WP7 Water resources

Action 7.3 – Report

Analysis of the contribution of permafrost ice to the hydrological water regime

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(1) The hydrologic balance of the Lazaun cirque, Schnals Valley

The Lazaun cirque was chosen for computing this hydrologic balance because discharge measurements of the rock glacier runoff were available, the catchment area is very well defined and documented by geological field mappings. In addition a thermo-pluviometric station was available at Kurzras.

The hydrologic balance of the hydrologic watershed indicated in Fig. 1 and it is given by the following equation:

$$P = R + Er + I + dw + dq$$

where:

P = precipitation

R = runoff

Er = reference evapotranspiration

I = infiltration

dw = the variation of the quantity of groundwater reserves

dq = the result of human intervention

Considering the factors dw and dq as negligible, this equation becomes:

$$P = R + Er + I$$

<u>**Precipitation and Evapotranspiration**</u>

Hydrometeorological data as temperature and precipitation (snow + rainfall) are available from the thermo-pluviometric station of Kurzras (2012 m s.m./ü.M.), which is located very closely to the interested watershed (Fig. 1).

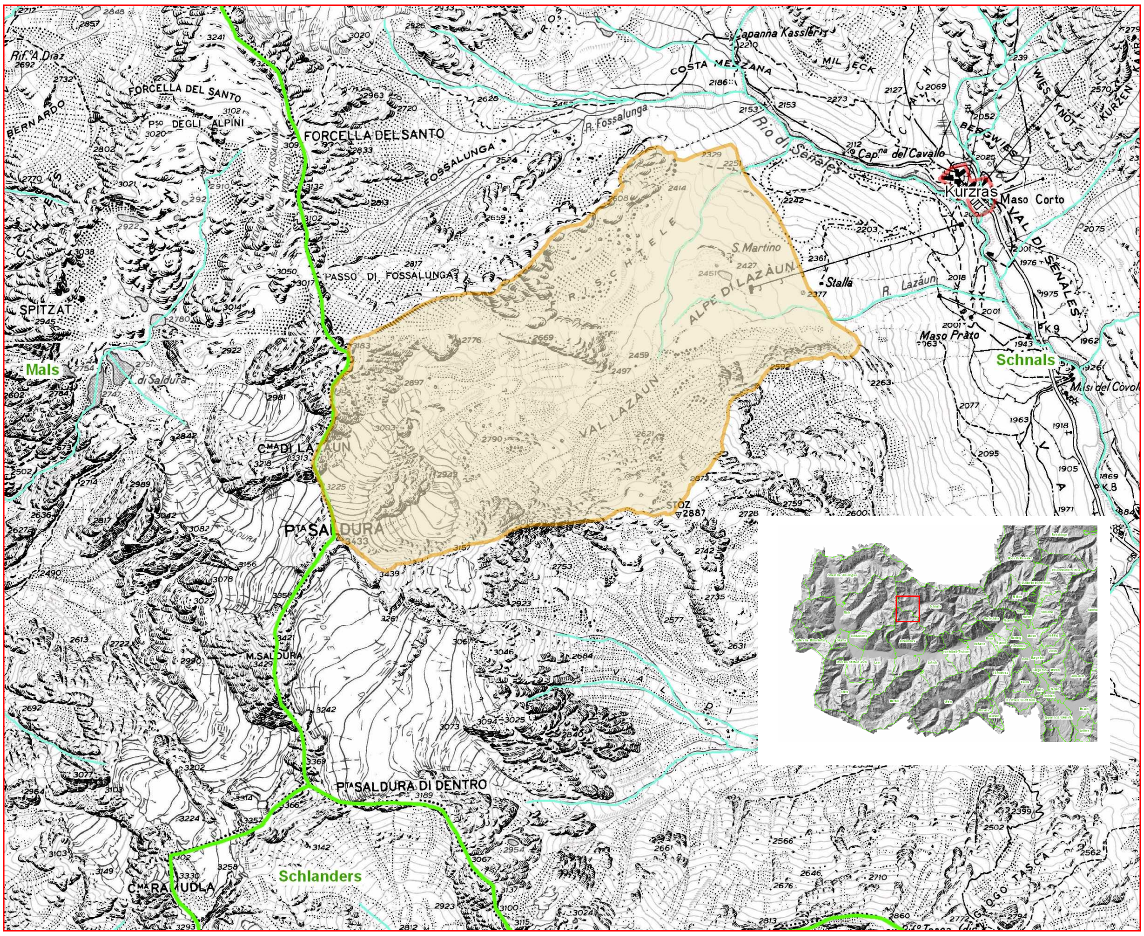

Fig. 1 – Interested area and Kurzras station location

Average monthly precipitation (snow+rainfall) (Kurzras, period 2001-2010):

	Pi mm/month	**Pi * 1,15** mm/month
January	20,8	23,92
February	17,6	20,24
March	33,5	38,53
April	34	39,10
May	78,2	89,93
June	90,1	103,62
July	97,6	112,24
August	102,1	117,42

September	53	60,95
October	51,1	58,77
November	78,1	89,82
December	23,3	26,80
Mean annual precipitation	**679,4**	mm/a
maP Mean annual precipitation * 1,15	**781,31**	mm/a

Correction of precipitation data with the altitude requires the use of a coefficient (1,15) suitable for the Senales Valley (suggested by the Hydrographic Office of The Autonomous Province of Bolzano).

Basing on precipitation data the **reference evapotranspiration (Er)** was calculated from the mean monthly temperatures from the years 2001-2010 (Kurzras station), basing on the empirical equation of *Turc*:

$$Er = \frac{P}{\sqrt{0{,}9+(P^2/L^2)}}$$

where **L** is defined as the evaporation power of the atmosphere and calculated:

$$L= 300+25Tc+0{,}05Tc^3$$

Tc = the mean monthly temperature corrected with the rainfall (as expected by Turc method)

$$Tc = \frac{\sum Ti*Pi}{\sum Pi}$$

Pi = average monthly rainfall (mm)

Ti= average monthly temperature (T°C)

The average monthly air temperatures (Kurzras, period 2001-2010) were adjusted with the altitude of the watershed, considering a decrease of ca. 1°C / 100 m of altitude and, at the end, with the rainfall (Tc):

	T °C measured	**Ti** T°C/altitude	**Pi * 1,15** mm/month	**Ti*(Pi *1,15)** T°C/altitude*(Pi*1,15)
January	-4	-10	23,92	-239,20
Febrauary	-5	-11	20,24	-222,64
March	-5	-11	38,53	-423,78
April	1	-5	39,10	-195,50
May	7	1	89,93	89,93
June	10	4	103,62	414,46
July	12	6	112,24	673,44
August	11	5	117,42	587,08
September	7	1	60,95	60,95
October	4	-2	58,77	-117,53
November	-1	-7	89,82	-628,71
December	-4	-10	26,80	-267,95
			781,31	-269,45
Tc (Average T °C corrected)	**-0,3449**			**∑ Ti*(Pi*1,15)**

Er Reference evapotranspiration (Turc)			
L =	**291,38**		
Er =	**274,69**	mm/a	**35,16 %** of maP

A rough of the effective precipitation has been calculated:

$$maP - Er = Pe = I + R$$

Effective precipitation (Pe)	**506,62**	mm/a

Potential infiltration and potential infiltration coefficient

The **potential infiltration (Ip)** depends on the structural and lithological features of the ground and it is given by the following relation:

$$Ip = Pe*P.i.c.$$

where P.i.c. is the potential infiltration coefficient and represents the percentage of the water able to infiltrate into the underground. Basing on the geological map elaborated by Bressan D. in 2007 and transferred with ArcMap, the area of each lithotype has been calculated and associated with a P.i.c. (http://151.100.152.9/website/people/ltulipano/dispense/idro/0607/cap2_0607.pdf) (Fig. 2).

Areas covered by glacier, active rock glaciers and lakes are considered with P.i.c = 0. Their contribution is not considered as infiltration contribution but only in terms of runoff **(1*).**

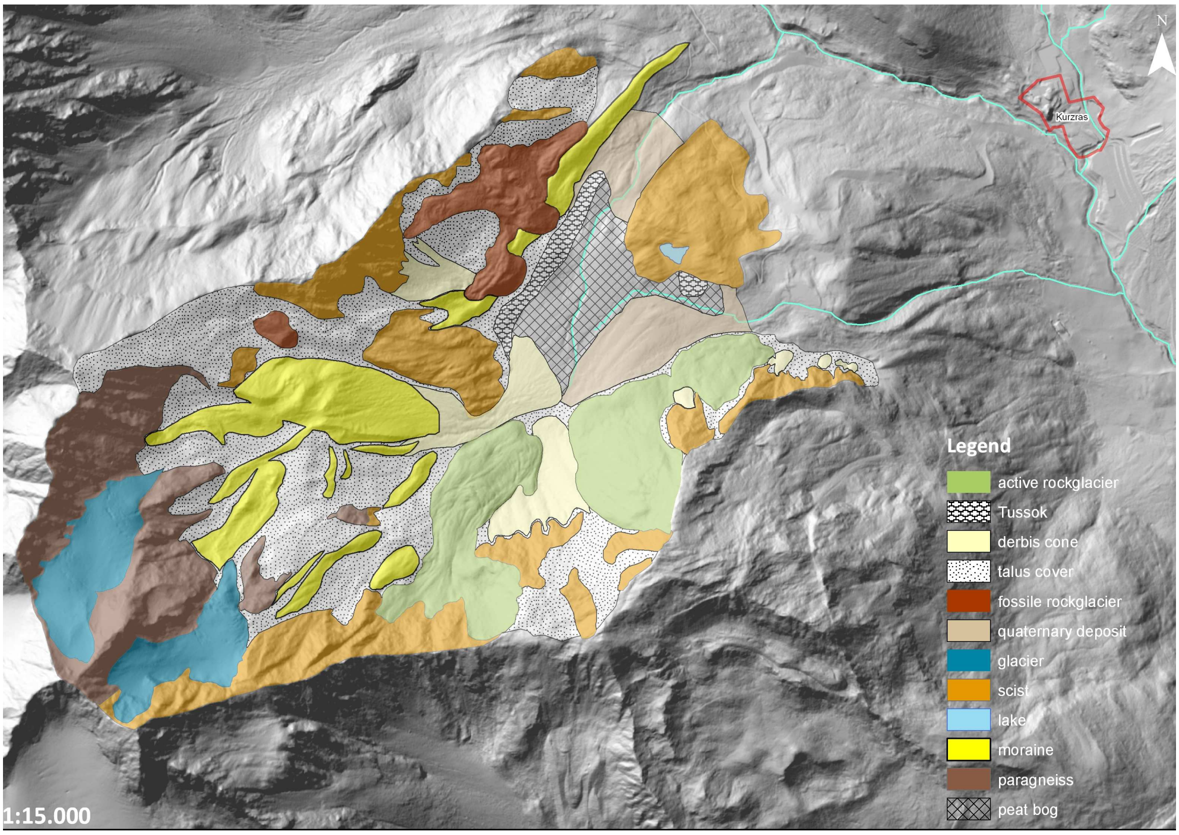

Fig. 2 – Geological map (each lithotype corresponds to a different P.i.c.)

	Area (m^2)	P.i.c.	Area*P.i.c.
Quaternary deposit	116.942,27	0,40	46.776,91
Tussok	46.063,93	0,30	13.819,18
Debris cone	177.233,87	0,70	124.063,71
Talus cover	824.570,58	0,60	494.742,35
Fossile rockglacier	139.776,64	0,80	111.821,31
Scist	732.021,24	0,15	109.803,19
Moraine	369.604,49	0,22	81.312,99
Paragneiss	375.405,71	0,15	56.310,86
Peat bog	151.804,83	0,30	45.541,45
(1*)Watershed area less glacier/rockglacier area **(Wa)**	**2.933.423,57**	**Area*P.i.c. sum**	**1.084.191,94**

Weighted mean P.i.c.	**0,37**	= Wa/Area*P.i.c sum

Pe =	506,62	mm/a
	1.486.127,01	m^3/a
	0,05	m^3/s
	47,12	**l/s**

Ip = Pe * P.i.c.

Ip =	187,25	mm/a
	549.271,83	m^3/a
	0,02	m^3/s
	17,42	**l/s**

<u>Runoff</u>

Pe – Ip = R where R is the runoff

R =	319,37	mm/a
	936.855,18	m^3/a
	0,03	m^3/s
	29,71	**l/s**

The water contribution to the balance of the remaining area covered by glacier and active rockglacier are considered in terms of runoff:

	Area (m²)
Glaciers	227.311,74
Active rockglacier Lazaun	188.716,71
Other active rockglaciers	207.932,34

Runoff from glacier area (melting + runoff)

R glacier =	36.897,12	m^3/a
	1,17	**l/s**
*glacier discharge => Ölgrube glacier = 15,4 l/s*km²*		

The contribution of the glacier was calculated considering the data collected for the Ölgrube glacier (Ötztal).

Runoff from the rock glaciers (melting + runoff)

Lazaun rockglacier

Runoff contribution from melting **Rm** (value indicated in the Action 7.2 Report by Karl Krainer, estimated from the surface subsidence achieved from the DGPS measurements):

Rm rockglacier Lazaun =	9.100	m^3/a
	0,29	**l/s**

Runoff contribution from precipitation **R** (assumption: precipitation = runoff)

R rockglacier Lazaun =	95.607,4	m^3/a
	3,03	**l/s**

Other rock glaciers

Runoff contribution from melting **Rm**

Rm other rockglacier =	7.519,94	m^3/a
	0,24	**l/s**

The water contribution of this area considered as active rock glacier is related to their extension and assume only for 75%

Runoff contribution from precipitation **R** (assumption: precipitation = runoff)

R other rockglacier =	105.342,40	m^3/a
	3,34	**l/s**

At watershed level the result of the **hydrologic balance** (referred to one year) is:

Effective precipitation **Pe**	506,62 mm/a	**47,12 l/s**
Potential infiltration **Ip**	187,25 mm/a	**17,42 l/s**
Runoff **R**	319,37 mm/a	**29,71 l/s**
Runoff glacier contribution		**1,17 l/s**
Runoff melting Lazaun rockglacier		**0,29 l/s**
Runoff Lazaun rockglacier		**3,03 l/s**
Runoff melting other rockglacier		**0,24 l/s**
Runoff other rockglacier		**3,34 l/s**
Total runoff from the whole Lazaun cirque		**37,78 l/s**

The rock glacier runoff discharge from melting permafrost is about **1,4%** (0,53 l/s) of the total runoff (37,78 l/s) which is very small.

(2) Hydrologic balance of the Lazaun rockglacier watershed

As indicated within the action 7.2 report the average runoff discharge from the rockglacier watershed results about 26 l/s (between July-October, direct measurements) including precipitation and ice melting. This corresponds to a value of **8,67 l/s** per year.

Proceeding with the hydrologic balance of the Lazaun watershed we have to calculate the **potential infiltration (Ip)** in the Lazaun watershed not covered by ice with the definition of the weighted mean **p.i.c.** (**potential infiltration coefficient**).

Geology of Lazaun watershed	Area (m^2)	p.i.c	Area*p.i.c
Debris cone	15.087,03	0,70	10.560,92
Talus cover	129.653,24	0,60	77.791,95
Scist	154.907,70	0,15	23.236,16
Moraine	45.614,30	0,22	10.035,15
Paragneiss	8.734,30	0,15	1.310,15
Watershed area less glacier/rockgkacier area **(Wa)**	**353.996,58**		**122.934,31**
	Area (m^2)		
Rockglacier Lazaun	188.716,71		

Weighted mean p.i.c.	**0,35**	= Wa/(Area*p.i.c)

Effective precipitation **Pe** was already calculated

Pe =	506,62	mm/a
	179.341,26	m^3/a
	0,01	m^3/s
	5,69	**l/s**

Ip = Pe*WmP.i.c.		
Ip =	175,94	mm/a
	62.280,81	m^3/a
	0,002	m^3/s
	1,97	**l/s**

Rp = Pe – Ip	330,68	mm/a
	117.060,45	m^3/a
	0,004	m^3/s
	3,71	**l/s**
Rm rockglacier Lazaun =	9.100	m^3/a
	0,29	**l/s**
Rr rockglacier Lazaun =	95.607,3996	m^3/a
	3,03	**l/s**
Rp + Rr + Rm	**7,03**	**l/s**

The calculated value (7,03 l/s) fits very well with the value (8,67 l/s) directly measured by Karl Krainer.

(3) Contribution of rock glacier melting to the hydrologic balance of South Tyrol

Considering that in South Tyrol about 18.773.519m² are covered by active and 7.281.233m² by inactive rock glaciers we get the following assumptions:

- % of the overall rockglacier area covered by ice: **53%** (*) of active and **15%** (**) of inactive rockglaciers.

  (*) calculated from the Lazaun rock glacier

  (**) assumption
- considering a thickness of the frozen core of 6m for active and 1,5m for inactive rock glaciers.
- Considering that an active rock glacier releases about 0,3 l/s by melting (0,2 l/s inactive rock glacier).
- Ice Volume active rock glaciers: 59.699.790,42m³
- Ice Volume inactive rock glaciers: 1.638.277,43m³
- Melting active rock glaciers: 179,10 l/s in one year
- Melting inactive rock glaciers: 3,28 l/s in one year

The total melting of rock glaciers is about 182,38 l/s (= 0,18 m³/s), this is about **0,13%** of the total runoff of South Tyrol (142,76 m³/s).