum of the outputs. In the context of the expansion of satellite constellations, the conditions of taking pictures are optimized and they become more accessible for the handling and use for the surveyor software of Surface Mining in the Territory.

The rise in popularity of satellite images does not mean that paper maps become obsolete. They complement each other successfully. The product, combining the space and aerial photographs, thematic layers, built on their bases, as well as the terrain model, allowing one to convert the map into a three-dimensional image of the terrain, lead to the creation of "geographic information systems" (GIS). Digital technology, simplifying the procedure for processing the data, makes it possible to display not only static objects and terrain, but also the processes, occurring in a particular area, in particular open mining.

One of the necessary directions in the operational decision surveying tasks, as well as a retrospective analysis of the situation is to create digital plans on the basis of a paper mining-graphic documentation. All mining companies have mining and surveying archives. They represent systematized maps, plans, diagrams, plates, either paper-backed or hard-backed. The information, which they contain, is of value is periodically used. When transferring this information into a digital form, it is possible, without reducing the accuracy and quality of the original edition, to quickly copy, print at any scale all images, or some of its elements, as well as to create digital archives of data, the information in which can be stored indefinite time, while maintaining the accuracy and quality of the original document.

To perform digitization, the specialized software is applied. As a result of these operations, a quality bitmap image maximally approximated to the original are obtained, which can already be placed in an electronic archive, and later used in a variety of CAD and GIS systems. The created bitmap is also converted to the vector format.
4. Creation of three-dimensional models of open cast mining

One of the necessary directions is to create digital plans and 3D models of the mining industry, given the current trend of transition from two-dimensional to three-dimensional graphics, which has already secured a number of regulations in international and domestic practice.

Computer modeling of mining facilities is carried out using the graphical surveying documentation and immediate data of the survey field notes. In solving the volume problems, a digital model is converted to a math one, thus increasing the information density of the model hundreds of times due to the addition of calculated points.

Basically, the surface is created using triangulation networks. They are formed of triangles; the sides of these triangles form a line network (Figure 2). The three-dimensional surface models is expedient if the entire complex of digital information is available. In addition, based on the generated digital database, it is possible to most effectively find, organize and use on a daily basis all the accumulated material and to conduct a retrospective analysis that is the basis of industrial safety during opencast mining, integrated with the instrumental survey of remote sensing and three-dimensional visualization capabilities.

The above-mentioned methods of the survey, ensuring the open cast mining of mineral extraction and their combination, were tested in practice of mining companies of Primorsky Krai. At low cost, they have proven their effectiveness (Figure 2, 3).

![Figure 2. The representation of the Baranovsky pit in the form of a triangulation network](image-url)
5. Conclusion

Field and laboratory work was carried out by students and post-graduates under the guidance of teachers of the Department of Mining and Integrated Development of Georesources of the Engineering School of the Far Eastern Federal University. The results of these studies were used in the formation of educational disciplines "Surveyor support of open pit mining", "Computer simulation of open pit mining", "Special surveyor work" for senior students of the specialty" Mining" and specialization "Mine Surveying" and "Surface Mining".

References
[1] Usoltseva L A, Lushpei V P, Vasjanovich Y A, Muratov N A, Murzin V A 2013 Surveying methods to ensure the monitoring of public works as a factor of industrial safety. Problems of georesources of Far East. Mining informational and analytical bulletin 3 91-102
[2] Usoltseva L, Lushpei V, Vasyanovich Y, Murzin V 2014 Monitoring surveyor work for opencast mining development in Primorsky Region. "Geoinformation sciences and environmental development: New approaches, methods, technologies" - Collection of articles of the II International Conference - Limassol, Cyprus, May 5-9, 56-61
[3] Antonovich K M 2006 The use of satellite navigation systems in geodesy. Monograph. V.1 (Moscow, Federal State Unitary Enterprise "Kartgeotsentr") p 334
[4] Antonovich K M 2006 The use of satellite navigation systems in geodesy. Monograph. V.2 (Moscow, Federal State Unitary Enterprise "Kartgeotsentr") p 360
[5] Kashkin V B 2001 Remote sensing of the Earth from space. Digital image processing: a manual (Logos, Moscow) p 253