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Developing and Application of Software for Determining Parameters of Drainage on Designed Embankment

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Abstract— The aim of this paper is to demonstrate a software development process for estimation of drainage parameters and its concrete application in practice. It is necessary to use knowledge from the field of programming and mathematics to create the software, which can find its application in various conditions of earthworks as well as the landfills, earthen embankments, etc. With this paper is integrated a design process of the earthen embankment with drainage canals, process of program development for calculation of the parameters and dimensions of drainage canals and display the results of calculations as different methods contained in on methodology for obtaining results. Results of this investigations are established design of embankments and software for estimation of drainage parameters at designed location. This process shows how it is possible to include discipline of the engineering design, information technology and the software engineering. Advantages of this approach are multiple efficiencies in process of the embankments and waste dump design and estimation of drainage parameters. This approach to problems in mining, civil engineering and geology, greatly facilitates and accelerates the process of decision making as well as offering multi-variant solutions.

Keywords— design, drainage, earth embankment, programming, software

I. INTRODUCTION

The target of mine design is the extraction of ore in the most cost-effective way, and including protection the miners and environment. Mine design is not easy and must consider many variables in achieving its goals. Surface mining technology is developing as the mining industry which can respond to the challenges of deeper layers, difficult climate, steep slope with changing properties of rock materials, but also the difficult economic situation. Because of need of seeking operational improvements with lower labor costs, it is necessary to draw up the project of opening, maintaining and closing with different directions and with different assumptions [1,2]. Scheduling is absolutely crucial to the successful running of any mining operation, whether surface or underground, in both practical production and financial accounting terms. Water is often a major stumbling block in the development, operation or closure of a mining operation. Often, potential impacts to water resources become the major concern for the environmental regulation of mines, and the migration pathway of potential contaminants to vulnerable receptors such as rural communities, livestock and aquatic ecosystems[1]. Consequently, it is essential that trough all stages of mine life cycle, that water management is both effective and applicable[2]. Mine drainage process is essential for the clear operation of any mining and is also an environmental problem as concentrations of suspended solids in the water has to be addressed. Mine software allows mines to better plan for the short, medium and long-term through productions phases [3,4,5]. Software industry helps drive greater modelling, simulation and functionality capability in mining planning. Particularly with regard to 3D modelling, virtual mines and interactivity the world of mining software is rapidly changing. More effective and more real time simulation whether in surface or underground mining will allow for faster decision making for miners [6].

In some cases we can use our own knowledge and resources to develop software for specific conditions and specific input parameters [7]. In this case, the universal mathematical and software solution was created for calculation of the parameters of drainage in mining, geotechnical and civil engineering works and for that purpose used generally known formulas given in Section 5 of this paper. Based on those formulas was developed software with graphical user interface (GUI-Graphical User Interface) for Windows application in FORTRAN (FORmula TRANslation), as one of the most efficient programming language for engineering calculations. In this paper have been highlighting the connection between classical engineering design, software engineering and design process of earthen embankment. For that kind of the embankment has designed drainage canals in according with calculated dimensions of the canal, its pitch and type of material through which will be provide flow of drainage water. As part of any mining application study, a trough risk evaluation is imperative to

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[1] Mining magazine, Vol.201, No.1/2, 2010
[2] Idrysy at al., 2011

ensure that all risks for the project have been identified, analyzed and mitigated to acceptable levels[1].

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II. LITERATURE REVIEW

Mining is one of the oldest industry in the world and many authors are devoted to this problematic and give to us many solution related to processes in the mining. How to use advanced in new technology and techniques to improve production of ore in mining industry are topics of numerous issues and many authors like De Lemos [1], Moor [3], Wilkinson [8] and Walker [9]. Mine planning is crucial to the successful mining operations and using good strategic plan as well as god software for planning operation in mining industry. Short review of scheduling software suppliers and importance of using of software is given in Mining Magazine [10], Moor [11], Lovejoy [12], Goodbody [2], Mining Magazine [13], Moor [6], Carter [14]. Mine design depends on amount of information that can be used in particular moment same as the way of data processing for decision making. How to work with huge number of data and how to successful use information technology wrote Carter [15].

In order to properly decide about application certain types of pumps for drainage, must be done a detailed hydro-geological study and then do a conceptual and numerical model of water flow. As an essential item lists are constantly monitoring the level of groundwater that is necessary to control depending on the methodology and technology of ore mining. With this problem are dealing authors Lang and Buhl [16]. Prediction of groundwater inflow into a deep open pit by using software for numerical modelling is presented by authors Aryafar A., et al. [17]. The use of digital model in determining the boundaries of pit and geometric parameters of pit considered in paper Future lignite mines of Serbia [18].

At the front end of an operation, dewatering is key to maintaining production, from underground or an open pit [19]. Struzina and Benndorf in the paper [20] considered the traditional approach of drilling, planning and groundwater modelling as extended by the dimension of geological uncertainty using the technique of conditional simulation in geostatistics. Mine water management is an essential consideration in successful mine design and operation. Integrating this discipline with other elements of mine development and management is necessary in order to effectively address the assessment, development, operation and closure of mining operation. Dewatering process has influence on all other processes in mining operations [21]. Way of maintaining the slope and mining area dry is considered by Carter [15] and Boyce [22].

III. METHODS

A. Methods for Mine Design

Mine design involves modelling the optimum layout for the workings that reach the most ore at the lowest cost with the greatest safety. Mine engineers need to known where the ore is, what rock types will be encountered, groundwater data, how to support the rock and ventilate working underground, and best to move personnel and materials around safely and cost effectively [2,8]. In addition to the classic design of the mine, with the progress in the development of techniques and technologies we are able to use sophisticated design methodology. In this sense, there are many software solutions as assist in the design process of the mine, its development and finally closure. By using the software, we can accelerate the process of selecting the optimal variant appearance of the mine due to the amount of information currently known. It also leaves enough space for quick change variant solutions with new information gathered during the development of the mine.

It is necessary to investigated different mine development variants for both of the mining fields considering the geological situation and in particular ore quality situation. Based on digital geological model the mining boundaries could be reviewed and detailed mass calculations could be performed.[3] Also, we have to know that key of successful open pit mines is infrastructure management and development. The methods, equipment and technological capability of industry must modify to tomorrow's need [11]. Mine design system has to providing the total framework for getting the most out of available deposit, in tonnage and financial terms [9].

B. Methods for Applications of Software for Pit Mine Design

Software is a key component in managing the complexities while at the same time optimising process flow. One of the biggest benefits of mine design software is the time saving. Then there are reduce costs, increase production and improve safety [2, 8]. The most of engineers want effective software that would allow operators to reduce the amount of time needed to update pit design; that could be easily to use but with advanced editing capabilities; that it has automated tools; and requires minimal training. Intelligent mining implies the application of information technology at every phase of the mining processes, from exploration and geological modelling

[3] Hohna et al., 2010

to equipment, operations and maintenance, and logistics and transportation [14,23,24]. There is a significant amount of information in software packages that firms can use from management and productivity perspective and so can maximise the productivity of their resources and personnel. The technology of surface mining design, planning and mapping is becoming digitalized, driven by electronic and software innovations that are permanently changing point of view at digitalized data.

The logical product of the evolving mine site, in the area of sophisticated machine-guidance systems and high-speed data collection and analysis, is a mine plan that can be regarded as living document, presenting changes and progress to the operations and management staff in near real time. Although a number of available technologies have been developed to minimize the necessity of having surveyors walk the pit or scramble across rough terrain, occasions still arise that require conventional, on the ground survey techniques[4]. Mine design software manufacturers and many products are now available to assist in the planning, design and simulation of open-pit and underground mines[5]. Software of various types is involved in every stage of modern mining. The demands of mining industry require capabilities and features tailored more closely to user needs [14].

C. Methods for Mine Dewaterings

As mining industry grows, so grows the need for good dewatering solutions. Mining area requires dry ground and stable walls [14,22]. Control of groundwater plays an important part in operations at many open pit mines. Overburden, especially sand and gravel layers, requires dewatering to guarantee a safe and efficient digging, conveying, and dumping process in both continuous and discontinuous mining environments. Selection of an efficient and cost effective dewatering program that will improve slope stability of the pit walls is complicated by the complex and uncertain hydrogeologic environment found at most mine sites [20, 25, 26].

There are three major issues related to groundwater in mining projects that need to be addressed: mine dewatering requirements, stability of pit walls and environmental impacts on groundwater levels and on groundwater quality, during mining and post mining periods.

Mine dewatering reduces water inflow into mine and can comprise a simple in-pit sump with dewatering pump, to sophisticated schemes involving perimeter abstraction well sand drainage galleries. When dewatering a saturated formation and thereby decreasing pore pressure, the effective normal stress in the rock mass is increased, resulting in more stable slopes. Pore water depressurisation is often incorrectly or only partially integrated into slope analysis, and requires geotechnical engineering and hydrogeology discipline to work closely together for optimal results. Other advantages of mine dewatering include: improvement in mining conditions, drilling, blasting, loading, hauling and scheduling, all which positively impact mine productivity[6].

[4] Carter R., 2013
[5] Harcus M, 2011
[6] El Idrysy at al., 20112

IV. Location Data

Ribnica bearing diabase, is locate south of the border Banovici area of Bosnia and Herzegovina, and it is the most appropriate exploration area in Tuzla canton for establishing a resource base for production of quality aggregates from so-called "igneous rocks". The area has more than 6 km^2, and belong ‘ofiolit’ central zone, or part Krivaja – Konjuh massive [27]. Location of reservoir has been showing in Fig. 1.

V. Mathematical Model of Calculation of Drainage Parameters

Input data, for dimensioning of the drainage facilities, has been including data expressed by the maximum rainfall on first day, first hour in a fifty-year return period for canals and the maximum rainfall of first, second and third day, the return period over the last fifty-years in the moment of water chamber dimensioning (according to Bosnia and Herzegovina mining standards and regulations). It has to be taken into account flow of the groundwater if reported that groundwater at related field appear in significant yield. In addition, significant input values are size of water table, water table contour of open pit or quarry and method of development of the plateau (or waste dump). Estimation of absorption loss during plunge and evaporation was performed empirically by similar examples at this site [28,29]. Assessment of potential rainfall loss is about 5% at this site.

The average inflow of water (q) into the canal at corrected runoff coefficient (due to water absorption in soil and partial evaporation) was calculated by using (1).

$$q = F \cdot h_s \cdot K_0 / 3600 \quad \left(m^3 / s\right) \tag{1}$$

Figure 1. The spatial location of the diabase deposit ‘Ribnica’: Waste dump ‘Streliste’ and Quarry ‘Ribnica’ (Figure made by Elvir Babajic)

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F – water table (m^2),
h_s – precipitation first hour, first day of 50-year return period ($m^3/m^2/h$),
K_o –runoff coefficient (K_o=0.95).

Approximately is adopted the flow rate (according to empirical data for similar types of terrain which makes the canal) v=1.0 m/s. The speed of water flow through the canals must be greater than the minimum speed at which occur a mud deposition and freezing water at low temperatures. Also, the velocities must not exceed the maximum size, because at high speeds come to water erosion profile of the canal.

Required cross-section of the canal was calculated by (2).

$$A = q / v \quad (m^2) \tag{2}$$

v – velocity flow through the canal (m/s).

For a trapezoidal cross section of the canal (Fig. 2), with a lateral inclination α=60°, its area was estimated by (3):

$$A = (B + b) / 2 \cdot h = \left[\frac{(2 \cdot h \cdot ctg\,\alpha + b) + b}{2} \right] \cdot h = \frac{2 \cdot (h \cdot ctg\,\alpha + b)}{2} \cdot h = (h \cdot ctg\,\alpha + b) \cdot h \quad (m^2) \tag{3}$$

$$A = (h \cdot ctg\,\alpha + b) \cdot h \quad (m^2) \tag{4}$$

$$h = \sqrt{A / 1{,}7324} \quad (m) \tag{5}$$

Imbrued scope of the canal:

$$O = 2 \cdot h / (\sin \alpha) + b \quad (m) \tag{6}$$

Hydraulic radius:

$$R_h = A / O \quad (m) \tag{7}$$

Minimum velocity:

$$v_{min} = a \cdot h^{0.64} \quad (m / s) \tag{8}$$

a – coefficient that depends on dimensions of a suspension (a=0.5 for medium-sized pellet),

h – water depth in the canal (m).

According to Bazen, the velocity of flow through the canal is:

$$(v / C)^2 = R_h \cdot i \tag{9}$$

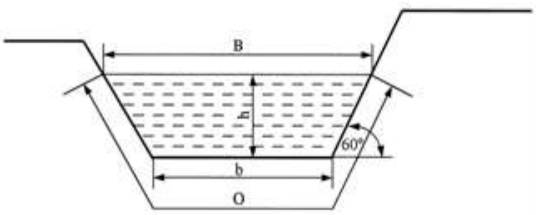

Figure 2. Cross-section of the canal

The required inclination in the canal is:

$$i = v^2 / (R_h \cdot C^2) \quad (\%) \tag{10}$$

$$C = 87 / (1 + \alpha / \sqrt{R_h}) \tag{11}$$

R_h –hydraulic radius (m),
C – Bazen's coefficient,
α - coefficient, which size depends on the type of the canal wall (α=0.75 for the canal made in relatively hard soil and rock).

Parts of software made according to the algorithm are shown in Fig. 3, 4, 5 and 6.

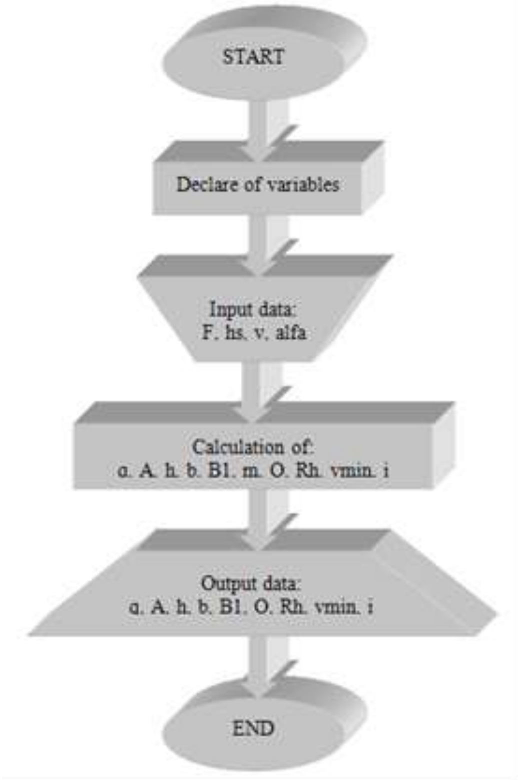

Figure 3. Block sheme for calculations

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```
    use user32
    use kernel32
    use iflogm
    use drainageGlobals
    implicit none
    integer*4 hInstance
    integer*4 hPrevInstance
    integer*4 lpszCmdLine
    integer*4 nCmdShow
    include 'resource.fd'
    external odvodnjavanjeSub
    external odvodnjavanjeApply
    type (T_MSG)            mesg
    integer*4               ret
    logical*4               lret
    ghInstance  = hInstance
    ghModule  = GetModuleHandle(NULL)
    ghwndMain  = NULL
    lret =
DlgInit(IDD_odvodnjavanje_DIALOG,  gdlg)
    if (lret == FALSE)  goto  99999
lret = DlgSetSub(gdlg,
IDD_odvodnjavanje_DIALOG,
odvodnjavanjeSub)
lret = DlgSetSub(gdlg,  IDM_APPLY,
```

Figure 4. Part a) of FORTRAN code

```
  SUROUTINE drainageApply( dlg, id,
  callbacktype )
    use iflogm
    implicit none
  include 'resource.fd'
    type (dialog) dlg
    integer id, callbacktype
  real::q,F,hs,k0,A,v,h,b,B1,m,alfa,O,Rh,v
  min,a2,i,C,alfa1,inov
  character(20)::n1,n2,n3,n4,n5,n6,n7,n8,n
  9,n10,n11,n12,n13
  logical::ulaz,izlaz
    if (callbacktype == dlg_clicked) then
    ulaz=dlgget(dlg,idc_edit1,n1)
    read(n1,*) F
    ulaz=dlgget(dlg,idc_edit2,n2)
    read(n2,*) hs
    ulaz=dlgget(dlg,idc_edit3,n3)
    read(n3,*) v
    ulaz=dlgget(dlg,idc_edit4,n4)
    read(n4,*) alfa
    k0=0.95
    q=(F*hs*k0)/3600.
    Write(n5,*) q
    izlaz=dlgset(dlg,idc_edit5,n5)
    A=q/v
   write(n6,*) A
    izlaz=dlgset(dlg,idc_edit6,n6)
    h=sqrt(A/1.7324)
    write(n7,*) h
    izlaz=dlgset(dlg,idc_edit7,n7)
    b=1.155*h
```

Figure 5. Part b) of FORTRAN code

```
write(n8,*)  b
izlaz=dlgset(dlg,idc_edit8,n8)
=cos(alfa*3.14/180)/sin(alfa*3.14/180)
B1=2.0*m*h+b
write(n9,*)  B1
izlaz=dlgset(dlg,idc_edit9,n9)
O=(2.0*h)/sin(alfa*3.14/180)+b
write(n10,*)  O
izlaz=dlgset(dlg,idc_edit10,n10)
Rh=A/O
write(n11,*)  Rh
izlaz=dlgset(dlg,idc_edit11,n11)
a2=0.5
vmin=a2*h**0.64
write(n12,*)  vmin
izlaz=dlgset(dlg,idc_edit12,n12)
alfa1=0.75
C=87.0/(1.0+alfa1/sqrt(Rh))
i=v**2/(Rh*C**2)
inov=i*100
write(n13,*)  inov
izlaz=dlgset(dlg,idc_edit13,n13)
endif
END  SUBROUTINE  drainageApply
```

Figure 6. Part c) of FORTRAN code

For calculation, it is necessary to design a layout of earth embankments to get knowledge about water table areas for individual segments of the circumference drains.

VI. RESULTS

Design of the earth embankments, from excess material generated through the exploitation of stone at the quarry Ribnica diabase reservoir in Banovici (B&H), is made according to rules for an open pit and the quarry planning and design. To accomplish this task it is necessary to have a great knowledge in the field of open pit mine design. Complete design of layout of the earth embankments at considered location is given in Fig. 7.

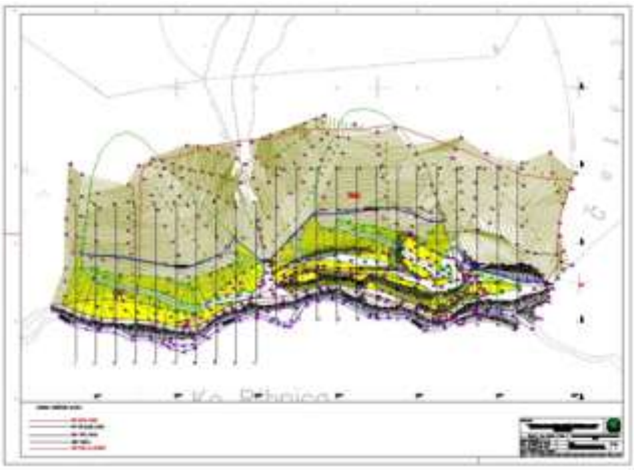

Figure 7. Complete design of layout of the earth embankments "Streliste"

Design of the earth embankment is carried out in three parts. The first part relates to the bottom of the embankment, which is presented in Fig. 8 and Fig. 9, with bench height of 20 m.

The second part refers to the top of the embankment to the E460 bench, and the third part of the upper part of the embankment ended with E480 bench, and a total height of the embankment is of 40 m, which is presented in Fig. 10, Fig. 11 and Fig. 12. All parts of embankment design are made by AutoCAD software and additional presentation of 3D model is made by SURFER software [27,30,31].

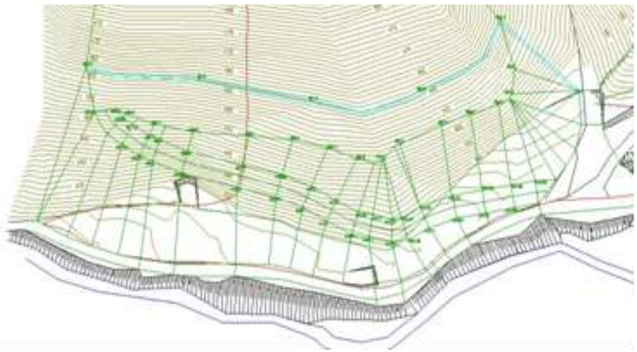

Figure 8. Design of first part of the plateau with boundary drains

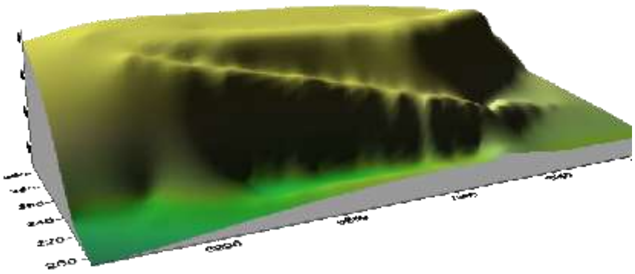

Figure 9. 3D SURFACE map of delayed earth masses on lower part of the plateau

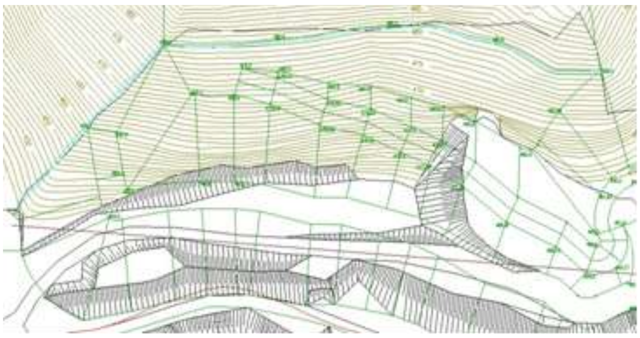

Figure 10. Design of second part of the plateau with boundary drains

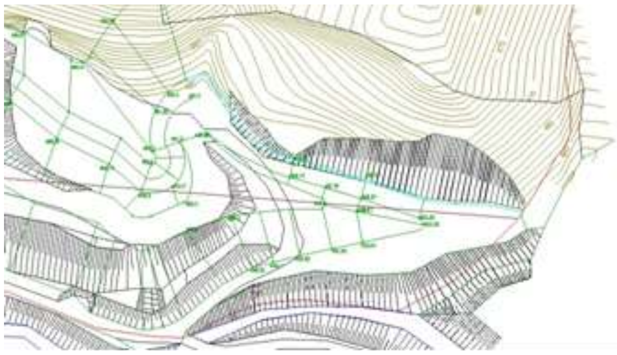

Figure 11. Design of third part of the plateau with boundary drains

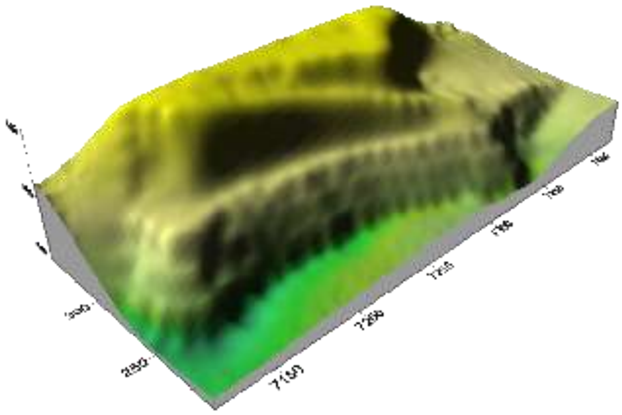

Figure 12. 3D SURFACE map of delayed earth masses on upper part of the plateau

A. *Dimensioning of the Northern Canal OK1*

In the table is showed the flow of water depending on the amount of rainfall on 1 km^2, for the fifty-year return period. Hourly, monthly and annual precipitation is taken from meteorological station for Banovici [30,32].

Water table of the northern water-table contour (marked as boundary canal - OK1 the first part of the plateau formed to level 460) is F=20560.2 m^2, and length is 210 m. The maximum of rainfalls was 29.4 mm/m^2 for first day (data from the previous table), first hour of fifty-return period.

TABLE I. FLOW OF WATER AT LOCATION RIBNICA

Period of precipitation		Return period (year)	Precipitation H (mm/m^2)	The amount of water in water table (m^3/km^2) at runoff coefficient K_s = 0,95	Average flow $(m^3/s)/km^2$
Hourly (3600 s)		50 100	29,4 72,9	27 930 69 217	7,758 19,227
The two-hour (7200 s)		50	37,2	35 340	4,908
Day (86400 s)	Third	50	16,4	15 580	0,1803
	Second	50	34,0	32 300	0,3738
	First	50	77,3	73 435	0,8499
Month (2592000 s)	Averaged		72,0	68 400	0,0264
	Maximal		246	233 700	0,0902
Year	Minimal		-	-	-
	Maximal		1 234	1 172 300	-
	Averaged		-	-	-

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Results of calculation are obtained with the software, which is made in FORTRAN programming language, and it is presented on Fig. 13. Therefore, the minimum (required) inclination of canals is i=0.75%. Circumferential canal (water-table contour) with corresponding elements is showed on the map with drowned plateau level of about 460 m (Fig. 7). In order to achieve greater water resistance of the canal, the edge of the plateau must be covered with excess material from the quarry with high clay content [28,32,33].

B. Dimensioning of the Northern Canal OK2

Water table of the northern boundary of the drainage canal marked as OK2 of the plateau (formed to level approximately 480 m) is $F=15550.0\ m^2$, and length is approximately 166 m. The calculation results are presented in Fig. 14. Therefore, the minimum (required) inclination of the canal is i=0.94%. Water-table contour with the corresponding elements is showed on the map with drowned plateau level of about 480.4 to 480.8 m.

C. Dimensioning of the Northern Canal OK3

Water table of the northern boundary of the drainage canal marked as OK3 of the plateau is $F=22106.0\ m^2$. The length of this canal is 133 m. The drainage head is at ground level 461 m, and ending at elevation 458 m. The canal is positioned along the edge of the road ascending or descending ramp which used for access to the bench 460 plateau and continues to the upper bench 480 m. The calculation results are presented on Fig. 15.

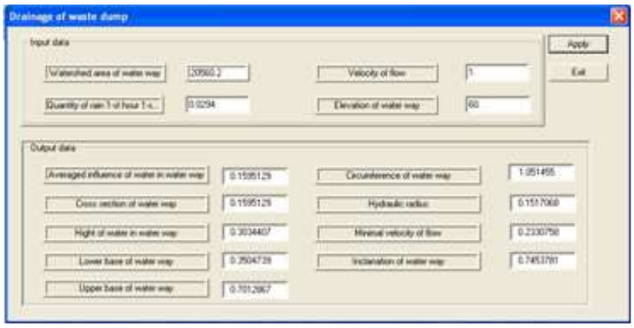

Figure 13. Output of software calculations

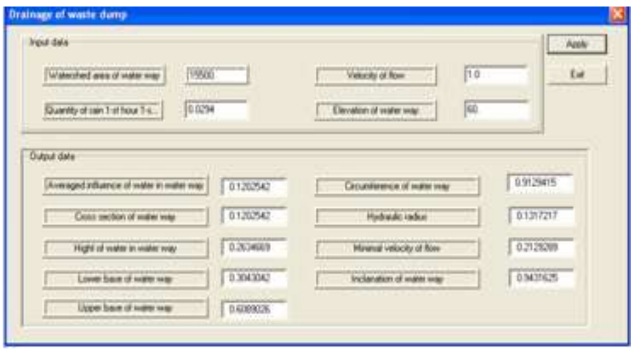

Figure 14. Output of software calculations for the second part

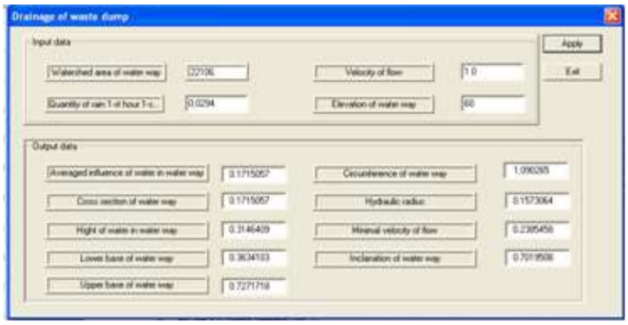

Figure 15. Output of software calculations for the third part

Therefore, the minimum (required) decrease of the canal is i= 0.7%. However, this canal is continuation of the canal that is made along the edge of a road that connects the bench 480 and 460. It is necessary to make canal with calculated dimensions from point at elevation 461. The inclination of the canal is largely controlled longitudinal slope or inclination of the road, which is higher than the minimum required canal gradient. At the point where the peripheral drainage canal cut the road it is necessary to carry out spraying of large pieces of stone, in order to drainage water-table stream from canal, and at the same time allow the movement of people and machines [33].

VII. Discussion

The mining is a technically difficult and risky industry. All process and operations in this industry working with extremely variable and limited inputs data necessary for forecasting and planning of design variations. Therefore, it is particularly difficult to optimize operational processes in this industry. Technical challenges create needs for expensive and complex engineering skills. This work study demonstrate importance of integration of the theoretical knowledge in design of the earthen embankments and the computer design as well as the advantages of developing own software for calculation the design parameters of drainage and sewers. This approach to problems in mining, construction and geology, greatly facilitates and accelerates the process of decision making as well as offering multi-variant solutions of design and dewatering of mining area.

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