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Project report of

Study of runoff conditions in Khoshi catchments,

Logar district, Afghanistan

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Study of runoff conditions in Khoshi catchments, Logar district Afghanistan zadavatel MZV,

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1. Introduction

Research study of rainfall-runoff conditions in Logar/Afghanistan is a pilot project of Czech province reconstruction team. It aims to help with a decision process of solving problems concerning irrigation water availability. The first purpose is to help the Khoshi catchments as a selected pilot area. The second purpose is to prepare a methodology for solving similar projects in other regions of Afghanistan.

The Khoshi valley presents typical landscape type of an agricultural part of Afghanistan. Upper steep mountain region stays unsettled while sharply defined valley with by permanent stream hosts relatively dense population living on agriculture. There is enough rainfall for useful agricultural production, but precipitation time distribution makes it difficult with summer dry period.

Situation might be changed by building a reservoir in suitable part of the valley. The reservoir would work for two purposes – storing a winter period runoffs for irrigation in summer and flood protection from spring storms.

2. Study area

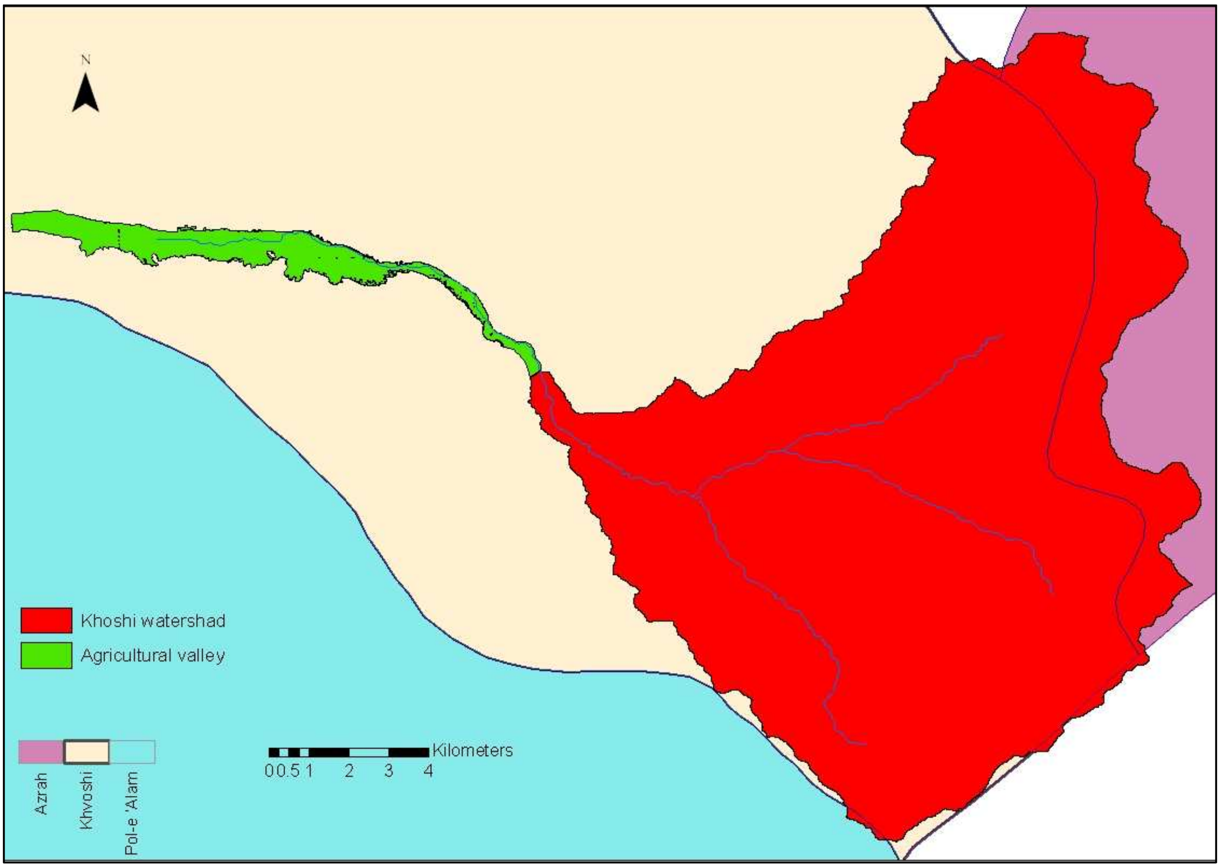

Fig 1: Target area

Khoshi watershed (147.3 km^2) is located in Logar province Logar district ca 60 km south of Kabul. It lies in eastern side of mountains dividing district Azra from different parts of Logar province. Watershed altitudes vary from 2349 m asl in the outlet to 3974 m asl in the top of the divide. Morphologically it is a part of the southern Hindu Kush. The main stream of the watershed is continuous and it is filled by snowmelt, storm rainfalls and subsurface baseflow. The Khoshi watershed was chosen by province reconstruction team (PRT) experts as a target area for its typical conditions and typical problems of a surrounding region. The advantage of the target area is its single outlet valley with important agriculture areas surrounding the stream. Moreover the area was relatively safe and calm during the project setup so it is suitable for the reconstruction activities.

The divide is formed by sharp rocks without any vegetation cover. The inside area consists of steep rocks and debris slopes (prevailing). In the centre of the watershed several deep cut valleys are forming the streams. Closer to the outlet the narrow valley widen and having flat bottom that is suitable for agricultural production. The valley is rarely occupied here and it is wide from several tenths of meters to ca 1 km.

The watershed area is terminated by narrow pass only about 20 meters wide and about 30 meters high. This pass is assumed as a potential dam profile – with an unoccupied part of a valley above.

Under the outlet profile there is the agricultural valley located. This is the region with irrigation water demand. Here the valley is either flat or formed by flat terraces. In the floodplain there is a setup of small fields and orchards surrounded by walls and yards – this area has a strong agricultural potential (with very early annual production dates compared to other regions) so it is intensively used. The fields are irrigated by a simple system of open channels with available water. In combination with highly variable outflow rates during vegetation season the recent irrigation system is ineffective and undersized resulting in harvest loses.

3. Objectives

Objectives of the project can be listed in following points:

- Gather available target area data concerning
  - Morphology (topography)
  - Climate
  - Soil and soil physics
  - Agronomy and agro-technical practices
  - Hydrology
- Set up the hydrologic model of the target area
- Based on the model find the long-term balance and annual precipitation variability
- Based on data find the intensive rainstorm characteristics concerning flood generation
- Estimate total water demand of the produced plants and the annual variability of the deficit
- Assess the potential capacity of the proposed reservoir and its suitability for storage of the spring flows and redistribution of the flow to summer period
- Prepare a clear methodology that would allow repeated and simpler assessment in other regions of the area

The assessment and design will be provided for 4 rainfall scenarios:

- Average year
- Abnormally dry year
- Abnormally wet year
- Extreme rainfall event

Moreover one additional scenario was defined to describe and consider possible alternatives for region development under variable climates:

- Six years dry period (based on measured rainfall data)

Based on the scenarios not only actual agricultural production stabilization will be assessed. Also capacity for productive area enlargement will be considered allowing further development of the region.

The basic single steps of the assessment are:

- Complete rainfall-runoff assessment and water balance
- Flood protection
- Irrigation demand and water sources
- Reservoir dimensions and storage capacity

4. General methodology

4.1 Hydrological balance

The calculation of hydrological balance has been worked out using simple balance equation, mentioned in chapter 6.2. This equation is generally valid in both of annual or shorter time intervals. Monthly time step has been applied for purposes of presented Study and balance itself has been performed as difference between positive values (monthly rainfall sums) and negative values (infiltration, evaporation and surface retention). Positive difference has been then presented as runoff or increment of water storage within the catchment.

Calculation process has been described in detail in chapter 6.2.

4.2 Flood situation

To assess flood events, modelling interface WMS (Watershed Modeling System) has been applied. It is software package, which offers GIS oriented user interface for comfortable application of number of various hydrological and hydraulic methods and models.

Model HEC-1 has been selected for application within the Study, due to available input data at first and good experience with the model in similar conditions at second. Detailed configuration of calculation (selected partial methods and procedures are more detail described in chapter 6.3 or in original of report in Czech Language.

Synthetic rainfall events with duration of 6 hours were considered with temporal distribution either constant over the entire interval, or symmetrically triangular, which were found as more critical from point of view of peak discharge generation.

4.3 Design of water reservoir

The design of water reservoir always is a compromise between available retention space and sources and need of water supply and flood protection.

Using characteristic lines, storage space of the reservoir has been determined, to cover the most unfavourable scenario of water inflow into reservoir and water demand for irrigation.

Retention space has been determined by simplified estimation to be larger than 30 % of design flood wave volume.

Entire balance has been performed in monthly temporal step.

4.4 Design of irrigation necessity

Standard, simplest method, practically used and derived for European conditions, but applicable everywhere, with relevant inputs, has been applied for irrigation necessity assessment.

The target area definitely need irrigation, due to occurrence of so called climatic drought, which is caused mainly by high temperatures in summer months and unfavourable spatial distribution of precipitation over the year.

4.4.1 Basic terms

4.4.1.1 Water demand of plants V_c

Is amount of water over unit area, which plant needs during entire vegetation period or its part in given climatic conditions to cover its physiologic processes and evaporation?

4.4.1.2 Irrigation amount M_z

Is amount of water, which has to be delivered to the plant in vegetation period over unit area to balance natural moisture and all losses, occurred during irrigation at the locality?

Irrigation amount can be determined by two methods and approaches:

- Using effective irrigation volume
- Using method of ideal precipitation

Calculation, using effective irrigation volume $\boldsymbol{M_u}$ is given by equation:

$M_z = k_1 * M_u$

resp:

$M_z = k_1 * (V_c - \alpha S_v - W_z - W_k)$ (m^3/ha)

Then

$M_u = V_c - \alpha S_v - W_z - W_k$

where:

k_1 – coefficient of losses of water related to technology of irrigation, excluded of transportation of water from source to field

V_c – moisture demand of the plant during vegetation period (m^3/ha)

α – coefficient of effectiveness of rainfall during vegetation period

S_v – precipitation over vegetation period in mean design year (m^3/ha)

W_z – water storage in the soil profile in the beginning of vegetation period (m^3/ha)

W_k – applicable effective amount of water available by capillarity (m^3/ha)

Coefficient of losses k_1 for available types of irrigation technology in target area is listed in following table Tab 1

Tab 1: Loss coefficient for different types of continuous irrigation

Irrigation type	k_1
Spray irrigation	1.15 – 1.25
Furrow irrigation	1.25 – 1.45
Surface watering	1.45 – 1.65
Flood irrigation	1.65 – 2.50

Calculation using approach of Ideal precipitation adopts even simpler assumptions. Ideal precipitations are such ones, which are expressed by monthly sums, when there was good harvest at given locality reached.

Irrigation volume then can be expressed as:

$$M_z = k_1 * (S_i – S) \qquad (m^3/ha)$$

Where

S_i – ideal precipitation over entire vegetation period (m^3/ha) (practically, it can be assumed as moisture demand of the plant V_c.

S – actual precipitation over vegetation period (m^3/ha).

4.4.2 Application of mathematical model CROPWAT

Number of more complex and sophisticated simulation methods and models can be used as alternative to above described simple approaches. One of the most effective and spread ones especially for conditions with high uncertainty can be mentioned model CROPWAT, which has been developed and optimized mainly for arid climatic conditions.

(http://www.fao.org/nr/water/infores_databases_cropwat.html).

Recently, version CROPWAT 8.0 is available for practical use. All calculation procedures used within the model are standardized with agreement with FAO publications dealing with irrigation and drainage: No. 56 "**Crop Evapotranspiration - Guidelines for computing crop water requirements**” and No. 33 "**Yield response to water**

4.5 Formulation of scenarios

Following critical scenarios will be formulated and assessed:

- Average year – year with average annual rainfall total sum, distributed into individual months
- Critically dry year – year with lowest observed (occurred within 46 years of modelled time series) rainfall total sum, distributed into individual months

- Critically wet year - year with highest observed (occurred within 46 years of modelled time series) rainfall total sum, distributed into individual months
- Critical storm event – target area is hit by storm event with duration 6 hours, which will cause flood wave. Scenario for retention space design.

The scenarios will be in detail described, derived and discussed in following chapters.

5. Input data

There has been number of individual data sources available for the Study calculation. Most of them have been provided by submitter, who can dispose with various data sources, however several data sources provided also contractor – mostly from public opened sources.

5.1 Source data available

5.1.1 Data delivered by submitter

5.1.1.1 Data delivered by civil part of PRT

- 17 disturbed soil samples, included their location and photographs from its origin
- Set of inclined land photos (III.2008 – V.2009)
- Set of photos from helicopter missions and survey (II.2009 – VIII.2009)
- Historical hydrological data for various profiles for potential comparison
- GPS records from land survey, collected by civil part of PRT (V.2008 – II.2009)

5.1.1.2 Data delivered by submitter, in cooperation with Czech Army

Tab 2: List of data, delivered by submitter in cooperation with Czech Army

No	title	type	purpose	source
1	dem_5m	Raster with hypsography	DTM and slope map generation	CEDAR 5m
2	Satellite images tiff	GeoTIFF - color	Land-use	*Not known*
3	Satellite images Cbi	GeoTIFF - bw	Land-use	*Not known*
4	AAL020_Zastavba	Polygon	Land-use	PRT Logar - MGCP
5	ABH140_Reka	Polygon	Land-use, river network	PRT Logar - MGCP
6	ADA010_Povrch	Polygon	Land-use	PRT Logar - MGCP
7	AEA010_ZemPuda	Polygon	Land-use, agricultural land	PRT Logar - MGCP
8	AEB010_Trava	Polygon	Land-use	PRT Logar - MGCP
9	AEB020_Kere	Polygon	Land-use	PRT Logar - MGCP
10	AEC030_Les	Polygon	Land-use	PRT Logar - MGCP
11	LAP010_Cesta	Polyline	Land-use	PRT Logar - MGCP

12	LAP030_Silnice	Polyline	Land-use	PRT Logar - MGCP
13	LBH010_Akvadukt	Polyline	Land-use, river network	PRT Logar - MGCP
14	LBH030_ZavlKanal	Polyline	Land-use, river network	PRT Logar - MGCP
15	LBH140_Reka	Polyline	Land-use, river network	PRT Logar - MGCP
16	PAL015_Budova	Point	Land-use	PRT Logar - MGCP
17	PAL020_Zastavba	Point	Land-use	PRT Logar - MGCP
18	PBH010_QanatSachta	Point	Land-use, river network	PRT Logar - MGCP
19	AFG_Max_Snow_Cover	Shapefile_point	Determination of precipitation and snow cover	ISSAF (AIMS)
20	afg_nis_f12_groundwater	Shapefile_polygon	Determination of infiltration	ISSAF (AIMS)
21	AFG_Climate	Shapefile_polygon	Determination of precipitation and snow cover	ISSAF (AIMS)
22	AFG_Geology	Shapefile_polygon	Determination of infiltration	ISSAF (AIMS)
23	AFG_Irrigation	Shapefile_polygon	Land-use in large scale	geodatabase AIMS
24	afg_nis_f14_soils	Shapefile_polygon	Determination of infiltration	ISSAF (AIMS)
25	afg_nis_f17_groundstate_cold	Shapefile_polygon	Determination of precipitation and snow cover	ISSAF (AIMS)
26	afg_nis_f18_groundstate_warm	Shapefile_polygon	Determination of precipitation and snow cover	ISSAF (AIMS)
27	Meteorological records FOB Shank	database	Determination of precipitation and snow cover	Field recorded data SOUMOP
28	Meteorological records Kabul Air Port	database	Determination of precipitation and snow cover	Data recorded by Czech Army at Kabul Air Port
29	Meteorological records Gardez	database	Determination of precipitation and snow cover	ISSAF (AIMS)
30	Maps of precipitation for Logar province from ALADIN model,	database	Determination of precipitation and snow cover	ISSAF (AIMS)

31	AIMS Cultivated Areas	Shapefile_polygon	Land-use	geodatabase AIMS
32	AIMS Irrigated Areas	Shapefile_polygon	Land-use	geodatabase AIMS
33	Other relevant data about precipitation and snow cover	---	Determination of precipitation and snow cover	
35	Images Rampant Lion II – resolution 0,6 m, delivered 1/2010.	Raster, color	Land-use	Czech Army

5.1.2 Data, collected by contractor

Some additional data were later collected also by contractor. There were:

- Rainfall sums in time interval of 6 hours for nodes of grid ERA40 - ECMWF No.: A = 35N 67.5E, B = 35N 70E; C = 32.5N 67.5E; D = 32.5N 70E
- Further mainly hydrological information were processed from report, prepared for Ministry of Foreign Affairs of Germany (Tünnermaier, 2005), which is available at address: http://www.bgr.bund.de/cln_101/nn_327782/EN/Themen/Wasser/Projekte/TZ/TZ__Afghanistan/hydrogeology__kabul__basin__1__pdf,templateId=raw,property=publicationFile.pdf/hydrogeology_kabul_basin_1_pdf.pdf

5.2 Data preparation and processing

5.2.1 Precipitations

5.2.1.1 Source data

Following data were used for determination of design rainfall – there were at first **data historical** - **recorded**, measured in several localities within neighbour areas:

- Mean monthly and maximum 24 hours sums for rainfall gauging station (WMO No. 40950) (Herman et al., 1971), recorded during 1958 – 1970, which was located at capital of the province Baraki Barak
- Historically recorded monthly sums from same station – verified data from 1976-7, 1979, 1982-3
- Precipitation, measured by Czech Army at FOB Shank (2008 – 2009), in daily sums
- Reference data from airport Kabul also in daily intervals, without any supplementary information

And data **synthetic – modelled**. Their disadvantage was coarse spatial distribution and distance from target area, but important advantage has been found as acceptable temporal resolution (6 hours) and time series length (46 years).

This data source has been data, provided from database of European Centre for Medium-Range Weather Forecasts (ECMWF) (http://www.ecmwf.int/) (Uppala et al, 2005), which were generated for entire plant by reanalyze of weather conditions. There were data series with duration of 46 years available with broad band of various climatic characteristic for spatial grid with resolution of 2.5 by 2.5 degree. Rainfall sums with temporal resolution of 6 hours were downloaded and used as source for hydrological balance.

Four grid nodes were selected, located nearest to target area of Khoshi catchment – see Fig 2.

Fig 2: Target area of Khoshi catchment and localization of 4 nearest grid nodes of ECMWF (map GoogleEarth)

The area of Khoshi catchment is located approximately in the centre of the square, defined by four grid nodes. That means in the first step to compare temporal distribution of standardized monthly rainfall sums in individual grid nodes (A, B, C, D) with ones, measured directly around Khoshi (see paragraph above). Distribution of these characteristics is documented on Fig 3 and Fig 4.

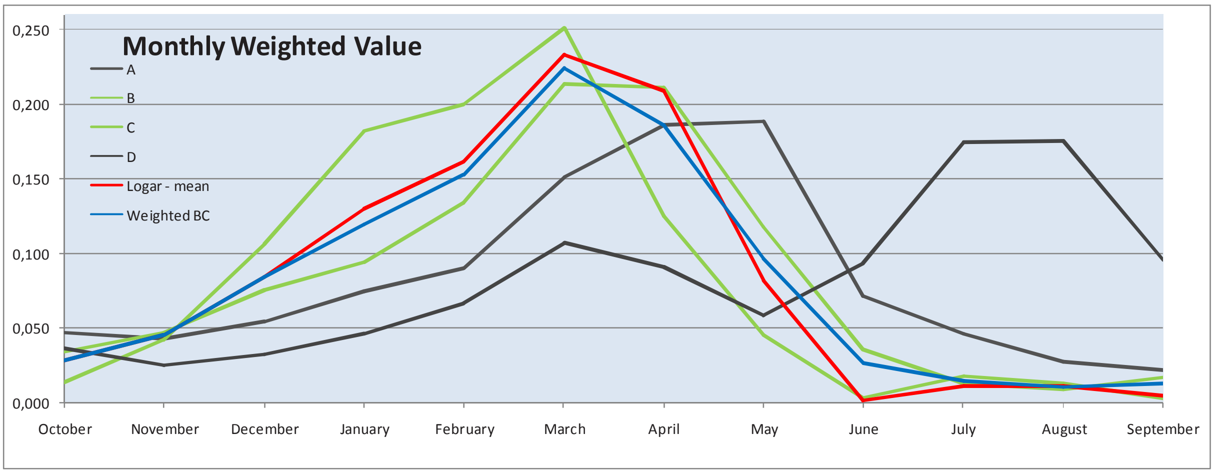

Fig 3: Monthly standardized precipitation at grid nodes of ERA 40 and recorded at Logar

Temporal distribution of standardized values presented good agreement in case of precipitation in grid nodes B and C. Next step there was comparison of real (absolute) values of monthly sums within individual nodes and alternatives and scenarios of their combinations. This analysis is documented on Fig 3

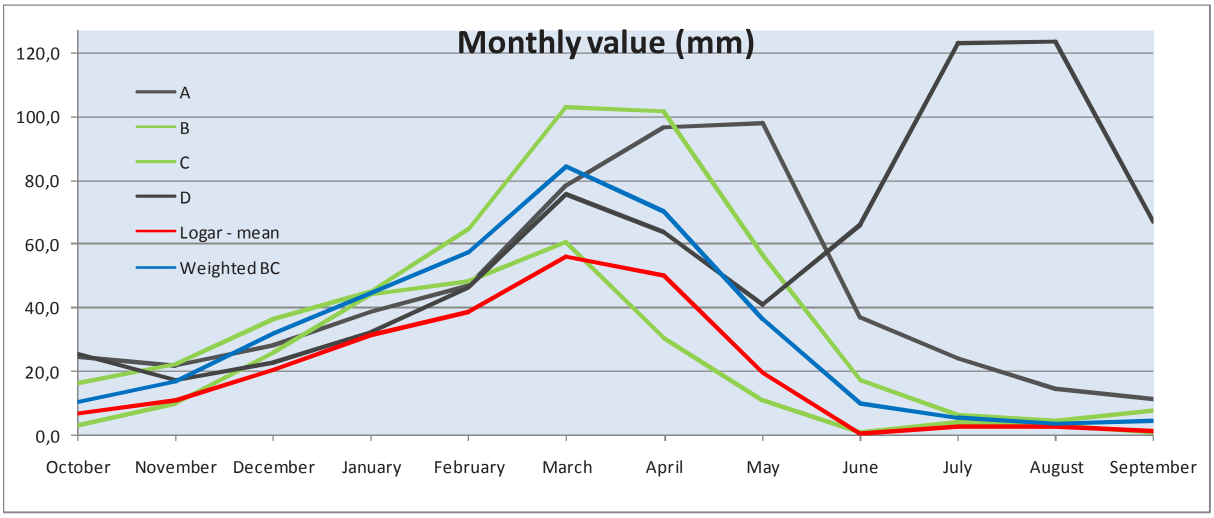

Fig 4: Monthly absolute precipitation at grid nodes of ERA 40 and Logar

Fig 4 Shows comparison of temporal distribution of monthly rainfall sums during hydrological year in absolute values.

On the following chart (Fig 5) there are in blue colour marked temporal distribution of precipitation at individual grid nodes A, B, C, D. Red columns determines standardized mean values and red line shows mean value, which is design rainfall amount.

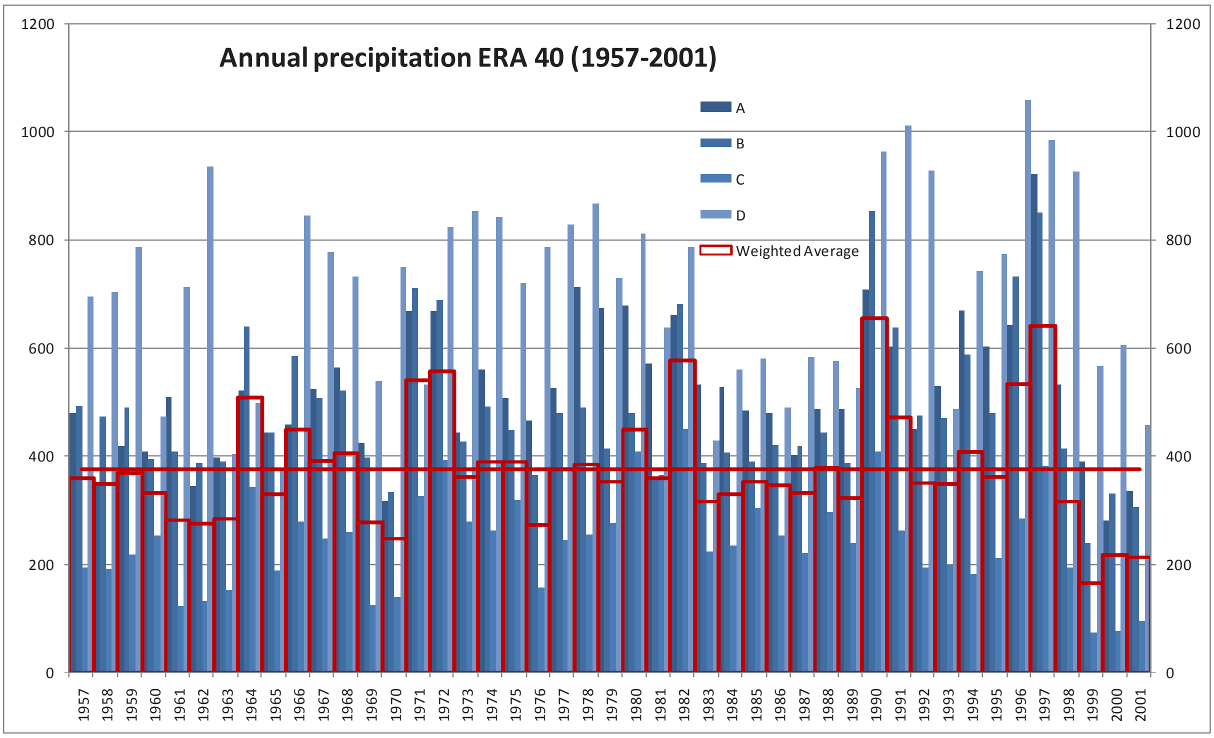

Fig 5: Annual sums of precipitation at grid nodes of ERA 40 (mm)

There can be concluded from results of described analyses that grid nodes B and C are by their character and absolute values with the best agreement to recorded values.

Therefore, only nodes B and C were used to determine design precipitation characteristics. Balance design values were then determined as their weighted average. Weighting criteria included distance of nodes from gravity centre of target area and elevation.

Tab 3: Calculation of weights used for mean monthly precipitation totals calculation in Khoshi basin from points B and C

	Elevation (m a.s.l.)	Distance to Khoshi (km)	Weight according elevation	Weight according distance	Resulting weight
B	2059	134	0.478	0.633	0.555
C	2250	231	0.522	0.367	0.445
Total			1	1	1

5.2.1.2 Determination of design values

Design values were determined individually for all three climatic/hydrological alternatives (scenarios) and for storm event:

- Average (standard) year
- Abnormally dry year
- Abnormally wet year
- Extreme rainfall event

5.2.1.2.1 Average (standard) year

Average (standard) year consider mean temporal distribution and total sum of precipitation over the year. Design values are listed at Tab 4

The difference between absolute values (totals) of design rainfall and recorded precipitations (see Tab 4 and chart Tab 6) is given by different morphology. While Khoshi catchment is located at foothill of high mountain ridge, recorded data came from relatively low located station.

5.2.1.2.2 Abnormally wet year

Abnormally wet year has been defined as selected year with highest recorded (modelled) annual total (sum). This sum has been then addressed to individual months with agreement with relative distribution, adopted for average standard year. Occurrence of such year can be expected roughly approximately once in 50 years.

Specific design values are listed at Tab 4 and following Fig 6.

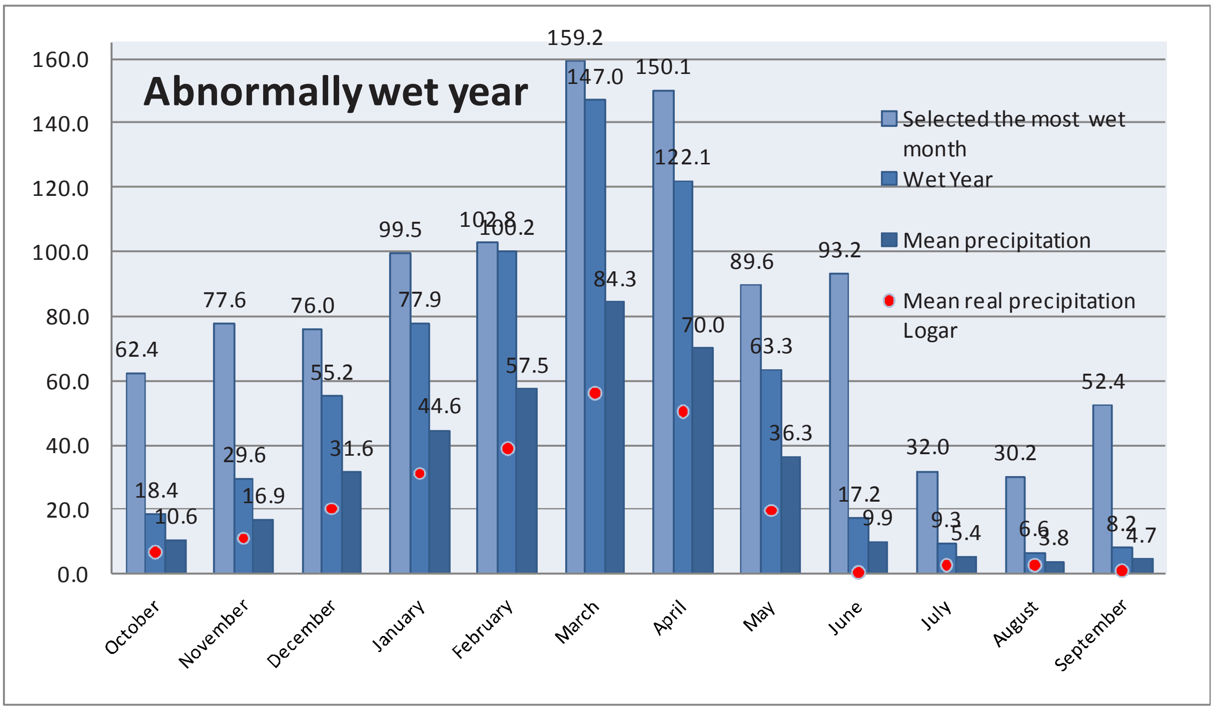

Fig 6: Comparison of absolute monthly precipitation totals for extremely wet year with the selection of the most wet months, monthly precipitation averages and measured precipitations in Logar

5.2.1.2.3 Abnormally dry year

Abnormally dry year has been defined as selected year with lowest recorded (modelled) annual total (sum). This sum has been then addressed to individual months with agreement with relative distribution, adopted for average standard year. Occurrence of such year can be expected roughly approximately once in 50 years.

Specific design values are listed at Tab 4 and following Fig 7.

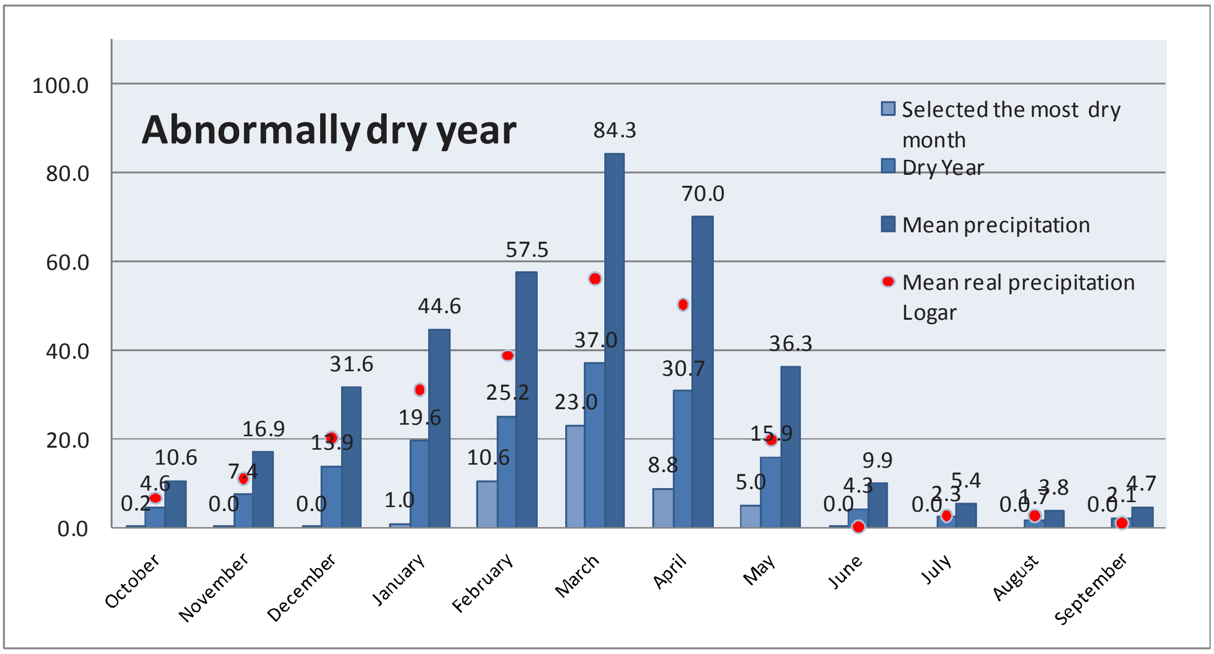

Fig 7: Comparison of absolute monthly precipitation totals for extremely dry year with the selection of the most dry months, monthly precipitation averages and measured precipitations in Logar

Regarding to water reservoir, there can be relevant to talk about multi-annual management, when balance can consider several dry years in series. This fact has been adopted as next scenario and will be modelled as in total six years series. First year in the series has been defined as abnormally dry one (see above) and sixth will be average (standard) year. Rest four years will be distributed between mentioned limits linearly (Tab 5).

Tab 4: Monthly precipitation total values used for different calculated scenarios (mm)

Month	October	November	December	January	February	March	April	May	June	July	August	September	Total
Average year	10.6	16.9	31.6	44.6	57.5	84.3	70.0	36.3	9.9	5.4	3.8	4.7	**375.6**
Average of measured precipitation in Logar	6.7	11.0	20.3	31.2	38.8	56.1	50.3	19.7	0.3	2.7	2.6	1.1	**240.7**
Dry year	4.6	7.4	13.9	19.6	25.2	37.0	30.7	15.9	4.3	2.3	1.7	2.1	**164.7**
Wet year	18.4	29.6	55.2	77.9	100.2	147.0	122.1	63.3	17.2	9.3	6.6	8.2	**655.0**
Selection of dry months	0.2	0.0	0.0	1.0	10.6	23.0	8.8	5.0	0.0	0.0	0.0	0.0	**48.7**
Selection of wet months	62.4	77.6	76.0	99.5	102.8	159.2	150.1	89.6	93.2	32.0	30.2	52.4	**1024.9**

Described scenario is related to reality, as 6 years dry period is longest one, observed in 46 years long time series, which is available for design values determination. Annual sums during this period reached about 400 mm.

Specific design values are listed in Tab 4.

Tab 5: Design scenario of long term drought – monthly precipitation totals (mm)

	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	Total
1	4.64	7.43	13.87	19.58	25.20	36.97	30.69	15.92	4.34	2.35	1.67	2.06	164.72
2	5.82	9.34	17.43	24.59	31.65	46.44	38.55	20.00	5.45	2.95	2.10	2.58	206.90
3	7.01	11.24	20.98	29.60	38.10	55.90	46.41	24.07	6.56	3.55	2.53	3.11	249.07
4	8.20	13.14	24.53	34.62	44.56	65.37	54.27	28.15	7.67	4.15	2.96	3.64	291.25
5	9.39	15.05	28.08	39.63	51.01	74.84	62.13	32.22	8.78	4.76	3.38	4.16	333.42
6	10.57	16.95	31.63	44.64	57.46	84.30	69.99	36.30	9.89	5.36	3.81	4.69	375.6

5.2.1.2.4 Storm event

Storm event, which is crucial for determination of flash flood characteristics has also been derived from modelled time series ERA40. Original precipitations in time interval 6 hours from grid nodes B and C were adopted for determination.

Rainfall duration 6 hours has been accepted as compromise with two reasons:

- Concentration time for Khoshi catchment up to profile of designed dam, determined by simulation software WMS has been calculated as ca 3 hours. Causal rainfall event with duration is longer than concentration time, but the difference is not principal
- 6 hours is basic time interval of meteorological data, supplied by ECMWF. Their further manipulation and interpolation to shorter time interval would introduce further errors and uncertainties into calculations.

There are several important information and characteristics for determination of design of storm event:

- Maximal reached sum within 6 hours time interval: 40.7 mm
- Highest values of weighted average between grid nods B and C in one day is: 29.2 mm/6 hours
- Extreme values occur usually in summer months, and they are summer short and intensive local storms
- The sum of 6 hours rainfall in wet months (November to April) does not exceed 25 mm, and most of them occur during months, when snow is melting (March to April)
- Value higher than 15 mm/6 hours occurs in average in 82 % of years and is therefore close to return period of one year.

Based on information mentioned above, design storm events were determined with duration 6 hours and total sums: 40, 35, 30, 25 20 mm/6 hours. Value 40 mm/6 hours is understood as maximum. There are number of events, exceeding set limits listed at Tab 6.

Tab 6: Numbers of excedances of 6-hour storm events (ERA 40) for rainstorm totals used for flood analysis

mm/6hr	B	C	Weighted average B a C
20	8	18	7
25	2	6	1
30	1	3	0
35	1	1	0
40	0	1	0

There are 10 highest 6-hours rainfall events listed at Tab 7, for better illustration. Events are separated to wet (winter) and dry (summer) months. Values are ordered from highest to lower.

Tab 7: Ten 6-hour extreme rainfall events distinguished according to season (dry vs. wet

	B – wet months	C –wet months	B – dry months	C – dry months		Weighted average B and C	
						mm/6hr	month
1	24.7	22.2	40.7	35.6		29.15	VIII
2	22.8	21.2	34.0	25.5		24.94	VII
3	22.0	18.7	31.2	23.6		22.21	VI
4	19.8	18.4	28.4	23.6		21.73	IX
5	19.0	18.4	27.6	22.1		20.73	VII
6	18.2	18.1	26.0	22.0		20.47	VI
7	17.7	17.9	23.6	18.5		20.36	VIII
8	17.3	17.3	22.4	17.6		19.45	VIII
9	16.8	17.1	22.1	16.5		18.54	IV
10	16.5	17.0	21.6	15.6		18.08	III

5.2.2 Digital terrain model

Data layer, provided by Central European Environmental Data Request Facility (CEDAR) has been used as a source for DTM generation. CEDAR is geographical data, acquired by stereoscopic satellite survey in angle coordination, which after conversion to Cartesian system UTM (zone 42N) corresponds to resolution ca 3.5 x 4.2 m.

Desired resolution for DTM has been selected 5 m (what is approximately original angle resolution of source data) for hydrological modelling. For all other analyses model has then been resampled to 10 x 10 m, which is fully sufficient.

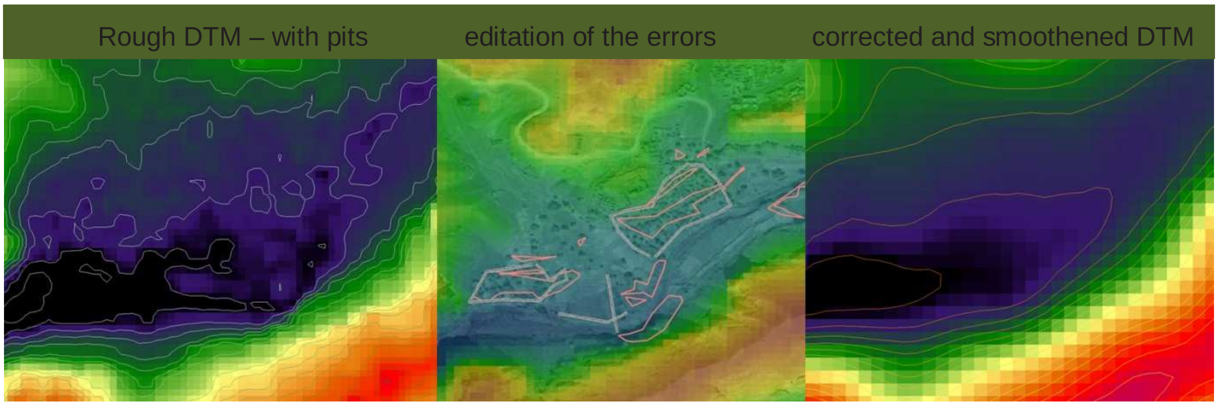

Fig 8: Preparation and editing of digital elevation model – removal of wrongly evaluated places

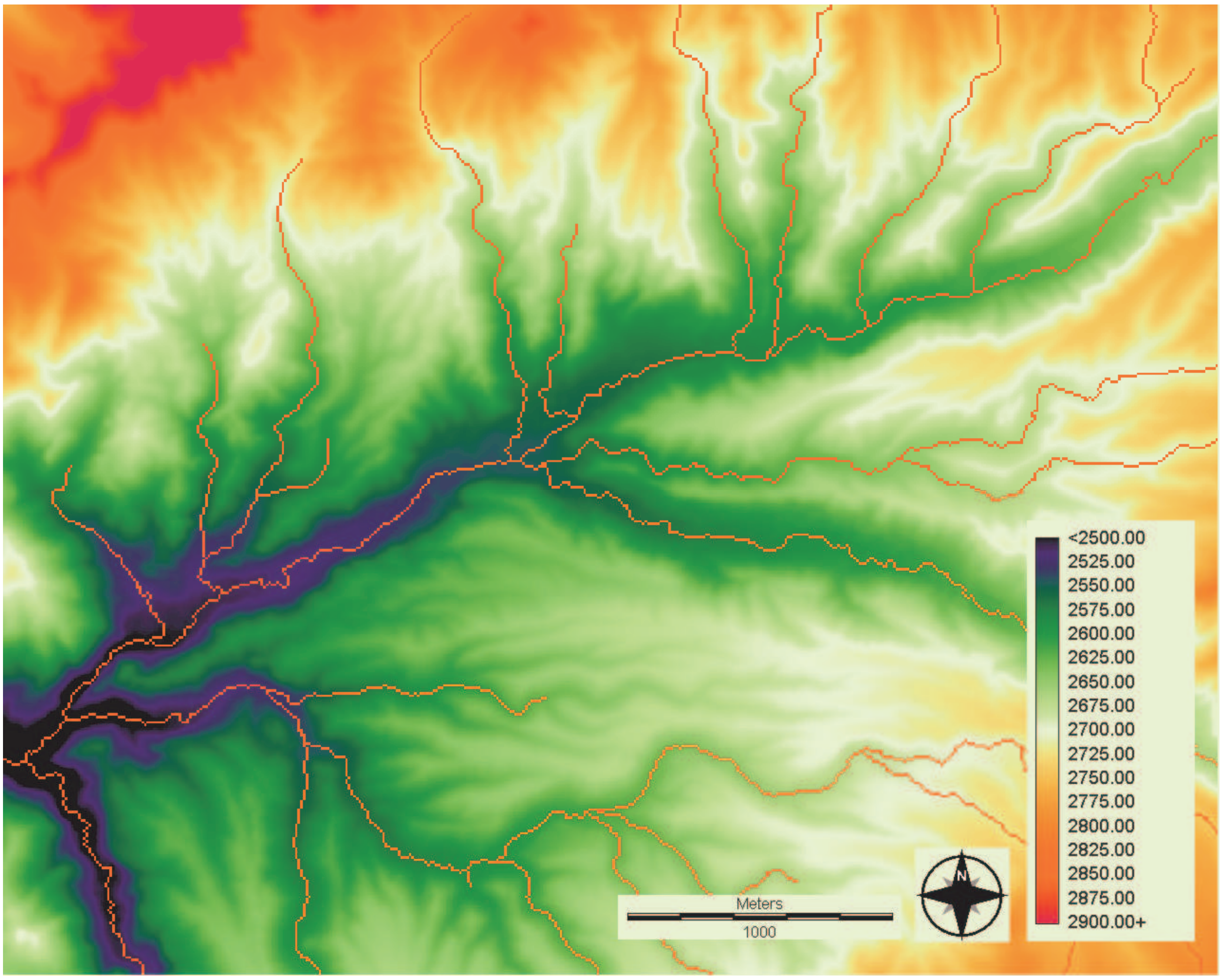

Fig 9: Part of final DEM and thalweg network

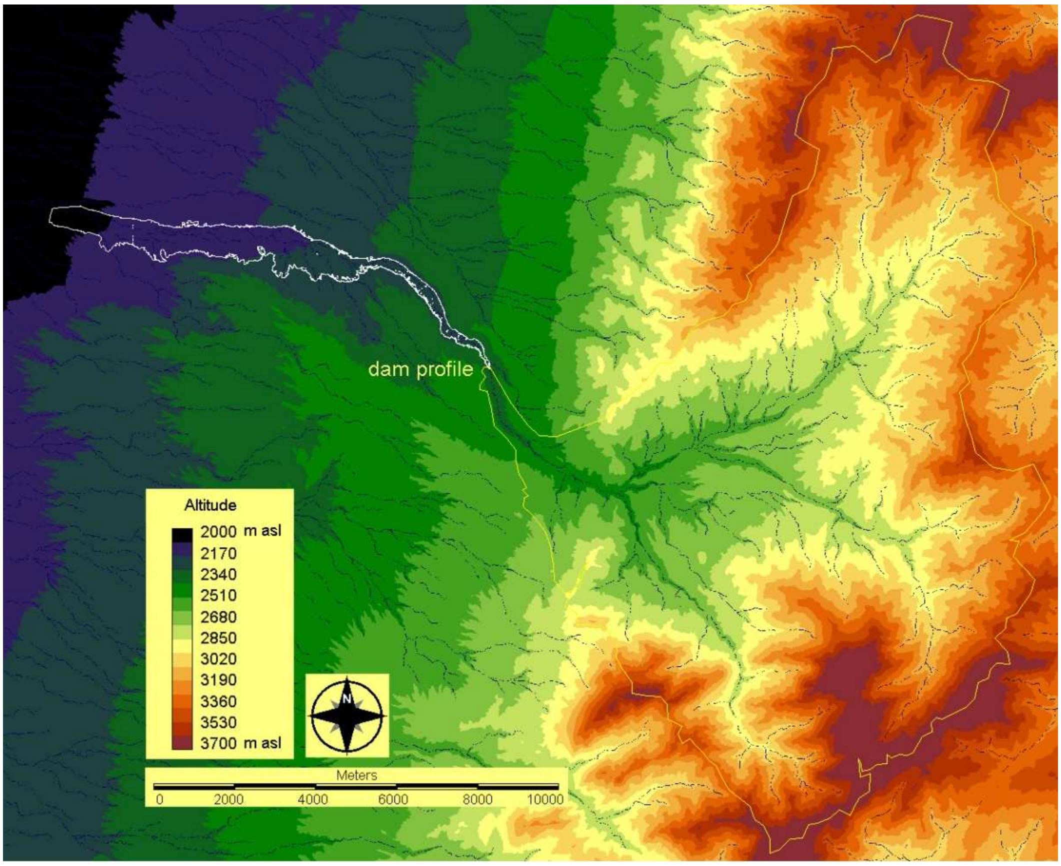

Fig 10: Elevation conditions of Khoshi basin area including irrigated area

5.2.3 Soil data

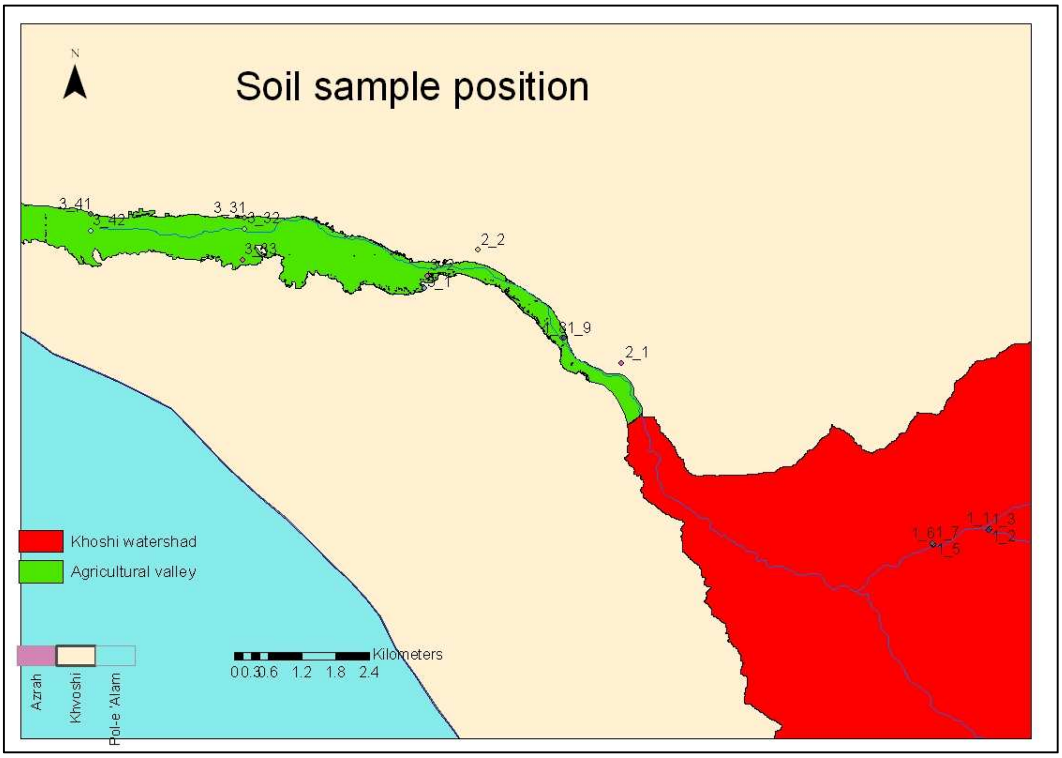

Fig 11: Area of the interest with depicted points of soil sampling

Soil conditions at target area have been determined at first from GIS layers delivered by PRT and at second from soil samples, which were collected by PRT directly at Khoshi catchment according to request of contractor.

The GIS data, available for entire Afghanistan related to soil conditions are very general and entire Khoshi catchment falls into one spatial unit.

Therefore PRT at Logar with support of the Czech Army taken together 17 disturbed soil samples, which were delivered to the Czech Republic and contractor then provided their laboratory analyses.

5.2.3.1 Laboratory analyses of disturbed soil samples

Following tables present basic soil characteristics, obtained from disturbed soil samples analyses.

Tab 8: Selected soil properties of samples from Khoshi basin area

Sample number	k_s	Clay	Silt	Sand	Skeleton	pH_{KCl}	CO_3^{2-}	C_{ox}	Humus	Class	Soil type
	$(m.s^{-1})$	(%)	(%)	(%)	(%)	Replaceable	(%)	(%)	(%)	1-5	Classification after Novak
1-1	$7.1 \cdot 10^{-7}$	13	42	45	15 B	7.72	15.2	1.36	2.35	3	Loam
1-2	$1.1 \cdot 10^{-7}$	18	60	22	34 C	7.70	14.3	0.51	0.88	3	Loam
1-3	$6.8 \cdot 10^{-7}$	17	52	31	30 C	7.81	15.3	1.38	2.39	3	Loam
1-5	$5.1 \cdot 10^{-7}$	8	31	61	32 C	7.83	14.3	1.41	2.43	1	Loamy sand
1-6	$6.8 \cdot 10^{-6}$	7	28	65	59 D	7.73	14.4	0.67	1.16	1	Loamy sand
1-7	$5.9 \cdot 10^{-6}$	4	15	81	52 D	7.71	13.3	0.52	0.89	1	Loamy sand
1-8	$1.6 \cdot 10^{-6}$	7	24	69	5 A	8.05	14.5	0.41	0.71	1	Loamy sand
1-9	$9.3 \cdot 10^{-6}$	3	19	78	63 D	7.77	12.5	0.70	1.20	1	Sand
2-1	$2.2 \cdot 10^{-7}$	20	36	44	47 C	7.80	24.9	0.56	0.96	3	Loam
2-2	$2.4 \cdot 10^{-7}$	7	29	64	31 C	7.96	18.5	0.52	0.89	1	Loamy sand
3-1	$2.3 \cdot 10^{-7}$	17	69	14	4 0	7.78	9.8	0.42	0.72	4	Clay loam
3-2	$3.2 \cdot 10^{-7}$	16	59	25	1 0	7.82	15.2	0.53	0.92	3	Loam
3-31	$6.2 \cdot 10^{-6}$	9	51	40	21 B	7.79	16.5	0.99	1.70	2	Sandy loam
3-32	$4.3 \cdot 10^{-7}$	9	39	52	5 A	7.98	14.8	0.68	1.17	2	Sandy loam

3-33	$8.8 \cdot 10^{-8}$	8	33	59	4 0	7.94	14.1	0.65	1.11	2	Sandy loam
3-41	$4.9 \cdot 10^{-8}$	15	67	18	0 0	7.80	16.4	0.41	0.71	3	Loam
3-42	$3.3 \cdot 10^{-7}$	6	28	66	5 A	7.91	12.6	0.60	1.04	1	Loamy sand

clay d<0,002 mm   silt d=0,002-0,05 mm   sand d=0,05-2,0 mm   gravel d>2 mm

Tab 9: Hydrophysical characteristics of soils in Khoshi basin area

Sample nr.	θ_{mom}	MKK_{2h}	HP	SP	KP	P	ρ_d	K_s
	% vol.	% vol.	%	%	%	%	$kg.m^{-3}$	$m.s^{-1}$
1-1	7.7	40.5	4.8	14.9	32.9	52.6	1254.0	$7.1 \cdot 10^{-7}$
1-2	11.1	32.2	8.0	7.0	27.8	42.8	1514.6	$1.1 \cdot 10^{-7}$
1-3	6.9	41.2	5.4	13.6	35.4	54.4	1208.4	$6.8 \cdot 10^{-7}$
1-5	10.3	41.8	4.7	9.2	35.8	49.7	1332.7	$7.9 \cdot 10^{-7}$
1-6	11.7	29.6	8.0	11.9	22.8	42.7	1519.5	$6.8 \cdot 10^{-6}$
1-7	9.2	22.2	8.4	15.2	16.6	40.2	1584.7	$5.9 \cdot 10^{-6}$
1-8	7.9	37.2	4.7	13.4	25.0	43.1	1508.5	$1.6 \cdot 10^{-6}$
1-9	7.8	18.1	8.6	13.6	14.2	33.4	1763.8	$9.3 \cdot 10^{-6}$
2-1	14.7	33.5	4.9	7.7	29.2	41.8	1542.7	$2.2 \cdot 10^{-7}$
2-2	12.7	32.8	3.7	8.4	26.1	38.2	1636.4	$2.4 \cdot 10^{-7}$
3-1	13.7	47.7	4.7	8.7	41.7	55.1	1192.1	$2.3 \cdot 10^{-7}$
3-2	7.7	45.3	3.8	8.0	40.4	52.2	1266.7	$3.2 \cdot 10^{-7}$
3-31	6.1	41.1	3.3	14.3	37.1	54.7	1199.2	$6.2 \cdot 10^{-6}$
3-32	8.8	37.4	4.4	10.2	31.8	46.4	1419.6	$4.3 \cdot 10^{-7}$
3-33	8.6	35.4	4.9	10.4	30.5	45.8	1435.1	$8.8 \cdot 10^{-8}$
3-41	7.7	44.5	5.4	8.4	38.5	52.3	1264.2	$4.9 \cdot 10^{-8}$
3-42	7.3	35.4	6.5	13.1	27.3	46.9	1406.6	$3.3 \cdot 10^{-7}$

Grain size distribution lines are attached in Appendices part of the report. All information about procedures used and results of analyses are included in full Czech version of report and are stored at contractor (CTU Prague).

5.2.4 Land-use

The land-use information is the very key source for hydrological balance and rainfall-runoff modelling. Basic classification, which is essential for hydrological balance and runoff conditions, includes surfaces permeable and impermeable, agriculturally used and not used land and land, which potentially can be used for agriculture.

Classification of land-use has been done separately for "catchment" (upper part above profile of designed dam) and for "lower part" (agriculturally used part under designed profile of dam).

Mechanism land-use creation is described in detail in chapter 5.2.4.3.

5.2.4.1 Catchment – part above profile of dam

Target area, called "catchment" includes hydrological catchment up to profile of designed dam. The area is nearly not inhabited; the exception is only several small farms surrounded by fields, which are located far and high enough above dam profile.

Total area of catchment to dam profile is 147.3 km^2 and detailed classification into characteristic types of surface is documented at Tab 10.

Tab 10: Areas of single land cover types in Khoshi basin area (upstream from the dam profile)

Category	Area (ha)	Comments
Trees	76	Tree vegetation consists mainly of isolated Gross of trees or single trees and brushes, larger areas of orchards are situated along a stream on agricultural land
Built-up area	12	Only in valleys, not important class comparing to the total basin area.
Floodplain	298	Area affected by flooding in flat parts of valleys, only hardly distinguishable from debris areas
Agricultural land	166	Manually digitalized polygons, crops are not distinguished
Path, road	5	Neglectable category (very small total area)
Rock	2 299	Rocks and rock outcrops visually distinguishable mainly by shadows, higher contrast variability; somewhere can be confused rock by debris
Snow field	1 134	Snow fields – reflects snow cover at the time of image origin, not permanent snow cover
Debris	10 740	Most of basin area usually without vegetation cover
Total	14 729	**Total area of Khoshi basin**

5.2.4.2 Agricultural area – land under dam profile

Target area under dam profile is limited basically by agriculturally used land along flat floodplain and stream channel and its terraces. From above, it is limited by dam profile and as outlet point (lower border) the profile, where agricultural land ends, due to change of nearly permanent stream to dry channel, where water appears only during flood events is assumed.

Total area of this part has been measured as 656.88 ha and distribution to individual land-use classes is presented at Tab 11.

Tab 11: Areas of single land cover types in target area underneath the dam profile

Category	Area (ha	Comments
Trees	13	Tree vegetation consists of all isolated dark green areas which do not below to large areas, this category includes also unclassified shadows (approx. 6 ha) – it was manually verified that these shadows really avers mainly tree vegetation
Orchard, alley	153	Also tree vegetation – in larger formations, category can include other grown vegetation as well as very green fields which couldn't be visually distinguished; for calculations both categories were suggested to be joined
Urban area	33	Only built-up areas including buildings and walls – mainly manually classified
Floodplain - dry	21	Watercourse and its neighbourhood which is not used as agricultural land with significant erosion marks, areas in valleys which are not formed into rectangular shapes of fields, it is assumed as dry according to high reflectance close to white colour
Floodplain - wet	59	Watercourse and its neighbourhood which is not used as agricultural land with significant erosion marks, areas in valleys which are not formed into rectangular shapes of fields, it is assumed as not completely dry or wet according to low reflectance close to white colour, not suitable for agricultural use
Field - used	195	Clearly defined parcels with vegetation cover – at the time of imaging covered by different crops, these parcels are assumed to be presently used and therefore important for irrigation
Field - unused	179	Clearly defined parcels with vegetation cover – at the time of imaging without any crops, it was impossible to distinguish between parcels which are not in use and parcels which were freshly sown or which were just harvested, category includes parcels with different reflectance (wetness), it is not possible to estimate how long are these parcels unused, these parcels are not considered for irrigation at the present state but they are considered for purposes of agriculture development and expansion
Debris	7	Areas which are not suitable for agriculture, does not include watercourse and floodplain
Total	660	**This is not total area of Khoshi valley – just solved area**

5.2.4.3 Processing and classification of land-use data

The data had been necessary to process into two basic information layers according to their application:

- Land-use map of the catchment – source of information for rainfall-runoff modelling and hydrological balance
- Detailed map of land-use of agricultural area under dam profile – i.e. area, potential for irrigation. Main task has been determination of used, potentially usable and not used land.

All data processing has been complicated by low quality of satellite data available, what is documented at following Fig 13 - Fig 18.

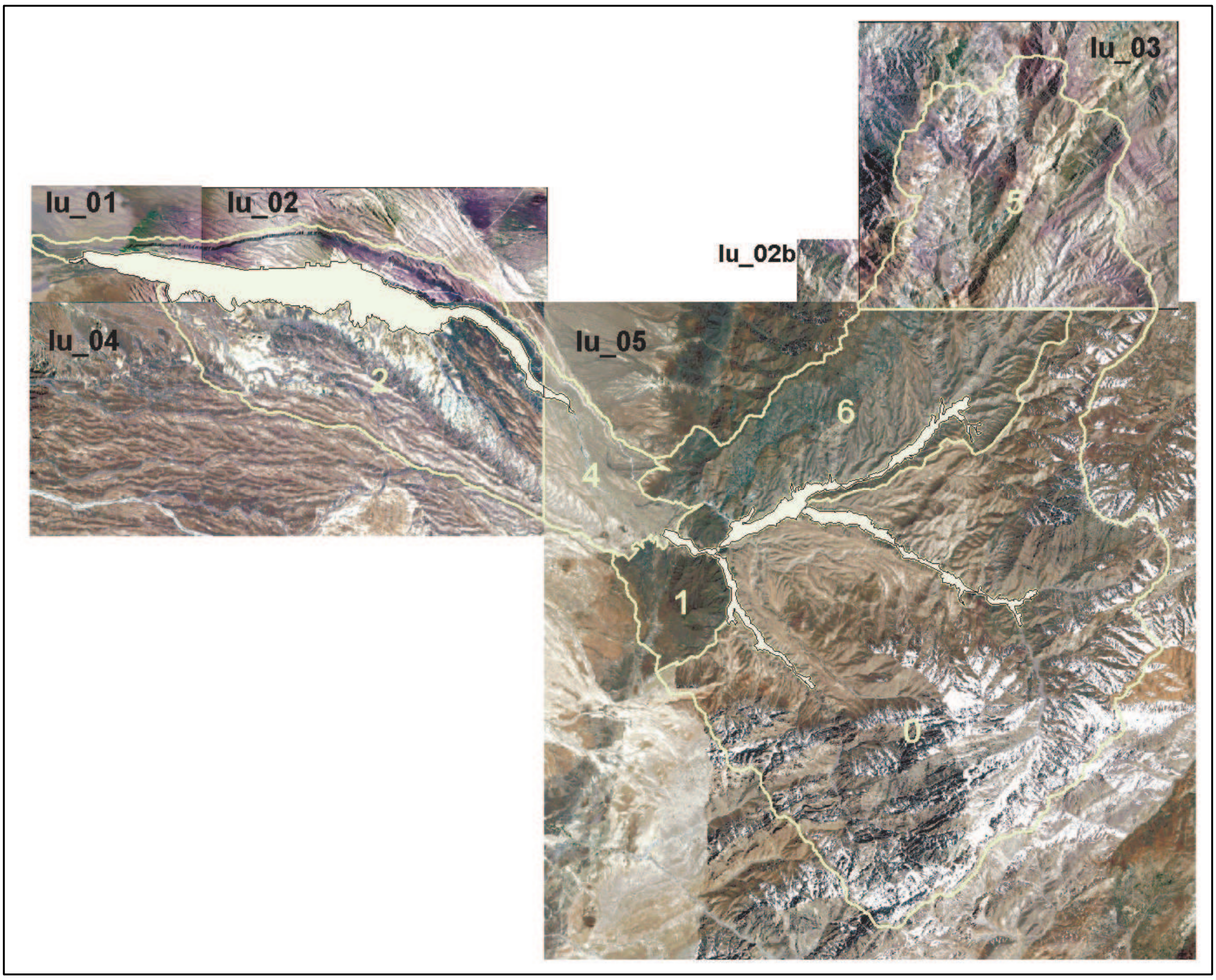

Fig 12: Overview of single spatial images and individually classified parts of the basin

Final digital data layers are shown on Fig 13 and Fig 14.

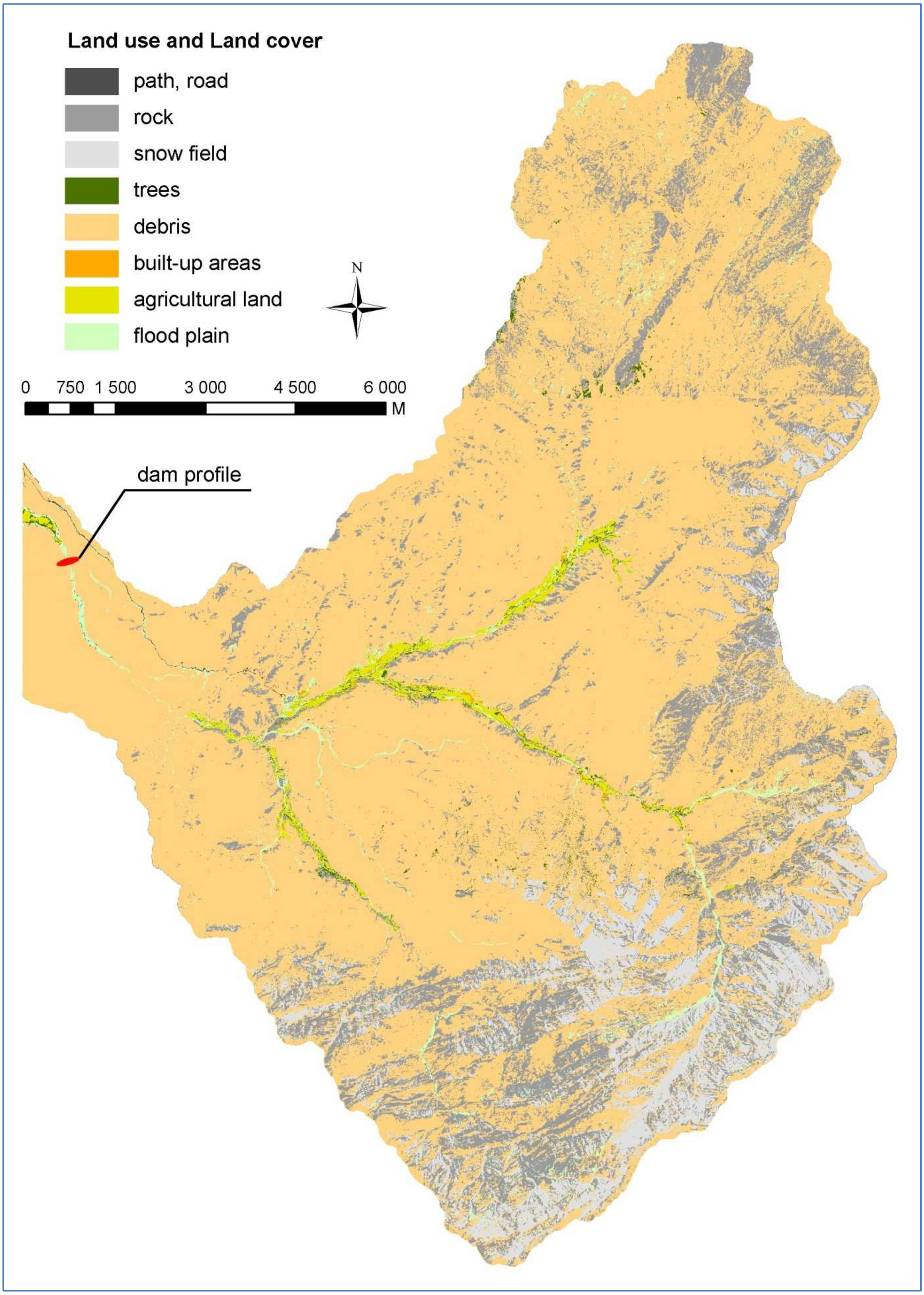

Fig 13: Land use map of Khoshi basin area.

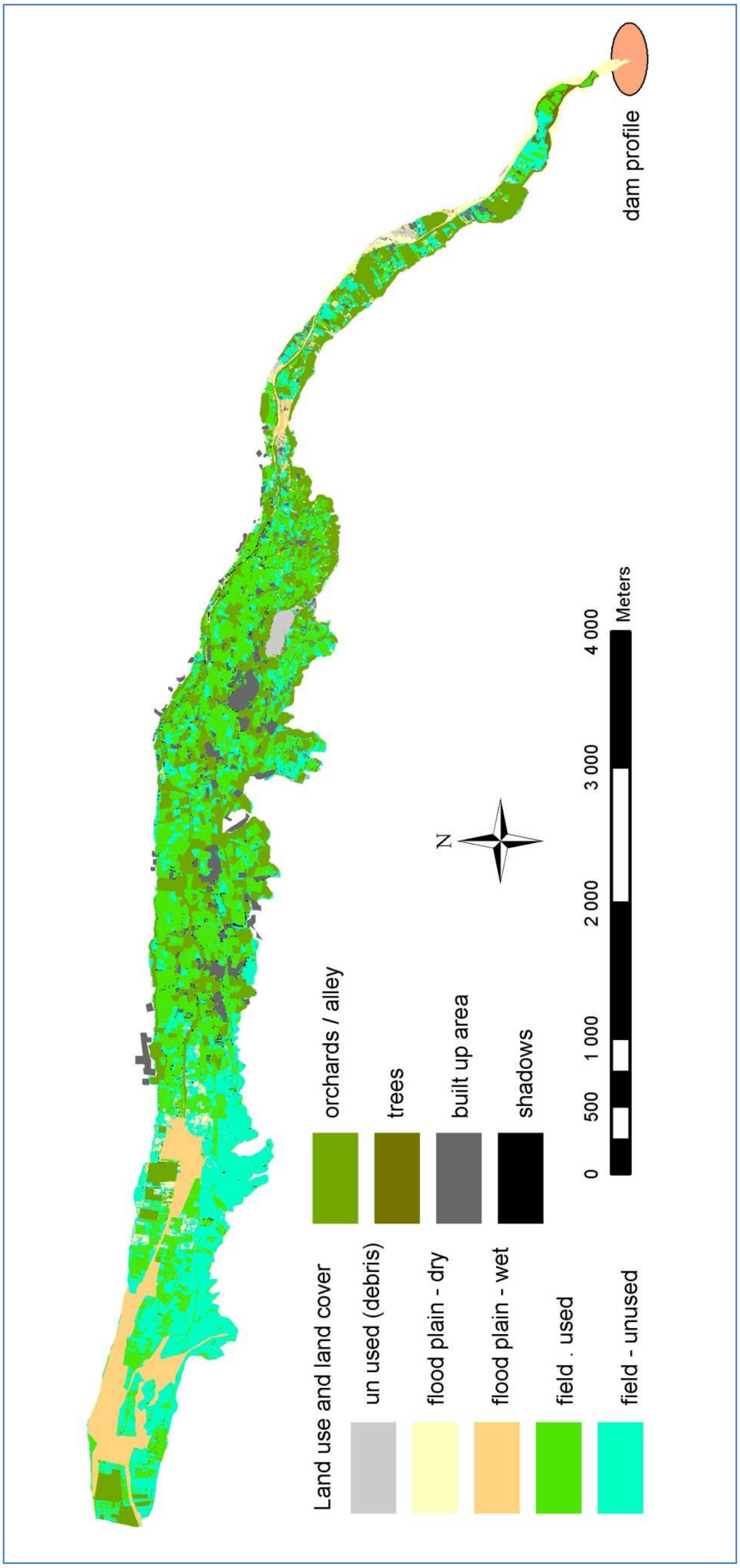

Fig 14:Land use map of agricultural - irrigated area

Fig 15: Data errors – orthophoto – damaged stripe with clouds

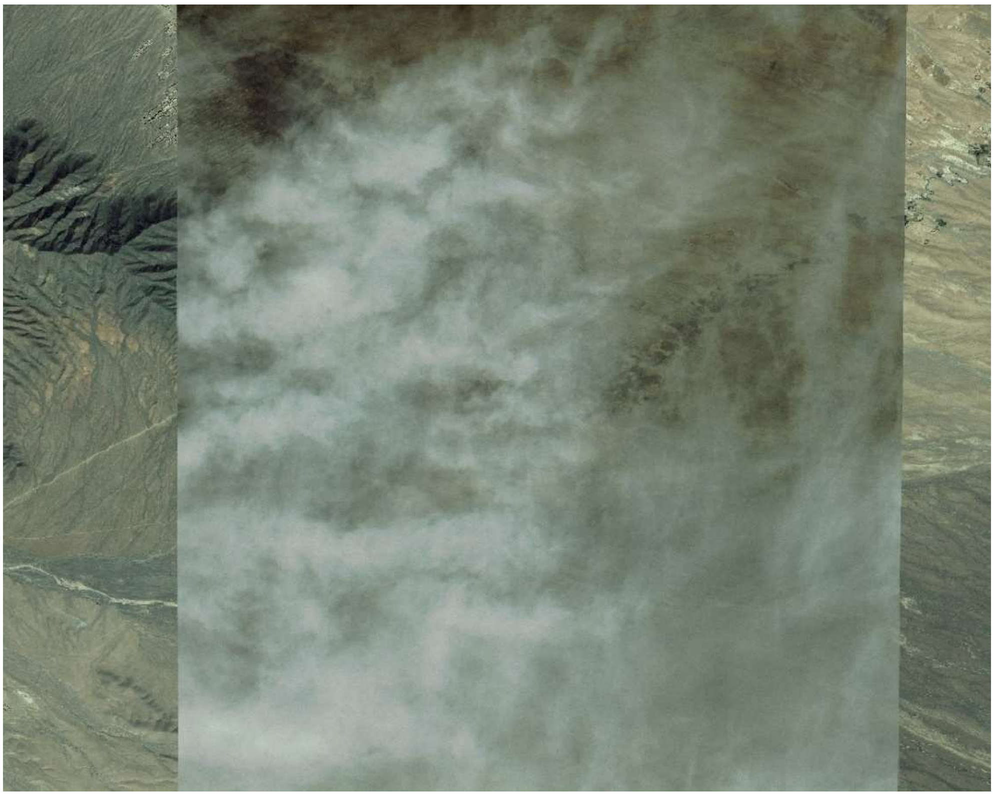

Fig 16: Data errors – orthophoto – damaged data stripe

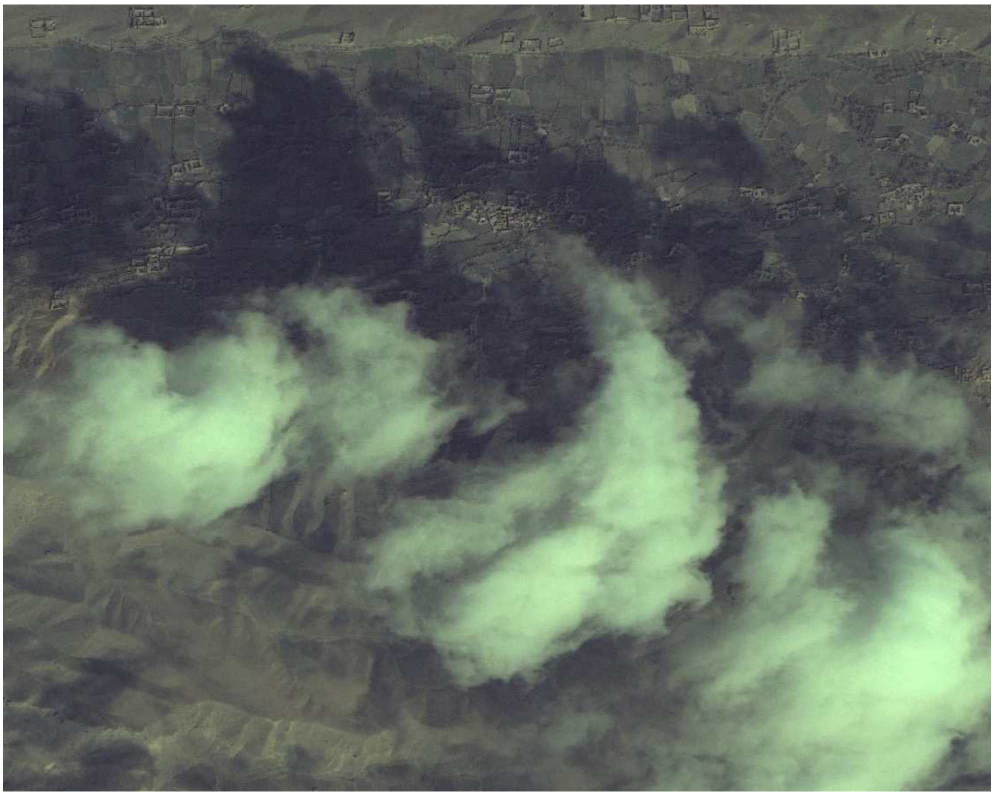

Fig 17: Data errors –Quickbird satellite – clouds and shadows.

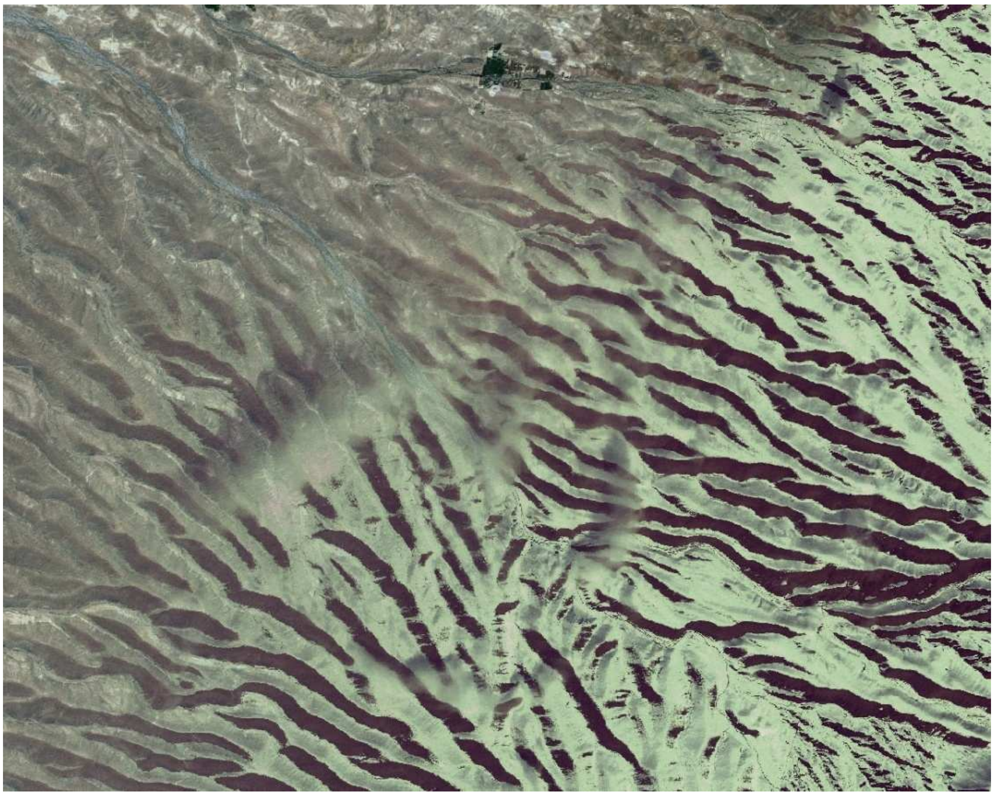

Fig 18: Errors in data – satellite Quickbird – damage during data preprocessing

6. Materials and methods

6.1 Basic assumptions

To be able to compute the hydrological balance in the complicated conditions of Afghanistan several simplifying assumptions had to be taken into account. These simplifications do not aim to change the computation results on purpose. They had to be done due to lack of detailed data or due to input data uncertainties.

- Rainfalls were considered as two main groups – summer intensive storms and winter precipitation of lower intensities but longer periods.
- River is permanent stream but in present time it is completely used as a water source – and the permanent flow was not taken into consideration for the balance purposes. Only rainfall runoffs are used for storage.
- The base flow is also not considered for the balance, it is completely used for various purposes today.
- The water power plant in the valley does not interact with the hydrological balance; it uses recent permanent water sources.
- Other water use (than irrigation) is not taken into account for the water balance purposes (drinking water, waste water, water for animals, water for vegetables and housing).
- The flood for reservoir retention capacity assessment will be caused by summer intensive rainfall. The worst scenario peak flow will be considered.
- Concerning the land-use, the watershed outline is formed by solid rock hills. The foothills (out of the agricultural valley) are formed by debris with bedrock.
- The flat valley regions are the only areas used for agriculture.
- The irrigation is only done by contour ditch and furrow flooding. Here the 50% losses are assumed for irrigation and 50% losses for water transport to the field (evaporation and infiltration in open channels).

6.2 Hydrological balance

Simple hydrological balance was provided, based on following equation.

$$P = R - ET \pm \Delta S$$

where

P Precipitation [mm]

R Runoff height [mm]

ET Evapotranspiration [mm]

$\pm\Delta S$ Watershed storage volume change [mm]

Since the data available for the study did not allow assessing the transpiration and storage volume in the watershed, only the rainfall, runoff and evaporation were directly computed.

Evaporation was formulated in several steps. Firstly the ratio between total annual precipitation and total annual evaporation was defined. Here the study of Tünnermeier for Kabul was used (Tünnermeier 2005). The volumes of annual rainfalls and annual evaporation are shown in Fig 19.

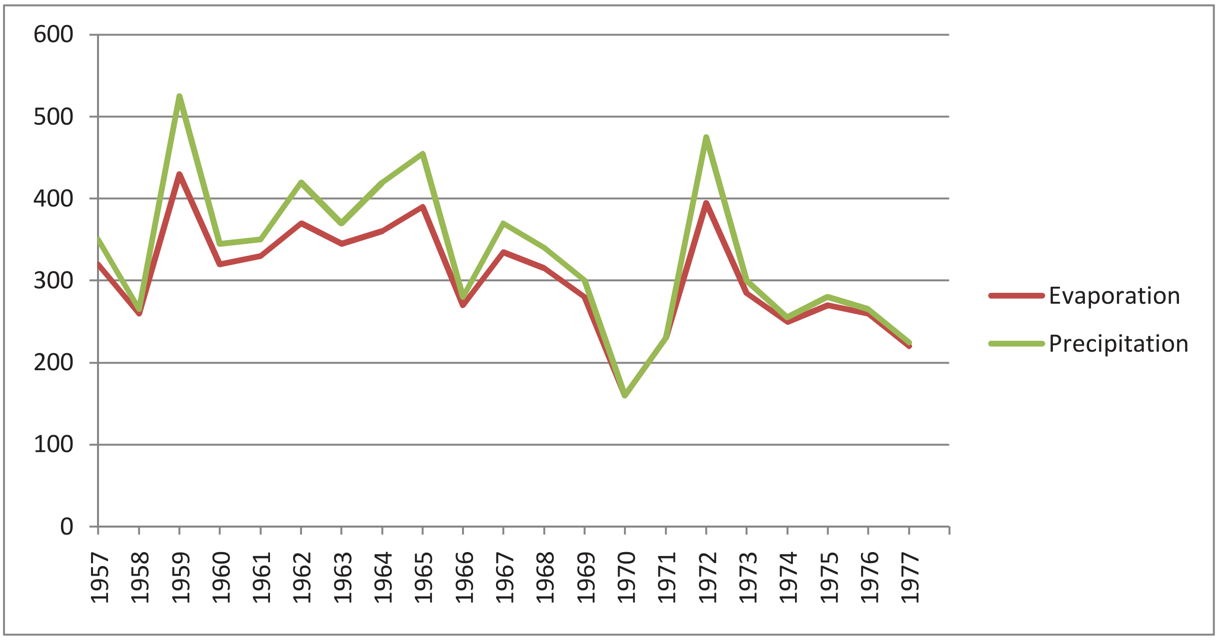

Fig 19: Annual values of measured precipitation totals and total annual evaporation calculated after Turc in period from 1957 to 1977; taken from (Tünnermeier, 2005)

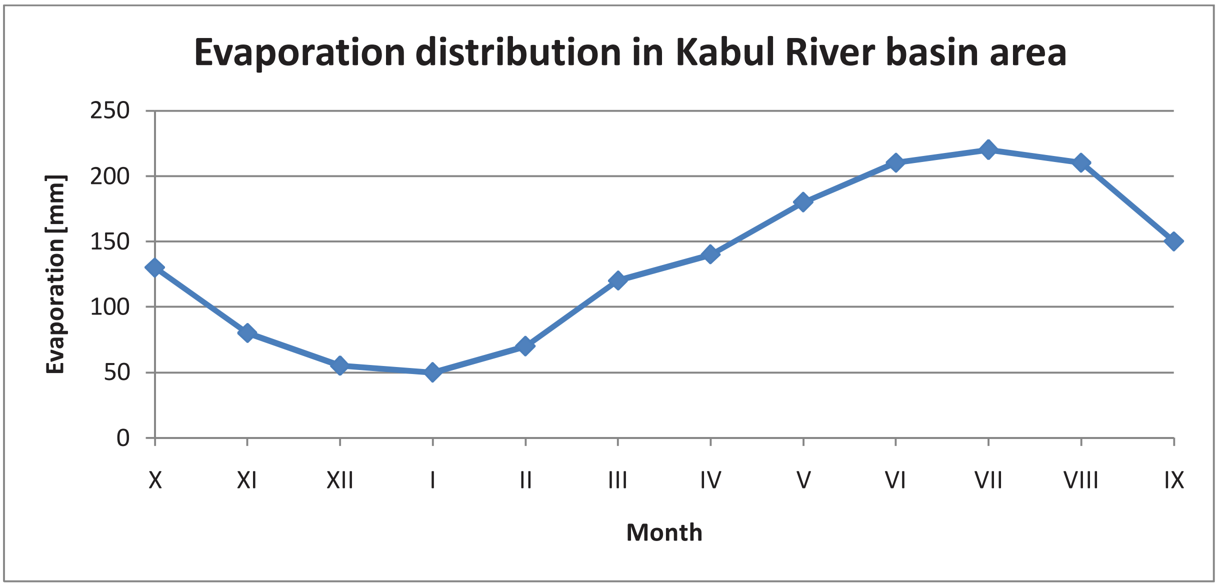

Fig 20: Evaporation distribution over year in Kabul River basin area; taken from (Tünnermeier, 2005)

The evaporation differs here from 80 to 100% of annual rainfalls. The Khoshi catchment is located in higher altitudes (otherwise similar conditions), the 80%

(evaporation/precipitation) value was used for the assessment. Concerning the scenarios - for dry year 70% and for wet year 90% were considered.

Tab 12: First step of evaporation calculation (mm) taking into account only evaporation distribution from (Tünnermeier, 2005)

	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Total
Average year													
Precipitation	10.6	16.9	31.6	44.6	57.5	84.3	70.0	36.3	9.9	5.4	3.8	4.7	375.6
Evaporation	24.2	14.9	10.2	9.3	13.0	22.3	26.0	33.5	39.1	40.9	39.1	27.9	300.5
Runoff ± storage change	-13.6	2.1	21.4	35.3	44.4	62.0	43.9	2.8	-29.2	-35.6	-35.3	-23.2	75.1
Dry year													
Precipitation	4.6	7.4	13.9	19.6	25.2	37.0	30.7	15.9	4.3	2.3	1.7	2.1	164.7
Evaporation	11.9	7.3	5.0	4.6	6.4	11.0	12.9	16.5	19.3	20.2	19.3	13.8	148.3
Runoff ± storage change	-7.3	0.1	8.8	15.0	18.8	26.0	17.8	-0.6	-14.9	-17.8	-17.6	-11.7	16.5
Wet year													
Precipitation	18.4	29.6	55.2	77.9	100.2	147.0	122.1	63.3	17.2	9.3	6.6	8.2	655.0
Evaporation	36.9	22.7	15.6	14.2	19.9	34.1	39.7	51.1	59.6	62.5	59.6	42.6	458.5
Runoff ± storage change	-18.5	6.8	39.6	63.7	80.3	113.0	82.3	12.2	-42.4	-53.1	-53.0	-34.4	196.5

Tab 13: Final water balance of the catchment (mm)

	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Total
Average year													
Precipitation	10.6	16.9	31.6	44.6	57.5	84.3	70.0	36.3	9.9	5.4	3.8	4.7	375.6
Evaporation	10.6	13.2	24.7	34.8	44.8	65.7	54.6	28.3	9.9	5.4	3.8	4.7	300.5
Runoff ± storage change	0.0	3.7	7.0	9.8	12.6	18.6	15.4	8.0	0.0	0.0	0.0	0.0	75.1
Dry year													
Precipitation	4.6	7.4	13.9	19.6	25.2	37.0	30.7	15.9	4.3	2.3	1.7	2.1	164.7
Evaporation	4.6	6.5	12.2	17.2	22.1	32.4	26.9	15.9	4.3	2.3	1.7	2.1	148.3
Runoff ± storage change	0.0	0.9	1.7	2.4	3.1	4.6	3.8	0.0	0.0	0.0	0.0	0.0	16.5
Wet year													
Precipitation	18.4	29.6	55.2	77.9	100.2	147.0	122.1	63.3	17.2	9.3	6.6	8.2	655.0
Evaporation	18.4	19.8	37.0	52.1	67.1	98.5	81.8	42.4	17.2	9.3	6.6	8.2	458.5
Runoff ± storage change	0.0	9.8	18.2	25.7	33.1	48.5	40.3	20.9	0.0	0.0	0.0	0.0	196.5

The second step was defining temporal distribution of evaporation during the year. For this purpose the Tünnermeier study was used according the Fig 20.

Looking at the distribution it is clear that total evaporation (and precipitation) volumes are higher than precipitation volumes in Khoshi catchments. The values published in the Tünnermeier study were accordingly reduced and final hydrological balance is shown at following table and figures. Tab 12., and from Fig 21 - Fig 23.

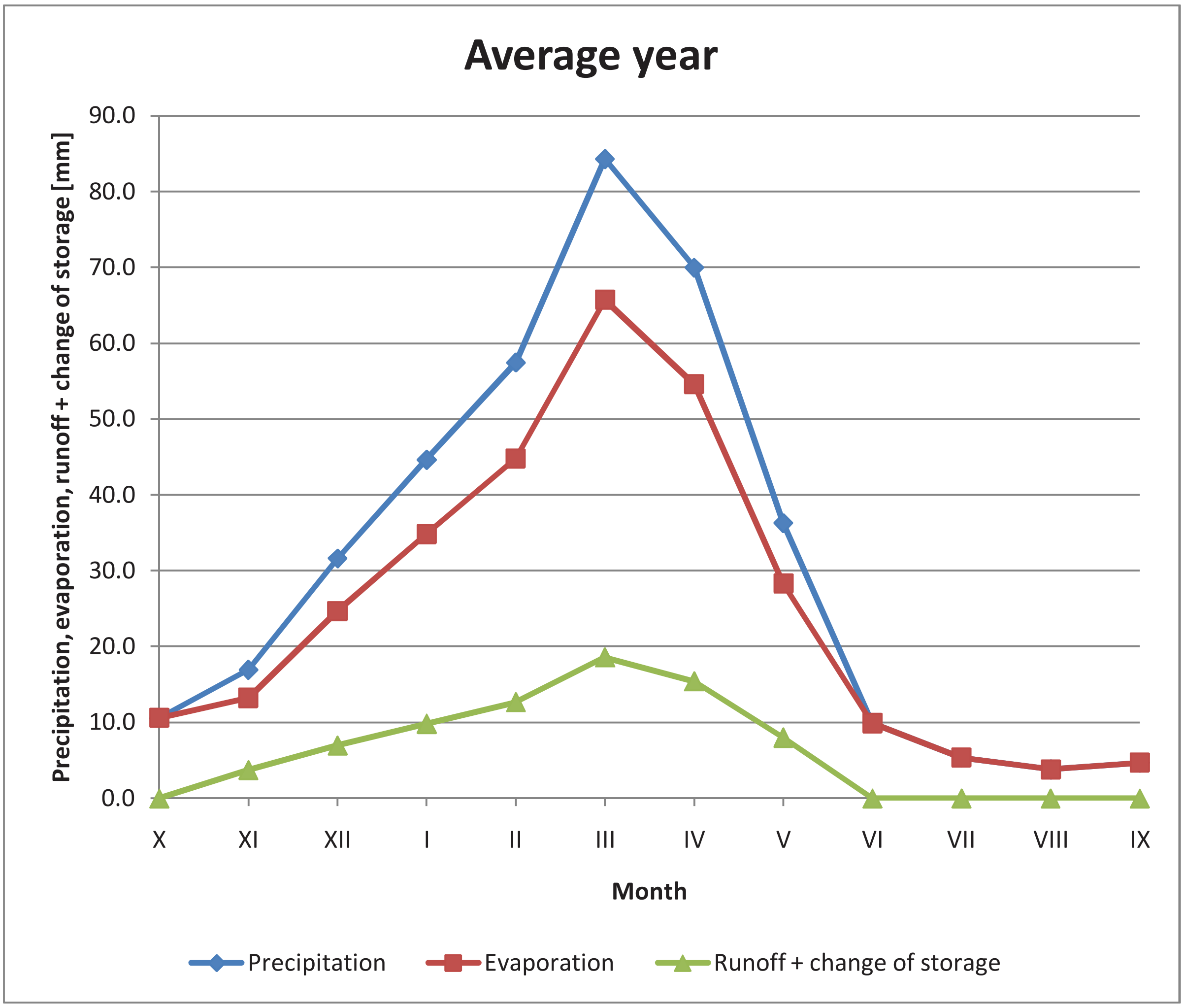

Fig 21: Water balance in average year

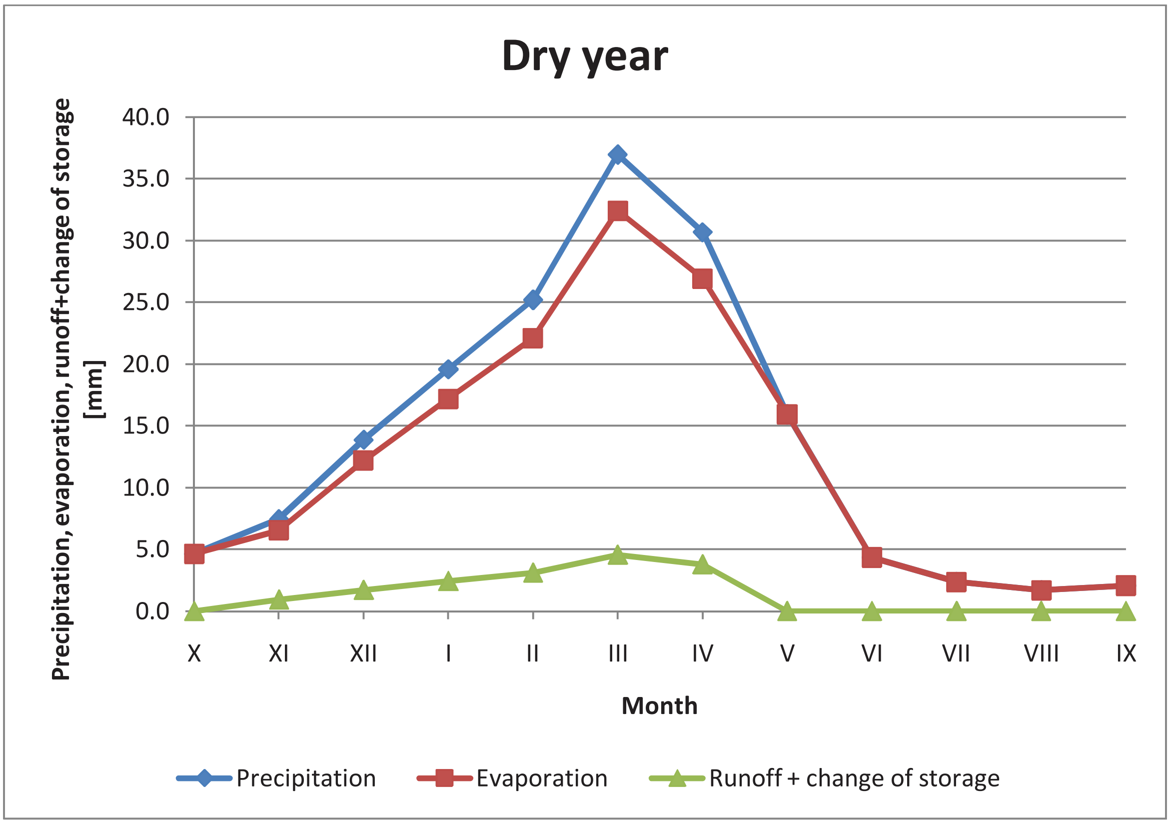

Fig 22: Water balance in dry year

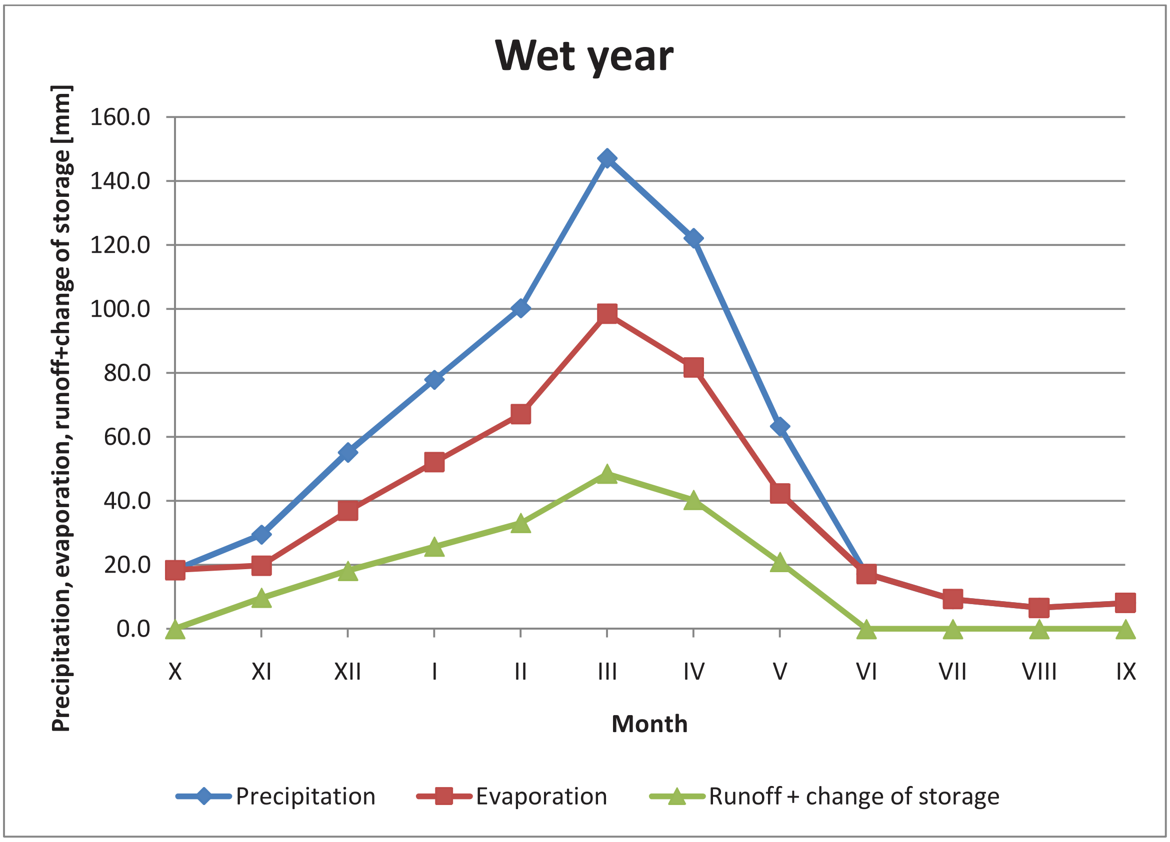

Fig 23: Water balance in wet year

6.3 Hydrological modelling – flood assessment using WMS software

Simulation model HEC-1 under WMS (Watershed Modeling System) has been used to determine flood discharge and other flood wave characteristics for retention space estimation. It is semidistributed, event based simulation model for determination of hydrograph of direct runoff. Parameters of calculation can be controlled by various used methods. Following methods were selected for performed calculation:

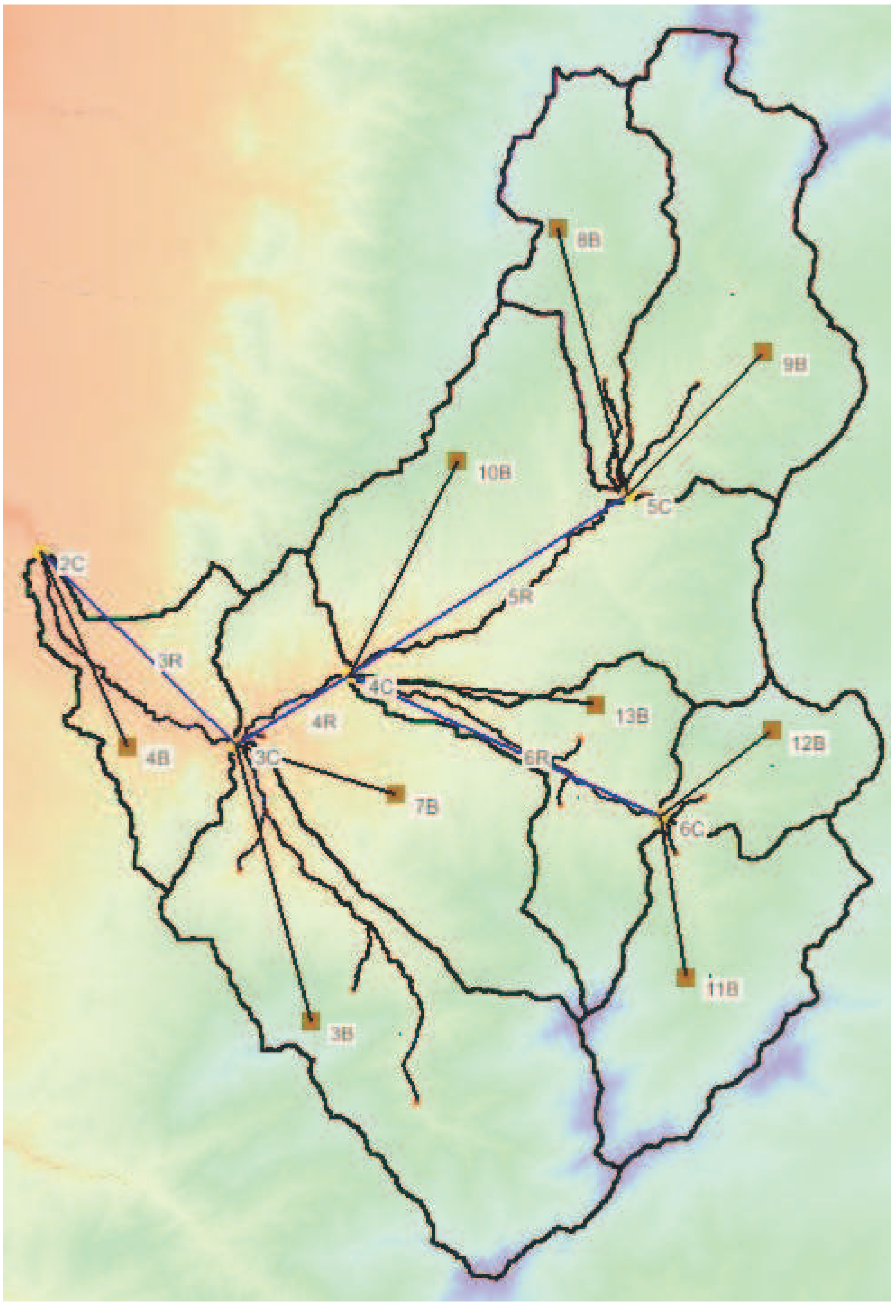

Fig 24: Hydrologic tree of Khoshi basin area

- Green-Ampt equation for direct runoff determination
- Clark method for unit hydrograph estimation, where Kirpich method has been used for determination of parameters for bare soil surface without vegetation cover
- Muskingum-Cunge method for flood wave transformation during flood wave routing trough channel

Tab 14: Catchment characteristics

Characteristic	Unit	Value
Catchment area	[km^2]	147.30
Average slope	[m·m^{-1}]	0.487
Shape factor	[km^2·km^{-2}]	1.44
Mean elevation	[m a.s.l.]	3029
Time of concentration	[hr:min]	2:12

Tab 15: Characteristics of subcatchments

Subcatchment	Area	Average slope	Shape factor	Mean elevation
Unit	[km^2]	[m·m^{-1}]	[km^2·km^{-2}]	[m a.s.l.]
3B	26.67	0.646	3.47	3115
4B	9.81	0.348	3.51	2589
7B	18.39	0.361	2.81	2808
8B	10.80	0.499	4.52	3222
9B	19.82	0.517	2.94	3180
10B	28.93	0.417	1.95	2924
11B	14.63	0.571	2.23	3330
12B	6.64	0.507	2.21	3144
13B	11.63	0.444	3.93	2941

6.3.1 Input parameters for assessment of infiltration

As proportion of vegetated or urbanized surfaces within the target area is very low, there has been used infiltration equation of Green-Ampt instead of usually applied approach of SCS-CN. Infiltration is very crucial phenomenon in such conditions.

There has been used following parameters for Green-Ampt equation application within HEC-1 model under WMS interface:

- Initial loss (mm)
- Volumetric moisture deficit (-), value equal to 0 means fully saturated soil profile
- Suction pressure height at infiltration head (mm)
- Saturated hydraulic conductivity (m/s; mm/hour)
- Proportion of impermeable surfaces (-)

Saturated hydraulic conductivity K_s value has been the most important parameter. Its values were derived for purposes of the study based on values, determined by laboratory analyses of 17 disturbed soil samples, delivered from target area. Representative mean value has been determined, using logarithmic scale for individual samples. Calculation can be followed at Tab 16.

Tab 16: Calculation of representative K_s value

Sample nr.	Soil type	K_s [m·s^{-1}]	$Log_{10}(K_s)$	K_s [m·s^{-1}]
1-1	Loam	$7.10 \cdot 10^{-07}$	-6.15	
1-2	Loam	$1.10 \cdot 10^{-07}$	-6.96	
1-3	Loam	$6.80 \cdot 10^{-07}$	-6.17	
1-5	Loamy sand	$5.10 \cdot 10^{-07}$	-6.29	
1-6	Loamy sand	$6.80 \cdot 10^{-06}$	-5.17	
1-7	Loamy sand	$5.90 \cdot 10^{-06}$	-5.23	
Resulting value		**$2.45 \cdot 10^{-06}$**	**-5.99**	**$1.01 \cdot 10^{-06}$**

Value of saturated hydraulic conductivity equal to $1.01 \cdot 10^{-06}$ m/s has been applied for entire target area for all design events.

Next important parameter is proportion of impermeable surfaces in each of individual subcatchments. This parameter has been derived from digital layer of land-use, processed based on satellite images (see chapter land-use determination). Categories of rocks and roofs have been assumed as impermeable.

Tab 17: Different land cover type percentages in single subcatchments and resulting ratio of impermeable areas

	Subcatchment name								
Land use	**3B**	**4B**	**7B**	**8B**	**9B**	**10B**	**11B**	**12B**	**13B**
1 - trees	0.30%	0.11%	0.59%	0.51%	0.23%	0.43%	0.41%	1.08%	1.75%
3 - roofs	0.02%	0.00%	0.18%	0.00%	0.00%	0.16%	0.00%	0.11%	0.29%
5 - floodplain	2.56%	2.75%	1.90%	2.46%	1.19%	1.19%	3.22%	3.16%	1.34%
7 - field	0.84%	0.90%	1.12%	0.00%	0.00%	2.24%	0.09%	0.32%	3.92%
10 - road	0.00%	0.23%	0.08%	0.00%	0.02%	0.02%	0.00%	0.00%	0.00%
12 - rock	26.28%	4.39%	5.94%	14.80%	19.90%	10.41%	22.36%	21.12%	10.64%
13 - snow	12.13%	0.00%	2.91%	0.00%	2.47%	1.55%	33.99%	6.43%	10.59%
14 - debris	57.87%	91.63%	87.28%	82.23%	76.19%	84.01%	39.94%	67.77%	71.47%
Impermeable (3 +12)	**26.30%**	**4.39%**	**6.12%**	**14.80%**	**19.90%**	**10.57%**	**22.36%**	**21.23%**	**10.93%**

Another two parameters of estimation of infiltration process were determined based on information about soil classes from literature and other information sources (e.g. Maidment, 1993). Used values can be seen at Tab 18.

Tab 18: Calculation of further infiltration process parameters

Parameter	Δθ (volumetric initial soil moisture deficit) [-]	Ψ_f (suction head at the wetting front) [mm]
Loam	0.346	88.9
Loamy sand	0.382	61.3
Used values	0.360	75.0

6.3.2 Stream channels parameters

Regarding to the area of the catchment, transformation of routed flood wave trough river (stream) network was necessary to take into account. Value of Manning roughness coefficient equal to 0.035 has been assumed in all calculated channels.

Tab 19: Used parameters of river reaches

Reach	Length	Average slope	Manning´s roughness	Bottom width	Bank slope
Unit	[m]	[m·m^{-1}]	[-]	[m]	[-]
3R	5502	0.022	0.035	5	3
4R	2377	0.030	0.035	8	3
5R	6105	0.036	0.035	8	3
6R	5960	0.042	0.035	7	3

6.3.3 Rainfall event

Methodology of design rainstorm preparation has been described at chapters above.

From point of view of temporal distribution, two scenarios were considered: rainfall event with constant intensity over entire interval of 6 hours and triangular temporal distribution of rainfall intensity over entire 6 hours. Total sums of rainfall event from 20 mm to 40 mm with step 5 mm were introduced into the model. Sum 40 mm is higher value, which has been observed at target area over entire time series (ERA 40). Used temporal distribution can be seen at Fig 25.

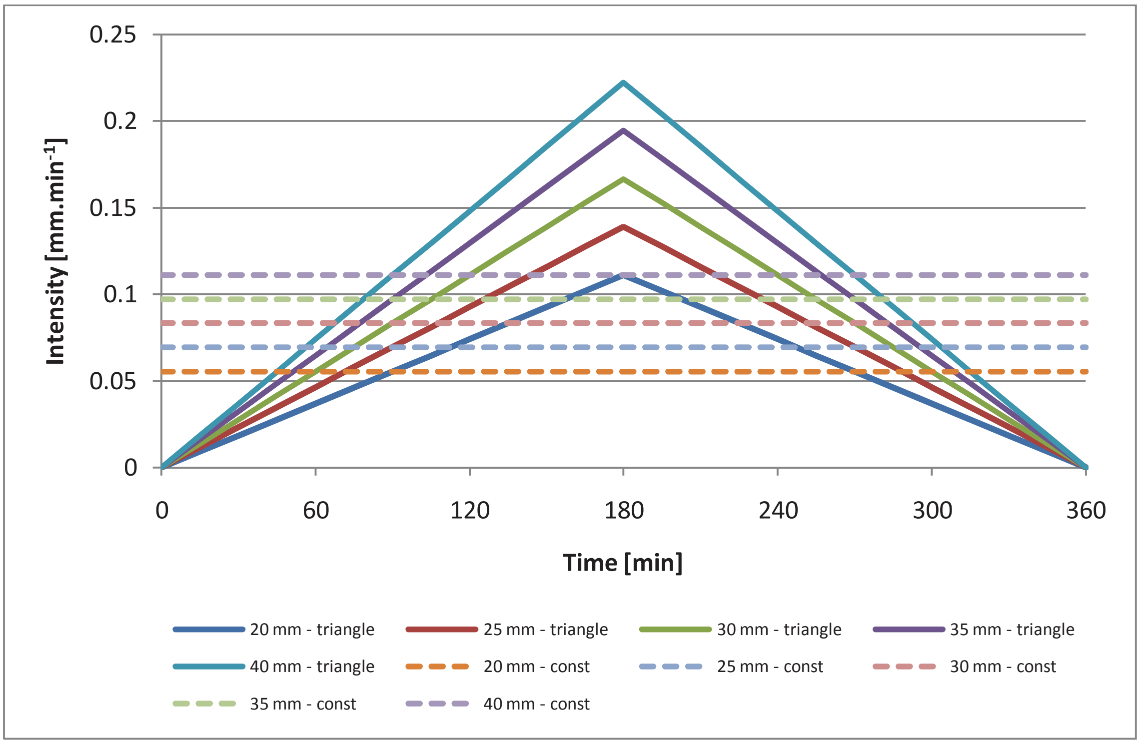

Fig 25: Distribution of precipitation intensities used for flood simulations

6.3.4 Results

Main results of hydrological simulation using model HEC-1 under WMS interface there are runoff hydrographs at all nodes of the catchment.

From obtained results of the simulation, there is clearly visible, that peak discharges are higher in case of triangular temporal distribution of rainfall intensities. Maximum reached peak discharge value of 113 m^3/s has been obtained for total sum of 40 mm over 6 hours. This value is recommended as input assumption of lowest considered discharge for emergency spillway design. If also transformation of flood wave in retention space of the reservoir is relevant task, volume nearly 1.5 mil. m^3 should be considered.

Tab 20: Runoff characteristics for precipitations with triangularly distributed intensities

Precipitation total [mm]	Peak discharge [$m^3 \cdot s^{-1}$]	Time to peak [min]	Direct runoff volume [m^3]
20	29.6	300	461 147
25	37.0	300	576 441
30	44.4	300	690 876
35	68.9	285	951 154
40	113.2	285	1 410 270

Detailed results can be seen at the charts and tables.

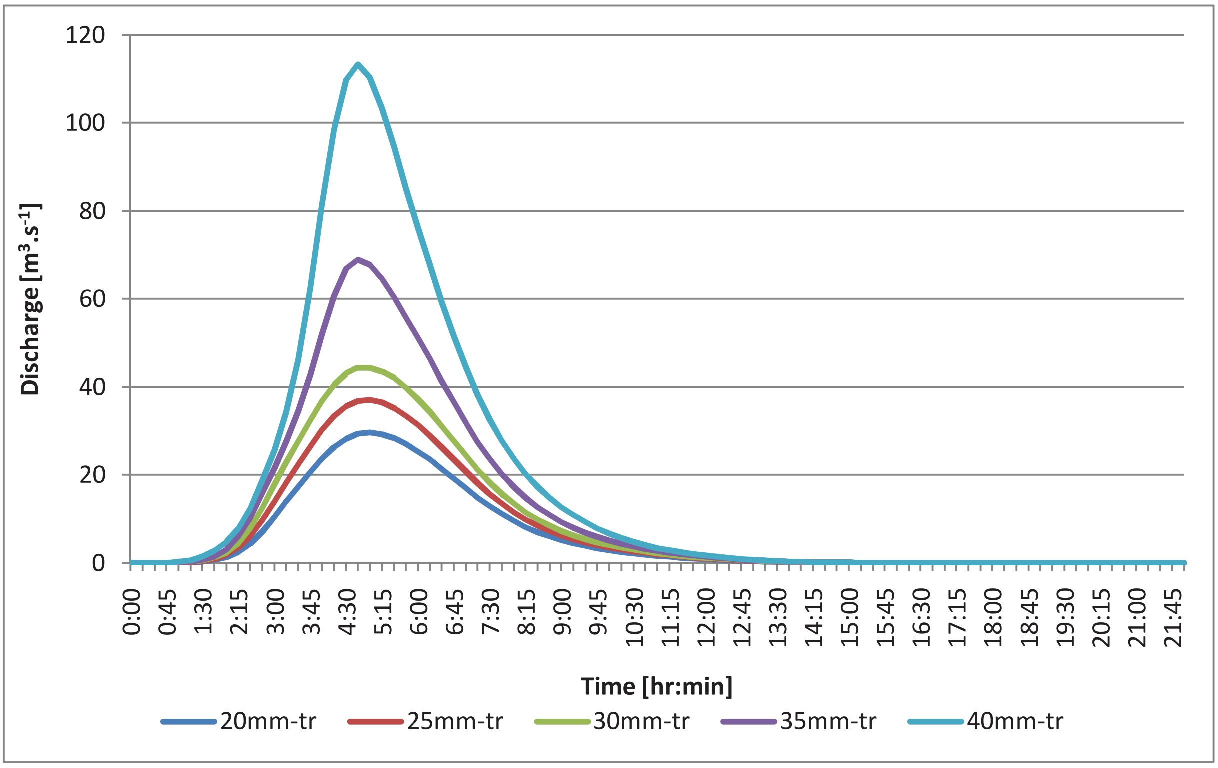

Fig 26: Runoff hydrographs for precipitations with triangularly distributed intensities

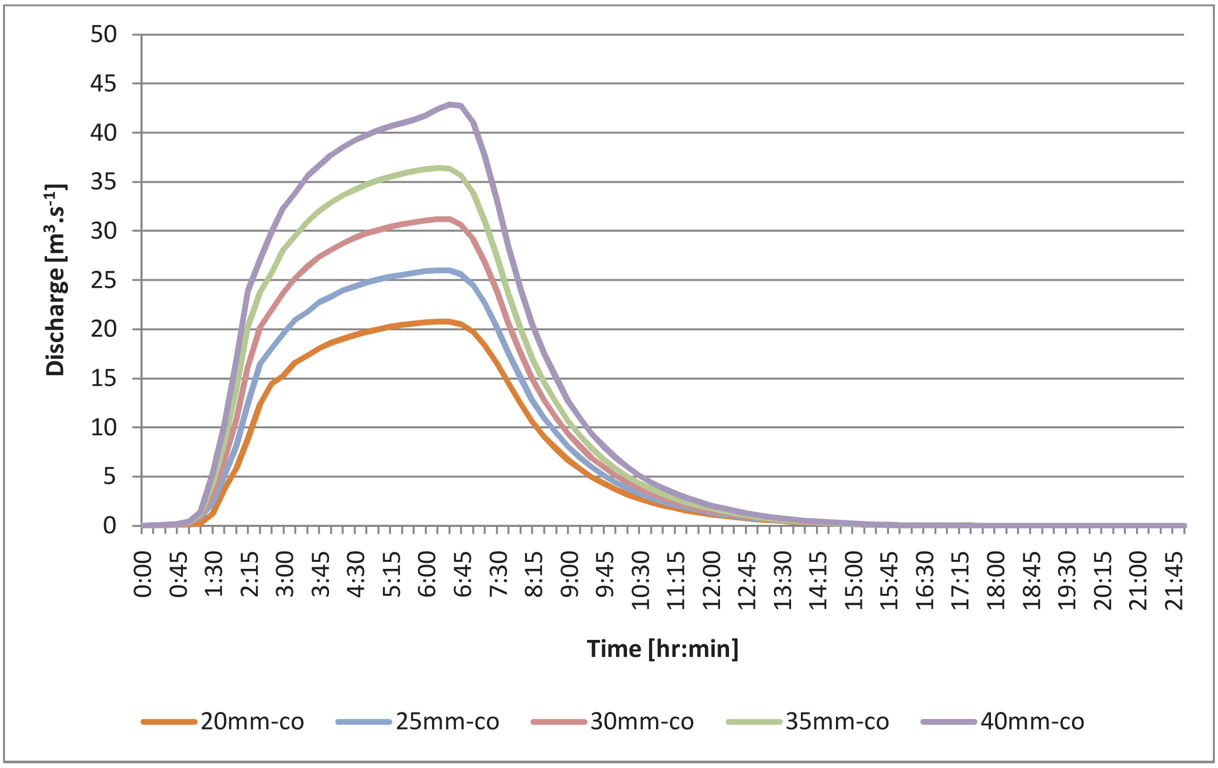

Fig 27: Runoff hydrographs for precipitations with constant intensities

Tab 21: Runoff characteristics for precipitations with constant intensities

Precipitation total [mm]	Peak discharge [$m^3 \cdot s^{-1}$]	Time to peak [min]	Direct runoff volume [m^3]
20	20.8	375	460 756
25	26.0	375	575 947
30	31.2	375	691 087
35	36.4	375	806 357
40	42.9	390	942 793

6.4 Calculation of necessity of irrigation

Basic hydrological balance and water demand for irrigation has been worked out using simulation model CROPWAT 8.0 for scenario of hydrological Average year.

6.4.1 Modelling of typical crop rotation for Average year

Simulation model CROPWAT 8.0 has been used for water demand and balance assessment within this task.

Tab 22: Moisture requirements for different crops

Crop	Water demand (mm/month)												
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Winter wheat	50.2	87.4	150.3	203.0	223.6	32.1				54.4	69.5	58.6	929.1
Spring wheat			113.2	230.4	313.8	229.7	19.2						906.3
Fruit baring trees	32.1	53.4	86.0	120.5	164.5	167.7	176.6	184.0	144.3	78.0	40.8	38.1	1286.0
Potatoes				89.2	235.0	294.1	284.5	65.9					968.7
Vegetables			86.3	130.6	248.3	259.5							724.7
Fodder crops			101.4	210.0	239.4	20.1	60.0	221.4	313.0	154.8	17.8		1337.9

Tab 23: Irrigation amount for different crops in conditions of Khoshi basin area (m^3/year.ha)

Crop	Irrigation amount (mm/month)												
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Winter wheat	8.8	35.2	77.4	140.8	189.4	22.4				44.0	53.1	28.6	599.7
Spring wheat			40.3	168.2	279.6	220.0	13.8						721.9
Fruit baring trees		1.2	13.1	58.3	130.3	158.0	171.2	180.2	139.6	67.6	24.4	8.1	952.0
Potatoes				27	200.8	288.4	279.1	62.1					853.4
Vegetables			13.4	68.4	214.1	249.8							545.7
Fodder crops			28.5	147.8	205.2	10.4	54.6	217.6	309.3	144.4	1.4		1118.2

6.5 Irrigation demands for individual scenarios

Irrigation demand for sample hectare of agricultural land has been assessed in previous chapter using simulation model CROPWAT 8.0, based on composition of obviously used crops.

For all other scenarios, assessment has been simplified for average use of arable land (mean crop rotation). Proportion of individual crops has been supposed according to statement of expert for agriculture, whit local experience. Temporal distribution of precipitation over year and vegetation season has been adopted from hydrological scenarios, defined above. Effective rainfall and its temporal distribution has been derived from hydrological scenarios applying the same proportion, as model CROPWAT did for Average year – see Tab 24. Necessary water volume has been then increased for 50 %, what corresponds to water losses during water transportation from water reservoir to fields – which is done by opened channel with permeable bottom, as is recent practice in the area.

The balance now covers only recently agriculturally used land. Its enlargement for new fields will be concerned in next steps at design level.

6.5.1 Average Year

As seen from Tab 24, the highest irrigation water demand coincide with summer months, which is very unfavourable, concerning temporal distribution of design rainfall (see Tab 4). Calculation already includes water losses of 50 %, related to irrigation technology used for water distribution around the field for the most often used ones (furrow irrigation, surface watering or flood irrigation). Columns, marked as “included losses” includes additional loss of 50 %, which correspond to transportation of water from source to irrigated field (open channel with permeable bottom is concerned, as it is usual in the region.

Tab 24: Irrigation amount in average year for single crops in case of present state of agriculture (m^3)

Irrigation amount total (m^3/month)							
	Winter wheat	Spring wheat	Fruit baring trees	Potatoes	Fodder crops	Irrigation total per month	Irrigation total per month including losses
October	55891	0	103658	0	42309	201858	302788
November	67344	0	37324	0	396	105064	157596
December	36269	0	12372	0	0	48640	72960
January	11124	0	0	0	0	11124	16685
February	44729	0	1895	0	0	46624	69936
March	98252	7870	20079	0	8349	134550	201825
April	178743	32850	89372	5275	43299	349539	524309
May	240425	54604	199716	39215	60111	594070	891106
June	28447	42966	242188	55543	3049	372194	558291
July	0	2703	262466	54514	16006	335689	503534
August	0	0	276184	12126	63741	352051	528076
September	0	0	213986	0	90316	304302	456453
Total	761223	140993	1459240	166672	327576	2855705	
Total including losses	**1141834**	**211490**	**2188861**	**250008**	**491364**		4283557

6.5.2 Abnormally dry year

Rainfall sum and distribution derived for Abnormally dry year (see Tab 4) has been concerned for calculation. Effective rainfall for individual months proportionally corresponds to the same calculated by CROPWAT model for Average year. Calculation and results are again increased by 50 % due to primitive water distribution system from source to fields.

Tab 25: Irrigation amount for different crops in case of present state of agriculture (m^3)

	Winter wheat	Spring wheat	Fruit baring trees	Potatoes	Fodder crops	Irrigation total per month	Irrigation total per month including losses
October	63280	0	112580	0	44014	219874	329810
November	79067	0	51479	0	3101	133647	200470
December	57668	0	38209	0	0	95877	143815
January	40655	0	21346	0	0	62001	93001
February	81906	0	46784	0	0	128690	193036
March	150206	15863	82811	0	20338	269219	403829
April	223067	39669	142891	12094	53528	471248	706872
May	264799	58354	229146	42965	65736	660999	991499
June	35353	44029	250526	56606	4643	391157	586735
July	0	3291	267080	55102	16888	342361	513542
August	0	0.0	279462	12543	64367	356373	534559
September	0	0.0	218023	0	91088	309110	463665
Total	995999	161206	1740339	179309	363703	3440555	
Total including losses	**1493999**	**241808**	**2610508**	**268964**	**545554**		**5160833**

6.5.3 Abnormally wet year

Rainfall sum and distribution derived for Abnormally wet year (see Tab 4) have been concerned for calculation. Effective rainfall for individual months proportionally corresponds to the same calculated by CROPWAT model for Average year. Calculation and results are again increased by 50 % due to primitive water distribution system from source to fields.

Tab 26: Irrigation amount for single crops in case of present state of agricultural land use (m^3)

	Winter wheat	Spring wheat	Fruit baring trees	Potatoes	Fodder crops	Irrigation total per month	Irrigation total per month including losses
October	46088	0	91821	0	40047	177955	266933
November	51810	0	18568	0	0	70378	105567
December	7900	0	0	0	0	7900	11851
January	0	0	0	0	0	0.0	0
February	0	0	0	0	0	0.0	0
March	29401	0	0	0	0	29401	44102
April	120012	23814	18457	0	29746	192029	288044
May	208126	49635	160717	34246	52658	505381	758071
June	19295	41558	231137	54135	937	347063	520594
July	0	1925	256360	53736	14839	326861	490291
August	0	0	271836	11572	62910	346318	519478
September	0	0	208641	0	89295	297936	446904
Total	482632	116932	1257539	153689	290431	2301223	
Total including losses	**723948**	**175399**	**1886309**	**230533**	**435646**		**3451834**

6.5.4 Multi-annual dry period

Rainfall scenario, describing hypothetical multi-annual dry period as it was described in previous chapters has been applied.

Results of calculation and balance are summarized at

Tab 27, Tab 28 and Fig 28 for scenarios of arable land with average crop rotation.

Tab 27 presents water demands for irrigation, included losses of 50 %, related to technology of irrigation at the field (m^3). Tab 28 and Fig 28**Chyba! Nenalezen zdroj odkazů.** present results, including also next loss of 50 %, related to water transportation from source to fields in form of opened channel with permeable bottom.

Tab 27: Total amount of water needed for agricultural land considering average use of agricultural land in single months during long term drought excluding water losses connected with distribution from the reservoir to fields

Year	October	November	December	January	February	March	April	May	June	July	August	September	Total
1	219 873	133 647	95 877	62 001	128 690	269 219	471 248	660 999	391 157	342 361	356 373	309 110	**3 440 556**
2	216 283	127 921	86 416	48 964	112 281	242 277	446 917	647 600	387 357	341 030	355 506	308 154	**3 320 709**
3	212 669	122 214	76 972	35 933	95 873	215 359	422 573	634 234	383 567	339 701	354 637	307 186	**3 200 921**
4	209 055	116 507	67 528	22 930	79 440	188 413	398 228	620 835	379 776	338 371	353 768	306 219	**3 081 075**
5	205 442	110 771	58 084	17 027	63 032	161 467	373 884	607 469	375 985	337 019	352 920	305 269	**2 968 373**
6	201 858	105 064	48 640	11 124	46 624	134 550	349 539	594 070	372 194	335 689	352 051	304 302	**2 855 711**

Tab 28: Total amount of water needed for agricultural land considering average use of agricultural land in single months during long term drought including water losses connected with distribution from the reservoir to fields

Year	October	November	December	January	February	March	April	May	June	July	August	September	Total
1	329 810	200 470	143 815	93 001	193 036	403 828	706 872	991 499	586 735	513 542	534 559	463 665	5 160 834
2	324 424	191 881	129 624	73 446	168 421	363 415	670 376	971 400	581 036	511 546	533 260	462 231	4 981 062

6	5	4	3
302 788	308 162	313 583	319 003
157 596	166 156	174 761	183 321
72 960	87 126	101 292	115 458
16 685	25 541	34 396	53 899
69 936	94 548	119 160	143 810
201 825	242 201	282 620	323 039
524 309	560 825	597 342	633 859
891 106	911 204	931 253	951 351
558 291	563 977	569 663	575 350
503 534	505 529	507 556	509 551
528 076	529 379	530 653	531 956
456 453	457 904	459 328	460 779
4 283 563	4 452 557	4 621 611	4 801 380

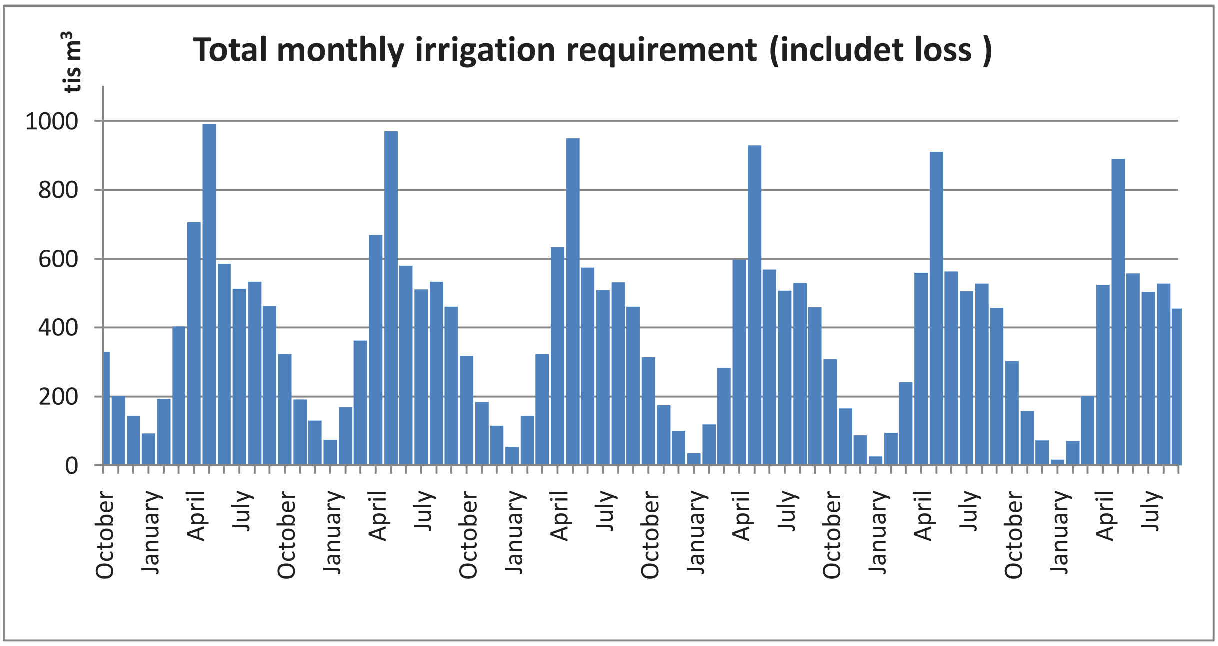

Fig 28: Graphic description of irrigation water demand including losses according to different irrigation technologies

6.6 Theoretical available reservoir volume – characteristic lines of the reservoir

The bottom of the reservoir has been concerned at level 2348 m a.s.l. for available volume assessment. This value comes from both of DTM and GPS measurement during field survey of civil experts of PRT at target area. Calculation of reservoirs volume has been done on the basis of DTM data CEDAR 5m. But, as it has been declared above, quality of delivered DTM especially at flat areas was that low that calculated volume should only be presented as rough estimation and especially absolute levels are not mentioned.

Theoretical volumes of the reservoir are listed in Tab 29. Calculated volumes do not exceed water depth 36 m, as practical and technical limit of the locality.

Tab 29: Theoretic reservoir volumes (relation of volume and area of water level to water depth))

Water depth (m)	Water surface area (m^2)	Water surface area (ha)	Water level (m a.s.l.)	Volume (m^3)
1	40 654	4.07	2 349	40 654
2	44 601	4.46	2 350	83 282
3	50 320	5.03	2 351	130 742
4	57 277	5.73	2 352	184 541
5	63 007	6.30	2 353	244 683
6	71 762	7.18	2 354	312 067
7	79 947	8.00	2 355	387 922
8	86 245	8.62	2 356	471 018
9	92 966	9.30	2 357	560 623
10	99 541	9.95	2 358	656 877
11	107 596	10.76	2 359	760 445
12	114 796	11.48	2 360	871 641
13	122 534	12.25	2 361	990 306
14	131 000	13.10	2 362	1 117 073
15	139 282	13.93	2 363	1 252 214
16	147 250	14.73	2 364	1 395 480
17	155 342	15.53	2 365	1 546 776
18	164 005	16.40	2 366	1 706 450
19	172 287	17.23	2 367	1 874 596
20	181 252	18.13	2 368	2 051 365
21	190 783	19.08	2 369	2 237 383
22	200 167	20.02	2 370	2 432 858
23	209 267	20.93	2 371	2 637 575
24	218 291	21.83	2 372	2 851 354
25	227 912	22.79	2 373	3 074 455
26	237 679	23.77	2 374	3 307 251
27	246 649	24.66	2 375	3 549 415
28	256 652	25.67	2 376	3 801 065
29	267 098	26.71	2 377	4 062 940
30	277 553	27.76	2 378	4 335 266
31	288 613	28.86	2 379	4 618 349
32	298 472	29.85	2 380	4 911 891
33	308 871	30.89	2 381	5 215 563
34	318 531	31.85	2 382	5 529 264
35	328 110	32.81	2 383	5 852 584
36	338 050	33.81	2 384	6 185 664

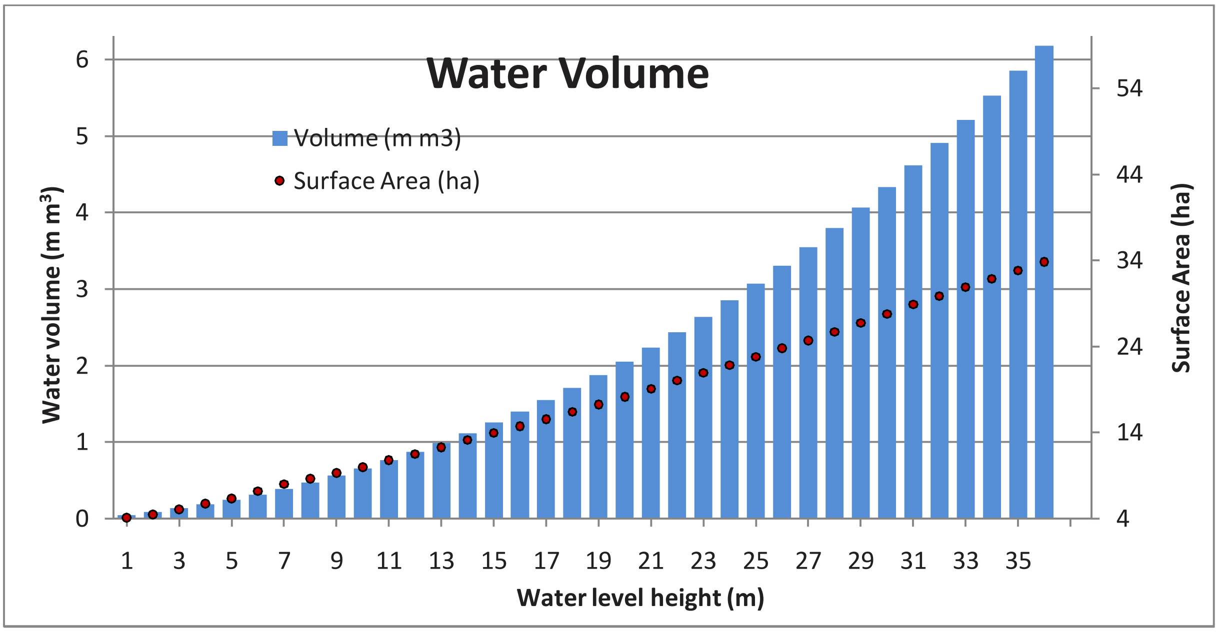

Fig 29: Relationship between water depth and volume in planned reservoir

Water reservoir, described above by its characteristic lines would have in case of maximum water level length of back water ca 2.3 km and length of the dam ca 260 m. Mean water level width would be ca 150 m.

6.7 Water reservoir balance, related to irrigation water

Water reservoir, designed as described by characteristic lines in previous chapter in Tab 29 and at Fig 29**Chyba! Nenalezen zdroj odkazů.** can for certain conditions provide water for irrigation during single- or multi-annual cycle.

The principle of balance has been theoretically described in chapter 4.3. Following processes have been included into balance:

Positives:

- Inflow to reservoir from the catchment

Negatives:

- Water withdrawal for irrigation
- Evaporation from water level

6.7.1 Inflow to the reservoir

Monthly runoffs from the catchment (inflow to the reservoir) have been concerned as positives within hydrological balance. Original values of runoff (mm) were recalculated to discharge units (m^3/month) using catchment area.

Tab 30: Total volumes of inflow to the reservoir (mm and m^3/month)

month		average	dry	wet		average	dry	wet
X	Runoff and change of storage (mm)	0	0	0	Runoff and change of stora (m^3)	0	0	0
XI		3.7	0.9	9.8		545 010	132 570	1 443 540
XII		7	1.7	18.2		1 031 100	250 410	2 680 860
I		9.8	2.4	25.7		1 443 540	353 520	3 785 610
II		12.6	3.1	33.1		1 855 980	456 630	4 875 630
III		18.6	4.6	48.5		2 739 780	677 580	7 144 050
IV		15.4	3.8	40.3		2 268 420	559 740	5 936 190
V		8	0	20.9		1 178 400	0	3 078 570
VI		0	0	0		0	0	0
VII		0	0	0		0	0	0
VIII		0	0	0		0	0	0
IX		0	0	0		0	0	0
total		**75.1**	**16.5**	**196.5**		**11 062 230**	**2 430 450**	**28 944 450**

Tab 31: Total volumes of inflow tot the reservoir (m^3/month) during modelled long term drought

year m^3/month	1	2	3	4	5	6
X	0	0	0	0	0	0
XI	132 570	215 058	297 546	380 034	462 522	545 010
XII	250 410	406 548	562 686	718 824	874 962	1 031 100
I	353 520	571 524	789 528	1 007 532	1 225 536	1 443 540
II	456 630	736 500	1 016 370	1 296 240	1 576 110	1 855 980
III	677 580	1 090 020	1 502 460	1 914 900	2 327 340	2 739 780
IV	559 740	901 476	1 243 212	1 584 948	1 926 684	2 268 420
V	0	235 680	471 360	707 040	942 720	1 178 400
VI	0	0	0	0	0	0
VII	0	0	0	0	0	0
VIII	0	0	0	0	0	0
IX	0	0	0	0	0	0
total	**2 430 450**	**4 156 806**	**5 883 162**	**7 609 518**	**9 335 874**	**1 1062 230**

6.7.2 Evaporation from water level of the reservoir

Evaporation from water level of the reservoir is the most important and in preliminary step of design the only one type of water loss, which is included into balance. The evaporation has been expressed in (mm) for individual months based on Study, mentioned above (Bock in Tünnermeier & Houben, 2005), worked out for Kabul region.

The absolute values of evaporation from water level of the reservoir were obtained by conversion evaporation height using water level area. As it will change due to water level fluctuation, level area has been concerned as 30 ha, what means water depth ca 32 m (full reservoir, i.e. calculation has been overestimated = security side.

Tab 32: Annual distribution of evaporation from the water surface in the reservoir

Month	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Total
Evaporation from water surface (mm)	130	80	55	50	70	120	140	180	210	220	210	150	1 615
Evaporation from water surface (m^3)	39 000	24 000	16 500	15 000	21 000	36 000	42 000	54 000	63 000	66 000	63 000	45 000	484 500

6.7.3 Water withdrawal from reservoir for irrigation

Water withdrawal from reservoir for irrigation should cover irrigation demand of individual crops, losses related to technological distribution of water around the field (combination of furrow irrigation, surface watering and flood irrigation), estimated to 50 % and water loss due to primitive water transportation from source to fields (evaporation and infiltration), estimated as 50 %.

6.7.4 Total balance of reservoir for current land-use

Balance has been calculated for individual months and for full cover of water demands of crops with current crop rotation and current and locally obvious types and technological processes, related to irrigation.

6.7.4.1 Average year

Tab 33: Water balance of the reservoir for average year

Average year (m^3)				
Month	Inflow	Irrigation	Evaporation	Total balance
X	0	302 289	39 000	-341 289
XI	545 010	157 344	24 000	363 666
XII	1 031 100	72 846	16 500	941 754
I	1 443 540	16 660	15 000	1 411 880
II	1 855 980	69 830	21 000	1 765 150
III	2 739 780	201 513	36 000	2 502 267
IV	2 268 420	523 484	42 000	1 702 936
V	1 178 400	889 684	54 000	234 716
VI	0	557 349	63 000	-620 349
VII	0	502 666	66 000	-568 666
VIII	0	527 165	63 000	-590 165

IX	0	455 676	45 000	-500 676
Total	11 062 230	4 276 506	484 500	6 301 224

Total balance for Average year shows, that total annual balance of discharges trough outlet point is positive, which means that water demand can be covered within one year if all balanced components are included. On the other hand, there is time period of 5 months (June – October), when monthly balance are negative. This fact means that during this period water demand will not be covered directly by withdrawal from stream, but water reservoir has to be built. From the table Tab 33, which summarizes balance is clear, that total deficit in dry months is in total 2.6 mil m^3 of water, while total annual excess reaches ca 8.9 mil m^3 of water. It means, that with high probability, water deficit in summer months can be solved by ware reservoir with storage volume at least 2.6 mil m^3.

6.7.4.2 Abnormally dry year

Tab 34: Water balance of the reservoir for dry year

Dry year (m^3)				
Month	Inflow	Irrigation	Evaporation	Total balance
X	0	329 267	39 000	-368 267
XI	132 570	200 147	24 000	-91 577
XII	250 410	143 583	16 500	90 327
I	353 520	92 852	15 000	245 668
II	456 630	192 726	21 000	242 904
III	677 580	403 187	36 000	238 393
IV	559 740	705 751	42 000	-188 011
V	0	989 914	54 000	-1 043 914
VI	0	585 748	63 000	-648 748
VII	0	512 656	66 000	-578 656
VIII	0	533 637	63 000	-596 637
IX	0	462 876	45 000	-507 876
Total	2 430 450	5 152 346	484 500	-3 206 396

Total balance for Abnormally dry year shows (in agreement with scenario, described above), that total annual balance of discharges trough outlet point is negative, what means, that when all balanced items are included, water need cannot be covered within one year. There is continuous time period of 8 months (April – October), when monthly balance are negative. This fact means that during this period water demand will not be possible to cover directly by withdrawal from stream, but water reservoir has to be built. But in difference to previous scenario, excess of discharges in rest 4 months are so low, that they are not able to cover deficit from dry months. Balance therefore stays negative during all year and even reservoir is not able to balance water needs within one year. From the table Tab 33, which summarizes balance is clear, that total deficit in dry months is in total 4.0 mil m^3 of water, while total annual excess in wet months reaches ca 0.8 mil m^3 of water. This means, that no reservoir will be able to balance deficit within one dry year, but on the other hand, water excess in Average year is high enough to balance deficit from Abnormally dry year. In case of combination of dry and average year, there is necessary to have available water reservoir with ca 4.0 mil m^3 of storage volume.

6.7.4.3 Abnormally wet year

Tab 35: Water balance of the reservoir for wet year

Wet year (m^3)				
Month	Inflow	Irrigation	Evaporation	Total balance
X	0	266 493	39 000	-305 493
XI	1 443 540	105 401	24 000	1 314 139
XII	2 680 860	11 833	16 500	2 652 527
I	3 785 610	0	15 000	3 770 610
II	4 875 630	0	21 000	4 854 630
III	7 144 050	44 036	36 000	7 064 014
IV	5 936 190	287 604	42 000	5 606 586
V	3 078 570	756 865	54 000	2 267 705
VI	0	519 714	63 000	-582 714
VII	0	489 445	66 000	-555 445
VIII	0	518 581	63 000	-581 581
IX	0	446 144	45 000	-491 144
Total	28 944 450	3 446 117	484 500	25 013 833

Total balance for Abnormally wet year shows, that total annual balance of discharges trough outlet point is significantly positive, what means, that when all balanced items are included, water need can be covered within one year. On the other hand, there is time period of 5 months (June – October), when monthly balance are negative. This fact means, that during this period water need will not be possible to cover directly by withdrawal from stream, but water reservoir has to be built. From the table Tab 35, which summarizes balance is clear, that total deficit in dry months is in total 2.5 mil m^3 of water, while total annual excess reaches ca 27.5 mil m^3 of water. It means, that with high probability, water deficit in summer months can be solved by ware reservoir with storage volume at least 2.5 mil m^3.

6.7.4.4 Design multi-annual dry period

Tab 36: Water balance of the reservoir for long term drought

Long term drought – total balance (m^3)						
month/year	1	2	3	4	5	6
X	-368 267	-362 890	-357 478	-352 067	-346 655	-341 289
XI	-91 577	-515	90 519	181 553	272 632	363 666
XII	90 327	260 633	430 913	601 193	771 474	941 754
I	245 668	483 194	720 713	958 188	1 185 034	1 411 880
II	242 904	547 347	851 788	1 156 268	1 460 709	1 765 150
III	238 393	691 180	1 143 930	1 596 723	2 049 516	2 502 267
IV	-188 011	190 162	568 356	946 549	1 324 742	1 702 936
V	-1 043 914	-788 167	-532 471	-276 726	-21 029	234 716
VI	-648 748	-643 058	-637 381	-631 703	-626 026	-620 349
VII	-578 656	-576 664	-574 673	-572 681	-570 657	-568 666
VIII	-596 637	-595 340	-594 039	-592 737	-591 466	-590 165
IX	-507 876	-506 444	-504 995	-503 546	-502 125	-500 676
Total	-3 206 396	-1 300 562	605 183	2 511 014	4 406 148	6 301 224

Total balance for design multi-annual dry period shows, that total annual balance of discharges trough outlet point is significantly positive, what means, that when all balanced items are included over entire six years period, water demand can be covered within period. But there is the dry period with negative balance and continuous duration at least 5 months (8 months in first most dry year) in each year.

To determine necessary storage volume of the reservoir, to cover deficit, cumulative balance has to be calculated over all period. Highest deficit equal to 4.9 mil m^3 will be reached in the beginning of third year of dry period. This should be storage volume of the reservoir, to cover design multi-annual dry period.

6.7.4.5 Total balance

Tab 37: General balance of water reservoir

	Irrigation demand (m^3)	Available water (m^3)	Total balance (m^3)
Average year	-2 621 145	8 922 368	6 301 224
Dry year	-4 023 687	817 291	-3 206 396
Wet year	-2 516 378	27 530 211	25 013 833

General summary table documents amounts of water, missing and exceeding within individual design years to cover water demands for irrigation. No other losses or hygienic minimum discharge under dam profile have been taken into account within the balance performed.

6.7.5 Land-use scenarios

The main goal of presented study has been to provide water supply for irrigation of agricultural land. Next step, there was to assess how much further agricultural land can be cultivated and used newly, if water reservoir is built there and will work as source of water for irrigation.

To keep the study in frame of reality, there were areas identified within the target area (in GIS layer LAND-USE), which were in past agriculturally used, but now they are not used any more.

Based on Tab 11, which summarizes proportion of individual types of surface and crops, there has been identified, that recently 195 ha has been used as arable land and 153 ha as orchards. Additionally, there has been identified further 179 ha of recently unused fields, which are assumed to be potentially used again.

As it, generally there has been assumed following land use change within target area in 8 scenarios – see Tab 38. Individual scenarios differ by proportion of used agricultural land, of total available. All newly used agricultural land has been assumed as arable one.

Tab 38: Land use scenarios in case of agriculture expansion (ha)

Scenario nr.	Orchards and alleys (ha)	Arrable land (ha)
1	153	195
2	153	220
3	153	250
4	153	275
5	153	300
6	153	325
7	153	350
8	153	374

Final area 374 ha represents scenario of full use of agricultural land, which has been identified within target area (195 ha of currently used and 179 ha recently not used).

Tab 39: Irrigation water balance for different climatic and land use scenarios

Scenario	1	2	3	4	5	6	7	8
Arable land (ha)	195	220	250	275	300	325	350	374
Average year								
Inflow to the reservoir	11 062 230	11 062 230	11 062 230	11 062 230	11 062 230	11 062 230	11 062 230	11 062 230
Irrigation	4 276 506	4 544 655	4 866 433	5 134 581	5 402 730	5 670 878	5 939 026	6 196 449
Total balance	6 301 224	6 033 075	5 711 297	5 443 149	5 175 000	4 906 852	4 638 704	4 381 281
Dry year								
Inflow to the reservoir	2 430 450	2 430 450	2 430 450	2 430 450	2 430 450	2 430 450	2 430 450	2 430 450
Irrigation	5 152 346	5 478 820	5 870 590	6 197 065	6 523 539	6 850 014	7 176 489	7 489 905
Total balance	-3 206 396	-3 532 870	-3 924 640	-4 251 115	-4 577 589	-4 904 064	-5 230 539	-5 543 955
Wet year								
Inflow to the reservoir	28 944 450	28 944 450	28 944 450	28 944 450	28 944 450	28 944 450	28 944 450	28 944 450
Irrigation	3 446 117	3 646 524	3 887 014	4 087 421	4 287 829	4 488 236	4 688 644	4 881 035
Total balance	25 013 833	24 813 426	24 572 936	24 372 529	24 172 121	23 971 714	23 771 306	23 578 915

Tab 40: Reservoir water balance for scenario of long term drought and arable land area expansion (m^3)

Year/arable land area (ha)	195	220	250	275	300	325	350	374
1	-3 206 396	-3 532 870	-3 924 640	-4 251 115	-4 577 589	-4 904 064	-5 230 539	-5 543 955
2	-1 300 562	-1 615 369	-1 993 138	-2 307 945	-2 622 753	-2 937 560	-3 252 367	-3 554 583
3	605 183	302 036	-61 740	-364 887	-668 034	-971 181	-1 274 328	-1 565 349
4	2 511 014	2 219 538	1 869 767	1 578 292	1 286 816	995 341	703 865	424 049
5	4 406 148	4 126 339	3 790 568	3 510 758	3 230 949	2 951 139	2 671 330	2 402 713
6	6 301 224	6 033 075	5 711 297	5 443 149	5 175 000	4 906 852	4 638 704	4 381 281

It is clear from results, that approx. from area of agricultural land 275 ha (i.e. enlargement for ca 80 ha compared to recent situation), total balance of multi-annual (six years design period) dry period is negative, therefore no water reservoir can balance water demand for irrigation within multi-annual dry period (regardless to storage volume of the reservoir.). The same area is also limiting for Abnormally dry year, due to available storage volume of the reservoir. In case of Average year, full extent of available agricultural land can be used and designed water reservoir will manage to supply it with water.

Tab 41: Total water balance of reservoir from the pint of view of irrigation water supply for different climatic scenarios and arable land area expansion (m^3)

Arable land (ha)	195	220	250	275	300	325	350	374
Average year								
Total balance	6 301 224	6 033 075	5 711 297	5 443 149	5 175 000	4 906 852	4 638 704	4 381 281
Available water	8 922 368	8 744 011	8 529 981	8 359 223	8 256 589	8 153 955	8 051 321	7 952 792
Water demand	-2 621 145	-2 710 935	-2 818 684	-2 916 074	-3 081 588	-3 247 103	-3 412 617	-3 571 511
Dry year								
Total balance	-3 206 396	-3 532 870	-3 924 640	-4 251 115	-4 577 589	-4 904 064	-5 230 539	-5 543 955
Available water	817 291	746 890	662 408	592 007	521 606	451 205	380 803	331 110
Water demand	-4 023 687	-4 279 760	-4 587 048	-4 843 122	-5 099 195	-5 355 269	-5 611 342	-5 875 065
Wet year								
Total balance	25 013 833	24 813 426	24 572 936	24 372 529	24 172 121	23 971 714	23 771 306	23 578 915
Available water	27 530 211	27 413 588	27 273 641	27 157 019	27 040 396	26 923 774	26 807 151	26 695 194
Water demand	-2 516 378	-2 600 163	-2 700 705	-2 784 490	-2 868 275	-2 952 060	-3 035 845	-3 116 279

Results, presented at Tab 41 show, that to cover water demand for irrigation in Average year, there will be necessary reservoir with storage volume ca 3.5 mil m^3. Such reservoir would cover water demand even for full use of available agricultural land – increment to 374 ha. In case of Abnormally dry year, water reservoir will cover not even water demand of recently use land. In case of combination of Abnormally dry ad Average years, water reservoir would cover increment of agricultural land up to total area ca 300 ha. But to reach this, water reservoir with storage volume nearly 5.0 mil m^3 would be necessary, what is in fact on the edge of reality.

6.8 Flood control

From point of view of flood control, there is the most important, how large retention volume in the reservoir has been designed.

Start point for design, there is initial assumption, that 32 m is technically acceptable height of dam in conditions of locality.

Maximum water level of the reservoir will be set 1.5 m bellow top of reservoir – i.e. 30.5 m above the bottom.

Maximum spill height at emergency spillway for discharge 113 m^3/s (according to Tab 20 it correspond approx. to Q_{50}) has been designed to 1.0 m. Head of emergency spillway therefore will be at level 29.5 m above bottom.

Volume of flood wave with return period of ca 50 years has been calculated (see Tab 20) as ca 1.4 mil m^3.

Retention volume of the reservoir, which will provide significant flood wave transformation, should be equal to at least 30 % of flood wave volume, in accordance with generally accepted hydrological standards.

Volume, available between head of emergency spillway and maximum water level (see Tab 29) is approx. 300 000 m^3. This volume represents less than 25 % of total design flood wave volume. Therefore, it is not enough, to provide sufficient transformation.

Therefore there has been designed to reserve additional 1.0 m under head of emergency spillway. Storage volume (standard water level) will then be set to 28.5 m above bottom and retention volume will reach ca 500 000 m^3, what represents ca 36 % of total flood wave volume.

7. Design

7.1 Water reservoir

Construction of the dam with head height 32 m above valley bottom has been designed as ideal solution of situation. Basic parameters are summarized in Tab 42

Tab 42: General summary of main characteristics of designed reservoir

	Height above valley bottom (m)	Stored volume (m^3)
Dam crest height	32	4 900 000
Maximum water level H_{max}	30.5	4 500 000
Emergency spillway crest	29.5	4 200 000
Water level of standard storage H_{nn}	28.5	4 000 000

7.1.1 Current area of agricultural land

Water reservoir of mentioned parameters will be with high probability able to cover irrigation water demand for recently applied technology of irrigation and current areas of agricultural land and crops within hydrological Average year and wet year. In case of Abnormally dry year, it will cover water demands only in case of its combination with Average year. In case of multi-annual year, the reservoir will not be able to fully cover water need and in third year of the period irrigation have to be limited. In next years full water supply will be provided again.

7.1.2 Enlargement of agricultural land

In case of agricultural land enlargement, if assumed, that all newly cultivated land will be used as arable with current crops, water reservoir will be able to cover irrigation water demand for hydrological Average year for full enlargement ((total 374 ha of arable land and current orchards). In case of drought occurrence (designed as Abnormally dry year), reservoir is not even fully cover current demand (only solution is combination years dry and average). If drought comes, there will be necessary to reduce irrigation, or to store water from previous, more wet years. In case of multi-annual drought, area of agricultural land can be enlarged for ca 80 ha, but in the mod of dry period, irrigation has to be strongly limited.

7.2 Potential economy measure

7.2.1 Change of crops, land-use and land management

Savings in amount ca 10 % of total water demand in dry period can be reached in case of stopping irrigation at land, which is every year left unused. This is practiced from management reasons, to leave the soil resting and to increase content of organic matters in it. This part of land has been included into previously described scenarios, as it is during dry periods used only for occasional pasture.

7.2.2 Change of water transportation from source to the fields

In case if this loss can be neglected, irrigation water demand would drop down for ca 25 %. As ideal technical solution, underground channel in concrete or plastic tubes is recommended.

To water demand only evaporation from water level has to be added as only one last balanced negative item. Designed water reservoir will then cover water demand in Average and Wet year, but also in Dry period and even in designed multi-annual drought for current area of agricultural land.

7.2.3 Change of irrigation technology at the field

Further reserve is high water loss, caused by primitive technology of irrigation around the fields. Only used irrigation technologies at target area are furrow irrigation, surface watering and flood irrigation – according to information from local experts. But these technologies can hardly be changes in current conditions at target area.

7.2.4 Scenario of smaller water reservoir

There exists an infinitive number of alternative designs, related to combination of lower height of dam and lower security of irrigation water supply.

If the task is formulated, that irrigation should be provided for hydrological Average year, sufficient storage volume for currently used agricultural land, can decrease to 2.6 mil m^3, what corresponds to water depth 23 m and height of head of the dam equal to 26 m.

In case of decrease of security of flood protection from current return period ca 50 years to lower values and taking into account very high probability, that flood will occur in summer period, when water level is significantly lower and empty space is available in the reservoir, another 1.5 m of dam height can be spared.

If more economical technologies of water transportation from the reservoir to irrigated area (covered channel) water level of storage volume can drop down to ca 19.0 m.

8. Summary and conclusions

The basic hydrological study of the catchment above agricultural area has been performed. Balance confirmed significant seasonality of rainfall temporal distribution and therefore also runoff. Temporal distribution is very unfavourable, as most of precipitation occurs in winter, while dry period coincide with vegetation season. To cover water demand of crops, it is necessary to provide irrigation in summer months, which even during average year cannot be provided from the stream without accumulation. Scenarios of hydrological Average, Abnormally dry and Abnormally wet year have been formulated for balance. Additionally, multi-annual dry period with duration 6 years have been formulated. These scenarios, same as design storm event with duration 6 hours, have return period equal to ca 50 years.

Next problem of the area were identified floods, caused mainly by summer storm events. Retention volume of the reservoir is necessary control measure.

Water reservoir with dam height of 32 m and total storage volume ca 4 mil m^3 and retention volume ca 0.5 mil m^3 for flood wave transformation has been designed as compensation measure. Designed storage volume will cover irrigation water demand in wet, average and with some limitations also in dry year. With relatively small shortage it will work also in multi-annual drought.

In case of agricultural land enlargement, the reservoir will cover water demands in wet and average year. In occurrence of dry year or multi-annual drought, there will not be possible to fully irrigate all fields. Further enlargement of agricultural land is therefore possible in principle.

There can alternatively be designed also smaller water reservoir instead of large mentioned above. Such smaller reservoir will provide lower security of irrigation water supply and also lower flood control. Alternative of construction of second additional water reservoir, located above first one, to provide higher security of water supply has been considered. This upper profile has been found not as favourable as lower one. Much more effective way to cover irrigation water demands there is recommended to economize losses of water during its transportation and distribution.

No other water demands, except of irrigation of agricultural land and related water losses were considered for water balance. Mainly, there were not included irrigation of crops (mainly vegetable) within yards, water demands for hygiene, drinking and other human activities and respecting minimum hygienic discharges in stream channel under dam profile.

High uncertainties are around input parameters for all parts of hydrologic balance, mainly due to low quality of nearly all source data.

In case of building and operation of water reservoir, there is necessary to keep attention to sediment production and transport. Mountainous character of the catchment and corresponding morphology, soil characteristics and rainfall distribution show, that catchment is prone to high production of sediment. There were same local experiences recorded. Storage volume of the reservoir should therefore be protected by suitable measures. As preferred one, sedimentation sub-reservoir at inlet is preferred, which should regularly be cleaned.

There is very desirable for technical design itself directly at the target area or for further similar projects, to set up network of gauging station at the catchment. Set of digital rainfall, temperature and discharge gauging station is technically and economically easy nowadays, that several such points should be realized soon and would record very valuable data.

8.1 Discussion of results and designs

Outputs of the study give good frame overview and relatively reliable information for basic design. Results nevertheless have to be properly interpreted.

There has to be mentioned from point of view of reliability, that number of simplifications, hypothesis and assumptions were adopted and introduced into calculations. All modelling nevertheless stays on the side of security (always the most unfavourable alternative was concerned), therefore, design should not collapse.

Main factors, which should be mentioned as limiting accuracy of calculations, are:

- Lack of meteorological data from target area or near locality with comparably conditions
- Lack of data about soil and geological conditions
- Any reliable verification of hydrological data from field or hydrological measurement
- Satellite images with number of errors

All mentioned limits introduces uncertainty into design, which then has to be compensated by adoption another hypothesis and assumptions.

Basic limits of preformed calculations and modelling can be presented as follows:

- No sediment transport has been introduced into calculations and design, which is however very important process in such conditions. Designed water reservoir will definitely be necessary to protect for instance by sediment trapping sub-reservoir.
- Due to lack of relevant input data, there was not possible to introduce standard used excedance curves (in case of discharges flow duration curve) and return periods into analyses. Design values were derived from modelled time series with duration of 46 years. Extremes, recorded within mentioned time series, were declared as design values. Rough return period of design parameter is therefore ca 50 years.
- Rough return period 50 years nevertheless seems to be fully relevant to intensity of inhabitation and land-use and even lower security could be acceptable
- Satellite data, which doubtless are used by army were not available in any form for presented study. Only data recorded by current high resolution civil satellite IKONOS and QUICK BIRD has been delivered. But their quality has been very much

negatively affected by previous preprocessing. This is potential source of errors in land-use classification. Nevertheless, as manual classification has been finally selected as only applicable, expected error is nearly negligible.

- Delivered DTM also showed number of errors, especially in flat areas along stream channel. DMT, used for hydrological and hydraulic modelling had been therefore generated using number of procedures to remove pits and hills, which are only partly manually driven. The bottom of the reservoir and elevation of head of the dam, the same as all designed water levels, are therefore characterized in relative values – as heights above bottom and not in absolute elevations above see level. DMT modifications very probably did not affect basic morphology of the valley, that characteristic lines of the reservoir and volumes are correct.
- Water level fluctuation in the reservoir has also not been evaluated from point of view of dam and banks security. The design assumes, that reservoir, with water depth 30 m will be fully emptied during ca 3 months and then during next ca 3 months it will be filled back again. Before final detailed design is specified, this task has to be assessed seriously.
- Water reservoir balance considered only inflow, withdrawal for irrigation and evaporation from water level. Neither any other losses, nor hygienic minimum discharges under dam profile were considered.
- For any further activities at Khoshi catchment or any other locality in Logar, there is strongly recommended to set up several gauging stations directly in the catchments. As very valuable there are measurements of precipitations, temperatures and discharges.

Generally there can be stated that Study in farm as it is presented and properly interpreted in agreement with listed information fulfilled setting can be applied as reliable source for further planning and decision making in Khoshi valley, or be used as sample and methodology for other similar activities and projects

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10. Appendics

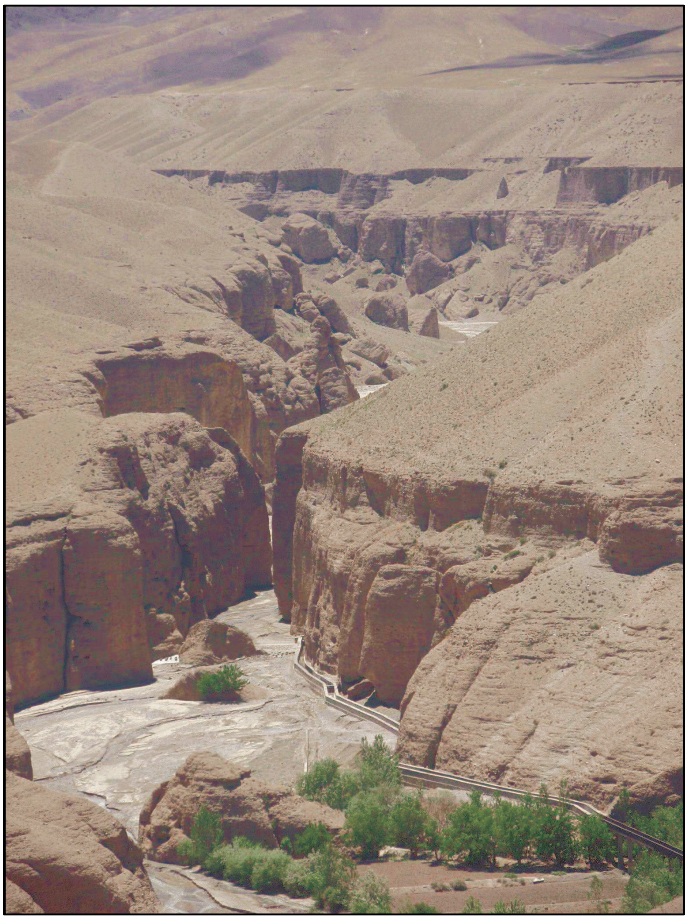
10.1 Photos

Photos should illustrate character of target area. They were shot by members of PRT

Agriculturally used area (Khoshi)

Valley above designed dam profile

River channel in place, where it operates also as local road (Shinkay)



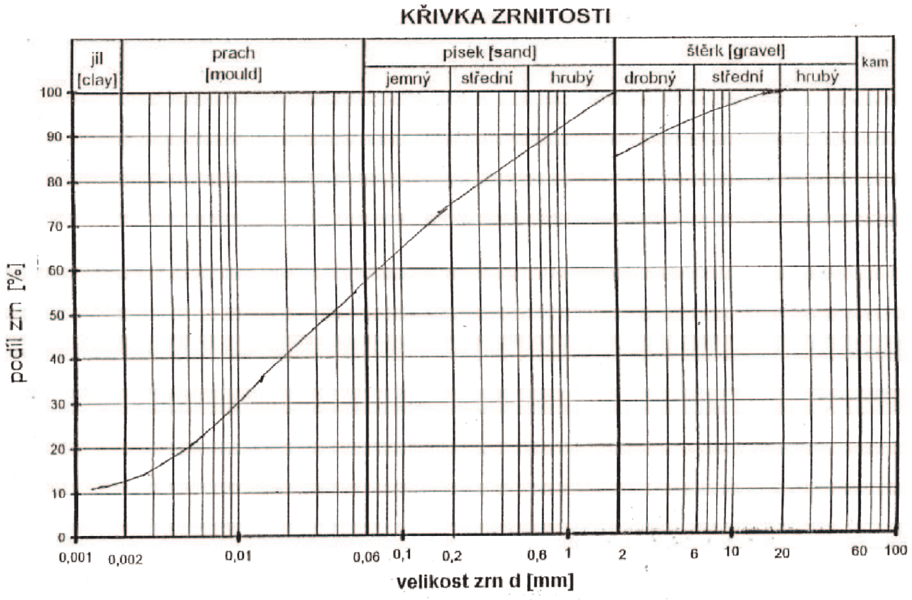
Profile of designed dam and beginning of agriculturally used area

Typical view to river within target area

Gravel cones with sparse vegetation

Panoramic view to agriculturally used area

10.2 Grain size distribution lines for soil samples



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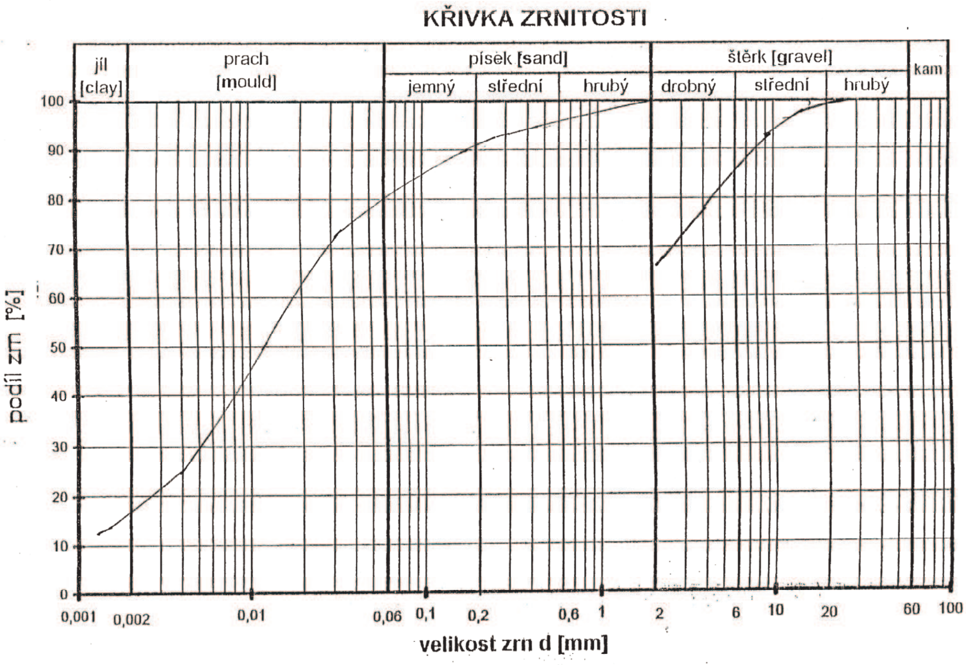

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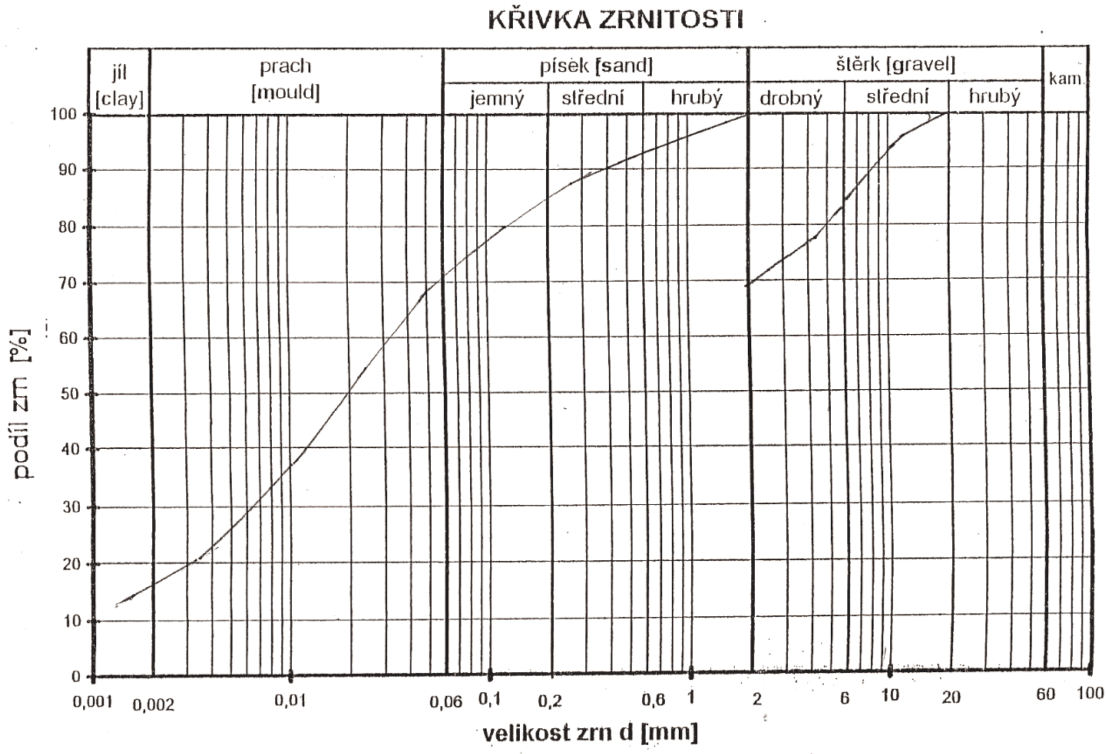

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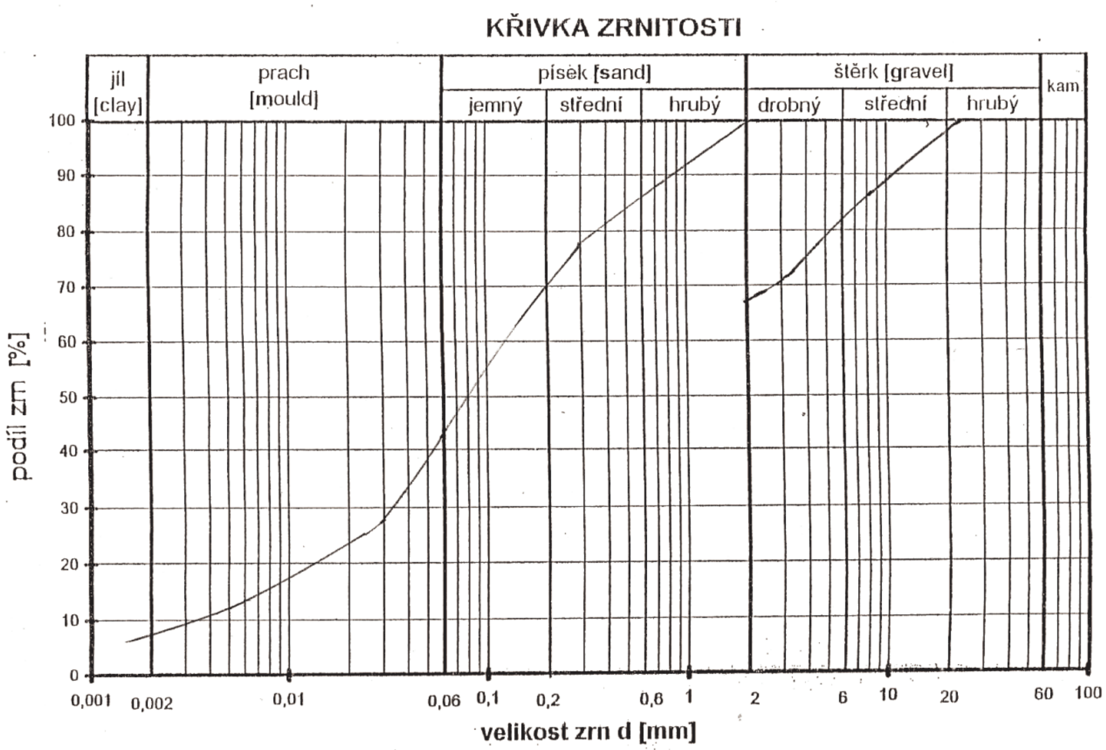

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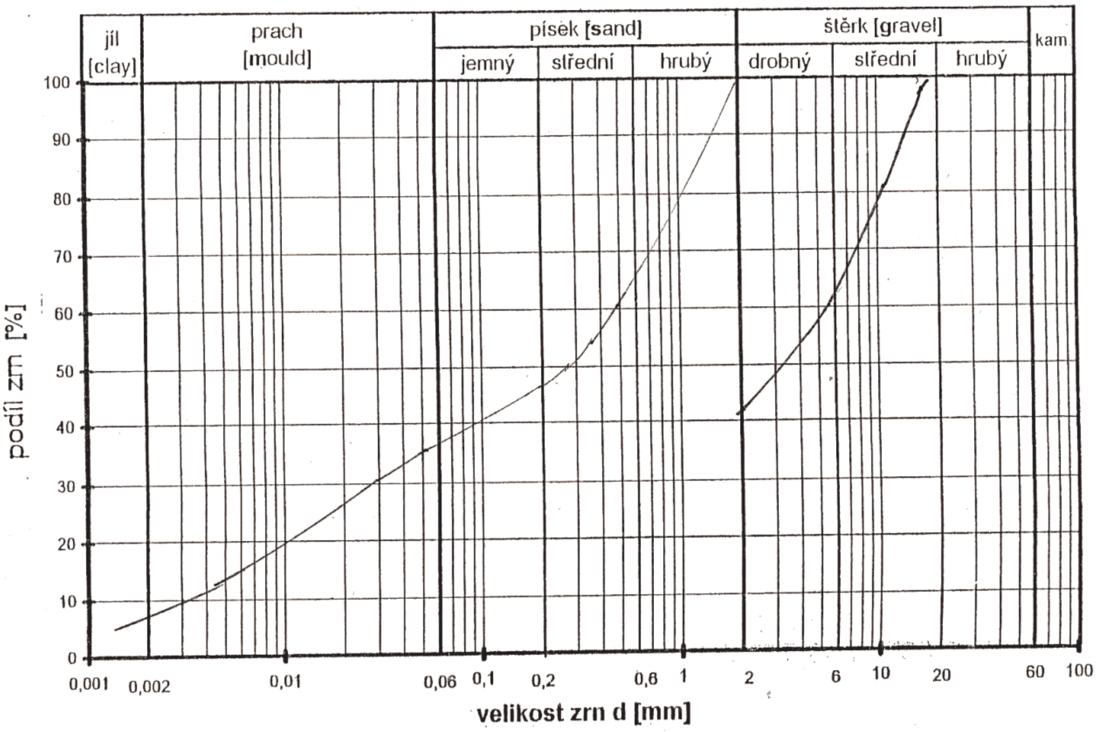

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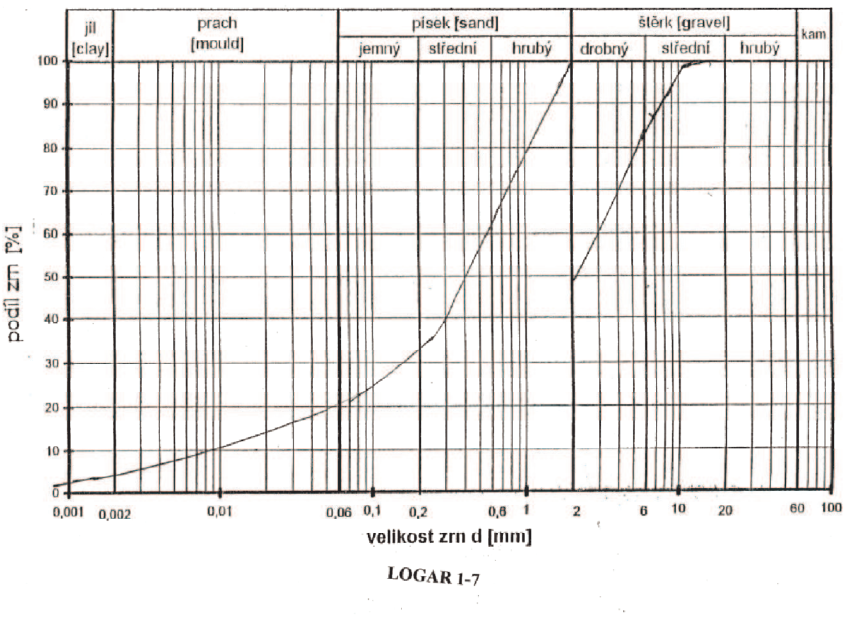

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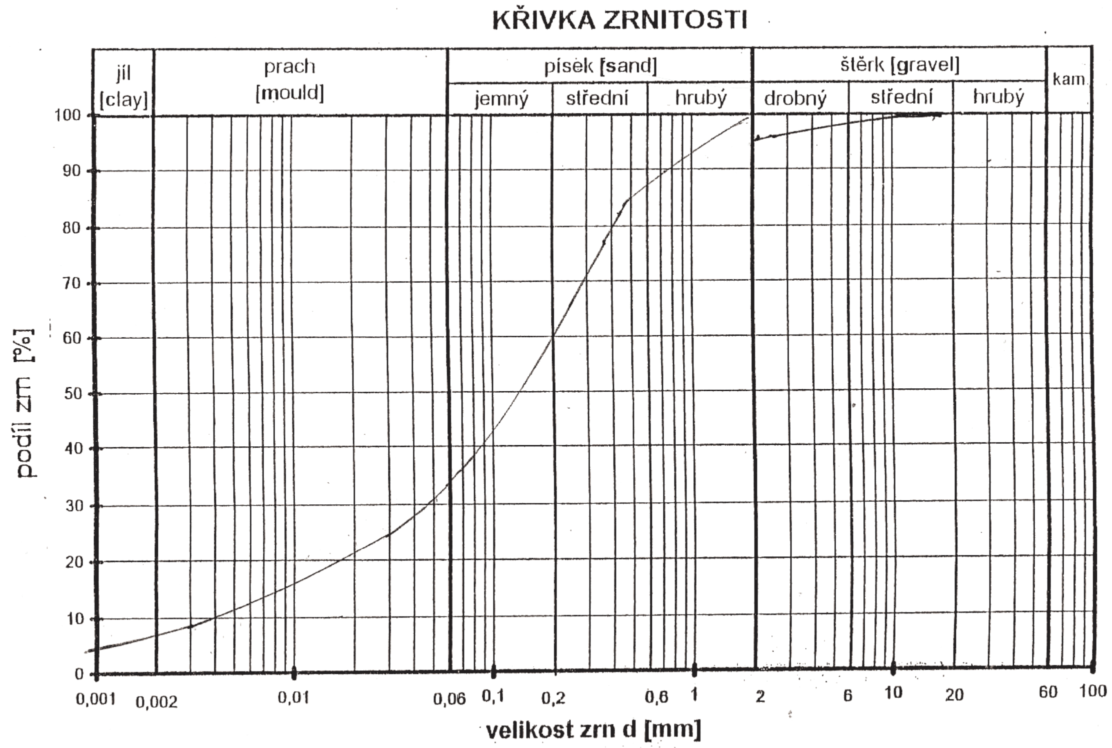

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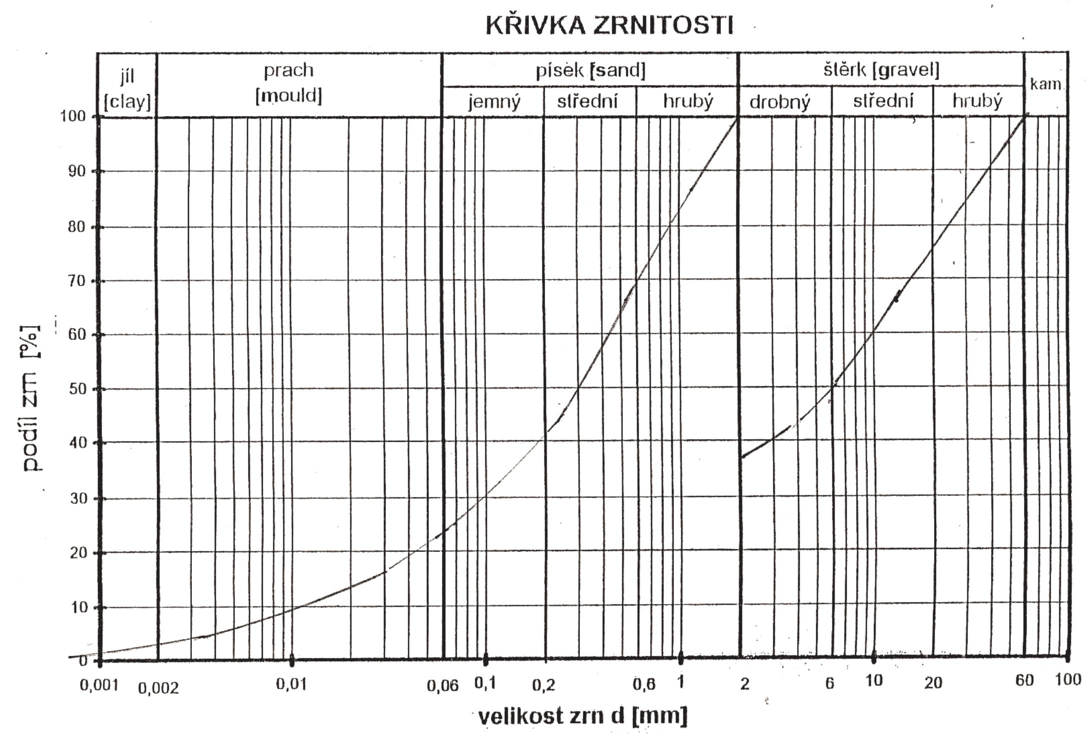

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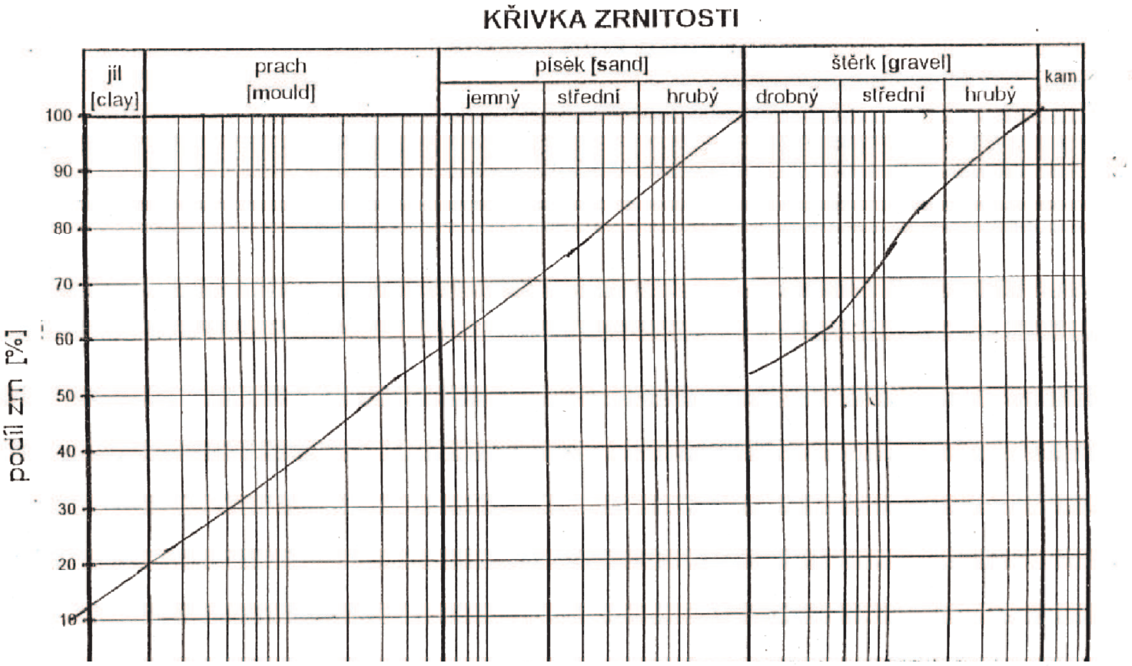
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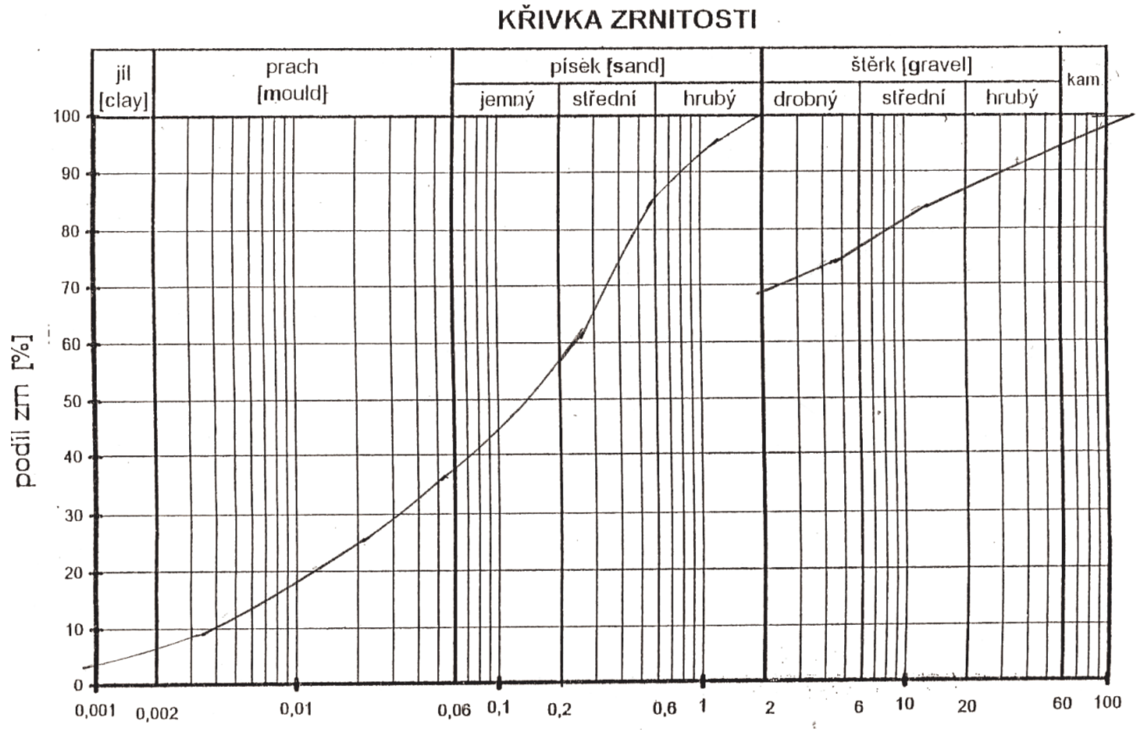
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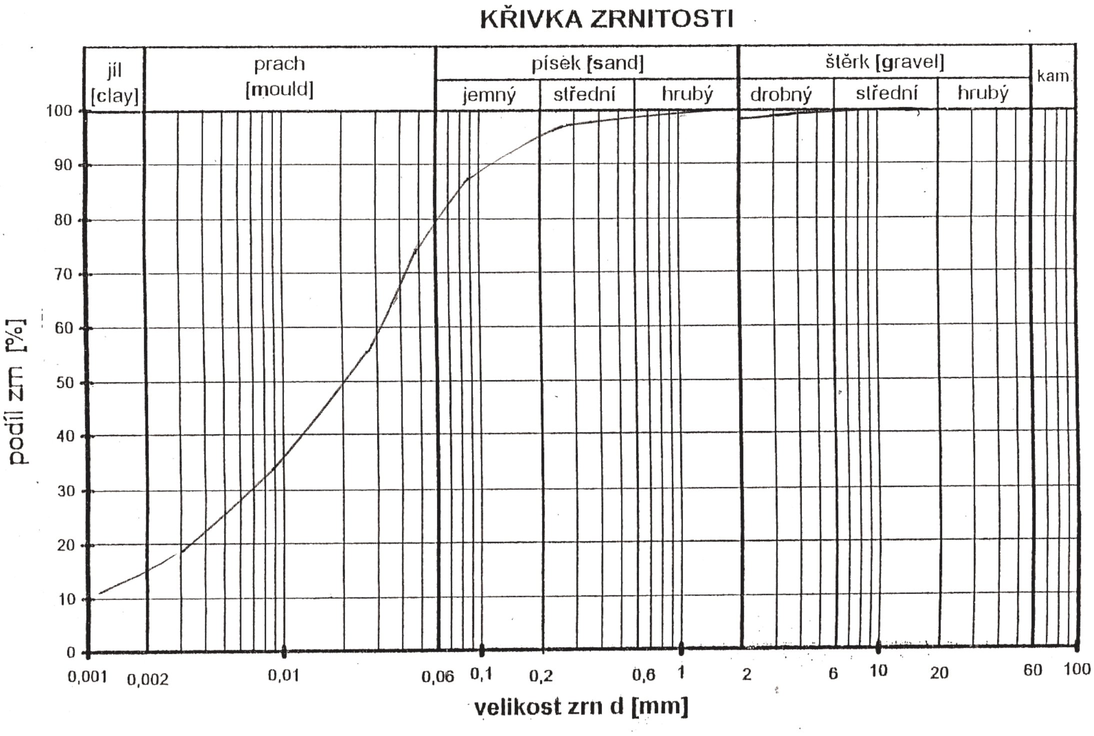
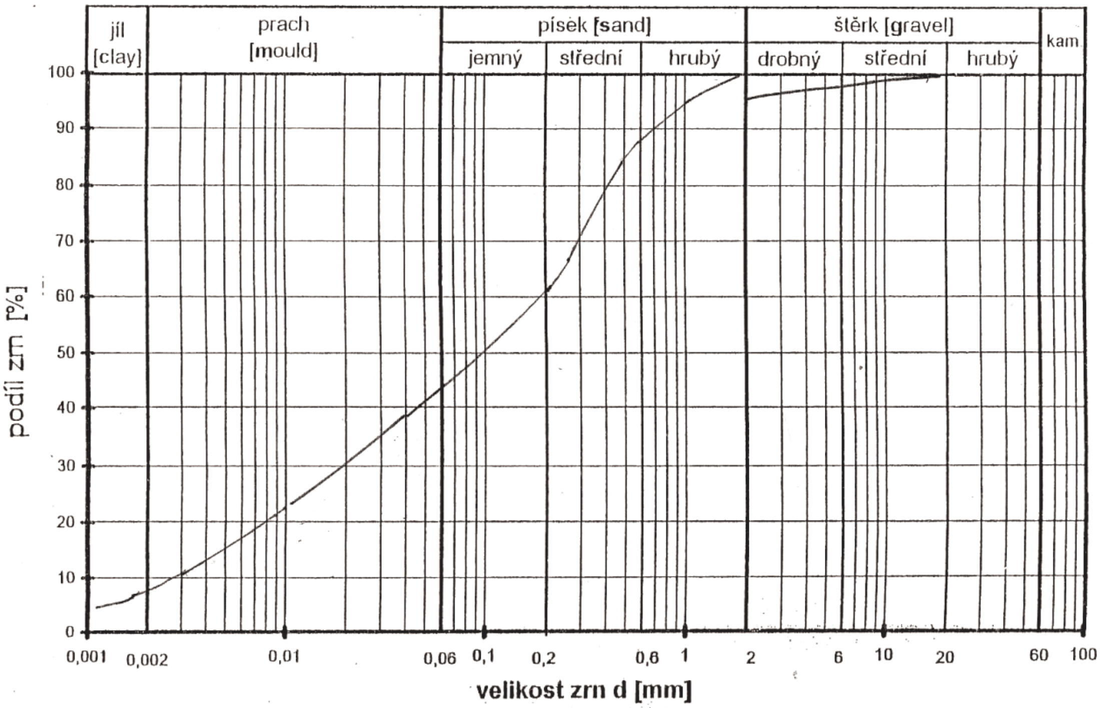
jíl [clay]
prach [mould]
písek [sand]
jemný
střední
hrubý
štěrk [gravel]
drobný
střední
hrubý
kam
podíl zrn [%]
100
90
80
70
60
50
40
30
20
10
0
0,001
0,002
0,01
0,06
0,1
0,2
0,6
1
2
6
10
20
60
100
velikost zrn d [mm]

LOGAR 2-2


KŘIVKA ZRNITOSTI
jíl [clay]
prach [mould]
písek [sand]
jemný
střední
hrubý
štěrk [gravel]
drobný
střední
hrubý
kam.
podíl zrn [%]
100
90
80
70
60
50
40
30
20
10
0
0,001
0,002
0,01
0,06
0,1
0,2
0,6
1
2
6
10
20
60
100
velikost zrn d [mm]

LOGAR 3-2

KŘIVKA ZRNITOSTI



LOGAR 3-33

11. Lists

11.1 List of figures

11.2 List of tables