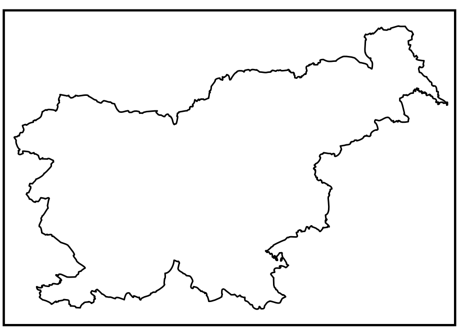
SUMMER STORMS IN SLOVENIA IN 1994 (SURVEY, BASIC CHARACTERISTICS, AND DETAILED ACCOUNTS OF SELECTED CASES)

POLETNA NEURJA LETA 1994 V SLOVENIJI (PREGLED, OSNOVNE ZNAČILNOSTI IN PODROBNEJŠI PRIKAZ IZBRANIH PRIMEROV)

Miha Pavšek

In the upper course of the Kotredeščica (The Sava Valley region) nearly the entirely narrow valley bottom was flooded (photography M. Pavšek).
V zgornjem toku Kotredeščice, nad Zagorjem ob Savi je, bilo poplavljeno dolinsko dno po vsej širini zasuto s plastmi hudourniških nanosov (fotografija M. Pavšek).



Abstract UDC 911.2:502.5(497.12)

Summer Storms in Slovenia in 1994 (Survey, Basic Characteristics, and Detailed Accounts of Selected Cases)

In the summer months of 1994, the weather over Slovenia was often very turbulent. Many storms occurred mainly in the interior of Slovenia, in a belt from Nova Gorica and the Soča Valley and Gorenjska across the Ljubljana Basin and the Sava Valley through Dolenjska and Bela Krajina to northeastern Slovenia where they were the most numerous. The phenomenon of transitory storms with intense rainfall, hail, lightning, and strong wind is quite common for this time of year; but in individual cases the local intensity of accompanying events exceeded any that had previously been recorded in these areas. The regional consequences in the most affected areas were of exceptional dimensions, and the amount of estimated damage was correspondingly high.

Izvleček UDK UDC 911.2:502.5(497.12)

Poletna neurja leta 1994 v Sloveniji (Pregled, osnovne, značilnosti in podrobnejši prikaz izbranih primerov)

V poletnih mesecih leta 1994 je bilo vremensko dogajanje nad Slovenijo pogosto zelo burno. Številna neurja so se pojavljala predvsem v notranjosti Slovenije, v pasu od Nove Gorice in Posočja do Gorenjske, v Ljubljanski kotlini in Zasavju, na Dolenjskem, v Beli krajini pa vse do severovzhodne Slovenije, kjer so bila najštevilnejša. Pojavi kratkotrajnih neurij z intenzivnimi padavinami, točo, strelami in močnim vetrom so za ta letni čas povsem običajni, v posameznih primerih pa je krajevna intenzivnost spremljajočih pojavov presegla vse dosedaj zabeležene na teh območjih. Pokrajinske posledice na najbolj prizadetih območjih so bile izjemnega obsega, temu ustrezna pa tudi višina ocenjene škode.

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1. Introduction

Slovenia, which is characterized by extremely diverse relief, lies at the junction of the Alpine, Pannonian, and Mediterranean areas of climatic influence. The weather formations which create summer weather events above Slovenia come largely from the west. Here the influence of the shape of the earth's surface and the proximity of different climatic areas are reflected in the power of vertical air currents above the heated basin-valley areas and along mountain barriers. Minor physical variations are sufficient for the formation of storms with their accompanying phenomena (lightning, hail, etc.) above the heated surface which occur because of the inflow of new air masses. For this reason, the more precise and timely local forecasting of storms over Slovenia is very difficult.

In dealing with the overall problem of storms, in addition to the meteorological conditions over an affected area we must also consider the geographical characteristics of the affected area and of influential adjacent areas which frequently have a decisive influence on the level of threat from natural disasters. Equally intense weather events can have very different effects on the surfaces of the locally and ecologically diverse Slovene regions. Along with the physical geographical elements of the surface, the human element is the most important. The regional landscape of Slovenia is continually changing because of man and the primary activities through which he assures himself the basic elements for life and work. These are often in conflict with the landscape-forming elements, a fact which becomes particularly clear in the detailed study of natural disasters.

During exceptional weather conditions, any incorrect methods of dealing with and managing the environment are revealed, quite frequently with devastating effects. These are the result of natural processes, strengthened or even changed because of man, which have even greater destructive force. The consequences in affected areas are therefore not only the sum total of individual natural components that endanger an area but also very often the result of multiple factors (i. e., the “synergetic effect”) and man's influence. Thus, man is only increasing the natural level of threat to the environment due to natural disasters. Many examples of this can be found during the annual powerful storms that in the last decade have occurred with increasing frequency.

2. Starting Points for the Geographical Study of Storms

Through a general survey and several detailed reports on storms in the summer of 1994 we are throwing light upon specific causes and above all upon their regional consequences in the affected areas. Through better care of the environment, its management, and the use of land, some consequences can be avoided or at least their effects mitigated. We thus hope to call attention to specific examples of damage to particular buildings and infrastructural facilities and to their connection with the regional consequences of particular natural disasters. With cartographic supplements we are presenting some possibilities and degree of detail for dealing with individual natural disasters, depending primarily on the size of the affected area and the strength of regional consequences.

While defining our goals we are primarily revealing preventive and operative components, considering actual possibilities and existing conditions in the area of protection from natural disasters. One of the most important goals for the future is to reduce the damaging consequences of natural disasters in ecologically more unstable areas by considering the dynamics of regional development and with balanced environmental planning. Space interventions, normative precautions, and operative protection from natural disasters must, along with economic expenditures acceptable to the government, ensure the continuation of the harmonious development of Slovene regions. At the same time, it is necessary to consider and preserve the natural and cultural characteristics of particular Slovene regions.

By concurrently following natural disasters we hope to augment the database of Slovenia's geographical information system. Periodic detailed studies are not sufficient for a continuous and systematic coverage of natural disasters. The basic aim of detailed studies is also a more precise definition of what we want to reveal through the continuous observation (monitoring) of natural disasters as well as the presentation of various possibilities offered by modern technology considering an interdisciplinary approach to problems and the advancement of methodological principles. One of our more important goals is also the more detailed definition of areas of Slovenia actually and potentially endangered by natural disasters.

The latest legal provisions of the recently passed law on Protection against Natural and Other Disasters also oblige us to gain better knowledge of the problems of natural disasters and of actually and potentially threatened areas. These encourage regional research work on natural disasters from the protection point of view for all those regional administrative units which represent rounded geographical, urban, or otherwise linked areas of two or more local communities. Within this framework, knowledge is especially important regarding the probability of occurrence (danger) of defined types of natural disasters, of the kind and degree of threat to the environment because of them, of the damage they cause, of preventive measures through which we can prevent the occurrence of natural disasters, and of measures to mitigate their destructive consequences.

The total solution to the problem of natural disasters also includes a wider definition of the purpose and aims of these geographical investigations that are so undoubtedly important for Slovenia. However, it is still a long way to qualitative changes in the evaluation of the cultural landscape and to a different approach to its management. By warning of deficiencies in the current regional development, we can lower future high budgetary expenditures devoted by the government to the annual clean-up of the consequences of natural disasters. With this study, by elucidating in detail the consequences of the summer storms of 1994 in selected parts of Slovenia, we hope to call attention to part of the wide spectrum of problems connected with natural disasters.

3. Survey of Short Heavy Summer Rains in Slovenia in 1994

3.1. Survey of Most Significant Storms

In the survey map of Slovenia (Figure 1) all the significant locations of heavier storms between June 13 and September 15, 1994, are presented under sequential numbers. Short storms with heavy rainfall and their accompanying phenomena are generally most characteristic of the three summer meteorological trimester when the air in the ground layer and the lower layers of the atmosphere is most heated.

The numbers beside the points (1–78) show the sequence of occurrence of more intensive weather events across Slovenia in the period under discussion. All storms causing major changes in the landscape are indicated and presented in detail below (boxed numbers). This survey in no way includes all weather events in the period under discussion, which was not our intention. We primarily want to call attention to the regional and temporal diversity and the differences in the intensity of the occurrence of storms over the irregular relief of Slovenia.

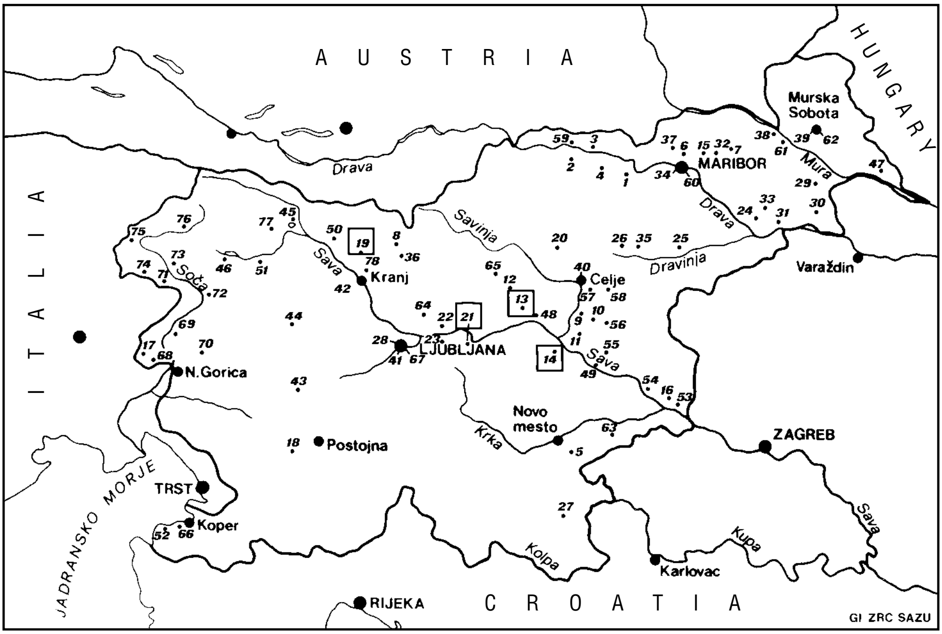
Below we present a short survey of storms in the summer of 1994. In fifteen different weather charts (I–XV) 78 locations are enumerated where summer storms raged with intensive accompanying phenomena in the course of one or more days. They occurred in the following sequence:

I. June 13 and 14, 1994 (1–5): Two days of heavy rainfalls across all Slovenia, serious consequences mainly on both sides of the Drava Valley (1–4) and in the vicinity of Novo mesto (5).

II. June 17, 1994 (6, 7): Storms with thunder and lightning, hail, and strong winds between Maribor and Gornja Radgona. Damage mainly to agricultural areas, particularly vineyards.

III. June 18, 1994 (8): Because of the heavy rain, a small landslide was triggered that blocked the Kranj–Jezersko road.

IV. June 2, 1994 (9–11): Heavier storms in the area of Laško (south of Celje).



Key – Legenda:
1–78. location of storms – lokacije neurij
19 affected areas presented in detail – prizadeta območja s podrobnejšo predstavitvijo:
13, 14. Sava Valley – Zasavje, 19. Golnik – Golnik
21. Litija – Litija.

Figure 1: Heavier storms in Slovenia in the summer of 1994 (survey map).
Slika 1: Močnejša neurja v poletju leta 1994 na območju Slovenije (pregledni zemljevid).

V. June 28–29, 1994 (12–18): Localized heavier storms, in some places with great intensity of rainfall and strong erosion and flooding activity by some smaller streams on the west margin of the Celje Basin (12), in the Sava Valley (13, 14), in a part of the Slovenske Gorice region (15), in the Sava region (16), in Goriška Brda (17), and in the vicinity of Postojna (18).
VI. June 30, 1994 (19): A heavy storm above Kriška gora, Golnik north of Kranj. A large amount of torrential detritus partially buried several houses. The basements and ground floors of several houses and part of the hospital grounds were flooded.
VII. July 5, 1994 (20–28): Numerous small local storms across Slovenia with major regional consequences particularly in the areas of Velenje (20), the Sava Valley east of Ljubljana (21–23), the surroundings of Ptuj (24), the Dravinja watershed (25, 26), Bela Krajina (27), and the fringes of Ljubljana.
VIII. July 18 and 19, 1994 (29–35): Storms with strong winds and hail in the Slovenske Gorice region and its fringes (29–30), Maribor and its surroundings (34), and near Slovenska Bistrica (35)
IX. July 19, 1994 (36): In the afternoon there was a major thunderstorm in the area along the Kokra River; a torrent carried large quantities of rocky material to the valley, and the swollen waters flooded two houses.
X. August 8, 1994 (37–46): Heavy storms with wind and hail in the Slovenske Gorice region north of Maribor (37, 38), Murska Sobota and its surroundings (39), the Celje area (40), Ljubljana (41), Kranj (42), between Idrija and Logatec (43), the highlands west of Škofja Loka (44), and Lake Bled (45) and Lake Bohinj (46).
XI. August 13, 14, and 18, 1994 (47–52): Smaller storms with intense rainfall, wind, and some hail at Lendava (47), repeatedly in the Sava region (48, 49), in Gorenjska (50, 51), and near Koper (52).

XII. August 22, 1994 (53–59): Very numerous storms with strong winds, hail, and intense rainfall between the Sava and Dravinja rivers, heavier mainly in the Sava Valley (53–55).
XIII. August 23 and 24, 1994 (60–65): Storms with local hail and strong winds over the greater part of Slovenia, the heaviest in the surroundings of Maribor (60), on both sides of the Mura River (61, 62), at the foot of the Gorjanci Hills east of Novo mesto (63), around Domžale (64), and repeatedly in the western part of the Celje Basin (65).
XIV. August 31 and September 1, 1994 (66, 67): Storms with powerful whirlwinds and gusts on the Slovene coast (66) and in the wider Ljubljana area (67).
XV. September 13–15, 1994 (68–78): Storms with strong wind and hail with local intense rainfall caused numerous landslides and torrential detritus in the Soča Valley north of Nova Gorica (68–70), in the central Soča Valley between Tolmin and Kobarid (71–74), in the upper Soča Valley (75, 76), on the Pokljuka plateau (77), and in the vicinity of Kranj (78).

3.2. Basic Geographical Characteristics of Natural Disasters in the Period Under Discussion and the Threat to Slovenia due to Storms

In the survey we have covered only those areas where the damage caused by storms was relatively large and the consequences were worse compared to previously known phenomena of this type in recent decades.

3.2.1. Local Survey

The local survey of the occurrence of storms in the summer of 1994 (Figure 1) tells us that they were most frequent in eastern and northeastern Slovenia. Several times they also ravaged the central part of Slovenia and the margins of the Ljubljana Basin, some valleys in the west and northwest, southeastern Slovenia, and the coast. Regarding the frequency of and area covered by storms, the Sava Valley region between the southern edge of the Celje Basin and the Sava River and the Slovenske Gorice region were in the foreground. The local occurrence of storms was also somewhat more frequent in Prekmurje, between the Pohorje Hills and Kozjak, on the Krško–Brežice Plain, and in the wider areas of Kranj and Ljubljana. In all these areas, many settlements with their adjoining farmland within the framework of a particular regional unit (plains, slopes, valley bottoms, and the like) were affected. In southern Slovenia, no major consequences were caused by the storms. This storm belt coincided with the largely forested Dinaric karst landscape with its karst hydrography.
For the remaining locations (Figure 1) we can speak of distinctly local phenomena. In many cases, the level of damage to affected areas was determined precisely by geographical elements. This is particularly important given the fact that the majority of storms most frequently originate west of Slovenia or above western or central Slovene regions and travel toward the east, thus passing over a good part of Slovenia.

3.2.2. Time Survey

The spatial characteristics of storm systems in Slovenia during the period under consideration can be compared with the time distribution of their occurrence. The detailed survey (Figure 1) shows considerable spatial diversity and irregularity in the occurrence of storms on particular days with regard to each weather map.
A) In some cases we can clearly distinguish the path of storm systems across an extensive area of Slovenia (for example, storms V, VII, X, XI, and XIII above). This is especially clear for storm X, since numerous storms occurred in Gorenjska, the vicinity of Logatec, Ljubljana, Celje, and farther from the western part of the Slovenske Gorice region all the way to Gornja Radgona and Murska Sobota. Storms affected larger geographical areas but distinctly localized storms also occurred, though always in the wider area of Slovenia.

B) Some storms affected less extensive areas. On the basis of a precise time definition, we determined that storms appeared simultaneously or followed one another from west to east in regular time intervals. Examples of such storms are VIII, XII, XIV, and XV. In the first case, storms mainly struck the areas of the Slovenske Gorice region and its fringes; in the second, the Lower Savinja Valley with its hinterland and the Sava Valley; in the third, the Slovene coast and Ljubljana; and in the fourth, the Soča Valley and part of Gorenjska. On the intervening highland surfaces, the consequences of storms were less distinctive, largely because of the more favourable landscape and ecological elements which diminished the erosive power of water.

C) Individual storms also occurred in regionally smaller areas, for example storms I, II, III, IV, VI, and IX. Here only parts of the highland world were affected as well as individual basins or valleys and their hinterland or only individual settlements.

If we join the spatial and time arrangement characteristics of the storm phenomena, we can link the spatially larger storms (A and part of B) with a frontal origin, while the storms covering smaller areas (part of B and C) were primarily of thermal origin. It happened very often that storms with thunder and lightning were of mixed origin since with the inflow of moister air masses, thermal storms were joined by prefrontal thunderstorms.

This would probably also become evident with a more precise time determination. Most of the storms occurred late in the afternoon, and some of the strongest at night as well. In comparing the quantity of rainfall from thunderstorms in Slovenia, it was determined that with storms of frontal origin the standard deviation in the quantity of rainfall at selected meteorological stations is much lower than when it is the result of thunderstorms of thermal origin (Gregorčič 1990). In the first case, the rainfall is more evenly distributed in quantity and space. We could also determine the type of rainfall origin with the help of selected meteorological data of measuring stations in the affected area and the wider influential area. However, here we already encounter difficulties, since storms often occur in exceptionally small areas where there are no meteorological stations. For storms with intense short rains, the accuracy of measuring rainfall is often disputable due to the technical nature of measuring rainfall (emptying of ombrometers). The measured values with storms of local character can therefore also be lower than the actual values.

3.2.3. Survey of Major Consequences

In examining the material damage caused by the summer storms, it is especially important to point out the dominant regional consequences and the damage to infrastructural, residential, economic, and other buildings and facilities. The most damaging accompanying processes and regional phenomena were:

- the bottom and side erosion of particular streams and increased surface erosion (landslides of all sizes, undercutting of banks by stronger streams, destruction or damaging of roads, road-related structures, and various pipelines and power lines);
- strong gusting winds and whirlwinds (wind damage to power lines, houses, and larger buildings with flat, mainly sheet metal roofs);
- accumulation of wood material (branches, tree trunks, logs, lumber);
- accumulation of rough and fine rock material (torrential detritus, sand, and mud deposits) on open surfaces and in the basements and ground floors of some buildings;
- overflowing (brief flooding) and flooding of exposed surfaces in settlement areas and in the vicinity of streams;
- destruction of agricultural land with field and garden crops due to flooding, hail, and erosive proceses.

The worst and most frequent damage was caused to structures along streams. Numerous ground stabilizing revetments, weirs, outlets, regulatory measures, bridges, bank protections, and dams for smaller water supply systems were demolished or undercut. Damage to road network was no less serious. Roads were most affected in vulnerable areas:

- along streams at the narrowing of valleys;
- on the outer banks of stream bends (in valleys with wider bottoms);
- below points where valleys or ravines join on slopes above roads;

- at places where side valleys join main valleys;
- at places where roads cross smaller brooks, ravines, and torrents (clogging of culverts, erosion);
- at places downstream from bridges (erosion) and at bridges with inadequate outlets or openings or arches which the abundance of flood debris simply blocked;
- at places where ravines were blocked leaving no outlets;
- at points where roads lead across steep slopes (erosion);
- at places threatened by landslides;
- at intersections and squares where several side streets meet (alluvium); and
- where houses are built close together along roads (erosion).

Roads were considerably damaged In other areas as well, and water also flooded several factories. Wind tore roofs even from larger buildings, felled numerous isolated trees, and in some cases devastated larger wooded areas. The fringe areas of larger settlements were most exposed where the wind gusts were strongest. The numerous fires caused by lightning cannot be overlooked: because many roads were impassable, it was impossible in some cases for the fire services to intervene. In several places hail caused quite considerable damage, though compared to other consequences this was relatively minor. This type of rainfall had no substantial influence upon the watersheds of the larger rivers as the rains were concentrated in limited sections of river basins. The more serious consequences were therefore of only local character.

3.2.4. Summer Storms in 1994 and the Threat to Slovenia From Storms

In surveying the basic geographical characteristics of summer storms we must not overlook the overall weather conditions in this period. From meteorological reports we can see that this summer was one of the hottest in the last century (author's comparison of Ljubljana weather data).

Hot days when daily temperatures exceeded 30°C occurred in eastern Slovenia as early as the beginning of June, and it was hottest between June 26th and 30th when the highest daily temperatures between 30°C and 35°C were recorded. In July and August there were twenty-nine hot days, and an unusually long twenty-day period of hot weather occurred between June 23rd and August 11th, one of the longest hot periods we have experienced in all the summers of this century. If we consider the fact that on average there are ten hot days annually in Ljubljana, we see how exceptional the summer of 1994 was. The more the air is heated, the larger quantities of humidity it contains and even minor changes in the atmosphere can cause atmospheric instability. This is the basic condition for the origin of powerful thunderstorms and their accompanying phenomena.

When all the conditions for the origin of thunderstorms are fulfilled, an enormous quantity of energy is released with the condensation of water vapour. Thunderstorms last a long time, and therefore the accumulated energy is released slowly. In spite of this, the consequences to the earth's surface can be very large, most often because of heavy rainfall, destructive winds, hail, and fires caused by lightning.

We must also consider the meteorological basis for the local occurrence of storms and their dynamics. Thunderstorms are a component part and the most frequent companion of storms (Figure 2). Their frequency in Slovenia is among the highest in Europe (Hočevar, Petkovšek 1984). The central part of the Ljubljana Basin and the Slovenj Gradec Basin have the greatest number of days with thunderstorms. The belt of highest thunderstorm frequency runs from southeastern Slovenia across central Slovenia to eastern Austria. The upper Soča Valley is also quite exposed to thunderstorms, and compared to neighbouring regions the rest of Slovenia also has a much larger number of days with thunderstorms. The values decrease mainly when we withdraw from the Mediterranean, that is, toward the central parts of the Pannonian flatlands where the continental climate dominates. The frequency of thunderstorms is very much one of the indicators of the transitional climatic conditions over Slovenia.

The origin of thunderstorms is closely connected with the Slovenia's irregular relief (the southeastern spur of the Alps with its subalpine highlands divided by larger valleys and basins, the margin of the Pannonian flatlands, the vicinity of the sea) and is stimulated by the increased inflow of warm moist air from above the northern Mediterranean Sea. Along with the passage of fronts, all this increases the instability of the atmosphere (Kajfež–Bogataj 1992). Vertical air currents are strengthened by

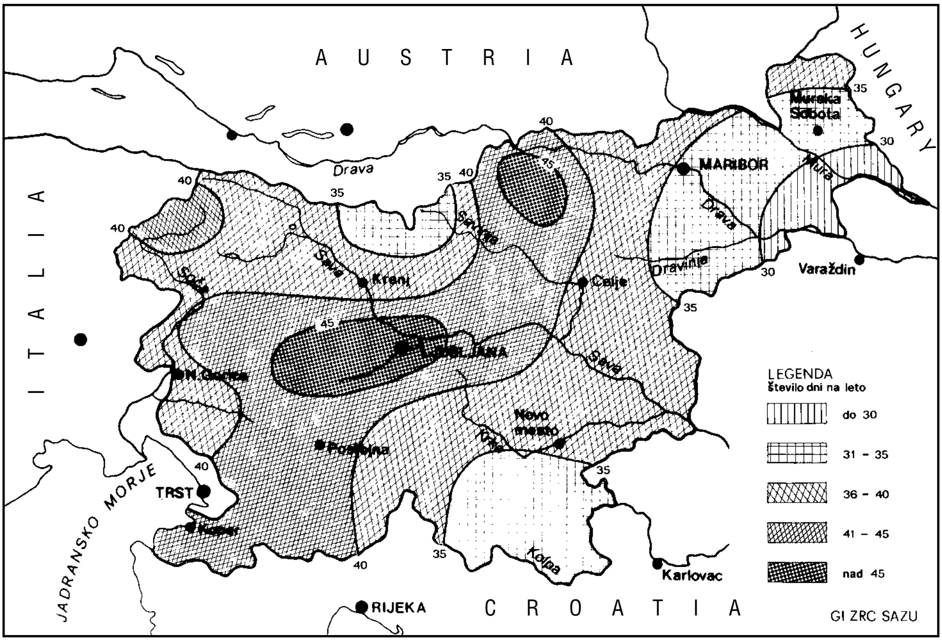


Figure 2: Average number of thunderstorms annually in Slovenia (Hočevar, Petkovšek 1984).
Slika 2: Povprečno število neviht na leto v Sloveniji (Hočevar; Petkovšek 1984).

mountain barriers and the intense solar radiation from flatland surfaces. Thunderstorms are frequently accompanied by hail which can destroy many crops in summer since during the period of their most intensive growth and ripening they are most sensitive to physical injury. In the greater part of Slovenia hail occurs at least once or twice a year (Kranjc 1983), but it is most frequent in western Slovenia in a triangle between Ajdovščina, Nova Gorica, and Tolmin. The efficiency of thunderstorms (the ratio between the average number of days with thunderstorms and days with hail) is also very important, since in many respects the local geographical components of the affected area are decisive for the formation of hail. The efficiency of thunderstorms is highest in the area of the above mentioned triangle, but it is also relatively high in the whole of the Vipava Valley, on the eastern margin of the Ljubljana Basin, in the Drava plain and the hills surrounding it on the south, in the western part of the Slovenske Gorice region, in the hilly world of Prekmurje, and in eastern Slovenia over the wider area of the Krško Basin. The fact that the parts of Slovenia with the highest thunderstorm efficiency coincide with agricultural regions where surfaces are quite intensively cultivated (fields, vineyards) is evidence of the high degree of threat to these areas because of storms and their accompanying phenomena. Also important for the local survey is the extent of thunderstorms, which depends on their type of origin. Thunderstorms are distinguished as thermal and frontal by their origin, and according to their extent, unicellular, multicellular, or supercellular thunderstorms (Kranjc 1983). In Slovenia, the later which affect larger areas are rather rare, while the unicellular thunderstorms are most frequent. These are rather stationary and develop mainly due to localized heating of the ground. The size of the area affected by a storm depends on the development of thunderclouds (cells) and the direction of their movement. Although from the meteorological point of view Slovenia is relatively small, its position and the irregularity of its surface cause major regional variations in the intensity and quantity of raifall in the warmest season of the year. In summer when rainfall of convective origin dominates, the difeences are even greater, sometimes over very short distances. The intensity of weather processes during storms further accelerates the inflow of relatively warmer air near the ground or of colder air in the heights (Kajfež–Bogataj 1992). As a rule, areas where the effects of storms on the landscape are most evident run in the form of narrow belts whose length by far exceeds their width. In Slovenia these belts can be only a few kilometers wide and up to several dozen kilometers long. Storms are accompanied mainly by heavy rainfall in the form of cloudbursts (great intensity in a short time), but quite often by hail, powerful whirlwinds and gusts, and thunder and lightning as well.

When storms are caused by the invasion of relatively colder air across the alpine barrier, thunderstorms occur simultaneously along the whole southern edge of the barrier and above the heated valley and basin areas of the subalpine highlands. The Slovenske Gorice and Prekmurje regions have particularly unfavourable positions for the origin of more powerful storms because they are more open toward the west due to the lower and more rounded nature of the easternmost Alps and the east-west orientation of the Drava Valley. Cold air therefore reaches these areas more rapidly while the natural geographic features of the surface encourage the development of thermal thunderstorms. Individual thunderclouds (cells) also form already over the warm Klagenfurt Valley and on the eastern side of the easternmost Alps above hilly Austrian Steiermark. On the western edge of Slovenia the embryos of thunderstorms develop above the flat and heated Friuli–Venezia Giulia region where the air is still very moist due to the proximity of the sea. The first higher barriers for these air masses are the high Dinaric plateaus (Banjšice, Trnovski gozd, Nanos, Javorniki, Snežnik) and the ridges of the western subalpine highlands. All the valleys and basins in this part of Slovenia are therefore among the more threatened.

As we can see, thermal thunderstorms were more frequent in the summer of 1994, but there were several frontal thunderstorms as well. In the second half of August even a supercellular thunderstorm formed over northern Italy and traveled eastward across Slovenia. We can place each storm under a microscope and by means of weather charts and radar pictures analyze it in detail (Cegnar, Mekinda–Majaron 1994).

The basic characteristic of thunderstorms is precisely their unpredictable occurrence in time and place, and forecasting them is therefore not reliable enough. There are too many chance influences that can fundamentally change atmospheric developments in a short time, a fact that only increases the inaccuracy of this kind of forecasting. The collecting and processing of data is becoming ever quicker, but location accuracy still remains on the level of larger spatial units such as regions at best.

In the summer of 1994, rainfall occurred mostly in the form of showers and cloudbursts which were quite irregularly distributed in space and time. Forecasting them was therefore somewhat difficult. The instability of the atmosphere was increased by the above-average temperatures. On one hand there were hot days with very warm ground layers, and on the other there was an inflow of colder air in the heights, most frequently with the passage of cold fronts or altitude areas of cold air from above Western Europe. On several occasions in the area of the Alps, some troughs branched off and detached area of cold air were formed that spread over Slovenia. Exceptionally heavy storms developed during their passage over the heated valleys and basins and the marginal subpannonian regions. Up to 100 l/m^2 of rain fell in an hour in some places. Such quantities cause changes in the dynamics of surface drainage, since the established natural balance in the region is destroyed.

In such cases a new situation is established in the region which adapts to the existing exceptional water conditions. Such large quantities of water cause the greatest damage to riverbeds, river banks, and corresponding flood areas. It is already difficult for streams whose riverbeds are largely in a natural state to carry away such high waters. Certain regulation work only makes the dynamics of natural drainage worse. We can certainly prevent bottom or side erosion by completely or partially embanking riverbeds, but in this case the power of water may be considerably increased. Therefore, the trapped and channelled water floods at every minor barrier or clogging and erodes heavily. Because of its greater power, it is also capable of carrying heavier rocks and larger pieces of wood. These clog passages under bridges, roads, and underground water channels that are frequently not large enough for such volumes of water.

The maximum daily rainfall in Slovenia follows the basic distribution of the annual quantity of precipitation, which drops from the west to the east or northeast. The map below (Figure 3) shows the 24-hour quantities of rainfall for the heavier autumn rains in 1980. A similar picture can also be seen with exceptional spring rains. On October 9, 1980, several hundred liters/m^2 of rain fell in the mountainous parts of western Slovenia, while in the Kamnik and Savinja Alps there was around 100 liters/m^2 less. In southwestern and central Slovenia amounts varied between 100 and 200 liters/m^2, while toward eastern and northeastern Slovenia the daily rainfall dropped to below 100 l/m^2.

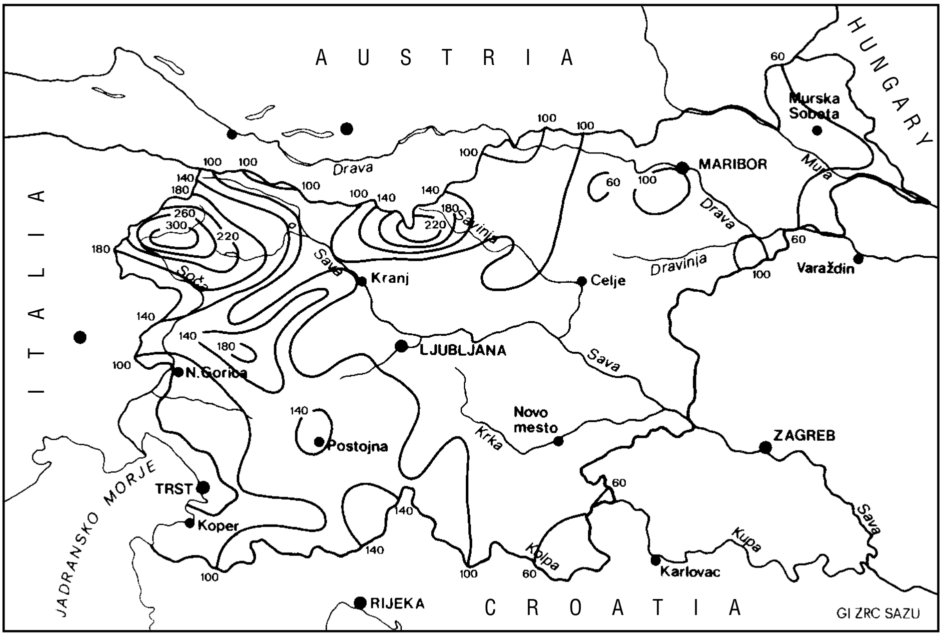


Figure 3: 24-hour precipitation (in l/m²), measured at 7:00 on October 9, 1980 (Pristov 1991).
Slika 3: 24-urne višine padavin (v l/m²), izmerjene 9. oktobra 1980 ob 7. uri (Pristov 1991).

On the basis of the collected data (Kajfež–Bogataj 1992) the highest probable 24-hour quantities of rainfall in Slovenia were also calculated for recurrent periods of 10,000 years (Figure 4). According to these calculations, the daily maximum quantities of rainfall in central Slovenia can be up to 250 l/m², in eastern Slovenia up to 200 l/m², and in the mountainous parts of western Slovenia more than 500 l/m² a day (Pristov 1991). These estimates are quite believable, since rainfalls over 300 l/m² have been recorded in Slovenia in the past: 404 in the central Soča Valley at Livek above Kobarid, 341 in the Polhov Gradec Hills at Lučine, 330 in the Upper Soča Valley at Bovec, 326 on the south side of Snežnik (1796 m) at Gomance, and 309 in the Bohinj region at Savica. If rainfall in an area is evenly distributed in time and space, there are no major consequences except in the case of unfavourable ecological conditions or due to flawed human intervention. The picture, however, is completely different for even smaller quantities of rainfall which fall in a very short time.

In calculating the 24-hour values for individual periods in the past century, it is significant that the data for recent decades shows these values have steadily increased (Kajfež–Bogataj 1992). An analysis of probable maximum rainfall and discharge for Slovenia has unfortunately not yet been done (Kompare, Steinman 1992). The maximum measured 24-hour rainfall in Austria (according to Aulitzky) is 670 l/m² on the southeastern margin of the Alps, 200–300 l/m² in the Karavanke Mountains, 200–300 l/m² on the northern margin of the Alps, and up to 170 l/m² in the interior.

For Slovenia two items of data are available: 122 l/m² fell in one hour in Nova Gorica on August 21, 1988 (Kompare, Steinman 1992) and nearly 80 l/m² during the last storm in the Sava Valley (90 l/m² in 70 minutes). In the interior of Slovenia these values are much lower, while in the areas of the Alps and the western subalpine highlands they are higher.

There are certainly other factors which contribute to the violence of water and the resulting consequences caused in a short time by its power and great quantity. These are mainly the development, the ramification, and the size of the hydrographic hinterland of streams. The regulation of riverbeds and their links with the systems for draining meteorological water from public and communal areas are also significant. The regulation of streams in catchment areas and their immediate surround-

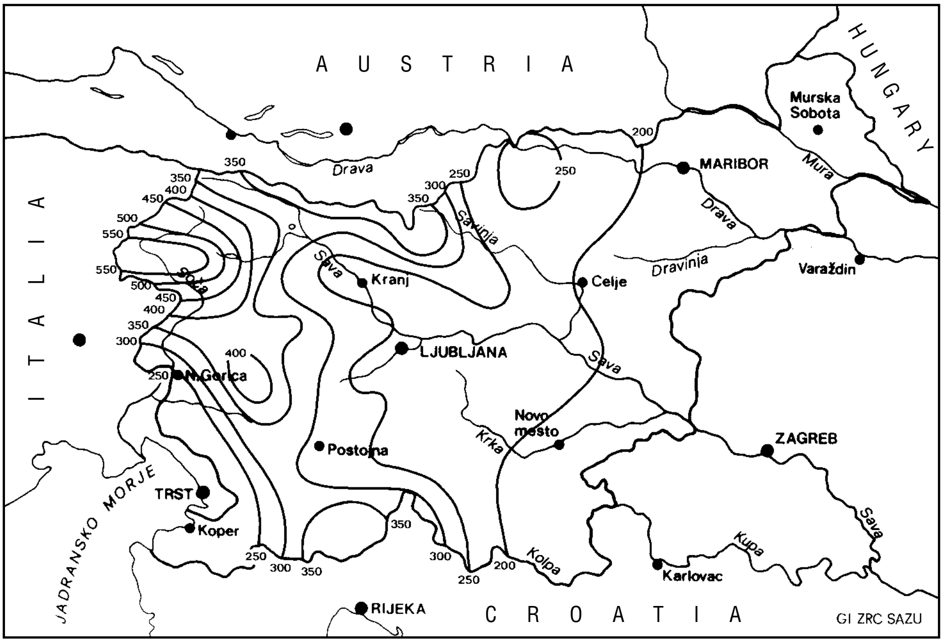


Figure 4: Highest possible amounts of rainfall (in l/m^2) in Slovenia for recurrent periods of 10,000 years calculated on the basis of data from the 1950–1979 period (Pristov 1991).
Slika 4: Najvišje možne 24-urne višine padavin (v l/m^2), v Sloveniji za povratno dobo 10.000 let na osnovi podatkov za obdobje 1950–1979 (Pristov 1991).

ings has been neglected, and here we find numerous uncontrolled refuse dumps and logging debris. Even some of controlled refuse dumps are too near streams whose torrential nature was not taken into account.

In cases of exceptional rainfall, the damage is therefore double. High waters sweep away part of the discarded material, and channels downstream from the dumps are blocked even more quickly. On steep forest surfaces, logging debris presents a major problem, because it is not removed after felling or logging areas are not correctly maintained (inadequate clean-up of logged areas and logging debris). Logging debris can easily cause blocked streams and flooding.

Particularly noticeable is the improper channelling of streams providing too little discharge capacity in the event of torrential waters, as well as the construction of buildings along unregulated banks of torrential streams, the construction of scarps along streams, the construction of bridges with inadequate openings for water flow, and last but not least, the construction of roads and the associated encroachments in the landscape.

Along with the basic relief characteristics it is necessary to consider the bedrock of the affected area and its hydrographic hinterland. If we place the summer storms of 1994 on the synoptic geographical map of Slovenia, we can see that mainly areas of non-karst surface were affected. In the majority of marked locations, the most damage was caused by water and the geomorphological processes associated with it. Thunderstorm belts frequently crossed southern Slovenia, but there were no major consequences there. The mostly karst character of the region contributed to this fact. Most affected were the areas of narrow valleys with largely impermeable hydrographic hinterlands such as the valleys along the Sava River, at the foot of the Pohorje and Kozjak mountain ranges, in the Slovenske Gorice region, and in the hinterland of the lower course of the Savinja River.

In several cases, the great fall of streams and the large average gradient of their hinterlands was decisively important. Of such locations, the majority were in the area of the Alps where during intense rainfall torrents carried great quantities of rock material (catchment areas of the Kokra, Nadiža, Soča, and Sava Bohinjka rivers). Several times accumulation dams directly threatened buildings or the torrential water poured around them and flooded surfaces at transitions from steeper to gentler sections of the riverbeds close to valley bottoms just above confluences.

The prior level of surface moisture is also very important. In some places heavier downpours were followed by an interval of only a few days. The soils was therefore still saturated during later rainfalls when even greater quantities of torrential waters flowed directly into the streams. This was characteristic particularly of the Sava Valley region, the western part of the Slovenske Gorice region, Ljubljana, the surroundings of Kranj, the Koper area, Goriška Brda, Prekmurje, and the Sava Valley region highlands between Celje and Sevnica. In these areas the steep slopes on impermeable bedrock were the most affected since the top layer of soil was still very unstable due to previous drenching. This phenomenon occurred primarily in the valleys between the southern edge of the Celje Basin and the Sava River and was most pronounced along the Lahomnica River near Laško.

The direction of movement of thunderstorms clouds is also very important since the form and size of water outflow from the affected part of a watershed depend upon it. The travel of a thunderstorm in the direction of streams shortens the concentration time and increases discharge peaks and conversely the movement of thunderstorms against the flow of streams prolongs the concentration time and reduces peak discharge (Kompare, Steinman 1992).

Finally we must stop with built-up areas. The dense settling of flood plain and catchment areas with the development of local economies and infrastructure has frequently not considered the characteristics of the environment and the local natural water regime. While encroaching on the environment, regional planners have not always considered the natural laws of landscape development. Numerous new buildings are located too near streams and at heights which do not ensure safety from flooding. It appears that older residents were more familiar with local surroundings since older houses were less affected. Some new buildings beside streams are also inadequate in their construction (no supporting or protective walls, poor foundations, lack of water outlets, insufficient drainage of meteorological waters, etc.) Many illegally erected buildings were affected, but there were also case when houses were damaged whose owners had all the necessary approvals and permits. For those areas concerned which are outside areas covered by regional planning, it was clear that in these cases the possibility of natural disaster phenomena had not been considered. Within the framework of regional planning, regulations regarding the components of threat from natural disasters are too lax, and threatened areas are poorly defined or restricted only by generally defined laws and regulations.

The survey of major storms in the summer of 1994 and their basic geographical characteristics shows that these kinds of natural disasters represent one of the greatest problems for regional planning in Slovenia. The affect on areas or the damage caused in individual cases is not as worrying as the very frequency of storms which sometimes occur several times a year in the same area. Along with becoming familiar in general with the problem of natural disasters, we must in future also concentrate on preventive actions against storms and their consequences. This must be present as much in the area of regional planning as in measures taken for the protection of residents and their possessions while at the same time we consider the basic natural laws of landscape development.

4. Survey of Selected Storms in the Summer of 1994

In the general survey we have already mentioned the importance of detailed investigations of some major natural disasters. In continuing we will therefore become familiar in detail with the actual consequences of three larger storms in the period under discussion and attempt to find the main causes of damage in the areas affected. The locations of these storms are indicated by the boxed numbers in Figure 1.

4.1. The Sava Valley Region, June 28, 1994.

One of the heaviest storms of 1994 struck the Sava Valley region lying east of Ljubljana on both sides of the Sava River between Litija and its confluence with the Savinja River (Figure 1; 13 and 14). This geographic regions is most often defined by the area of three districts situated here: Zagorje ob Savi, Trbovlje, and Hrastnik. All the larger towns, whose origins are linked to coal mining and the industry that developed with it, occupy narrow valleys relatively unsuitable for settlement.

In the area of these three Sava Valley districts, nearly half of the settlements were affected (Table 1). The Trbovlje district, where three quarters of all settlements were affected, stands out. During our field work, we observed that the damage to surface areas matched proportionately the damage to settlements

TABLE 1: NUMBER OF SETTLEMENTS IN SAVA VALLEY DISTRICTS AFFECTED BY THE SUMMER STORMS OF 1994.

	Hrastnik	Trbovlje	Zagorje	Total
number of settlements in district	19	17	72	108
number of settlements affected	11	13	32	56
number of more affected settlements	6	10	9	24
number of less affected settlements	5	3	23	32

Along with the Bolska River watershed which lies to the north, the central area affected stretched primarily across the valleys and catchment areas of the left tributaries of the Sava River in its course between Litija and Radeče. On its right, only the Sopota watershed above Rateče was more seriously affected. All the torrential streams in these watersheds, which are dry the greater part of the year, were filled.

The water achieved its greatest power in the beds of streams flowing directly into the Sava since there the relative height differences are the greatest and the fall is also large. Rock detritus closed some sections of main and local roads on both sides of the Sava River, particularly between Trbovlje and Zidani Most. Neighbouring areas did not suffer such great damage since substantially less rain fell there.

It was possible to follow the development of the storm with the radar at the meteorological station on Mount Lisca. The measured 24-hour quantity of rainfall at Čemšenik, which lies on the southern slope of the mountain of the same name, amounted to 113.8, and on Mount Kum to 116.2 l/m^2. Most of the rain fell in just over two hours. Elsewhere in Slovenia there was substantially less rainfall in the same period (by around 30 l/m^2) and a little more only in some areas of northeastern Slovenia and Notranjska (Cegnar, Mekinda–Majaron 1994).

The atmosphere became unstable the previous day when higher colder air started to flow in since a detached area of cold air had moved over the Mediterranean. The heating of the ground only increased the intensity of the process. On that day the highest temperatures in the greater part of Slovenia exceeded 30°C. In the morning and afternoon there were some thunderstorms in Primorska and Dolenjska, while in the evening many thunderclouds developed simultaneously, and the processes in two of them were especially intense. The first covered the Kočevje region and Notranjska, while the second, even more powerful, developed over the Sava Valley and part of Štajerska in about twenty minutes (between 21:30 and 22:00). From there it moved over Prekmurje. The exceptional local intensity of this storm is seen in Figure 5, which illustrates the spatial distribution of rainfall between the Sava and Bolska rivers. Over 100 l/m^2 of rain fell on both sides of the Posavje highlands in the area between Mount Čemšenik and Mount Mrzlica and around Mount Kum, the area's highest peak, on the other side of the deep gorge of the Sava River. In some places hail also fell with rain at the start. Somewhat less rainfall, about 70 l/m^2, fell in the wider area of Vransko. As the storm moved away from the central, most intensive rainfall area, the quantity of rain dropped quickly, amounting at Laško to 30 l/m^2 and at Celje to only 17 l/m^2.

The violence of the storm's erosive and accumulation processes was further increased by the unfavourable local surface relief of the mountainous terrain (part of the Posavje highlands) and the

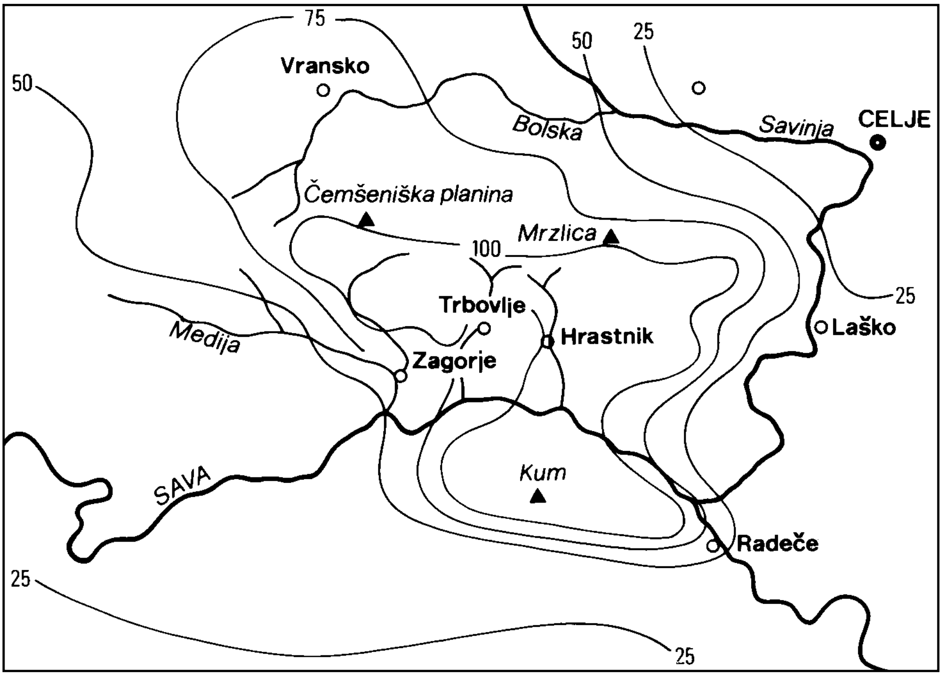


Figure 5: Spatial distribution of the 24-hour rainfall (in l/m²) in the area of the Sava Valley measured on June 29, 1994 at 17:00 a. m. (Cegnar, Mekinda–Majaron 1994).
Slika 5: Prostorska razporeditev 24-urnih padavin (v l/m²), na območju Zasavja, ki so jih izmerili 29. junija 1994 ob 7. uri zjutraj (Cegnar; Mekinda–Majaron 1994).

proximity of basins (the eastern edge of the Ljubljana Basin, the southwestern part of the Celje Basin, and the Litija Basin) over which the trapped stationary air was even more heated.

The bedrock in catchment areas and along streams as well as the width of the valley bottom also determined to a large extent the local consequences and indirectly the affects on settlements. The consequences of the storm were worst where impermeable bedrock coincided with the heaviest rainfall and the very steep slopes, at the foot of extensive, frequently unwooded steep slopes, or at the junctions of valleys.

The tops of the mountain folds between Čemšeniška planina, Mount Mrzlica, and Mount Kum are composed mostly of Triassic limestone and dolomitic layers with intermediate transitions (Basic Geographical Map, Celje and Klagenfurt pages, scale 1 : 100,000). These layers are in the form of separate insertions of clay shale, marl, and tuff. In some places the layers are stratified and stacked, in other places they are strongly crushed due to tectonic action. The prevalence of carbonate rock gives a permeable character to this region, and locally of karstified surface.

As the surface descends, the proportion of impermeable, mainly Permian carbonate rock increases, since from there the carbonate cover has been removed. Clay shale, flint, and conglomerate are prevalent, while in Permian patches siltstone and mudstone are also to be found (Basic Geographical Map, Celje and Klagenfurt pages, scale 1 : 100,000). Also less impermeable are the Oligocene and Miocene layers running along the Moravče–Trbovlje syncline where marl, flint, and sandstone and clay layers with insertions of limestone dominate. The major part of the Medija Valley runs along these layers, while other tributaries of the Sava River only cut them transversely. The northern side of the Sopota Valley above Radeče lies on carbonate (Triassic) rock, but its southern side lies on silicate (Permian carbonate) rock.

Local differences in permeability also influenced the extent and strength of slope processes. These differences determined the course of the outflow of rainwater from individual hydrographic hinterland

Figure 6: A completely destroyed section of road in the Kotredeščica catchment area. Here the valley narrows completely in limestone, and therefore the power of the water was even greater. The only thing that was remained was a buttress while almost the entire asphalt surface was carried away.
Slika 6: Popolnoma uničen del ceste v povirju Kotredeščice (Tesen). Tu se v apnencu dolina povsem zoži, zato je bila moč vode še večja. Ostal je le oporni zid medtem ko je skoraj v celoti odneslo asfaltno prevleko.

areas. Areas with a higher proportion of carbonate rock were therefore less affected than those on silicate rock. These were exposed mainly in places where there was some steep fall on the surrounding slopes and condensed settlements at the bottom of narrow valleys, on rock walls, or in very steep areas.

In narrow sections of valleys water swept away parts of or even whole roads (Figure 6). Above these narrow sections water flooded due to larger deposits under outlets (Figure 7) and the diminished natural flow, while below narrow sections it widely overflowed the flood plains, at first depositing flood debris and rubble and later fine sediment as well.

Along the Kotredeščica, which flows through Zagorje ob Savi before running into the Sava River, most bridges were swept away, around six kilometers of road was destroyed, and a athletics field and a fish pond were flooded completely. Over a distance of ten kilometers, the banks of the Kotredeščica and its tributaries were heavily damaged (Figure 8) and more than thirty residential buildings were flooded. Some landslides were triggered at new locations as well as at some old previously known acute foci areas. There was major damage to agricultural land, especially along both the Kotredeščica and the Sava. In Hrastnik the offices and working areas of numerous firms and private workshops were flooded.

The worst consequences occurred along the upper reaches of the Kotredeščica. In many places the river dug a new riverbed, deposited alluvium, and eroded its bottom and sides. The latter caused the triggering of landslides, especially on the slopes above the right bank where water ate away their feet. Houses standing beside the river were affected, in some places even those above the flood plain.

In one settlement, a torrential tributary undercut the foundation of a newly built house (Figure 9). It stood right on the outer side of the stream bed before the confluence with the Kotredeščica at the outlet of a side ravine into the gentler main valley with a relatively wide bottom. The foundations

Figure 7: Bridge in one of the settlements on the upper course of the Kotredeščica. Torrential alluvium soon blocked the inadequate outlet, and water flooded all the lower lying part of the settlement.
Slika 7: Most v enem od zaselkov v zgornjem toku Kotredeščice. Premajhen prepust so hudourniške naplavine kmalu zamašile, zato je voda poplavila ves nižjeležeči del zaselka.

together with the basement were swept away after half an hour, and the outer walls collapsed almost completely.

The damage in the Zagorje district just to river channels amounted to around five million dollars, while the total damage was estimated to be over fifteen million dollars.

The storm also caused considerable damage in Hrastnik and nearby settlements. Because of the clogging of its riverbed, the Boben stream was dammed in many places and the overflowing water flooded many houses. In two places the water supply system to Hrastnik was threatened. A torrent from the strip mining operation undercut the road and deposited large quantities of rock, soil, and trees. Near the glassworks it left a 1.5 meter deep and 2.5 meter wide eroded ditch. It flooded part of the factory and piled up rock, soil, and felled trees in industrial areas. According to the initial estimate, the damage here alone amounted to over 160,000 dollars.

The numerous deposits and landslides made the movement of local traffic impossible for several days, and a section of a regional road was closed to traffic for a longer period as well. During the storm, several already known landslide foci were activated. On agricultural surfaces the damage was considerable, as 40 to 50% of all field crops were destroyed. Almost the entire fruit crop was destroyed, since the hail easily smashed young shoots.

The storm also spread over areas east of Mount Kum between the Sopota and Sava rivers (Figure 1; 14). The settlements on the left bank of the Sava between Hrastnik and Zidani most were heavily affected.

In the Laško district the level of damage was estimated at somewhat over 2.5 million dollars, 70% of it to roads, 20% to waterworks, and the remaining 10% to residential buildings and agricultural surfaces. Previous storms (Figures 1; 9, 10, and 11) had already caused damage amounting to nearly 4.5 million dollars. The total damage caused by all the storms cost 5.7% of the district's GDP.

Figure 8: In some places the erosive indentations in the banks along the Kotredeščica were so extensive that they exposed water distribution pipes (on the right).
Slika 8: Erozijske zajede v brežine ob Kotredeščici so imele ponekod tako velik obseg, da so razgalile vodovodno napeljavo (na desni).

The June storm caused most damage in the immediate area of Trbovlje (Figure 1; 13), in settlements on the slopes above the town. Damage was so extensive, it was declared a disaster area.

In the town the drinking water supply was interrupted because rainwater flooded the connecting aqueduct and the main pumping station. Around 16,000 residents remained without drinking water, and the Hygiene and Epidemic Service warned the population to boil water. The lower part of the town beside the Trboveljščica stream was also without electricity. In many places gas escaped because of the damage to gas lines.

Immediately after the storm, all the roads in the Trbovlje area were impassable. Due to landslides, torrential deposits, felled trees, and damage to roads (eroded sections, raised and cracked asphalt), travel to all nearby settlements was impossible (Figure 10). In over thirty places local roads were covered with earth and rock left by landslides or as torrential deposits.

In addition to the city streets along the Trboveljščica stream and in several steeper side tributary ravines, the Trbovlje–Hrastnik regional road was partially damaged near the cement works, directly above the outlet of the Trboveljščica into the Sava River, and opposite the thermal power station. The majority of the bridges in Trbovlje (Figure 11) and the underground diversion of a stream near the cement works were damaged.

Soon after the heavy downpour started, the Trboveljščica began to overflow its reinforced and channelled riverbed across the surrounding open and built-up areas. It flooded along its entire length through the town. It exceeded its usual level by two meters, sweeping away trash bins and vehicles and flooding numerous residential, commercial, and business buildings and schools. For a short time, the central Trbovlje football field was transformed into a small lake. A machinery company was worst affected since water flooded its main production plant. The flood also destroyed factory floors, machinery was full of silt, and electric installations were destroyed. Along the whole length of the industrial area, the walled bed of the Trboveljščica and parts of the industrial roads beside factories were damaged. In the mentioned machinery factory alone, the damage was estimated at over one million dol-

Figure 9: The torrential Prešnik tributary undercut the foundation of a newly built house. It was built in an unsuitable location directly beside the riverbed. In the catchment area of the Kotredeščica, none of the older houses stand so near the streams.
Slika 9: Hudourniški pritok Prešnik je povsem spodjedel temelje pred kratkim zgrajene stanovanjske hiše. Zgradili so jo na neprimerni lokaciji neposredno ob strugi. V povirnih delih Kotredeščice ni starejših hiš, ki bi stale tako blizu potokov.

lars. Some important public institutions (a kindergarten, three school buildings, the cultural center, etc.) were also flooded.

Through a detailed geographical survey we can explain some of the causes and results for the exceptional local intensity of erosive and accumulative processes and the resulting damage. At the same time we must not ignore the influence of human activity in the region. We must expose some of the basic geographic elements which already by themselves increase the otherwise high degree of threat to Trbovlje and its surroundings. The most significant of these are:

- largely impermeable, steep, and only partly wooded hinterland (a high specific outflow and discharge quotient);
- great relief energy (large drop in height above sea level over short distances) and the corresponding discharge speed;
- height of the surrounding mountain ridges (some over 1100 m);
- narrowing of the valley and the corresponding natural decrease of the discharge capacity of the riverbed in the lower part of the town;
- numerous unregulated torrential tributaries in side ravines and valleys;
- unsuitable use of land in general (relationship between built-up and unbuilt-up areas) and in particular (abandoned areas);
- the too densely built-up valley bottom in the wide part of the valley;
- dependence of the population of the valley on coal and mining-related economic activities and the lack of consideration of natural conditions;
- disorder and too small capacity of water channel network and outlets;
- unsuitable regulation of the Trboveljščica through the town including obsolete buttresses, too low and narrow embanking of the riverbed, the partial channelling of the stream (in the area between the Post Office and the Rudis factory and at the cement works just before the outlet into the Sava River), and too low bridge construction (too small outlets);

Figure 10: One local road had been paved with asphalt only a few weeks before the storm. In the narrow ravine, the stream and its torrential tributaries cut into the road and completely destroyed it. From the size of the rock debris deposited along the edge of the road, we can see the force of the water.
Slika 10: Eno od lokalnih cest so asfalitrali le nekaj tednov pred neurjem. V ozki grapi so. se potok in njegovi stranski hudourniški pritoki zajedli v cestno telo in ga povsem uničili. S kakšno silo je drla voda vidimo po velikosti kamninskega gradiva, odloženega ob robu ceste.

- the generally neglected surroundings of streams (uncontrolled rubbish dumps, temporary log landings, abandoned quarries, etc.) and the communal disorder of the town and its suburbs.

The rainfall conditions in the June storms were undoubtedly exceptional. In spite of this we cannot deny that some anthropogenic interventions only increased the intensity and extent of the consequences of the storm. The slightly higher marginal sections of the town were flooded only briefly. Several hours after the storm the water had already drained away from these surfaces while it remained in some places along the Trboveljščica where the riverbed was blocked. During such heavy rainfall the canalization network could not cope with such large quantities of water or outlet shafts became clogged. In some places erosion undermined or destroyed canalization pipes, while in others they burst due to the exceptionally strong pressure of the draining rainwater (Figure 12). The function of the pipes was assumed by streets. The main road intersections at the bottom of the valley became confluences or division points for torrential streams carrying huge amounts of alluvial material. The course of the main road through the valley and its side road junctions also influenced the dimension and duration of the flooding.

In the much eroded and widened riverbed of the upper course of the Trboveljščica, great amounts of various alluvial material were deposited, among which much garbage could be found. In the entire catchment area of the Trboveljščica, numerous landslides occurred on the belt of Permian carbonate rock, mainly on steep grassy slopes and at curvatures in the relief (edges of cultivated terraces, slope ledges, dikes, roads, road and house cuttings). Due to erosion, the foundations of many houses were heavily undercut, and because the roads were impassable it was impossible to extinguish the fire in an outbuilding in one of the surrounding highland villages caused by lightning which also disabled the main rebroadcasting transmitter on Mount Kum.

Figure 11: The industrial bridge near one of Trbovlje's factories is a typical example of not considering the natural laws of the fluctuation of streams, since the size of the outlet was greatly underestimated during its construction.
Slika 11: Industrijski most pri eni od trboveljskih tovarn je eden od tipičnih primerov neupoštevanja naravnih zakonitosti kolebanja vodotokov, saj je bila velikost prepusta ob gradnji močno podcenjena.

The storm in the Trbovlje area caused the most damage along the Trboveljščica, and the only solution for exceptional (one-hundred-year) water levels is the complete technical and regional regulation of its riverbed through Trbovlje along with the regulation and professional engineering of its catchment area.

The property of most companies which reported major damage was not insured against flooding. The total damage in the area of the Trbovlje district was estimated at around 25 million dollars. Almost forty hectares of land were damaged by 29 landslides, and 75 farms were affected. Because of the storm local roads were covered by alluvial material in 42 places, and 12 outlets were destroyed. Nearly one half of the water and sewage system was damaged. Damage to 25 Trbovlje firms amounted to around 2.5 million dollars, water flooded the basements and partly also the ground floors of three school buildings and some business and industrial premises.

The final amount of damage in the storm on June 28, 1994, in the Sava Valley region was estimated at over 50 million dollars:

- in the area of Trbovlje about 25 million dollars;
- in the area of Hrastnik more than 15 million dollars;
- in the area of Zagorje more than 8 million dollars, and
- in the area of Laško 2 million dollars.

4.2. Golnik, June 30, 1994.

Only two days after the storm in the Zagorje area, a downpour occurred over Golnik, a small settlement north of Kranj lying at the foot of the western spur of the Kamnik–Savinja Alps (Figure 1; 19). This short intense rainfall covered a relatively small area on the southern side of the Kriška gora mas-

Figure 12: In the center of Trbovlje water came rushing from the mains and spread over the town streets. Part of the roadway was raised and carried away.
Slika 12: V osrednjem delu Trbovelj je pridrla na površje voda iz kanalizacije in se na široko razlila po mestnih ulicah. Pri tem je dvignilo in odneslo del cestišča.

sif and the settlements at its foot. Afternoon thunderstorms occurred with the passing of a weakened cold front.

Shortly before 20:00, Golnik and some neighbouring settlements were struck by a powerful storm with hail that lasted less than one hour. Torrential water carried huge amounts of rock material and wood from the steep forested slopes above the settlement. The first torrent brought a great quantity of various rock material and buried several houses in the upper part of the settlement. According to estimates, the water deposited about 5000 m^3 of material. The second torrent which appeared some hundred meters east of the first brought with it mostly rubble and smaller rocks, mainly causing major damage to the agricultural surfaces there. Water flooded some houses in the settlement, but it struck most severely the archive rooms and part of the laboratory of the Hospital and Institute for Pulmonary Diseases and Tuberculosis. The fact that local people do not remember a storm in this century with such consequences speaks for the extraordinariness of the phenomenon.

The meteorological conditions that brought about the development of the storm were as follows (Cegnar, Mekinda–Majaron 1994): above western and central Europe there was an area of high pressure, but in the afternoon a cold front reached the Alps and influenced the weather in Slovenia. In spite of somewhat less cold air in the heights than in previous days, the atmosphere was still unstable. Daytime temperatures exceeded 30°C, and therefore storms occurred in the evening and at night mainly in the mountains of northern Slovenia. Overall, no more than 10 l/m^2 of rain fell, but locally its intensity was much higher.

Figure 14 shows the spatial distribution of the 24-hour rainfall in the Golnik area. In the most affected area there is no rainfall observation station, but larger quantities of rainfall were measured a little to the north of Tržič (25 l/m^2), at Jezersko (23 l/m^2), and at Tržič (34 l/m^2). Given the consequences and an analysis of the radar picture, the amount of rainfall over Golnik must have been much higher, around 50 l/m^2 at least. This quantity of rain probably fell on the whole Kriška gora massif and

Figure 13: Traces of strong depth erosion at Hudi graben above Golnik. Almost in the direction of the greatest slope the route of a forest sledge route formerly used primarily for taking out logs became a powerful torrent in a very short time.
Slika 13: Sledovi močne globinske erozije v Hudem grabnu (ime!) nad Golnikom. Skoraj v smeri največjega strmca potekajoča gozdna vlaka, ki je nekdaj služila predvsem za spravilo lesa, se je v zelo kratkem času spremenila v mogočen hudournik.

Tolsti vrh, but only about 30 l/m^2 fell on the mountain ridge continuing across Mount Storžič to Mount Srednji vrh. The more distant valleys along the Kokra River and towards Ljubelj Pass already received less than 10 l/m^2.

The permeability of the Triassic massive limestone, grained dolomite, and slope rubble at the middle altitudes (and partly at the higher mountain altitudes) of the torrential hinterland and the impermeable bedrock of Oligocene marl and sandstone at the juncture of the steep ravined slope with the gentler sloping surface on which the settlement lies also contributed to the increased outflow (Basic Geographical Map, Klagenfurt and Kranj pages, scale 1 : 100,000). A special role was played by the wide sloping shelf below Tolsti vrh where there is also settlement. It functioned as a reservoir (a thicker layer of soil, cultivated land), and water poured over the edge of the shelf downhill towards Golnik. In doing so it chose the shortest route, rushing along old chutes, sledge routes, and cart tracks on this steep slope.

While crossing the mountain barrier created by the Karavanke Mountains (in this part the Košuta Massif), cold air passed over the much heated air mass at the northern edge of the Ljubljana Basin. This increased convection and the strong vertical development of thunderclouds. Water mixed with soil, rock debris, and individual larger rocks poured down the southern largely forested slopes of Kriška gora. All forest trails, former sledge routes, cart tracks, and roads in the settlement and above it became channels for carrying water and torrential material. In the steeper sections, the water was active mainly with depth erosion (Figure 13), but at the junction with the gentler section of the slope it began depositing the material it carried (Figure 15). All the "obstacles" blocking its progress were either

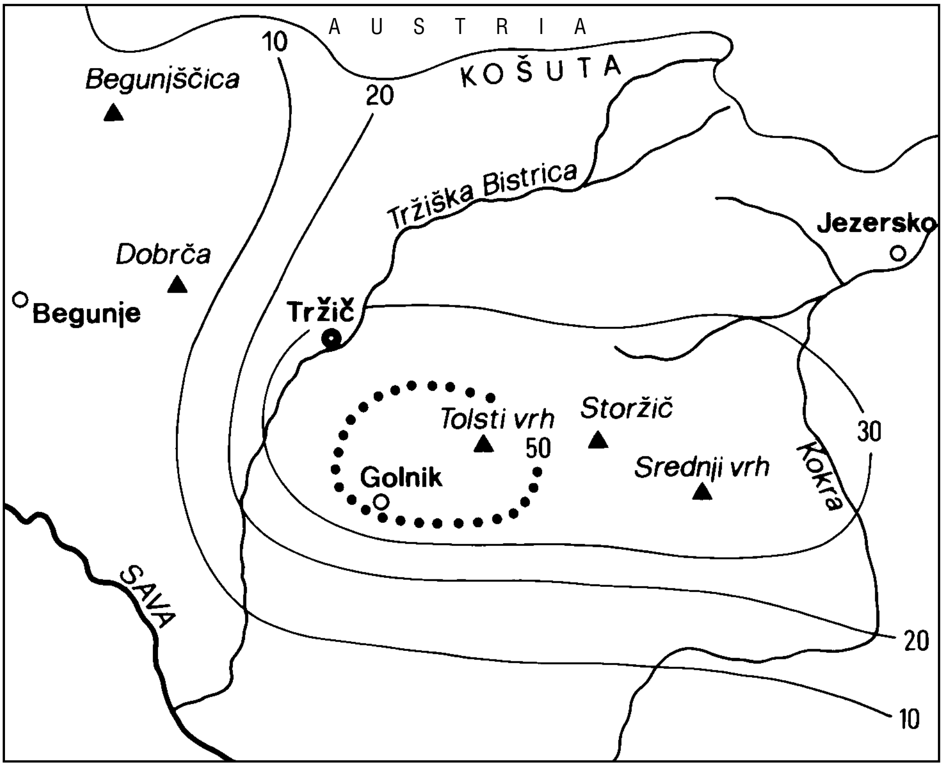


Figure 14: Spatial distribution of 24-hour quantities of rainfall (in l/m²) in the Golnik area, measured at 7:00 on July 1, 1994 (Cegnar, Mekinda–Majaron 1994).
Slika 14: Prostorska porazdelitev 24-urnih količin padavin (v l/m²), na območju Golnika, ki so jih izmerili ob 7. uri zjutraj 1.7.1994 (Cegnar; Mekinda–Majaron 1994).

flooded or covered with deep deposits of rubble, soil, sand, and wood debris. In the hospital building a wave of water and mud broke the door of the shaft up which food is transported, and water completely covered the basement archives room. By removing the debris at once and pumping out the water, major damage to the laboratories, the drug storage area, and the pharmacy was prevented. Ten years worth of archive data was destroyed.

The thundercloud began to form around 18:00, and the storm with hail started at 19:30. Water began to pour down numerous ravines and other routes into the central carelessly arranged forest chute (Figure 16) used for taking wood from the forest above the settlement. Recently a great deal of tree cutting had taken place here. In this part of the sledge route that became a torrent during the storm, deep traces of erosive activity of the water were left, a 2 to 3 meter wide and up to 1.5 meter deep trench with side erosion indentations (Figure 13). Above the upper edge of the settlement the torrent split and began to form two separate alluvial fans. In the two houses most affected by the alluvial fans, the basements and ground floors were flooded.

Several streets in the settlement and some nearby gardens were buried, and the basements of most houses above the hospital were flooded (Figure 16). The street network in the settlement collected waters that ultimately flowed together at the lowest point in the eastern wing of the hospital. The force of the water power broke down doors there and opened the way for the torrent. By opening the door at the lower end of the corridor they made it possible for the water to run from the ground floor at the same time. Because of its location, the hospital building functioned like a small reservoir since the building is rather long, slightly rounded, and built transversely across the direction of

Figure 15: Alluvial fan at the outlet of the torrential Hudi graben in the orchard above a house on the upper edge of the settlement.
Slika 15: Akumulacijski vršaj ob izteku hudourniškega Hudega grabna v sadovnjaku nad hišo na zgornjem robu naselja.

the torrential waters flowing down the slopes above the hospital (Figure 16). If the oblong hospital building had been at least partially divided or it wings connected by a raised corridor, there would probably have been no flooding or at least not to such extent. The flooding also damaged the hospital's beautifully arranged gardens and park.

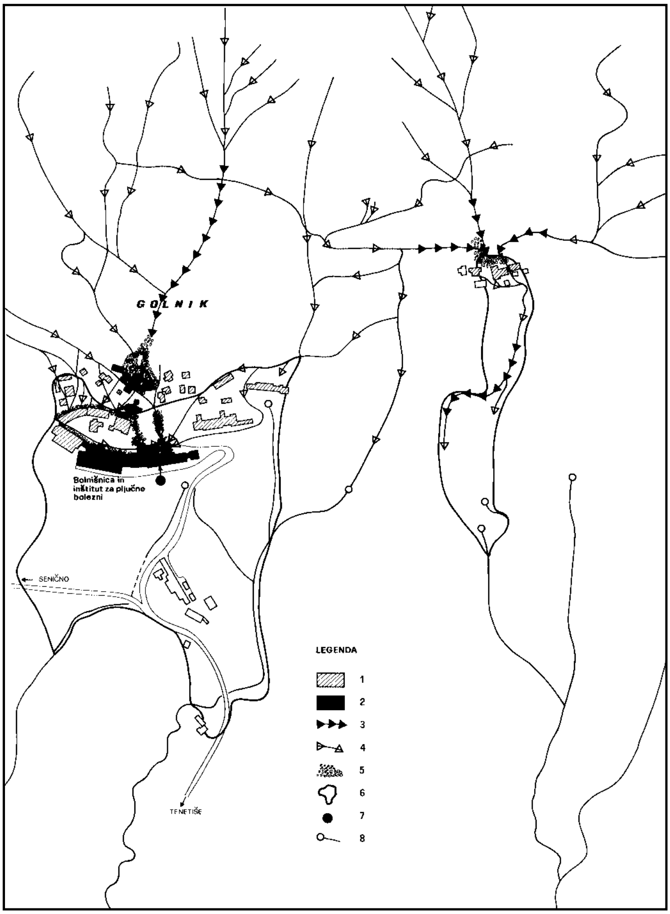
Nearby farms suffered damage mainly to pastures, meadows, fields, and gardens (erosion ditches, alluvial deposits, sand and rubble, topsoil washed away). Cart tracks deepened by erosion collected torrential water which spread over meadows and created erosion ditches. Farmhouses and their outbuildings in the eastern part of the settlement are built in such a way that the unimpeded flow of water towards the lower areas was possible (Figure 16). Here the agricultural land was eroded most heavily. Before flowing into the streams at the foot of the slope, the water spread widely and destroyed part of the crop.

The storm strongly damaged the majority of local roads. Some smaller damage also occurred to electricity transmission lines, the sewage system, and the water system.

The damage in the affected area was estimated to be nearly one million dollars, three quarters of it to the hospital, the remainder to individual buildings, the forest, and the agricultural land.

In closing, we can summarize the following conclusions reached during our study of the June storm at Golnik:

- the storm caused an exceptionally large amount of rainfall, the rapid runoff down the steep slopes contributed to the great erosive power of torrents;
- numerous forest paths, sledge routes, and cart tracks functioned as reservoirs for the central torrential ravines;
- extensive felling of trees in the steep forests above Golnik caused a large specific discharge from the torrential hinterland;
- unregulated sledge routes and abandoned chutes increased the erosive and carrying capacity of the torrents;



Key – Legenda:
1. mostly only flooded basements – poplavljeni večinoma le kletni prostori,
2. basements and ground floors flooded, larger deposits of mud – poplavljeni kletni in pritlični prostori; večji nanosi blata,
3. erosion gullies – erozijski jarki,
4. individual catchment branches and direction of temporary water streams during storms – posamezni zbirni kraki in smer trenutnih vodnih tokov v času neurja,
5. accumulation of rubble and sand – akumulacija grušča in peska,
6. areas flooded during the storm – med neurjem preplavljeno površje,
7. central point where water broke into the hospital building – osrednja točka vdora vode v prostore bolnišnice,
8. stream with source – potok z izvirom.

Figure 16: Consequences of the storm at Golnik on June 30, 1994 (topographical basis: map in scale 1 : 5000, Radovljica – 48 page).
Slika 16: Posledice neurja na Golniku dne 30.6.1994 (topografska podlaga: povečava Osnovne državne karte v merilu 1 : 5000, list Radovljica – 48).

- the site of the settlement at the transition from the steep permeable area to a gentler impermeable area (marl, sandstone) accelerated and strengthened the power of torrential water;
- some new houses were built on unsuitable locations at the outlets of still used and abandoned forest tracks;
- an unfavourable combination of relief and construction components caused irreparable damage at the hospital with the permanent destruction of archive records (Figure 17).

In examining this storm in the Golnik area, we can again state that some consequences could have been avoided or at least diminished if human influence and encroachments on the environment had not fundamentally increased the natural threat to the landscape.

4.3. Litija and its Surroundings, July 5, 1994

In the afternoon heavy rains with hail and strong wind struck the Litija area that lies thirty kilometers east of Ljubljana at a bend in the Sava River (Figure 1; 21). Thirty to one hundred percent of cultivated crops were destroyed, and great damage was caused to residential and business buildings and particularly to the municipal infrastructure. For a short time the town of Litija and the imme-

Figure 17: Height of water level in the hospital basement and shelves with ruined archive materials.
Slika 17: Višina vode v kletnih prostorih bolnišnice in police z uničenim arhivskim gradivom.

diate vicinity were without electricity. In the wider area of Litija, altogether more than 150 buildings were flooded. Total damage was estimated at more than eight million dollars.

The storm, accompanied in some places by hail, began soon after 14:00 (Figure 18). After an hour it abated, but around 18:30 it was repeated west of Litija. This tempest with hail activated torrents that demolished and undercut bridges and flooded and swept away fertile soil and crops. Roads were much affected, a large number of landslides were triggered, and numerous deposits of rock debris and other alluvial material were left on agricultural surfaces and roads. Torrential waters seriously threatened several residential buildings (residents were temporarily evacuated) and made some of the larger settlements inaccessible, especially in the more hilly parts of the Posavje highlands on both sides of the Sava River.

The meteorological conditions which caused the storms did not differ fundamentally from those in the Sava Valley area a week earlier. A weakened cold front moved over Slovenia, and the instability of the atmosphere (cooling at higher altitudes) triggered the formation of extensive thunderclouds over the greater part of Slovenia. The orography accelerated the movement of ascending air currents over the heated surface as the highest daily temperatures in the lowland areas of continental Slovenia at this time exceeded 30°C. Thunderclouds arrived above the Litija Basin from the south-east. As they passed over the highest section of the Posavje highlands, convection was further strengthened. The floor of the Litija Basin was also heated, accelerating the process.

The unfavourable geological composition of the surface on both sides of the Sava River contributed to the violence of the storm. The steep slopes are composed mainly of impermeable Permian carbonate flint sandstone, siltstone, slate, and conglomerate. Only the upper parts are of carbonate rock (limestone, dolomite, marl), but even slate and talus which are less permeable for water dominate

Figure 18: Felled trees and agricultural surfaces completely destroyed by hail near Litija. Hail damaged only a narrow belt of the total area struck by the storm.
Slika 18: Podrta drevesa in po toči povsem uničene kmetijske površine pri Litiji. Toča je prizadela le ožji pas v neurju prizadetega površja.

in some places. In the lower widened parts of the valleys that break up the hilly hinterland south of Litija, we find in the bedrock mostly clay mixed with boulders or rubble. The texture depends on the geological composition of the catchment area of individual tributaries of the torrential Reka River. Therefore in general, meadows dominate the moist valley bottoms while settlements are situated above the flood plains.

The rainfall during the June storm was so intense that within a short time roads were transformed into channels draining the torrential waters towards the lower parts of the valleys where there are larger settlements. Most seriously affected were settlements and roads along streams in narrow side valleys and at the foot of steep slopes of impermeable bedrock. The storm traveled in a belt two to five kilometers wide and some fifteen kilometers long. Over the central part of the Litija Basin the weather processes were the most intense, the hail was therefore the heaviest in this area, and the crops were almost completely ruined. The central area affected by the hail measured only a little more than 10 km^2.

While describing the type and extent of the consequences of storms, we have pointed out the influence of man and his unsuitable interventions in the environment and incorrect use of land. It was also demonstrated that the bridges and culverts of local roads were too small. In some places passages were clogged largely due to the large quantities of wood debris which the torrential streams picked up along their course (Figure 19). In the narrow and somewhat hidden valleys of the Posavje highlands there are numerous uncontrolled refuse dumps which are somewhat "emptied" during every heavier flooding.

As in the majority of smaller Slovene towns situated in highland areas, the unregulated drainage of meteorological water from public and communal areas also became evident in Litija during the storm. Several new houses have been built in locations threatened by torrential waters and landslides (Figure 20). The clean-up and repair of the houses affected and protective measures in potentially

Figure 19: Clearing an outlet in one of the numerous ravines in the surroundings of Litija. Torrential waters mainly carried wood debris among which there was considerable amounts of garbage from uncontrolled refuse dumps along the stream.
Slika 19: Čiščenje prepusta na enem od številnih grabnov v okolici Litije. Hudourniške vode so prinesle predvsem lesno plavje med katerim je bilo tudi veliko odpadkov z divjih odlagališč ob potoku.

threatened areas are clearly more expensive than seeking more suitable locations before issuing building permits.

In the area of Litija and its surroundings, a brief storm with intense rainfall of exceptional character occurred. There are numerous places here where the annual usual (in extent) and rather frequent thunderstorms create difficulties.

5. Conclusion

Following, studying, and documenting natural disasters must become one of the fundamental tasks in the context of the overall treatment of problems relating to the natural disasters which threaten Slovenia. On the basis of extensive studies and research in Europe, the participants at the last Conference on Climatic Changes held in Berlin in June 1995 determined that storms of exceptional dimensions with greater regional consequences will be more frequent in future. The warming of the atmosphere is increasingly evident and to some degree confirmed. Higher temperatures mean a larger quantities of heat that are a potential source of energy for all weather events over the earth's surface of above average power. Of course, each part of the surface (region) responds differently to these changes and the corresponding exceptional phenomena. Therefore it is of vital importance to be familiar with the local landscape and neighbouring areas in the context of the problem of the threat to Slovenia from natural disasters if we are to take further measures and make plans for protection and rescue

Figure 20: The riverbed of a smaller stream widened and deepened by erosion threatened a house near Litija. How deep the side erosion will be the next time a storm occurs and whether the house will then be far enough from the stream are questions we must answer in dealing with the issue of natural disasters as a whole.
Slika 20: Erozijsko razširjena in poglobljena struga manjšega potoka blizu Litije je ogrozila eno od tamkajšnjih stanovanjskih hiš. Kako globoke bodo bočne zajede prihodnjič, kdaj bo to in ali bo takrat hiša še dovolj odmaknjena od potoka so le ena izmed vprašanj, na katere bomo morali odgovoriti tudi s celostnejšim obravnavanjem problematike naravnih nesreč.

work in the sphere of safety from natural disasters, especially those measures which encourage prevention.

Preventive protection requires an integral system of solutions at the administrative, professional, and political levels. The proportion of budgetary funds intended for the ongoing regulation of streams has decreased in recent years, dropping to only 0.13% in 1993, and most of the funds available have been used for clean-up, that is, for curative activity. At the end of the 1970's, this proportion was 0.55%, and there was hope that genuine preventive work would begin on streams. Slovenia's riverbeds, torrents, and ravines (there are almost 8000 kilometers of river and stream beds of torrential character in Slovenia) are the conductors of high waters where all the power of the water concentrates during exceptional conditions. Here and in the immediate vicinity the regional consequences are the most serious. An unmaintained river network is very vulnerable, and the consequences are generally worse and largely unpredictable. Furthermore, disasters usually occur in the same places. After a disaster, work is concentrated only on repairing damaged objects while long-term solutions are put off. Any new construction or change means additional expenses which seem too high, and, of course, we fail to consider that short-term repairs will probably have to be repeated after the next major storm.

While dealing with natural disasters in Slovenia, we must not underestimate the influence and interference of man, who has increased the degree of natural threat to certain regions. Of particular significance are:

- unregulated construction: erecting buildings in threatened areas according to the “nothing has happened here for a long time” principle;
- building and paving roads without simultaneously arranging the drainage of waters, and
- excessive felling of trees in forests that diminishes their protective function.

We have already observed these deficiencies during our concrete examination of natural disasters. On the basis of these sample cases, we can develop positive thinking in relation to the problems of natural disasters. Warnings by older inhabitants and good judges of local conditions are often more effective than numerous letters and opinions from the responsible government offices. Insurance (premiums and compensation for damage) presents a special problem in the sense of responsibility or assigning blame for the damage. Very often we witness major damage even in the areas approved by the authorities as building zones within the framework of wider town planning. In their planning the potential or even actual degree of threat to planned areas has not been considered sufficiently with regard to natural disasters.
Following, documenting, and studying natural disasters requires a multilevel, multidisciplinary, and group approach (teamwork). In any case, the ultimate aim is a better knowledge of conditions in the field of safety and security from natural disasters and the determination of the degree and type of threat (actual and potential) to individual regions of Slovenia or their smaller surface units.

6. Sources and Literature – Viri in literatura

Cegnar, T., Mekinda–Majaron, T. 1994: Meteorološke razmere ob neurjih v juniju 1994. Hidrometeorološki zavod RS. Ljubljana.
Gregorčič, B. 1990: Neurja v Sloveniji v letu 1989 in vzroki njihovega nastanka. Ujma št. 4, str. 8–10. Ljubljana.
Hočevar, A., Petkvšek, Z. 1984: Meteorologija. Ljubljana.
Kajfež–Bogataj, L. 1992: Klimatske spremembe in vremenske ujme v Sloveniji. Poplave v Sloveniji, str. 37–44. Ljubljana.
Kompare, B., Steinman, F. 1992: Verjetne maksimalne padavine za Slovenijo. Poplave v Slovenji (zbornik), str. 45–58. Ljubljana.
Kranjc, A. 1983: Ogroženost Slovenije zaradi toče. Naravne nesreče v Sloveniji, str. 116–125. Ljubljana.
Osnovna geološka karta SFRJ 1 : 100.000, list Celje, 1978.
Osnovna geološka karta SFRJ 1 : 100.000, list Celovec, 1978.
Osnovna geološka karta SFRJ 1 : 100.000, list Kranj, 1974.
Osnovna geološka karta SFRJ 1 : 100.000, list Ljubljana, 1983.
Pristov, J. 1991: Razpored padavin in njihov vpliv na poplave 1990. Ujma št. 5, str. 10–15, Ljubljana.

Other sources – Drugi viri:

• Dnevni informativni bilteni Uprave za zaščito in reševanje Republike Slovenije, Oddelek za spremljanje naravnih in drugih nesreč.
• dnevno časopisje (Delo, Dnevnik, Slovenec, Republika).
• dnevna obvestila in opozorila Hidrometeorološkega zavoda RS.
• poročila izvršnih svetov prizadetih občin o posledicah in o nastali škodi.
• poročila posameznih občinskih štabov za civilno zaščito.
• poročila Podjetja za urejanje hudournikov o začasni sanaciji posledic neurja.
• dnevna poročila Republiške uprave za ceste oz. njenih regionalnih izpostav za vzdrževanje in varstvo cest.
• terenski zapiski in dokumentacija sodelavcev GI ZRC SAZU terenskih ogledov v poletju 1994
• Mesečni bilten junij 1994. Hidrometeorološki zavod. Ljubljana.

7. Povzetek – Summary

Poletna neurja leta 1994 v Sloveniji (pregled, osnovne značilnosti in podrobnejši prikaz izbranih primerov)

Miha Pavšek

Reliefno razgibano slovensko površje leži na stiku alpskega, panonskega in sredozemskega podnebnega vplivnega območja. Pri celostnem obravnavanju problematike neurij moramo poleg meteoroloških razmer nad prizadetim območjem upoštevati tudi geografske značilnosti prizadetega in sosednjega območja, ki pogosto odločilno vplivajo na stopnjo ogroženosti površja zaradi naravnih nesreč. Enako intenzivno vremensko dogajanje povzroča nad površjem raznolikih slovenskih pokrajin zelo različne učinke. Poleg fizičnogeografskih prvin površja je med najpomembnejšimi dejavniki tudi človeški. Pokrajinska podoba slovenskega površja se stalno spreminja tudi zaradi človeka in njegovih osnovnih funkcij, s katerimi si zagotavlja svoje temelje za življenje in delo. Ti so mnogokrat v nasprotju s pokrajinotvornimi prvinami, kar se še posebej kaže ob podrobnejšem preučevanju naravnih nesreč.

S splošnim pregledom in nekaterimi podrobnejšimi poročili o neurjih v poletju leta 1994 osvetljujemo posamezne vzroke in predvsem pokrajinske posledice na prizadetih območjih. Eden najpomembnejših ciljev je, da bi v prihodnje ob upoštevanju pokrajinske razvojne dinamike in z uravnoteženim prostorskim načrtovanjem zmanjšali škodljive posledice naravnih nesreč na ogroženih območjih. Prostorski posegi, normativna preventiva in operativna zaščita pred naravnimi nesrečami morajo ob za državo še sprejemljivih ekonomskih postavkah zagotavljati nadaljevanje skladnega razvoja slovenskih pokrajin. Pri tem je potrebno upoštevati in ohranjati naravne in poselitvene značilnosti posameznih pokrajinskih tipov slovenskega površja.

Na preglednem zemljevidu Slovenije (slika 1) so pod zaporednimi številkami prikazane vse pomembnejše lokacije večjih neurij med 13.6 in 15.9.1994. Kratkotrajna in padavinsko intenzivna neurja s spremljajočimi pojavi so nasploh najbolj značilna za poletno meteorološko trimesečje, ko se ozračje v prizemni plasti in v nižjih plasteh atmosfere najbolj segreva.

Opozoriti želimo predvsem na regionalno in časovno raznovrstnost ter na razlike v intenzivnosti pojavljanja neurij na reliefno razgibanem slovenskem površju. Nanizanih je kar 78 lokacij, kjer so pustošila poletna neurja ob 15 različnih vremenskih slikah, ki so privedle do neurij z intenzivnimi spremljajočimi pojavi v teku enega ali več dni. Neurja so bila najpogostejša v vzhodni in severovzhodni Sloveniji. Nekajkrat so pustošila tudi v osrednjem delu in na robovih Ljubljanske kotline, v nekaterih dolinah zahodne in severozahodne Slovenije, v jugovzhodni Sloveniji ter ob obali. Po pogostosti in površinski razprostranjenosti pojava neurij sta bili v ospredju območji Zasavja in Slovenskih goric z okolico. Krajevna pojavnost neurij je bila nekoliko pogostejša še v Prekmurju, med Pohorjem in Kozjakom, na Krško–Brežiški ravnini ter na širšem območju Kranja in Ljubljane. Na vseh omenjenih območjih je bilo prizadetih več naselij s pripadajočimi zemljišči v okviru posamezne pokrajinske enote (ravnine, pobočja, dna dolin ipd.). Pri preostalih lokacijah lahko govorimo o izraziti krajevni pojavnosti. Stopnjo poškodovanosti prizadetega površja so v mnogočem določale ravno geografske prvine teh območij. Prostorske značilnosti neurij na območju Slovenije za obravnavano obdobje lahko primerjamo tudi s časovno razporeditvijo njihovega pojavljanja.

A). Pri nekaterih primerih lahko jasno razločimo potovanje neurij prek obsežnega dela slovenskega površja. Prizadela so površinsko sklenjena večja območja, posamezna pa so se pojavljala izrazito točkasto (krajevni značaj), vendar na širšem območju Slovenije.

B). Del neurij je prizadel prostorsko manj obsežna območja posameznih kotlin oziroma nekaterih dolin. Na osnovi natančnejše časovne opredelitve smo ugotovili, da so se pojavila sočasno, ali pa so si sledila od zahoda proti vzhodu v enakomernih časovnih presledkih. Na vmesnem vzpetem površju

so bile posledice neurij manj izrazite, predvsem zaradi ugodnejših pokrajinskoekoloških prvin, ki so zmanjšale erozijsko moč in količino odtekajoče vode.
C). Posamezna neurja pa so se pojavljala tudi na pokrajinsko manjših območjih. Tu so bili prizadeti le deli gričevnatega sveta, posameznih kotlin ali dolin in njihovega zaledja ali pa le posamezna naselja.
Najbolj intenzivni spremljajoči procesi in posledice neurij so bili predvsem:

- globinska in bočna erozija posameznih vodotokov ter povečana površinska erozija (posedi, usadi in zemeljski plazovi, spodjedanje brežin agresivnejših vodotokov, porušitve in poškodbe cest, cestnih objektov in različnih cevovodov ter daljnovodov);
- močan, sunkovit in vrtinčast veter (vetrolomi, poškodbe na daljnovodih in stanovanjskih hišah ter večjih objektih z ravno, predvsem pločevinasto streho);
- akumulacija lesnega gradiva (vejevje, debla – svež in suh les);
- akumulacija grobega in finega kamninskega gradiva (hudourniški nanosi, peščene in blatne naplavine) na odprtih površinah in v kletnih ter pritličnih prostorih nekaterih stavb;
- preplavljanje (kratkotrajno poplavljanje) in poplavljanje izpostavljenih površin in prostorov na območju naselij in v bližini vodotokov;
- uničevanje kmetijskih zemljišč s poljščinami in vrtninami zaradi poplavljenosti oziroma preplavljenosti, toče in erozijskih ter akumulacijskih procesov.

Najhujša in najštevilčnejša je bila poškodovanost objektov na vodotokih. Porušeni in spodjedeni so bili številni talni (stabilizacijski) in zajezitveni pragovi, prepusti, regulacije, mostovi, obrežna zavarovanja in zajetja za manjše vodovodne sisteme. Ceste so bile najbolj prizadete na izpostavljenih delih, predvsem pa:

- vzdolž vodotokov ob dolinskih zožitvah;
- na zunanji strani potočnih okljukov (v dolinah s širšim dolinskim dnom);
- pod dolinskimi sotočji in grapami, ki se združijo v pobočju nad cesto;
- ob izstopih stranskih v glavno dolino;
- na mestih, kjer prečkajo manjše potoke, grape in hudournike (zamašitve prepustov, erozija);
- nizvodno od mostov (erozija) in na samih mostnih konstrukcijah (erozija in zamašitev), ki so imele premajhno prepustnost, ali pa se je odprtina zaradi obilice plavja zamašila;
- v vpadnici grap, kjer ni bilo prepustov;
- na delu, kjer so speljane v strmem pobočju (erozija);
- na mestih, kjer jih ogrožajo zemeljski plazovi;
- na križiščih in trgih, kjer se steka več stranskih cest (nanosi) in tam, kjer so hiše vzdolž ceste strnjeno pozidane (erozija).

Tudi ostale komunikacije so bile na nekaterih območjih precej poškodovane, voda pa je zalila tudi nekaj proizvodnih obratov. Veter je dvigoval ostrešja, med drugim tudi z večjih stavb, podiral številna posamična drevesa, nekajkrat pa je opustošil večje gozdne površine (vetrolom). Pri večjih naseljih so bili pri tem najbolj izpostavljeni obrobni deli, kjer so bili sunki vetra najmočnejši. Ne smemo tudi mimo številnih požarov, ki so jih zanetile strele. V nekaj primerih zaradi neprevoznosti cest ni bilo možno posredovanje gasilcev. Ponekod je napravila precejšnjo škodo toča, vendar pa je bila ta v primerjavi z ostalimi posledicami razmeroma majhna.
Obravnavano poletje je bilo eno najbolj vročih v zadnjem stoletju (primerjava podatkov za Ljubljano, op. a.). Vroči dnevi, ko najvišja dnevna temperatura zraka preseže 30°C, so bili v vzhodni Sloveniji že v začetku junija, najbolj vroče pa je bilo med 26. in 30. junijem, ko so bile najvišje dnevne temperature med 30 in 35°C. V juliju in avgustu je bilo vročih dni kar 29, posebej dolgo je bilo 20-dnevno obdobje vročih dni med 23.7. in 11.8.1994, ki je bilo eno najdaljših, kar smo jih imeli v vseh poletjih tega stoletja. Če upoštevamo dejstvo, da je letno v Ljubljani povprečno 10 vročih dni, vidimo, kako izjemno je bilo obravnavano poletje.
V obravnavanem obdobju so bile najpogostejše termične nevihte, nekaj pa je bilo tudi frontalnih. V drugi polovici avgusta je nastala nad severno Italijo tudi nevihtna supercelica, ki je potovala prek Slovenije proti vzhodu. V splošnem so se pojavljale padavine predvsem v obliki ploh in nalivov in so bile tudi zato prostorsko in časovno dokaj neenakomerno razporejene. Lokalno je padlo v uri tudi do 100 l/m^2. To pa je količina, ki povzroči spremembe v dinamiki površinskega odtoka (odvodnjavanja), saj se na določenem delu površja lahko že poruši ravnovesno pokrajinsko stanje.

Maksimalne dnevne višine padavin v Sloveniji sledijo osnovni razporeditvi letne količine padavin, ki se zmanjšuje od zahoda proti vzhodu oziroma severovzhodu. Na priloženem zemljevidu (slika 3) so prikazane 24-urne višine padavin (Pristov 1991) ob obilnejšem jesenskem deževju v letu 1980. Na osnovi izbranih podatkov so bile izračunane (Kajfež–Bogataj 1992) tudi najvišje možne 24-urne višine padavin v Sloveniji za povratno dobo 10.000 let (slika 4). Po teh izračunih so lahko dnevni viški padavin v osrednji Sloveniji do okrog 250 l/m^2, v vzhodni do 200 l/m^2 in v goratih predelih zahodne Slovenije tudi prek 500 l/m^2 dnevno (Pristov 1991). Te ocene so dokaj verjetne, saj je bilo v preteklosti v Sloveniji že izmerjenih tudi nad 300 litrov padavin dnevno na m^2 in sicer v srednjem Posočju (Livek nad Kobaridom) 440 l, v Polhograjskem hribovju (Lučine) 341 l, v zgornjem Posočju (Bovec) 330 l, na južni strani Snežnika (Gomance) 326 l in v Bohinju (Ukanc) 309 l.

Slika pa je povsem drugačna pri sicer manjši količini padavin, ki pade v zelo kratkem času. Pri računanju 24-urnih vrednosti po posameznih obdobjih v preteklem stoletju je pomembna ugotovitev, da se, ob upoštevanju podatkov za zadnja desetletja, te vrednosti stalno povečujejo (Kajfež–Bogataj 1992). Podrobnejše analize verjetnih maksimalnih padavin in odtokov za Slovenijo ni, maksimalne izmerjene 24-urne padavine v Avstriji (po Aulitzkyju) pa so na jugovzhodnem robu Alp do 670, v Karavankah od 200 do 300, na severnem robu Alp prav tako in v notranjosti do 170 l/m^2 (Kompare; Steinman 1992). Za Slovenijo sta na voljo podatka, da je v Novi Gorici (21.8.1988) padlo v eni uri 122 l/m^2, ob zadnjem neurju v Zasavju pa skoraj 80 litrov (90 litrov 70 minutah).

K vsej silovitosti vode in nastalim posledicam, ki jih povzročita v kratkem času njena moč in velika količina, gotovo prispevajo še nekateri drugi dejavniki. To so predvsem razvitost, razvejenost in velikost hidrografskega zaledja vodotokov. Pomembna je tudi urejenost strug in njihova povezanost s sistemom odvodnjavanja meteorne vode z javnih in komunalnih površin. Zanemarjena je urejenost vodotokov v povirjih in njihova bližnja okolica, kjer najdemo številna divja odlagališča smeti in lesne preostanke. Tudi nekatera urejena odlagališča so preblizu vodotokov, saj pri ureditvi niso upoštevali njihovega hudourniškega režima.

Posebej izstopajoče je neprimerno kanaliziranje vodotokov s premajhno zmogljivostjo v primeru hudourniške vode, gradnja objektov ob neutrjenih bregovih hudourniških potokov, gradnja škarp ob potokih, gradnja premostitev s premajhno pretočno odprtino in nenazadnje gradnja cest in s tem povezani posegi v pokrajino.

Poleg osnovnih reliefnih značilnosti je treba upoštevati tudi kamninsko podlago prizadetega območja in njegovega hidrografskega zaledja. Če primerjamo obravnavana neurja s pregledno geološko karto Slovenije lahko razberemo, da so bila prizadeta predvsem območja na nekraškem površju, predvsem pa ozke doline, ki imajo večinoma neprepustno hidrografsko zaledje. Taka območja so v Zasavju, ob vznožju Pohorja in Kozjaka, v Slovenskih goricah ter v zaledju spodnjega toka Savinje.

V nekaterih primerih je bil odločilnega pomena velik strmec vodotokov in velik povprečni naklon njihovega zaledja. Takih je večina lokacij v alpskem svetu, kjer so hudourniki ob intenzivnih padavinah prinesli obilo kamninskega gradiva (povirni deli Kokre, Nadiže, Soče in Save Bohinjke). Akumulacijski zasipi so nekajkrat neposredno ogrozili stavbe, ali pa se je za njimi razlila hudourniška voda in poplavila površine na prehodu iz strmejšega v položnejši del struge blizu dolinskega dna nad sotočjem.

Zelo pomembna je predhodna namočenost površja. Ponekod so si sledili močnejši nalivi le z nekajdnevnim presledkom in je bila prst že precej razmočena. Ob kasnejših padavinah je zato odtekla neposredno v vodotoke še večja količina hudourniških voda.

Pomembna je tudi smer gibanja nevihtnih oblakov (padavin), saj sta od tega odvisni oblika in velikost odtoka s prizadetega dela porečja. Potovanje nevihte v smeri vodnega toka skrajšuje čas koncentracije in povečuje odtočne konice in obratno (Kompare, Steinman 1992), pomikanje nevihte proti toku podaljšuje čase koncentracije in znižuje konične odtoke. Številne novogradnje so preblizu vodotokov in v višini, ki ne zagotavlja varnosti pred visokimi vodami. Kaže, da so starejši prebivalci bolj natančno poznali domače okolje, saj so bile v obravnavanih neurjih starejše hiše praviloma manj prizadete. Veliko je tudi črnih gradenj, kar nekaj pa je bilo primerov, ko so bile poškodovane hiše, katerih lastniki so imeli vsa ustrezna soglasja in dovoljenja. Ker je šlo za območja, ki so izven območij urejanja s prostorskimi izvedbenimi načrti, je bilo moč opaziti, da v teh primerih ni bila dovolj upoštevana ogroženost zaradi naravnih nesreč.

Pregled večjih neurij v poletju leta 1994 in njihovih osnovnih geografskih značilnosti nam kaže, da predstavljajo tovrstne naravne nesreče enega od večjih problemov pri gospodarjenju in urejanju prostora v Sloveniji.

Eno od najmočnejših neurij v letu 1994 je prizadelo območje **Zasavja** (slika 1, št. 13, 14). Tod je večina naselij v ozkih, za poselitev manj primernih dolinah, saj je bil njihov nastanek povezan s premogovništvom in na njem razvijajoči se industriji. Na območju treh zasavskih občin je bila prizadeta skoraj polovica naselij (preglednica 1).

Osrednje prizadeto območje je poleg severno ležečega porečja Bolske obsegalo predvsem pritočne doline in povirja levih savskih pritokov na njenem delu med Litijo in Radečami. Na desnem bregu je bilo močneje prizadeto le porečje Sopote nad Radečami. Oživele so tudi vse, večji del leta sicer suhe hudourniške struge v teh porečjih.

Voda je imela največjo moč v strugah vodotokov, ki se iztekajo neposredno v Savo, saj so tod relativne višinske razlike največje, velik pa je tudi strmec. Kamninski nanosi so povzročili zaprtje cestnih odsekov glavnih in lokalnih cest na obeh straneh Save, še posebej na odseku med Trbovljami in Zidanim Mostom. Sosednja območja niso utrpela tako velike škode, saj je tam padlo bistveno manj padavin.

Razvoj neurja je bilo moč sočasno zasledovati tudi z radarsko sliko meteorološkega observatorija na Lisci. Izmerjena 24-urna količina padavin v Čemšeniku, ki leži na južni pobočni polici istoimenske planine, je bila 113,8 in na Kumu 116,2 l/m^2. Večina padavin je padla v dobrih dveh urah (Cegnar, Mekinda–Majaron 1994). Izjemna krajevna intenzivnost neurja je vidna na sliki 5, ki ponazarja prostorsko porazdelitev padavin med Savo in Bolsko. Prek 100 litrov je padlo na obeh straneh Posavskega hribovja na delu med Čemšeniško planino in Mrzlico in okrog najvišjega Kuma, na drugi strani tod globoko vrezane prebojne doline Save. Ponekod je v začetku med dežjem padala tudi toča.

Silovitost erozijskih in akumulacijskih procesov je še stopnjevala neugodna krajevna izoblikovanost površja zaradi orografije (deli Posavskega hribovja) in bližina kotlin (vzhodno obrobje Ljubljanske in jugozahodni del Celjske kotline ter Litijska kotlina), nad katerimi se je ujet, mirujoč zrak še bolj segreval.

O pokrajinskih posledicah in s tem posredno tudi o prizadetosti naselij je v veliki meri odločala tudi kamninska podlaga v povirju in vzdolž vodotokov ter širina dolinskega dna. Posledice neurja so bile najhujše tam, kjer je neprepustna kamninska zgradba površja sovpadla z najmočnejšimi padavinami in velikim strmcem pobočij, v podnožju obsežnejših, pogosto negozdnatih strmali ali pa na dolinskih zožitvah.

Krajevne kamninske razlike v prepustnosti so vplivale tudi na obseg in jakost pobočnih procesov. Te razlike so določale postopnost odtekanja padavinske vode s posameznih hidrografskih zaledij. Območja z višjim deležem karbonatnih kamnin so bila zato manj prizadeta kot tista na silikatnih. Ta so bila izpostavljena predvsem na mestih, kjer se je pridružil še velik strmec okoliških pobočij in zgoščena poselitev v dnu ozkih dolin, na pobočnih policah ali pa v zelo strmem svetu.

Na dolinskih zožitvah je voda odnesla del, v posameznih primerih pa celo celotno cestišče (slika 6). Nad temi deli je poplavljala zaradi zastajanja večjega plavja pod prepusti (slika 7) in zmanjšanega naravnega pretoka, pod zožitvami pa se je na poplavni ravnici na široko razlivala in odlagala sprva plavje in bolj grobe, kasneje pa tudi fine sedimente.

Ob potoku Kotredeščici, ki teče pred izlivom v Savo skozi Zagorje ob Savi, je odneslo večino mostov, uničenih je bilo okrog 6 km cest, v celoti so bila poplavljena tudi športna igrišča in gojitveni ribnik. V dolžini 10 km so bile močno poškodovane brežine Kotredeščice in njenih pritokov (slika 8), vzdolž katerih je zalilo več kot 30 stanovanjskih objektov. Sprožilo se je nekaj zemeljskih plazov na novih lokacijah in tudi starih, že znanih, akutnih žariščih. Veliko škode je bilo na kmetijskih zemljiščih, predvsem vzdolž obeh vodotokov.

Neurje je povzročilo precej škode tudi v Hrastniku ter bližnjih naseljih. Pod vodo so bili poslovni in delovni prostori številnih podjetij in zasebnih delavnic. Potok Boben je bil zaradi zamašitve struge na več mestih zajezen, razlita voda pa je zalila več hiš. Na dveh mestih je bil ogrožen tudi mestni vodovod. Hudournik iz dnevnega kopa je spodjedel cesto in nanosil velike količine kamenja, zemlje in dreves. Pri steklarni je pustil za seboj 1,5 m globok in 2,5 m širok erozijski jarek. Poplavil je del tovarniških prostorov, na industrijske površine pa je nanosil kamenje, zemljo in podrta drevesa. Številni nanosi in zemeljski plazovi so za nekaj dni onemogočili odvijanje lokalnega prometa, dlje pa

je bil zaprt tudi odsek regionalne ceste. Škoda na kmetijskih površinah je bila precejšnja, saj so bili uničeni njivski posevki od 40 do 50 %. Skoraj v celoti pa je bil uničen pridelek sadja, saj je toča uničila mlade poganjke.
Neurje je zajelo tudi območje Laškega in predele vzhodno od Kuma med Sopoto in Savo (slika 1, št. 14). Hujše posledice so bile tudi v naseljih nad levim bregom Save med Hrastnikom in Zidanim Mostom.
Junijsko neurje je povzročilo največ škode na ožjem mestnem območju Trbovelj (slika 1, št. 13), v naseljih na pobočjih nad mestom. Posledice so dosegle takšne razsežnosti, da so razglasili izredno stanje. V mestu je bila prekinjena oskrba s pitno vodo. Spodnji del mesta ob potoku Trboveljščici je bil tudi brez elektrike, na več mestih pa je uhajal plin. Neposredno po neurju so bile neprevozne vse ceste na območju Trbovelj. Zaradi zemeljskih plazov, posedov, usadov, hudourniških nanosov, podrtih dreves in poškodb na cestišču (zajede, dvignjena in razpokana asfaltna plast) je bil onemogočen promet do vseh bližnjih naselij (slika 10). Lokalne ceste je zasulo na prek 30 mestih, zasutja pa so bila posledica zemeljskih plazov, hudourniških nanosov in usadov.
Trboveljščica se je že kmalu po začetku močnega naliva razlila iz utrjene, kanalizirane struge po okoliških odprtih in pozidanih površinah. Poplavljala je vzdolž celotnega toka skozi mesto. Svojo običajno višino je presegla za dva metra, odnašala je zabojnike za smeti in vozila, zalila precej stanovanjskih, trgovskih in poslovnih objektov ter šol. Osrednje trboveljsko nogometno igrišče se je za krajši čas spremenilo v manjše jezero. Od podjetij je bilo najhuje v Strojegradnji, saj je voda zalila glavno proizvodno dvorano, v vsej dolžini tovarniškega kompleksa pa je bilo poškodovano tudi obzidano korito Trboveljščice in del industrijskih cest.
Neurje na območju Trbovelj je povzročilo največ škode vzdolž Trboveljščice, zato je rešitev pred izrednimi (stoletnimi) vodami predvsem v celostni tehnični in krajinski ureditvi njene struge skozi Trbovlje ob sočasnem urejanju in strokovnih posegih v njenem povirju.
Nepremičnine večine podjetij, ki so prijavila veliko škodo, niso bile zavarovane proti poplavam, 29 zemeljskih plazov je poškodovalo približno 40 ha zemljišč, prizadetih pa je bilo 75 kmetijskih gospodarstev. Zaradi neurja so bile lokalne ceste zasute na 42 mestih, uničenih pa je bilo tudi 12 prepustov. Poškodovana je bila skoraj polovica vodovodnega in kanalizacijskega omrežja. Za okrog 300 milijonov tolarjev je bilo škode samo v 25 trboveljskih podjetjih, voda pa je zalila kletne in deloma tudi pritlične prostore treh šol in nekatere poslovne prostore podjetnikov in obrtnikov. Končna višina škode v neurju 28.6.1994 na območju Zasavja je bila ocenjena na prek 6 milijard tolarjev.
Le dva dni po neurju na območju Zasavja se je utrgal oblak tudi nad **Golnikom**, manjšim naseljem severno od Kranja (slika 1, št. 19). Tokrat so zajele kratkotrajne intenzivne padavine sorazmerno majhno območje na južni strani Kriške gore in naselja na njenem vznožju. Popoldanske nevihte so se pojavile ob prehodu oslabljene hladne fronte.
Nekaj pred 20. uro je prizadelo Golnik in nekaj sosednjih naselij močno neurje s točo, ki je trajalo manj kot uro. Hudourniška voda je prinesla ogromno kamninskega gradiva in lesa z gozdnih strmali nad naseljem (slika 13). Prvi hudournik je prinesel iz strmega gozda v pobočju nad naseljem veliko količino raznovrstnega kamninskega gradiva in zasul nekaj hiš v zgornjem delu naselja. Po ocenah je voda nanosila okrog 5000 m^3 gradiva (slika 15). Drugi hudournik, ki je oživel nekaj sto metrov vzhodno od prvega, pa je prinesel s seboj predvsem grušč in manjše skale. Večjo škodo je napravil predvsem na tamkajšnjih kmetijskih površinah. Voda je poplavila nekaj hiš v naselju, najhuje pa je prizadela prostore arhiva in del laboratorija Bolnišnice in inštituta za pljučne bolezni in tuberkulozo (slika 16).
Na sliki 14 je prikazana prostorska razdelitev 24-urnih padavin na območju Golnika. Na najbolj prizadetem območju ni padavinske opazovalne postaje, večjo količino padavin pa so izmerili še tudi severno od Tržiča (25 l/m^2), na Jezerskem (23 l/m^2) in v Tržiču (34 l/m^2). Količina padavin nad Golnikom je morala biti glede na posledice in analizo radarske slike znatno večja, vsaj okrog 50 l/m^2 (Cegnar, Mekinda–Majaron 1994). Takšno količino je verjetno prejel celoten masiv Kriške gore s Tolstim vrhom. Gorski hrbet, ki se nadaljujeje prek Storžiča do Srednjega vrha, pa le še okrog 30 litrov.
K povečanemu odtoku je pripomogla tudi prepustnost sredogorskega (delno tudi visokogorskega) hudourniškega zaledja (triasni masivni apnenec in zrnat dolomit, pobočni grušč) in neprepustna podlaga (oligocenski lapor in peščenjak) na pregibu strmega, z grapami prepredenega pobočja v položnejši del površja, na katerem je naselje. Voda, pomešana z zemljo, kamenjem in posameznimi večjimi

skalami je pridrla po južnih, večinoma gozdnatih pobočjih Kriške gore. Vse gozdne poti, vlake in kolovozi ter ceste v naselju in nad njim so se spremenili v kanale za prenos vode in hudourniškega gradiva. Na strmem delu je bila voda dejavna predvsem z globinsko erozijo, na pregibu pobočja v položnejši del pa je začela odlagati odnešeno gradivo. Vse "ovire", ki so zadrževale njeno napredovanje, so bile poplavljene, ali pa nasute z visokimi nanosi grušča, zemlje, peska in lesnega plavja. Zasulo je tudi del cest v naselju in nekaj bližnjih vrtov ter poplavilo kletne prostore večine hiš nad bolnico. Cestno omrežje v naselju je zbiralo vode, ki so se končno stekale v najnižji točki v vzhodnem krilu bolnišnice. Bližnji kmetje so imeli škodo predvsem na pašnikih, travnikih, njivah in vrtovih (erozijske zajede, nanosi, peska in grušča, odnešena prst). Erozijsko poglobljeni kolovozi so zbirali hudourniško vodo, ki se je razlila po travnikih in povzročala erozijske zajede. Neurje je močno poškodovalo tudi večino lokalnih cest. Nekaj manjših poškodb je bilo tudi na električnih daljnovodih, kanalizaciji in vodovodu.

Škoda na prizadetem območju je bila ocenjena na okrog 100 milijonov tolarjev, od tega tri četrtine v bolnišnici, ostalo pa na individualnih objektih, v gozdu in na kmetijskih zemljiščih.

Obilno deževje s točo in močnim vetrom je v popoldanskem času prizadelo tudi območje **Litije** (slika 1, št. 21). Kmetijske kulture so bile uničene od 30 do 100 %, nastala je velika škoda na stanovanjskih in poslovnih objektih, še posebej na komunalni infrastrukturi. Mesto Litija in bližnja okolica sta bila krajši čas tudi brez elektrike. Na širšem območju Litije je bilo poplavljenih skupaj več kot 150 objektov. Skupna škoda je bila ocenjena na okrog milijardo tolarjev.

Neurje, ponekod s točo (slika 18), se je začelo nekaj po 14. uri. Po uri se je poleglo, okrog 18.30 ure pa se je ponovilo zahodno od Litije. Vodna ujma s točo je oživila hudourniške vode, ki so podirale in spodjedale mostove, poplavljale in odnašale rodovitno zemljo ter poljščine. Močno prizadete so bile ceste, sprožilo se je večje število zemeljskih plazov in usadov, na kmetijskih površinah in cestah pa so bili številni nanosi kamninskega gradiva in drugih naplavin. Hudourniške vode so resneje ogrozile nekaj stanovanjskih objektov (prebivalce so začasno izselili) in povzročile nedostopnost številnih večjih naselij, predvsem v hribovitih predelih Posavskega hribovja na obeh straneh Save.

K silovitosti neurja je pripomogla tudi neugodna geološka zgradba površja na obeh straneh Save. Strma pobočja grade predvsem neprepustni permo-karbonski kremenovi peščenjaki, meljevci, skrilavci in konglomerati. Le vršni deli so iz karbonatnih kamenin (apnenec, dolomit in lapor), pa še tu ponekod prevladujejo skrilavci in meljevci, ki so za vodo slabše prepustni.

Padavine ob junijskem neurju so bile tako intenzivne, da so se ceste v zelo kratkem času spremenile v odvodnike hudourniške vode proti nižjim delom dolin, kjer so že tudi večja naselja. Najhuje so bila prizadeta naselja in komunikacije ob vodotokih v stranskih ozkih dolinah in pod vznožjem strmih pobočij z neprepustno kamninsko podlago. Neurje je potovalo v pasu, ki je bil širok od 2 do 5 km, dolg pa okrog 15 km. Nad osrednjim delom Litijske kotline so bili vremenski procesi najintenzivnejši, zato je bila na tem območju toča največja, pridelek pa skoraj v celoti uničen. Osrednje po toči prizadeto površje je merilo le nekaj več kot 10 km^2. Tudi na območju Litije in okolice je bilo kratkotrajno neurje z intenzivnimi padavinami izjemenga značaja.

Spremljanje, dokumentiranje in proučevanje naravnih nesreč zahteva večnivojski, multidisciplinaren in torej skupinski pristop. Končni cilj je vsekakor boljše poznavanje razmer s področja varstva in zaščite pred naravnimi nesrečami in določitev stopnje in vrste ogroženosti (aktualne in potencialne) posameznih slovenskih pokrajin ali njihovih manjših površinskih enot.