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# 4.1. Hydrography

Water relations, including runoff and retention, are shaped in polar catchments by the impact of specific elements of the natural environment. Of particular importance are the climate conditions, especially precipitation and air temperature. These factors determine the amount and type of precipitation, surface retention, evapotranspiration and sublimation, as well as runoff and its seasonal differences. In sub-zero temperatures, the waters in polar catchments are periodically retained nearly in full. In contrast, during periods with above-zero temperatures, different forms of runoff occur. The genetic criterion allows us to distinguish the following water types: proglacial, pronival, permafrost and rainwater. Another important factor in water circulation is the presence of permafrost, the thickness of which is estimated to be 200-500 m (Hisdal 1998).

## Runoff

Hydrological studies were carried out in summer seasons 1986-2005 in the area spread between the Bellsund to the north, the Chamberlindalen to the east, the Dunderdalen to the south and the Greenland Sea to the west. Investigations focused on hydrographic mappings, the goal of which was to identify the sources of water supply to local rivers, to determine the extent of glaciers and the dynamic and volume of glacier river runoff. Stationary hydrometric measurements were taken with regard to two basic hydrometric profiles, i.e. glacierised and non-glacierised catchments; patrol measurements were conducted in the remaining areas (Fig. 4.1.1).

In glacierised or partly-glacierised catchments the dominant component of runoff are glacier meltwaters. Whereas in non-glacierised catchments the runoff is comprised of snow water, rainwater and permafrost water. The phase changes of ice in active layer allows the periodic runoff to occur. Ground ice, which fills pores and small voids, is subject to graduate thawing during warm season of the year. During the polar summer, water accumulates on 'the waterproof' permafrost table and forms a saturation zone of varying thickness – the supra-permafrost layer. Water retention of the active layer depends on the thawing rate and to a large extent on the infiltration of meltwater and rainwater. Detailed studies concerning the conditions for occurrence and circulation of these waters within the active layer have been running in the area of Calypsostranda since 1989 (Michalczyk 1990). Studies focused on the raised marine terraces with good conditions for water infiltration, as the filtration coefficients, calculated using field methods, are between a dozen or so and several hundred meters per 24 hours. Drainage capacity rates, calculated using indirect methods, were between 0.05 and 0.25. The area is not very rich in water, as the supra-permafrost water layer is usually very thin – between several and a dozen or so $dm^3 \cdot m^{-2}$ (Michalczyk 1990).

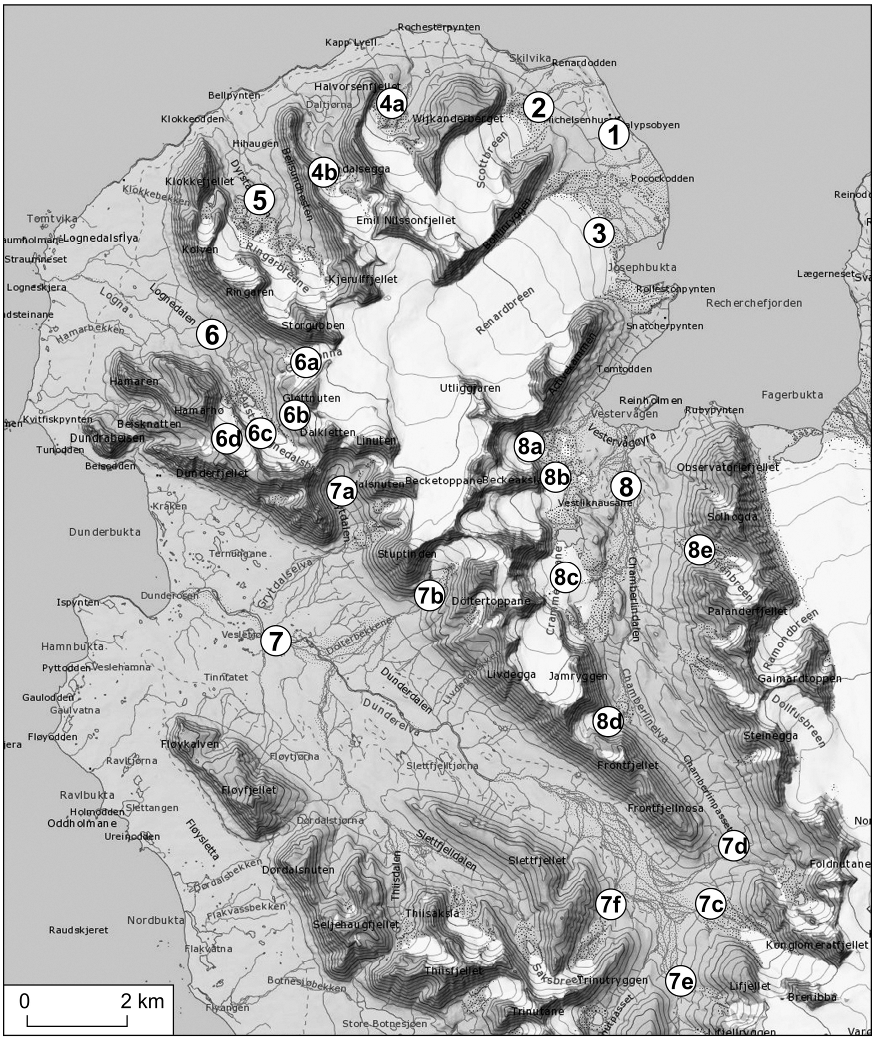


Fig. 4.1.1 Location of described catchment (background: Topo Svalbard, Norwegian Polar Institute): 1- Tyvjobekken, 2- Scottelva, 3- Renardbreen, 4a- Blomlielva, 4b- Tjørnelva, 5- Dyrstadelva, 6- Logna, 6a- Gløttfonna, 6b- unnamed glacier, 6c- Austre Lognebreen, 6d- Vestre Lognebreen, 7- Dunderelva, 7a- Grytdalselva, 7b- Dölterbekkene, 7c- Dunderdalsbreen, 7d- Konglomeratfjellet, 7e- Libreen, 7f- Saksbreen, 8- Chamberlinelva, 8a- Crammerbreen I, 8b- Crammerbreen II, 8c- Crammerbreen III, 8d- Crammerbreen IV, 8e- Bøckmanbreen.

The characteristics of the hydrological regime of the supra-permafrost layer were determined based on thickness measurements of the aeration and saturation zones, the analyses of location and dynamics of the groundwater table, the estimated amount of static and dynamic supplies and the relation between runoff intensity and the dynamic of groundwater table (Bartoszewski 1998; Bartoszewski *et al.* 1993). Geographical diversity of the environment, in particular the bedrock lithology, the soil humidity and the vegetation cover led to the formation of different polar ecosystems. The largest potential for water retention is in humid tundra ecosystems with moss patches, often on peat lands, with numerous little lakes of cryogenic genesis and various sorted circles formed in gravel and clay surfaces.

Changes in groundwater levels were similar throughout the years, and any observed differences were the results of the location and the amount of rainfall. At the beginning of the summer season the hydrograph of water levels was similar to a drying curve. The water supplies (both static and dynamic) from the active layer were diminishing. The decrease in underground retention was accompanied by a decrease in surface water sources. Already at the beginning of August the little tundra lakes were drying out and runoff from small streams stopped completely. During certain research seasons, e.g. in 1990, this tendency persisted all the way until autumn. On the other hand, if the volume of precipitation in the summer was high, e.g. in 1989 and 2002, the a rise in the ground water surface levels, the increase of retention and the reoccurrence of river runoff were observed (Bartoszewski 1998, 2007a; Michalczyk 1990). Data from a piezometer located on mossy-grassy tundra ca. 50 m from Tyvjobeken (Wydrzyca Stream), showed that on the of 25th August, 2002, the water table level rose 40 cm between 1:00 a.m. and 1:00 p.m. Such a rapid rise of groundwater level was associated with a heavy rainfall that reached 31.6 mm (Fig. 4.1.2).

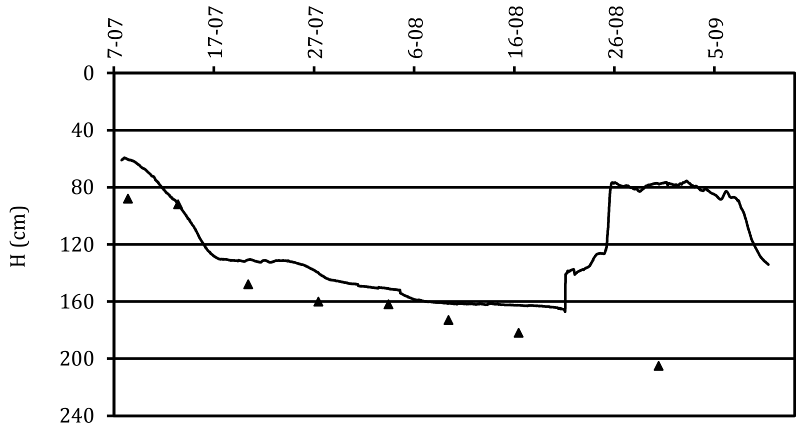


Fig. 4.1.2. The changes in underground water level position in piezometer (solid line) and the top of permafrost (triangles) in summer 2002.

The amplitude of groundwater table level fluctuations in respective ecosystems ranged between several dozen centimeters to 1.5 m. The static waters supplies calculated on the basis of the thickness of the saturation zone and the drainage capacity rates, ranged between 0 and 200 mm. The analysis of drying curves of selected tundra streams showed that water retention in the active exchange layer, i.e. the amount of water that could be drained due to gravity, was several times lower and amounted up to 20-30 mm.

In both types of catchments the course of runoff, its volume and variability was determined to a large degree, by the amount of the winter snow accumulation and the specific meteorological conditions occurring during the active hydrological period.

In the case of glacierised areas, the main subject of hydrographic studies was the Scottbreen catchment. Complementary studies took place in the catchments of Blomlibreen and Tjørndalsbreen located to the west of Scottbreen. No stationary hydrometric measurements were taken in the remaining catchments. Only patrol measurements of flow were conducted, allowing to estimate the volume of water supplies (Table 4.1.1).

Table 4.1.1. Differentiation of river discharge of NW part of Wedel Jarlsberg Land.

| Catchment | Catchment area to place the measuring point ($km^2$) | Mean discharge ($dm^3 \cdot s^{-1}$) | Discharge in 20.07-9.08 1988 ($dm^3 \cdot s^{-1}$) | Discharge in 27.07-11.08.2005 ($dm^3 \cdot s^{-1}$) |
|---|---|---|---|---|
| Scottelva | 10.1 | 890 | 1,252 | 1,015 |
| Renardbreen | 41.0 | | 5,374 | 5,794 |
| Blomlielva | 7.0 | 734 | | |
| Tjørnelva | 6.2 | 447 | | |
| Dyrstadelva | 14.8 | | 1,057 | 991 |
| Logna | 5.9 | | 1,360 | 1,394 |
| Gløttfonna | 2.9 | | 560 | 218 |
| Grytdalselva | 6.4 | | 693 | |
| Dölterbekkene | 4.6 | | 692 | 340 |
| Konglomerat-fjellet | 4.6 | | 527 | 286 |
| Dunderdalsbreen | 5.4 | | 1,182 | 829 |
| Libreen | 4.7 | | 1,861 | 588 |
| Saksbreen | 2.5 | | 350 | |
| Bøckmanbreen | 3.7 | | 150* | 196 |
| Crammerbreane | 18.9 | | 2,173 | 1,717 |
| Chamberlinelva | 51.0 | | 3,574** | 6,153*** |

* measurement in 27.07.1987, ** measurement in 4.07.1987, *** measurement in 10.07.1987

In the case of non-glaciersied areas, the detailed hydrographic study of the small river catchment draining into the Recherchefjorden was carried out. The participants of the first polar expedition organised in 1986 by the Maria Curie-Skłodowska University introduce the name the Wydrzyca River (the Tyvjobekken).

## Catchment characteristics

**Tyvjobekken catchment.** The area drained by Tyvjobekken covers 1.3 km$^2$. The river flows into the SE Bellsund to the south of Calypsobyen. The length of the river – i.e. the section through which water flows constantly – is 1.15 km, and the average gradient is 41 ‰. The river originates in two periodic streams, that flow out of the slopes of Bohlinryggen, at the height of 100 m a.s.l., 1 km downstream, these two streams join with another one that drains water from a section of the extramarginal outwash plain of the Renardbreen. From this point on, water flows in the creek continuously. Tyvjobekken runs here through a narrow, deep gorge, 0.7 km long. A water level station is located in the mouth of the gorge.

The highest point of the Tyvjobekken catchment is at the level of 315 m a.s.l., and covers the fragment of the south-western slope of Bohlinryggen (Bartoszewski 1996, 1998) (Photo 4.1.1). The south-western part of the catchment is a fragment of the dead extramarginal outwash plain of the Renardbreen. The outwash plain surface is gradually sloping in the direction of NW. All the way until the year 1940 this was the runoff area for proglacial waters, which ran through three gorges in the lateral moraine of the Renardbreen (Zagórski *et al.* 2012). The watershed between the catchments of Tyvjobekken and the Smithbekken (Kjeftbekken – informal name after: Birkenmajer & Zastawniak 2005) located to the south has a zonal character (Michalczyk 1990). During the peak meltwater discharge, in the middle of June 1987, the runoff flowed through shallow channels in snow and ice cover, the Smithbekken bifurcated. As a result of bifurcation the part of the meltwaters flowed directly into the Recherchefjorden, and the rest of meltwaters flowed into the Tyvjobekken catchment.

Thanks to observations and measurements carried out since 1986 we can determine that the average runoff volume is 400 mm (Bartoszewski 1998). In the annual runoff the dominant part is played by pronival waters. During the spring-melt flooding period ca. 75% of total runoff the whole active hydrological period was out of the catchment (Fig. 4.1.3). During the measurements of daily runoff two types of variations were identified.

During the spring we can see an ablative runoff rhythm, which is the result of diurnal air temperature variations. The second variation type is related to the changes of permafrost thawing rate and the occurrence of rainfall. In 1987 the maximum flow rate was 640 dm$^3$·s$^{-1}$, and the average annual flow rate was 94 dm$^3$·s$^{-1}$.

Photo 4.1.1. The Tyvjobekken catchment (Photo S. Bartoszewski 2005).

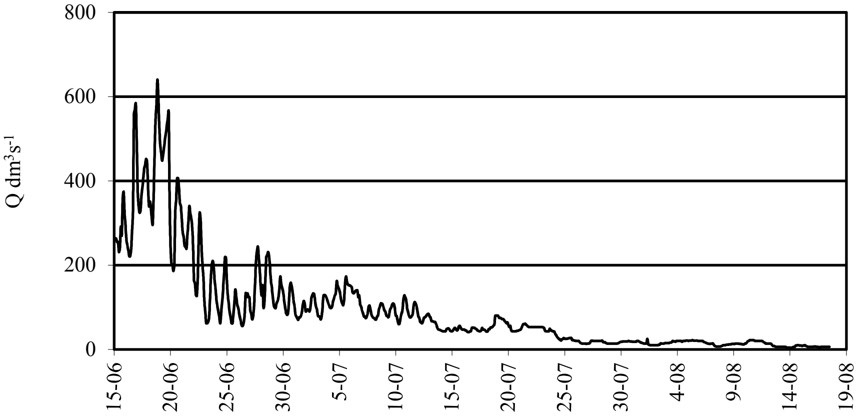


Fig. 4.1.3. The discharge of the Tyvjobekken in 1987.

**Scottelva catchment** The main object of comprehensive geographical studies within the group of glacierised catchments was the Scottelva catchment located in the direct vicinity of Calypsobyen. The glacier's catchment has been the main research interest during Maria Curie-Skłodowska University hydrographic studies since 1986 (Photo 4.1.2).

The catchment area of the Scottelva (Scott River) covers 10.1 km$^2$ and including 4.61 km$^2$ covered by Scottbreen in 2011 (see: Table 5.2.2). The glacier fills the mountain valley surrounded by the massifs of Bohlinryggen and Wijkanderberget. The upper part of Scottbreen reaches nearly 600 m a.s.l. In 2006 the glacier front was located at 80 m a.s.l. The glacier is 3.6 km long, and between 1.0 and 1.5 km wide, with an average gradient of 8°. At the level of approximately 300 m a.s.l. the glacier is strongly cracked; crevasses and glacial moulins receive a large portion of the waters flowing down from the upper parts of the glacier.

Photo 4.1.2. The Scottelva catchment (Photo S. Bartoszewski 2005).

The glacier's drainage system is very well developed. The surface runoff is governed by network of supraglacial streams. The supraglacial streams are best developed in the south-eastern (right) section of the glacier. The north-western section is drained only by a small number of little streams. The englacial drainage system is also best developed in the south-eastern section. This is the location of the glacier terminus, which accounts for over 50% of total glacial runoff. Studies conducted since 1986 have shown that the main subglacial outflow point shifts from the direction of NW to the SE. In 2002 the mouth of the tunnel was almost 2 m high and over 5 m wide. The glacier's largest moulin is located about 200 m above the front.

Proglacial waters are accumulated in a shallow marginal lake on the glacier forefield. From there, the Scottelva leads the waters away, through a gorge in the terminal moraine, towards the coastal plain. The outer out wash plane is intersected by a network of streams up to 1 m deep. The water flow rates in Scottelva were characterised by diurnal changes associated with hourly rhythm of changes in glacier ablation. Other irregular changes, were due to rainfall and led to significant increase of runoff. Fig. 4.1.4 presents changes of the flow rate observed during the longest (100 days) measurement period conducted between 1.07.1988 and 8.10.1988. The measurement profile closing the Scottelva catchment was located in a gorge incised in a raised marine terrace at the level of 30 m a.s.l. The average flow rate of the Scottelva measured at the keyprofile was ca. 0.90 $m^3 \cdot s^{-1}$, which corresponds to a runoff rate of 873 mm (Bartoszewski 2007b). The calculated runoff from the Scottelva catchment was similar to the results of other studies dealing with the central region of Spitsbergen. This was particularly evident when compared with the runoff of 1050 mm (in the period 1990-2001) measured in the Bayelva catchment, glacierised in 55% (Killingtveit *et al.* 2003).

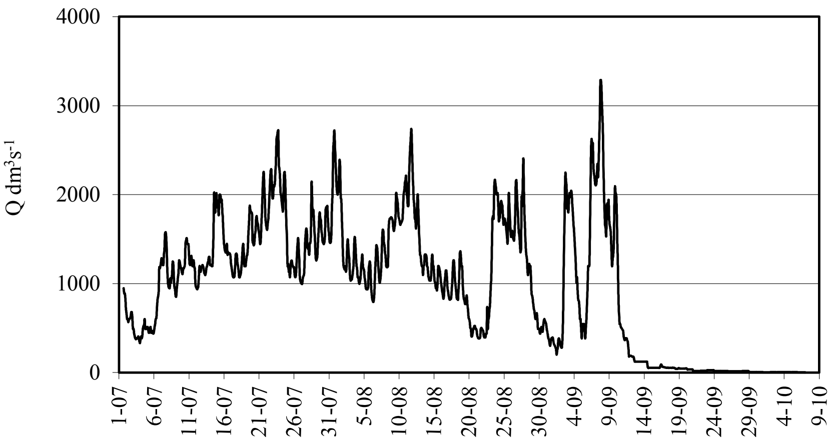


Fig. 4.1.4. The discharge of the Scottelva in 1988.

Period of high river discharges with high velocity of currents were characterised by intensive riverbed erosion and bed load transport of boulders. For example, during the flooding event which happened at the turn of 2nd and 3rd August, 1989 the riverbed was deepened by 0.3 m within a few hours, and the cross section increased by 1.25 $m^2$ (Fig. 4.1.5). The displacement of 20 x 30 x 20 cm rock blocks and high deposition of sediments in the mouth of Scottelva were observed.

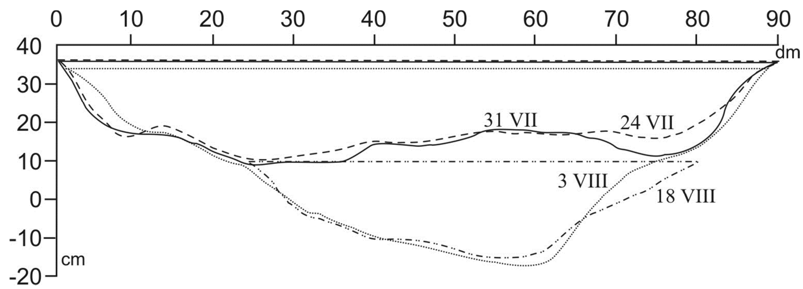


Fig. 4.1.5. The position changes of the bottom of the Scottelva in the water gauge in the summer of 1989 (dates indicate the position in the days of measurements).

**Renardbreen catchment.** Partially glacierised catchment covers 41 $km^2$, including 30.4 $km^2$ covered by Renardbreen (see: Table 5.2.2) Renardbreen is the largest glacier in the study area and is ca. 8 km long, and from 2.5 to 7.5 km wide (Zagórski *et al.* 2008b) (Photo 4.1.3A). The highest parts of the glacier are located at 720 m a.s.l., and its front is located at the sea level. Until 1990 the glacier terminated in waters of Josephbukta (Bartoszewski 1998, Zagórski *et al.* 2008b). The Renardbreen has a well-developed surface and internal drainage system. Glaciological studies of Renardbreen demonstrated the existence of a complicated system of internal drainage related to the polythermal character of the glacier (Bartoszewski 1998). Main subglacial outflow takes place through the glacier front (Photo 4.1.3B). One of the characteristic features of Renardbreen is the occurrence of the so-called Stenborg's effect (1969). Until the first part of July majority of subglacil channels are filled with snow and ice. In such a situation, a portion of the waters drained internally appears on the surface several dozen meters from the glacier front in the form of a large spring (Photo 4.1.3B).

The river network formed in Renardbreen proglacial zone is relatively young. It began to form once glacier started to retreat at the beginning of the 20$^{th}$ century after the termination of the Little Ice Age. In the period between 1936 and 2006 the glacier retreated ca. 720 m (Zagórski *et al.* 2008b).

Glacial waters flowed in several branches into the Recherchefjorden, what made it difficult to calculate the runoff. Between 1987 and 2005 more than 50 measurements of runoff were carried out. More than half of runoff volume is comprised of water runoff from the glacier front. The recorded flow rate values varied between 158 $dm^3 \cdot s^{-1}$ (27.06.1987) and 7153 $dm^3 \cdot s^{-1}$ (11.07.1990). The total value of glacial water runoff during the polar summer showed a similar dynamic to that observed in the Scottbreen catchment (Fig. 4.1.6). Based on this correlation, the average runoff in Renardbreen catchment was estimated to be 8.0 $m^3 \cdot s^{-1}$.

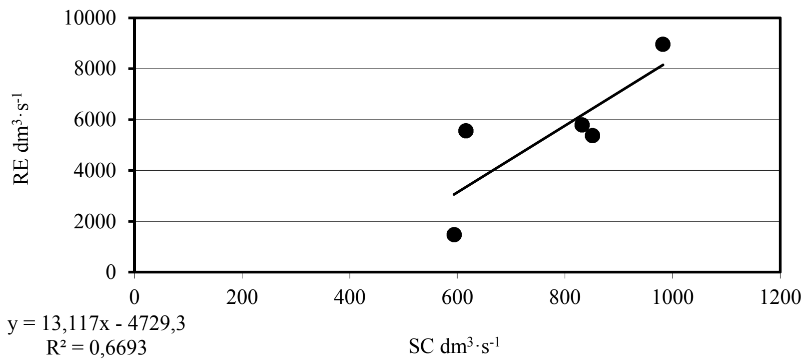


Fig. 4.1.6. Relations between the Scottelva discharge and total outflow from Renardbreen.

**Blomlielva and Tjørnelva catchments.** The areas of the Blomlielva and Tjørnelva catchments are slightly smaller than the Scottelva catchment (i.e. 7.0 and 6.1 $km^2$, respectively) and in the second half of the 20$^{th}$ century they were also glacierised to a lesser degree, the former in 25% of the area and the latter in 15% of the area (Photo 4.1.4AB). Blomlibreen and Tjørndalsbreen represent a transitional type between a valley glacier and a one cirque glacier. The highest part of the Blomlibreen is connected to the Scottbreen. The Tjørndalsbreen is located to the west of the Blomlibreen. These two are separated by the Emil Nilssonfjellet – 788 m a.s.l., the highest elevation point of the northern part of Wedel Jarlsberg Land. Glaciers fronts are located much higher than the the Scottbreen front: Blomlibreen at 270 m a.s.l. and Tjørndalsbreen at 400 m a.s.l. Glaciers fronts are surrounded by high terminal moraines and fields of roche moutonnées ('sheepbacks'). The ice thickness in the glacier fronts is significantly reduced. In the case of the Tjørndalsbreen areal deglaciation was observed. In the narrow marginal zone there are small reservoirs with an area of several hundred square meters that lack any form of surface drainage. These are shallow depressions in permeable ground consisting of angle-shaped rock blocks. Both glacier lack a direct surface runoff system. Former gorges that incised the frontal moraines are filled with rock debris. Water runoff occurs through tunnels eroded in ice-cored sections of the moraine. Beneath the moraine the proglacial waters appear in the form of highly efficient springs (Bartoszewski 1987). Springs supply rivers that erode up to 15 m deep gorges in the raised marine terraces.

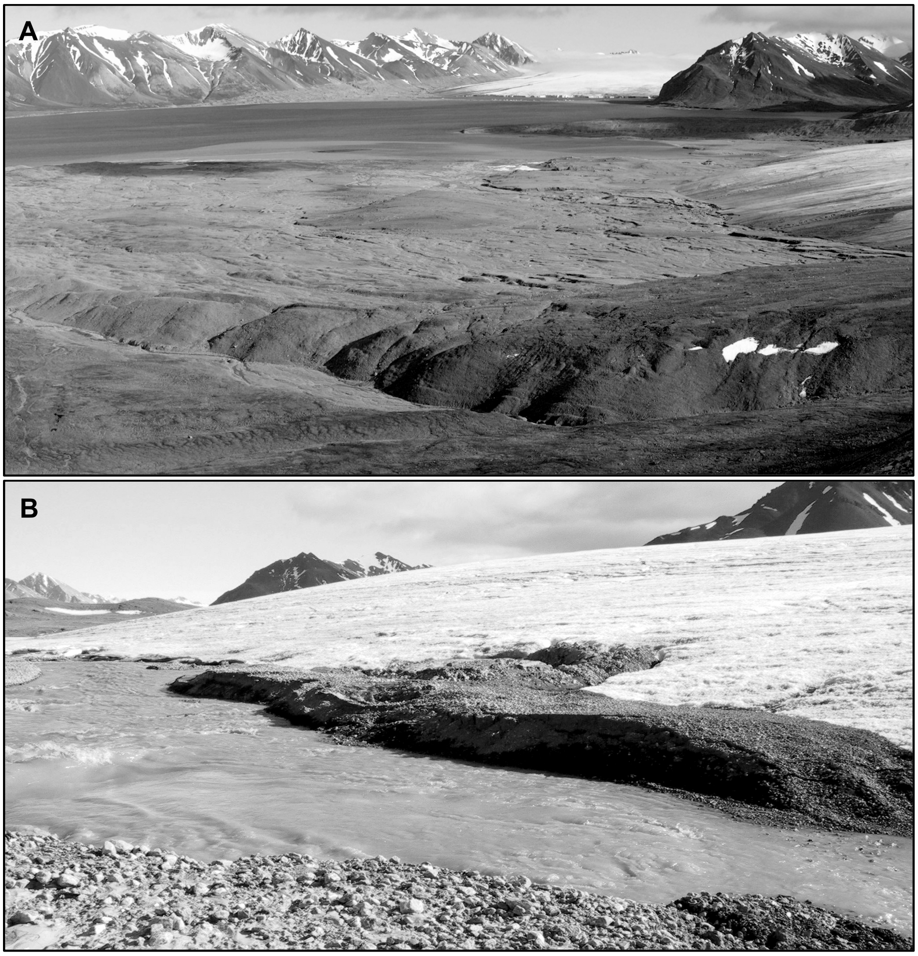


Photo 4.1.3. A- the Renardbreen catchment (Photo P. Zagórski 2006), B- outflow in front of Renardbreen (Photo S. Bartoszewski 2001).

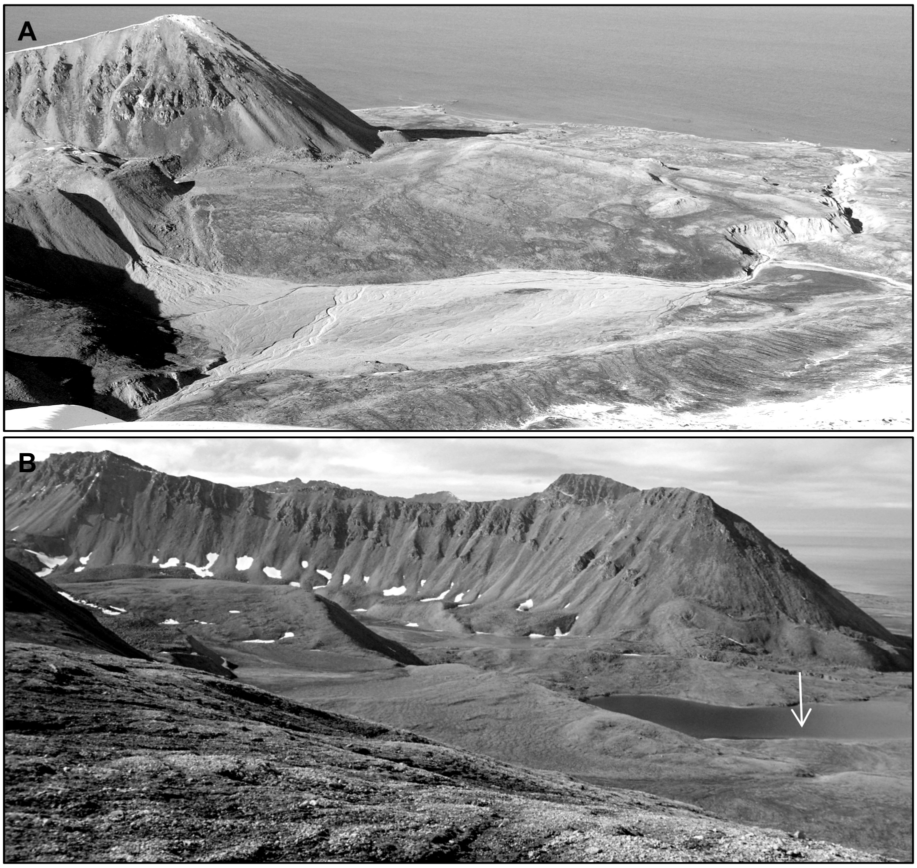


Photo 4.1.4. A- the Blomlielva catchment (Photo P. Zagórski 2008), B- the Tjørnelva catchment, Daltjørna (arrow) (Photo P. Zagórski 2000).

The characteristic element of Tjørnelva catchment is a  the small Daltjørna lake, located in the mouth of the glacier valley and covering ca. 0.1 km$^2$. Lake is supplied by several, small snow-fed streams and is devoid of any permanent surface runoff system (Photo 4.1.4B).

The Blomlielva is 2.69 km long and the mean gradient is 63 ‰ and the Tjørnelva is: 3.2 km long and has a mean gradient of 75 ‰. Runoff studies were carried out during summer seasons of 1986 and 1993 (Bartoszewski 1998). The mean discharge rates observed in Blomlielva were: 675 and 792 dm$^3 \cdot s^{-1}$ and in the Tjørnelva: 421 and 472 dm$^3 \cdot s^{-1}$.

**Dyrstadelva catchment.** The Dyrstadelva catchment covers an area of 14.8 km$^2$ (Bartoszewski 1998). Its upper part is occupied by the Ringarbreane (a complex of 3 receding glaciers) with a total area of nearly 3.0 km$^2$. The front of the western glacier retreated ca. approx. 250 m form the end of Little Ice Age. A 100 m long and 20 m wide marginal lake was created between the glacier front and the moraine. The proglacial rivers disappear into a ‘ponor’ and reappear in the form of a spring located 50 m below the former river gorge incised in the frontal moraine. The middle glacier is separated from the western one by a Ringaren massif forming a wide nunatak between glaciers. The eastern glacier is the source of the Dyrstadelva. River is 4.1 km long and has a mean gradient of 61 ‰ (Photo 4.1.5A). In the north-western part of the catchment a bead-rock knickpoint dams a small glacial lake (0.041 km$^2$) fed by supraglacial waters from the melting glacial cirque. This lake lacks any form of a surface runoff system. In the central part of the Dyrstaddalen there are two small water reservoirs fed by snow-melt streams and thawing of permafrost. A smaller-sized reservoir is also located in the area of Dyrstadflya.

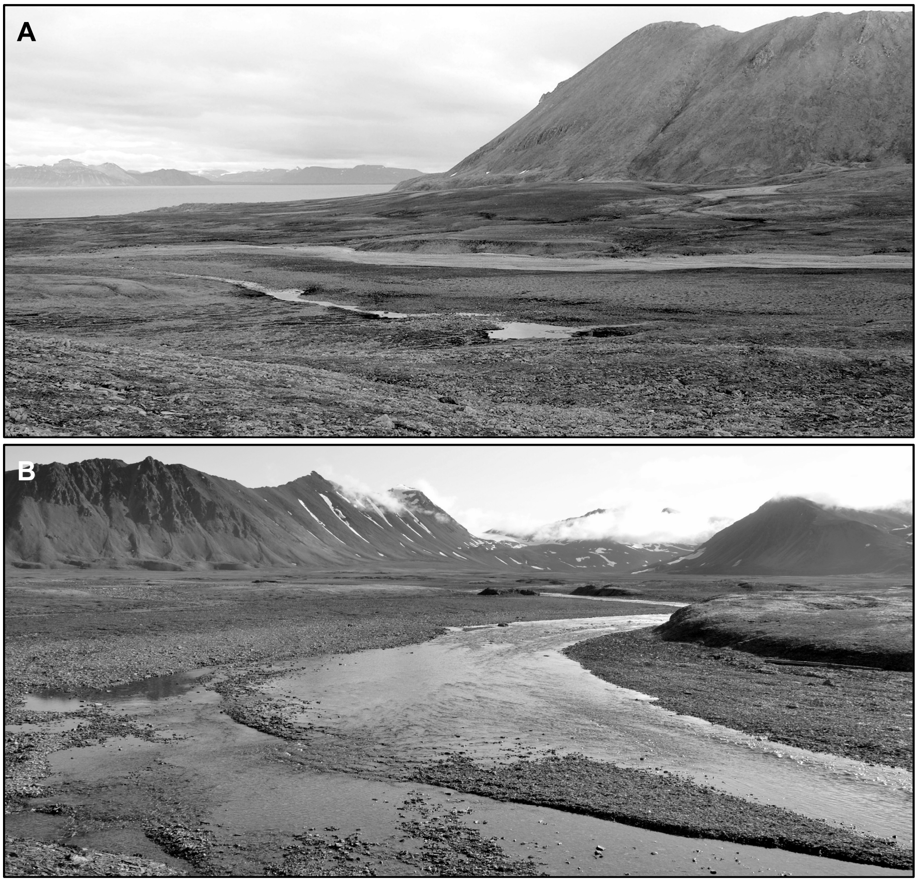


Photo 4.1.5. A- middle part of the Dyrstadelva catchment (Photo P. Zagórski 2007), B- the lower part of Logna catchment (Photo P. Zagórski 2012).

**Logna catchment.** The Logna catchment covers 20.4 km$^2$. Four glaciers: Gløttfonna, Vestre Lognebreen, Austre Lognebreen and a small unnamed glacier, located in the south-eastern part of the catchment cover ca. 2 km$^2$ (Bartoszewski 1998).

Gløttfonna occupies a trough in the slopes of Storgubben, and hangs about 200 m above the bottom of Lognedalen. The Gløttfonna catchment covers ca. 3.2 km$^2$, the main river is 1.85 km long with a gradient of 165 ‰ (Photo 4.1.5B). There is no surface runoff system for proglacial waters. Most ablation waters appear at the northern spring near the foot of Storgubben, among elevations of the lateral moraine rampart. Part of the stream bed is carved out in the dead ice. Southern outflow point is located in the centre of the terminus. There is a small lake here, whose bottom and shores are comprised of ice and snow. The runoff from the lake disappears into the moraine material. The water appears again in the form of a spring located on the slope of a low end moraine, which is cloven by a snow-filled trough. The small unnamed glacier found between Gløttfonna and Austre Lognebreen has no surface runoff system. Meltwaters flow along the the lateral moraine of Austre Lognebreen and join the Logna.

The Vestre Lognebreen is similar in character to an ice field glacier. Its accumulation zone reaches up to nearly 550 m a.s.l., and its front is located ca. 200 m a.s.l. The glacier tongue, with visible signs of recession, hangs from a bedrock knickpoint. The Austre Lognebreen occupies the space between the level of 150 and 450 m a.s.l. Numerous eskers and kames in the proglacial zone are remnants of the former subglacial runoff. A marginal lake emerged between the current glacier terminus and and frontal moraine. The lake has no surface runoff system. Water infiltrates the ground, flows underneath the moraine for ca. 30 m, and reappears in the form of several springs at the base of frontal moraine feeding the Logna. The river is 6.55 km long, with an average gradient of 15.3 ‰. On the territory of Lognedalsflya the river is braiding. Numerous small tundra streams feed the river along this section.

**Dunderelva catchment.** The south-western part of the study area is covered by poorly-glacierised of Dunderdalen, which extends up to 18 km in length and 5 km in width (Bartoszewski 1998). The research focused on the northern section of the valley. Dunderelva is supplied by meltwaters from Dunderdalsbreen (Bartoszewski 1998). It is a braided river with a well-developed channel system (Photo 4.1.6A). River drains into the Dunderbukta in the ca. 100 m wide estuary. Local tidal waves can migrate up to 1.5 km upstream. The Dunderelva catchment covers ca. 154 km$^2$. The main water suppliers in the system are: Grytbreen, Dölterbreen, Dunderdalsbreen, Libreen and Saksbreen.

The **Grytdalselva catchment** drains the area that constitutes the northern wing of Dunderdalen. The catchment covers ca. 8.1 km$^2$ (Photo 4.1.6B). In the drainage divide in the northern section of the catchment there is a front, through which a portion of ablation waters from the Renardbreen flowed in the summer of 1988 (approx. 200 dm$^3$·s$^{-1}$). Within the catchment there are 3 small glaciers with a total area of 0.3 km$^2$. In the last years, the south-eastern glacier, located at the lowest level, has been reduced to a snow and ice patch. The water runoff is dispersed, the water flows between the moraine material. The meltwaters from the middle glacier accounts for the main part of runoff. Third glacier has evolved into the rock glacier. In front of the glacier small, marginal lake is located and accumulates meltwaters which later infiltrate through the lake bed and reappears ca. 500 m in the form of the two springs. Springs are the origin of Grytdalselva (5.55 km long, with an average gradient of 52 ‰).



Photo 4.1.6 A- the lower part of Dunderelva catchment (Photo P. Zagórski 2012), B- the Grytdalselva catchment (Photo M. Świtoniak 2009).

The **Dölterbekkene catchment** covers 6.2 km$^2$. The north-western part of the catchment is covered by Dölterbreen occupying ca. 1.3 km$^2$ (see: Table 5.2.2). The glacier has no direct connection to the proglacial river. Meltwaters penetrate through the frontal moraine and reappear ca. 100 m away in the form of a spring at the base of the frontal moraine. Main river channel is 3.3 km long, with an average gradient of 58 ‰.

The **Dunderdalsbreen catchment** is located in the upper section of Dunderdalen. Its area from the source to the mouth of the first right tributary (that drains the slope of the pass to Chamberlindalen) is 5.9 km$^2$. Dunderdalsbreen covers 1.8 km$^2$. The current glacier forefield is covered with numerous eskers and kames as well as small lakes, the largest of which is 0.03 km$^2$. The river that springs from a small glacial terminus is 1.75 m long (up to the point when it joins the stream that flows from the pass located above the Chamberlindalen); and has a mean gradient of 34 ‰.

The **Konglomeratfjellet catchment** with an area of 4.5 km$^2$ is located in the region that extends out of Chamberlindalen, but its waters are drained into the Dunderelva catchment. The highest area in the catchment is Konglomeratfjellet with a height of

800 m a.s.l. To the north-west of the summit there are two glaciers with a total area of almost 1 $km^2$. From the end Little Ice Age the larger one, has horseshoe shape and, has retreated ca. 200 m. As a result, an 0.03 $km^2$ marginal lake was created before the glacier terminus. The stream drains the lake disappears undreneath the moraine. The waters burst back out in the vicinity of the frontal moraine in two springs. The smaller glacier has no surface runoff system. The former gorge is filled with snow and ice.

The **Libreen catchment** covers 4.7 $km^2$, including 0.9 $km^2$ area of Libreen and 0.3 $km^2$ unnamed glacier. The glacier river originates in a spring at the foot of the relict frontal moraine. A characteristic feature of the proglacial river is the intensive, grey-black colour of its waters.

The area of the **Saksbreen catchment** is 2.5 $km^2$. The glacier occupies upper sections of two valleys. The ice divide between two parts of the glacier runs at the level of approx. 470 m a.s.l. The eastern glacier has an area of 0.5 $km^2$. In the years 1960-1990 its front retreated ca. 200 m. Waters from the eastern part of Saksbreen flow into the upper part of Dunderelva, and waters from the western part – into the lower part. Mouths of both rivers are 10 km away from each other.

**Chamberlinelva catchment.** The meridional Chamberlindalen is over 10 km long and up to 2 km wide, and its basin occupies an area of 55 $km^2$. The valley begins at the pass that separates it from Dunderdalen. The valley floor in the upper and middle part is boggy and not easily accessible. The source of the Chamberlinelva lies at 450 m a.s.l. near the pass that leads to the Dunderdalen. River mouth is located in the shallow Vestervågen (Photo 4.1.7A). The river is 12 km long, with an average gradient of 37.5 ‰. The river is predominatly braided; the water usually flows in 2-3 main channels and a whole series of secondary streams. These numerous streams converge only at specific narrow points, e.g. the gorge made from metamorphic schist's in the upper part of the valley. In 2009 the glaciers occupied an area of 9.3 $km^2$, i.e. 17% of the total catchment area (Zagórski *et al.* 2012). A unique characteristic of this valley is the contrast between the glaciation level of its eastern and western arms. The latter is the location of 4 glaciers forming Crammerbreane.

Proglacial waters from Crammerbreen I and II flow directly into the Vestervågen, and the waters from two remaining glaciers feed the Chamberlinelva. In 1987, the main subglacial runoff from Crammerbreen III took place through a glacial terminus. In July 2005, marginal lakes existed in front of both glaciers. The reservoir before Crammerbreen III had an area of 0.3 $km^2$. The southern part of the glacier front formed a 15 m high ice cliff. Glacier calving to the lake was observed on several occasions (Photo 4.1.7B).

The eastern part of the Chamberlinelva catchment contains only two small-size glaciers. The largest of them is Bøckmanbreen, that covers ca. 0.5 $km^2$. The meltwatrs stream disappears underneath the frontal moraine. It reappears ca. 70 m downslope, as a spring at the foot of the moraine. It is highly possible that meltwaters that reach the bottom of Chamberlindalen are responsible for the formation of pingos (Pękala &

Repelewska-Pękalowa 1988b). The second, glacier is located 2.5 km south of Bøckmanbreen and covers ca. 0.4 km$^2$. Chamberlinelva runoff measured on 4.07.1987 (end of spring-melt period) and 10.07.1987 (peak of the summer floodings) was, respectively, 3,574 dm$^3$·s$^{-1}$ and 6,153 dm$^3$·s$^{-1}$.

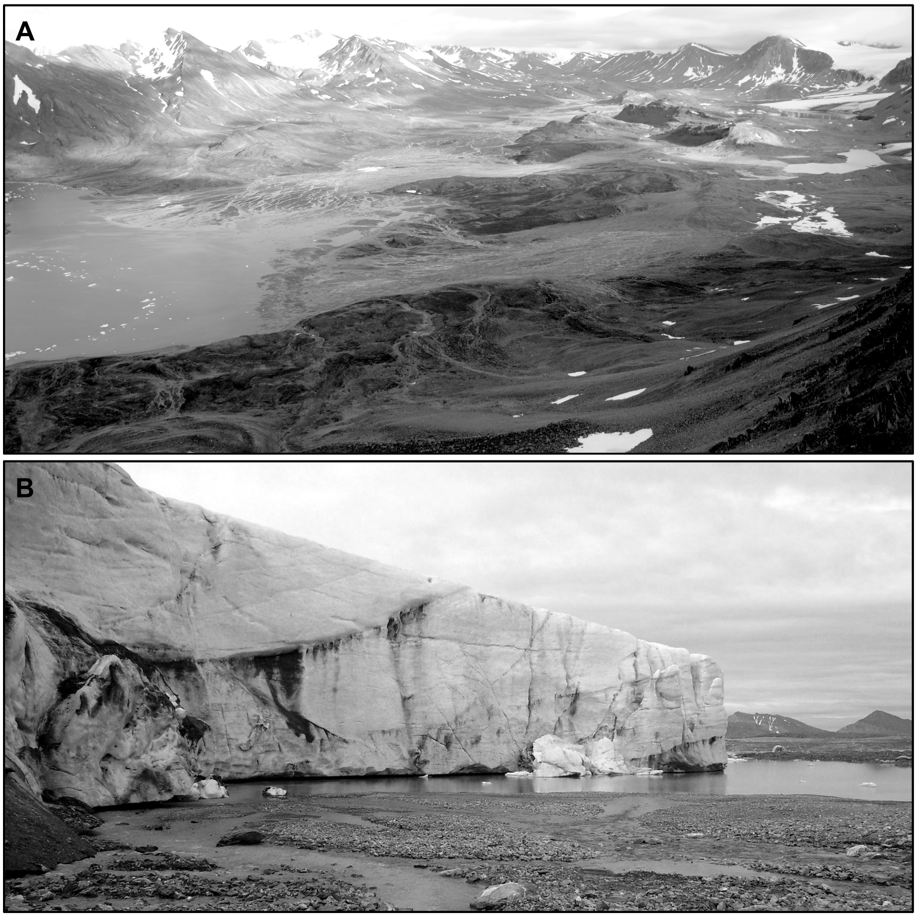


Photo 4.1.7. A- the Chamberlinelva catchment (Photo P. Zagórski 2011), B- ice cliff of Crammerbreen III (Photo S. Bartoszewski 2005).

## Summing up

The hydrographic investigations in the north-western part of Wedel Jarlsberg Land are conducted since 1986. The analysis of collected data allowed to select catchments that represent typical conditions of water circulation in the study area and to carry out various hydrometric measurements. The active hydrological period in the study area lasts for approx. 4 months. It begins in June when the water levels rise due to s melting of sanow cover on coastal plains and ends at the beginning of October when glacier ablation and thawing of permafrost, and the rivers freeze up all the way to the bottom.

Within the group of glacierised catchments the main object of study was the Scottelva catchment (10.1 $km^2$). The mean discharge in Scottelva was estimated to be 0.90 $m^3s^{-1}$, which corresponds to a runoff rate of 873 mm.

In the group of non-glacierised catchments researcher focused on the Tyvjobekken catchment (1.3 $km^2$). The runoff in Tyvjobekken was estimated to be 400 mm. Pronival waters play the most important role in the annual runoff. The runoff during the spring-melt period constitutes ca. ¾ of the total runoff of the whole active hydrological period. The remaining part of runoff is related to rainwater and permafrost thawing.

# Streszczenie

## Hydrografia

Badania warunków występowania i krążenia wód w północno-zachodniej części Wedel Jarlsberg Land prowadzono od 1986 r. Obszar badań obejmował 270 $km^2$; od północy był ograniczony brzegiem Bellsundu, od południa doliną Dunderelvy, od wschodu doliną Chamberlinelvy, zaś od zachodu wybrzeżem Morza Grenlandzkiego (ryc. 4.1.1). W obszarze tym wykonano przeglądowe kartowanie hydrograficzne, którego celem było zidentyfikowanie sposobów zasilania rzek, określenie zasięgu lodowców oraz ocena dynamiki i wielkości odpływu. Wybrano zlewnie do stacjonarnych pomiarów hydrometrycznych, obejmujących rejestrację stanów wody i pomiary przepływu. Odpływ rzeczny (czynny okres hydrologiczny) trwa w tej części Spitsbergenu około 4 miesiące. Rozpoczyna się w czerwcu wezbraniem wywołanym tajaniem pokrywy śnieżnej na równinach nadbrzeżnych, zaś kończy się na początku października wskutek zahamowania ablacji lodowcowej i tajania zmarzliny oraz zamarznięcia rzek aż do dna.

W grupie zlewni glacjalnych podstawowym obiektem badań była zlewnia Scottelvy (10,1 $km^2$), z lodowcem o powierzchni 4,61 $km^2$, znajdującym się w fazie recesji (fot. 4.1.B, tabela 5.3.2). Wody ablacyjne stanowią dominującą składową odpływu Scottelvy. Hydrogram przepływów cechowały dwa rodzaje wahań: regularne dobowe zmiany przepływu, jako konsekwencja dobowego rytmu ablacji lodowcowej oraz zmiany nieregularne, wynikające ze zróżnicowanego zasilania deszczowego. Dynamikę przepływu w najdłuższym (100-dniowym) sezonie pomiarowym 1.07-8.10.1988 przedstawia ryc. 1.4. Średni wieloletni przepływ Scottelvy za okres 1986-2005 oceniono w profilu kluczowym na 0,90 $m^3 \cdot s^{-1}$, co odpowiada rocznemu wskaźnikowi odpływu 873 mm.

Wśród zlewni niezlodowaconych badano zlewnię Tyvjobekken (Potok Wydrzycy) o powierzchni 1,3 $km^2$ (fot. 4.1.A). Wskaźnik odpływu ze zlewni oceniono na 400 mm. W strukturze rocznego odpływu ze zlewni Wydrzycy dominują wody pronivalne. Podczas wezbrania wiosennego odpływa zwykle ¾ całego odpływu wody w czynnym okresie hydrologicznym (ryc. 4.1.3). Pozostałą część odpływu tworzą wody deszczowe oraz pochodzące z tajania wieloletniej zmarzliny.

Na stropie zmarzliny, stanowiącej warstwę nieprzepuszczalną, gromadzi się podczas sezonu letniego woda, tworząc strefę saturacji (nadzmarzlinowy poziom wodonośny). Retencja wodna czynnej warstwy zmarzliny jest uzależniona od tempa jej wytapiania oraz od infiltracji wód roztopowych i deszczowych. Szczegółowe badania warunków występowania i krążenia tych wód w czynnej warstwie zmarzliny prowadzono w rejonie Calypsostrandy za pomocą sieci piezometrów, zlokalizowanych w różnych ekosystemach tundrowych. Wykorzystano także pomiary wydajności źródeł i przepływu cieków, drenujących poziom wód nadzmarzlinowych. Charakterystykę reżimu hydrologicznego wód poziomu nadzmarzlinowego oparto na pomiarach miąższości stref aeracji i saturacji, analizie położenia i dynamiki zwierciadła wody podziemnej, ocenie wielkości zasobów statycznych i dynamicznych oraz związku natężenia odpływu z dynamiką zwierciadła wody podziemnej. Zasobność wodna poziomu jest mała, gdyż na zmarzlinie utrzymuje się najczęściej cienka warstwa wody – od kilku do kilkudziesięciu $dm^3/m^2$. W następstwie intensywnych opadów rejestrowano gwałtowny wzrost stanów wód podziemnych (ryc. 4.1.2).

## Objaśnienia

### Ryciny

Ryc. 4.1.1. Lokalizacja opisywanych zlewni (tło mapa: Topo Svalbard, Norwegian Polar Institute): 1- Tyvjobekken, 2- Scottelva, 3- Renardbreen, 4a- Blomlielva, 4b- Tjørnelva, 5- Dyrstadelva, 6- Logna, 6a- Gløttfonna, 6b- unnamed glacier, 6c- Austre Lognebreen, 6d- Vestre Lognebreen, 7- Dunderelva, 7a – Grytdalselva, 7b- Dölterbekkene, 7c- Dunderdalsbreen, 7d- Konglomeratfjellet, 7e- Libreen, 7f- Saksbreen, 8- Chamberlinelva, 8a- Crammerbreen I, 8b- Crammerbreen II, 8c- Crammerbreen III, 8d- Crammerbreen IV, 8e- Bøckmanbreen.

Ryc. 4.1.2. Zmiany położenia zwierciadła wody podziemnej w piezometrze (linia ciągła) oraz stropu zmarzliny (trójkąty) w sezonie letnim 2002 r.

Ryc. 4.1.3. Przepływ Tyvjobellen (Potok Wydrzycy) w 1987.

Ryc. 4.1.4. Przepływ Scottelvy w 1988 r.

Ryc. 4.1.5. Zmiany położenia dna Scottelvy w profilu wodowskazowym w okresie letnim 1989 roku (daty oznaczają położenie dna w dniach pomiarów).

Ryc. 4.1.6. Związek między przepływem Scottelvy i łącznym odpływem wód z Renardbreen.

### Fotografie

Fot. 4.1.1. Zlewnia Tyvjobekken (Potok Wydrzycy) (fot. S. Bartoszewski 2005).

Fot. 4.1.2. Zlewnia Scottelvy (fot. S. Bartoszewski 2005).

Fot. 4.1.3. A- zlewnia Renardbreen (fot. P. Zagórski 2006), B- wypływ przed czołem Renardbreen (fot. S. Bartoszewski 2001).

Fot. 4.1.4. A- zlewnia Blomlielvy (fot. P. Zagórski 2008), B- zlewnia Tjørnelvy, Daltjørna (strzałka) (fot. P. Zagórski 2008).

Fot. 4.1.5. A- Zlewnia Dyrstadelvy (fot. P. Zagórski 2007), B- zlewnia Logny (fot. P. Zagórski 2012).

Fot. 4.1.6. A- zlewnia Dunderelvy (fot. P. Zagórski 2012), B- zlewnia Grytdals (fot. M. Świtoniak 2009).

Fot. 4.1.7. A- zlewnia Chamberlinelvy (fot. P. Zagórski 2011), B- klif lodowy Crammerbreen III (fot. S. Bartoszewski 2005).

### Tabele

Tab.4.1.1. Zróżnicowanie przepływów rzek NW części Wedel Jarlsberg Land.