# Chapter 13
# River Systems Under the Anthropogenic and Climate Change Impacts: Bulgarian Case

**M. Chilikova-Lubomirova**

**Abstract** River systems as main surface freshwater transportation systems play a significant role in the natural and man developed processes. They are connected both to the aquatic and terrestrial ecosystems function and services and man related needs and activities gratification. All related processes are under continuous interaction between the on-going natural cycles and man developments. As a result, various type impacts occur with regard to the anthropogenic and climate change influences. One of them is connected to the water availability. It is vital for the ecosystems function and in a great term result on the developed man activities. Thus the understanding how various type impacts influence on its state is of great importance. For the purpose many crosscutting tasks are constantly developed: scientific investigations concerning the on-going processes, various types applicable to the practical solutions, strategies planning and management approaches. To balance the possible connected problems equitably and to guarantee their sustainable implementation different legislative measures are also obtained.

To clarify the presented the material is focused on the existing problems in the area with regard to the Bulgarian river systems quantification status. It is connected to the following issues:

- Basic description of the Bulgarian river systems, accounting the influence of topological and climate issues;
- Legislative and management clarification with regard to the implementation of the Water Framework Directive, Floods Directive, Blueprint to safeguard European waters, and related documents;
- Specification and delimitation between the connection to the river systems water natural regime, extreme and risk events.

For their better clarification in the material briefly are presented some of the most applicable methods that are used worldwide, in the EC and Bulgarian practice. Described aspects are examined with regard to the needs and functions of the

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ecosystem. Presented issues are illustrated by the results of original assessments and practical examples from both real flood and drought investigations.

**Keywords** Water management · River systems · Water extremes · Floods · Droughts

## 13.1 Introduction

The important role of river systems as main surface freshwater transportation systems significantly depends on many factors connected both to the anthropogenic, climate and climate change influences. Practically all the elements: as river sources and streams, main rivers, river tributaries, river mouth and related floodplain, watershed, wetlands, etc. are under constant pressure. Climate specifics connected to the local properties as topography, ground cover, existing soil type, its physical properties and state, land coverage, available artificial structures, etc. predetermine the local natural conditions. However, sectors as water supply, irrigation, electricity production, industry, transport and navigation, recreation, etc. also impact on the water state. As a result, some of river system elements widely vary, affecting the related aquatic and terrestrial ecosystems and environmental function. Such variations are observed temporary, seasonally or for a long time, causing in many cases continuous modifications associated with anthropogenic, climate or climate change impacts. Some of these alterations are not negative, but in many cases, they are the reason for occurring of harmful impacts and damages. Related outcomes effect on all the related environment and society or on the ecosystems as a whole. Thus of great importance becomes timely and systematically to protect the vulnerable ecosystems, their function, and services, and to keep the resultant economic and social welfare in an equitable manner.

To keep such balance, an appropriate decision is the implementation of best applicable management practices. This opportunity is connected to the establishment of sustainable river basin management implementation with regard to the integrated water management principles based on the ecosystem approach. Presented approaches allow well to balance all connected needs and interests: from man to ecosystems, from the society to related sector needs holistically. Their implementation is connected to a very good knowledge of the on-going natural and man-handled processes with the main accent on water as a resource. For the purpose, its state is of vital interest and point of continuous in situ monitoring and additional investigations as short- and long-term forecasting, projections, and usual, extreme and risk events diagnostics.

In Bulgaria presented processes are very well developed and point of interaction within the requirements of the European Community. As an EU Member State Bulgaria strictly follows all connected EC Directives and Regulations, transposed into the domestic legislation. Main requirements are strictly implemented: the current rivers water status is permanently determined; second stage of River Basin

Management Plans (RBMPs) and Flood Risk Management Plans (FRMPs) are under implementation; investigations connected to drought and water scarcity are also delivered; future predictions and projections studies are also provided.

To clarify the presented following briefly will be described main connected aspects with regard to the Bulgarian river systems and obtained measures with regard to the anthropogenic and climate and climate change impacts. Briefly will be considered the rivers hydrography with a special accent on natural, extreme and risk events, and ecosystems specifics. Some authors investigations in the area will also be presented, accompanied within a short description of the main EU and world-wide most usable practices and enforced legislation.

## 13.2 Bulgarian River Systems Specification

Bulgaria is a country situated in southeastern Europe, on the Balkan Peninsula. Its geographical location and topographical, hydrogeological and soil properties, natural habitats of the certain flora and fauna and the anthropogenic and climate specifics are determinable for the character of the Bulgarian river systems.

Bulgaria covers a territory of 110,994 square kilometers. It is surrounded by four countries, as follow: on the west by Serbia and North Macedonia (FYROM), on the south by Greece and Turkey, on the north by the Danube River as a natural water border with Romania. On the east, the Black Sea Coastline is a natural water border. On such relatively small area, wide natural forms and species can be observed. There are mountains with a high-mountain relief and altitude above 1,600 m, plain territories, meadows, woods, valleys, rivers and gorges, Fig. 13.1.

The northern part of Bulgaria is covered by the Danubian Plain. Its territory is hilly, with numerous plateaus and river valleys. It goes south of the Danube River and runs until reaching the Balkan Mountains. There are some of the important Bulgarian natural protected areas as the Srebarna Natural Reserve, Perisna Nature Park, Rusenski Lom Nature Park. Srebarna is a freshwater lake home of almost 100 species of birds and 22 protected rare or endangered species.

The Balkans Mountain spreads from the Vrashka Chuka Peak that is situated on the Bulgaria-Serbia border on the west to the Black sea to the east. It is a natural limit that separate Bulgaria on two main northern and southern parts. Its highest peak is Botev at elevation 2,376 m. There are the river sources of almost all the northern situated rivers that tribute to the Danube river—the rivers Lom, Ogosta, Vit, Osam, Jantra, Rusenski lom. Only the Iskar river runs from the southern part of Bulgaria from the Rila mountain. There are several important protected areas as Central Balkan National Park, Vratchanski Balkan Nature Park, Bulgarka Nature Park, etc. It hosts most of the Europe's large mammals such as broun bear, wolf, boar, chamois, deer, etc. On the south of the mountain is situated the Sredna Gora mountain that borders on the south with The Upper Thracian Plain.

The Upper Thracian Plain is situated southern from the Sredna Gora mountains and northen from the Rhodopes, Sakar and Strandza mountains, the Black Sea


**Fig. 13.1** Map of Bulgaria, based on Google

coastline delimitate it at the eastern part. It is a fertile agricultural region. The Maritsa, Tundzha, Stryama, Topolnitsa, Vatcha and their tributaries are the most important rivers in the area, playing an important role in the social life and economy.

The Rhodopes Mauntain is a widespread mountain range running south to the Greece border. Its highest peak is Goljam Perelik at elevation 2,191 m. The range gives the name of the terrestrial ecoregion Rodope montane mixed forests, belonging to the Temperate broadleaf and mixed forests Biome and the Palearctic ecozone.

Western from the Rhodopes is situated the Pirin mountain with the highest peak Vihren at elevation 2,914 m. The northern part of the range is protected by the Pirin National Park—a UNESCO World Heritage Site from 1983 with rich flora and fauna and relicit species. It is separated by the Mesta river from the Rhodopes range and the Predela saddle from the Rila mountain.

Rila mountain hosts the highest peak Musala with an elevation of 2,925 m—the hightes peak on the Balkans. Among the Rila mountain are the Seven Rila Lakes a group of glacial lakes situated between 2,100 and 2,500 m elevation. Significant territories of both mountains are National Parks.

Bulgarian Black Sea Coastline covers the entire eastern border of Bulgaria—378 km coastline with sandy beaches running approximately 130 km. Part of the coastline in the northern part is characterized by rocky headlands with cliffs up to 70 m high. Rivers as Ropotamo, Kamchia, Veleka, etc. flows there. Some of the coastline and connected areas are part of National Parks as Strandzha Nature Park, Kamchia Biosphere Reserve, etc.

With regard to the specific conditions, Bulgaria is one of the countries with the highest biodiversity in Europe. Bulgaria's biodiversity is conserved in national parks, nature parks and biosphere reserves under the Natura (2000), Fig. 13.2.

Bulgaria has a population of about 7.2 million people. It is unevenly distributed across the country, and a high proportion of the population live in towns.

Bulgaria has a variable and complex climate that is influenced by the strongly contrasted continental and Mediterranean climate and connected topological and land coverage specifics. Great emphases cause the main Bulgarian geomorphological regions as the Danubian Plain, the Balkans Mountain, the Upper Thracian Plain and Rilo-Rhodope region. As a result, five main climatic zones are formed, Fig. 13.3 (Donchev and Karakashev 2004; Alexandrov 2005; National Programme for Action 2014):

- Continental zone—Danubian Plain, Pre-Balkan and the higher valleys of the Transitional geomorphologic region;
- Transitional zone—Upper Thracian Plain, most of the Struma and Mesta valleys, the lower Sub-Balkan valleys;
- Continental-Mediterranean zone—the southernmost areas of the Struma and Mesta valleys, the eastern Rhodope Mountains, Sakar and Strandzha mountains;
- Black Sea zone—along the coastline with an average length of 30–40 km inland and

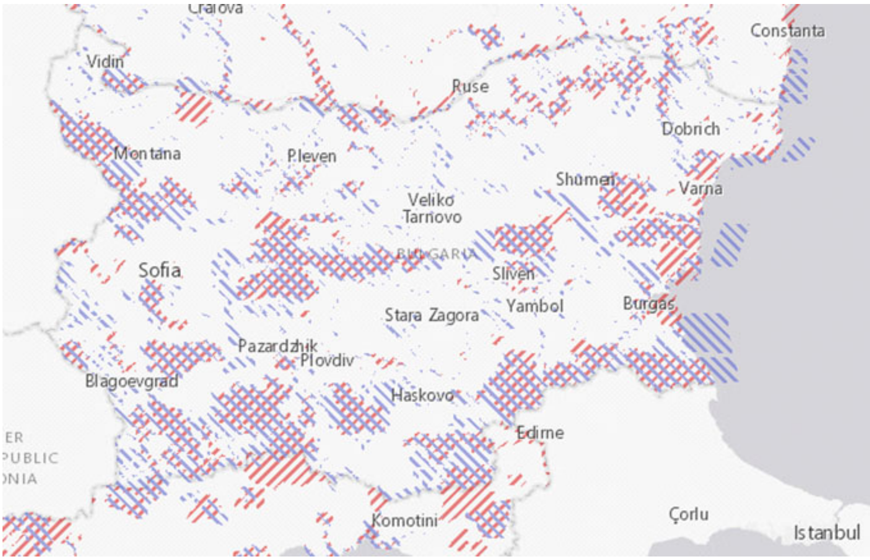


**Fig. 13.2** Natura 2000 sites, covering Bird Directive Sites (SPA) and Habitat Directive sites (pSCI, SCI or SAC), *Source* Natura (2000)


**Fig. 13.3** Bulgarian climatic zones, based on Agronet (National Programme for Action 2014)

- Alpine zone—in the mountains above 1000 m altitude like Central Balkan Mountains, Rila, Pirin, Vitosha, western Rhodope Mountains, etc.

The most important climate-forming factors are the Atlantic Ocean thought the atmospheric circulation of the Icelandic cyclone and the Azors anticyclone and the influence of the Mediterranean Sea influence, mainly throught the Mediterranian cyclones.

On the Danubian Plain, because of the flat and open to the north relief, the continental air masses easily flow into the flat and open to the north relief. During the spring, summer and autumn moist air masses easily occur, as in the winter the territory falls under the Eastern European anticyclone, that brings cold Arctic air mass and abundant snowfalls, about 12% of all precipitations there are form the snowfalls (Donchev and Karakashev 2004; Alexandrov 2005). The Balkans mountains become a natural barrier that stops the cool air masses coming from the north and the warm masses from the south. As a result, on average northern Bulgaria is about one-degree cooler and receives about 192 mm more rain precipitation than the lowlands of southern Bulgaria. The Rilo-Rhodope Massif deterrent the warm Mediterranean air masses and decrease the Mediterranean influences to the southern valleys of the rivers Struma, Mesta, Maritsa, and Tundzha. The influence of the Black sea affects approximately a 30–40 km strip along the coastline, where the breeze circulation is most pronounced (Donchev and Karakashev 2004).

For the majority of the country mean temperatures are higher than the relevant on the same latitude with 0,5 to 1,0 °C. The mean annual temperature varies from –3.0 °C—on the highest peak Musala to 13.9 °C at the town of Sandanski, in the southern Struma valley, and Sozopol town, near the Black Sea. The average temperature at the Danubian Plain is 11.4 and 13.9 °C at the Upper Thracian Plain. The highest temperature in the lowlands and the hilly regions is in June thus in the higher mountains is in August. The lowest temperatures are measured in January and February. Many valley basins scattered across the uplands have temperature inversions resulting in stagnant air. Sofia is located in such a basin, but its elevation (about 530 m) tends to lead to moderate summer temperatures and relieve oppressive high humidity.

Precipitations are not uniformly distributed on the Bulgarian Territory and over the year. They are closely linked to the atmospheric circulation peculiarities. The average precipitation in Bulgaria is about 630 mm per year. The north-eastern town of Dobrudja and a small part of the northern Thracian Plain usually receive precipitation less than 500 mm. The remainder of the northern Thracian Plain and the Danube Plateau get less than the country's average of rain. Summer droughts thus take effect in these areas. Elevated regions, which receive the most rainfall in the country, may average over 2,540 mm per year. In northern Bulgaria, the highest precipitation is in May-June, while in southern Bulgaria are during the winter.

Bulgarian river systems specifics are strongly influenced by the above-presented factors. As a result of the topography, the Bulgarian river systems network is dense, but with small relevant water catchments. There are not any large inland rivers. Crucial for the formation of the river is the Balkans Mountain that forms the natural watershed between the Black Sea and the Aegean Sea catchments.

One of the catchments is situated to the north of the Balkans, covering the rivers that tribute to the Danube River, the Rivers West of the groundwater shed of the Malm-Valange horizon and the Black sea rivers. There are distributed the main rivers Lom, Ogosta, Iskar, Vit, Osam, Jantra and Rusenski Lom and their tributaries that tribute to the Danube river, an international river, flowing to the Black Sea. Presented rivers source from the Balkans mountains, except the Iskar river, that is the only Danubian tributary that rise in the Rila Mountains, passes through the Sofia valley and after crossing the Balkan Mountains flows to the Danube. All of the presented rivers flow through the Danubian Plain, thus are under the connected continental zone climate influence.

Other rivers as Provadijska, Kamchija, Aheloy, Ropotamo, Veleka, etc. flow directly to the Black Sea. Most of them are typically short, except the Kamchija River. The Black Sea zone climate influences them.

On the south of the Balkans are situated the main rivers Struma, Mesta, Maritsa, Arda, Tundzha. They are transboundary rivers which upper part is situated in Bulgaria. Some of them after the Bulgarian borders confluence, e.g. Arda and Thudzha join to Maritsa (Evros, Gr. or Meriç, Tr.). All of them flow to the Aegean Sea.

The Sruma River sources from the Vitosha Mountain, flowing first westward, then southward gathering the waters of some of the highest Bulgarian Mountains—Rila and Pirin. The Mesta River sources from the Rila mountain and flow in between Rila, Pirin and Rhodopes Mountains reaching the Bulgarian-Greece border. Connected upland rivers tribute to both rivers. The upper parts of both rivers are under the Alpine zone climate influence, as the lower parts are impacted on the under the Continental-Mediterranean one. Presented circumstances contribute to the specific hydrological regime of the rivers.

Main rivers situated in southeastern Bulgaria are Maritsa, Thundza, and Arda. The Maritsa River sources from the Rila Mountains, flowing southeast through the Thracian Plain, passing between the Balkans, Rhodopes and Sakar Mountains, reaching the Bulgarian-Greek border, forming the Greek-Turkish border afterwards. Its main tributaries are the rivers Tundzha and Arda. The Tundzha river sources from the central part of the Balkans Mountain, flowing afterward east till Yamol city, where makes a sharp turn to the south, crossing the Upper Thracian Plain and reaching the Bulgarian-Turkey border. On the territory of Turkey, it join the Maritsa River. The Arda river sources from the Rhodope Mountains and afterward flows eastward until crossing the Bulgarian-Greek border. At the confluence of the Arda and Maritsa rivers lie the border between Greece and Turkey. With regard to the local topology presented three rivers are under both Transitional and Continental-Mediterranian zone climate influences that impact on the regime of the river.

In Table 13.1 are presented the main characteristics of some of the biggest Bulgarian rivers, based on the information presented in the Bulgarian River Basin Management Plans and connected literature (RBMP-DRBD 2016; RBMP-EARBD 2016; RBMP-WARBD 2016; RBMP-BSRBD 2016).

Bulgaria has about 400 natural lakes with a total area of 95 km$^2$. There are 179 glacial lakes in Rila and 164 in the Pirin. There are around 2,200 reservoirs serving different purposes—for water supply, electricity production, irrigation. The largest one is Iskar Reservoir, Ogosta Reservoir, Dospat Reservoir, Batak Reservoir, Kardzhali Reservoir, Studen Kladenets Reservoir, Koprinka Reservoir, Ticha Reservoir, etc. In Table 13.2 for some of them is presented brief information (RBMP-DRBD 2016; RBMP-EARBD 2016; RBMP-WARBD 2016; RBMP-BSRBD 2016).

**Table 13.1** List of some of the biggest Bulgarian Rivers characteristics (based on the information, presented in RBMP-DRBD 2016; RBMP-EARBD 2016; RBMP-WARBD 2016; RBMP-BSRBD 2016)

| Name | Length total, *, in the BG part (km) | Source | Catchment (km$^2$) | Mouth |
|---|---|---|---|---|
| Maritsa | 480 (321*) | Rila Mountain | 53 000 (21 084*) | Aegean Sea |
| Struma | 415 (290*) | Vitosha Mountain | 10 797 | Aegean Sea |
| Mesta | 230 (126*) | Rila Mountain | 2 767 | Aegean Sea |
| Tudzha | 350 | Balkans Mountain | 7 883 | Maritsa |
| Kamchia | 244 | Balkan Mountains | 5 358 | Black Sea |
| Yantra | 285 | Balkan Mountains | 7879 | Danube |
| Vit | 189 | Balkan Mountains | 3 220 | Danube |
| Iskar | 368 | Rila Mountain | 8 684 | Danube |

**Table 13.2** Specification of some main Bulgarian Reservoirs (based on the information, presented in RBMP-DRBD 2016; RBMP-EARBD 2016; RBMP-WARBD 2016; RBMP-BSRBD 2016)

| Reservoir | Area ($km^2$) | Volume ($m^3$) | Province |
|---|---|---|---|
| Iskar | 30 | 673 000 000 | Sofia City |
| Ogosta | 23.6 | 506 000 000 | Montana |
| Dospat | 22 | 448 220 000 | Pazardzik, Smolyan |
| Ticha | 18.7 | 311 000 000 | Shumen |
| Koprinka | 11.2 | 140 000 000 | Stara Zagora |
| Kamchia | 9.6 | 233 550 000 | Bourgas |

## 13.3 Legislation and Management Issues

Bulgaria is a Member State of the European Union. With this regard, European Union policies and legislation are transposed and enforced into the Bulgarian practice. Leading principle concerning WATER is the accepted ecosystem management approach with main connected documents:

- Water Framework Directive (WFD 2000). Directive 60/2000/EC;
- Directive 2007/60/EC (Floods Directive 2007);
- Directive 92/43/ECC (The Habitats Directive 1992);
- Common implementation strategy for the WFD, River Basin Management in a changing climate (CIS TR-2009-040 2009);
- River Basin Management Plans 2016 and connected documents,
- Convention on Biological Diversity (CBD 1992);
- United Nations Framework Convention on Climate Change (UNFCCC 1992) and connected The Kyoto Protocol (1998) and Paris Agreement (2015), etc.;
- Accepted issues are based both on integration between water, ecosystems and climate-related specifics. In help following National legislative documents are in force:
- Environment protection Law (2014);
- Water Law (2015);
- Regulation No 1/11.04.2011 (2011);
- Regulation No. H-4 from 14.09.2012 (2012);
- Regulation of terms and conditions for technical and safe exploitation of dams and associated facilities, as their technical state control (2016);
- Biodiversity Law (2017);
- Protected Areas Law (2013);
- National strategies and documents (National programs in the field of protection and sustainable development of waters, Marine Strategy, National Strategy for Management and Development of the Water Sector), etc.;

Main responsibilities for their best implementation at National Level carried the Ministry of Environment and Water (MOEW) and connected to it four River Basin

Directorates and sixteen Regional Inspectorates of Environment and Water, focused on the following main issues, (http://www.moew.government.bg/en/water/):

- Development and implementation of the Plans for River Basin Management and the Marine Strategy as main tools for integrated water management;
- Provision of sufficient quantity and quality of water for the needs of the population, economy, and ecosystems;
- Control of water resources and discharges of wastewater and development of monitoring systems;
- Mitigation of adverse climate impacts, associated both with floods, droughts, and water scarcity—development and implementation of specific preventive and protective measures, such as Plans for Flood Risk Management, etc.;
- Inland and transboundary waters protection and sustainable management.

River Basin Directorates operate on the following River Basin Districts:

- **Danube River Basin District**. It stretches between the Balkan Mountains and the Danube River, bordering with the East-Aegean River Basin Directorate to the southeast, West-Aegean River Basin Directorate to the Southwest and the Black Sea River Basin Directorate to the east. West border of the District is the National border with Serbia. This District spreads over 18 regional authorities, covering an area of 47 235 sq. km, about 42,5% of the Bulgarian territory. The territory is large and diverse—from mountain areas to wide plateaus. Main rivers associated with the District are the Danube, Ogosta, and rivers west of Ogosta, Islar, Vit, Osam, Yantra, Rusenski Lom, Danube Dobrudzha rivers, Erma, Nishava. All rivers flow from south to the north tributing to the Danube river. The Iskar river is the only river in Bulgaria that cross the Balkan mountains flowing to the north. There are artificial reservoirs as Iskar, Aleksandar Stambolijski, Yovkovci, Ogosta, and natural lakes and protected and zones like Sreburna, Persina, etc. Centre of the District is Pleven city.
- **Black Sea River Basin District**. It covers inland waters that directly tribute to the Black Sea and connected internal coastal waters. The district borders to the Danube River Basin District to the northwest and East-Aegean River Basin District to the southwest. The Black Sea forms its natural eastern border, 378 km long. It spreads over 8 administrative authorities, covering an area of 16 568 sq. km, about 15% of the Bulgarian territory. Most of them are important tourist centers. As a result, the population is irregularly distributed and significantly increases during the tourist summer season. Main rivers in the District are Shablenska, Provadijska, Kamchija, Fakijska, Ropotamo, Veleka, Rezovska, etc. There are situated complex water systems and dams as Kamchija, Ticha, Suedinenia and natural lakes as Shablensko, Durankolashko, Atanasovsko, Pomorijsko, etc. Centre of the District is Varna city.
- **East Aegean River Basin District**. It is situated in the central, southeast part of Bulgaria, bordering with the West-Aegean River Basin District to the west, the Black Sea River basin district to the east and the Danube river basin district to the north. South border of the District is the National border with Turkey.

It covers a territory of 35 230 sq. km, about 32% of the Bulgarian territory, situated in 12 regional authorities. The territory covers from mountain to plain areas, covering parts of the Balkans mountain system, Podbalkan, Upper Thracian Plain, Sakar-Strandja and the Rilo-Rhodope Massif. Main rivers are Maritsa, Tundzha, Arda, Byala. All of them sourced from the Bulgarian territory, forming the Maritsa transboundary river basin that tribute to the Aegean Sea. There are situated complex water systems and dams as Belmeken, Dospat, Vucha; natural lakes as Gurlata, Kabilsko lake, protected zones as Ormana, etc. Centre of the District is Plovdiv city.

- West Aegean River Basin District. It is situated in the southwest part of Bulgaria, bordering with the East-Aegean River Basin District to the east and the Danube River Basin District to the north. Its southern and western borders are formed by the Bulgarian national borders with Republic of Greece, North Macedonia (FYROM) and Serbia. It covers the territory of 11 965 sq. km, about 11% of the Bulgarian territory, spread by 6 regional authorities. A huge part of the territory is situated in the mountain areas of Rila, Pirin, and Vitosha, where sources the most of District rivers. Main rivers are Struma, Mesta, and Dospat. A specific of the District is that covers transboundary rivers both to Greece (Struma, Mesta, and Dospat), Serbia (Dragovistica river) and North Macedonia (Strumeshica and Lebnica rivers). There are artificial reservoirs as Pchelina, Stijkovci; natural lakes as Dospat, Gorno Gabrensko ezero, Rilski ezera, and protected areas as Messta valley, Rupite-Strumeshica. Centre of the District is Blagoevgrad city.

Presented river basin districts are organized with regard to the Bulgarian natural drainage districts, described following in part *4.2. Bulgarian River Systems Regime. Extreme and Risk Events Characterization.* Described River basin districts are graphically presented in Fig. 13.4. (RBMP 2016).

As it was already presented there is a huge variety concerning the Bulgarian river systems. This is connected to the size of the catchment area, the geology, altitude, slope, geology, flow regime, etc. In many cases, there are outer anthropogenic impacts that can be associated with the water utilization—both to water withdrawal and consumption. Thus in many cases, natural conditions are widely affected and heavily modified. This once again brings the matter to the attention of river systems appropriately investigation that requires implementation of suitable and reliable methods and tools for their real conditions description. In help of the Bulgarian Academy of Sciences Institutes and other organizations provide investigations in the area, supporting all processes of water policy preparation, improvement and implementation.

The effective water management processes connected to river systems level implementation requires good knowledge and information of many tasks. It is needed to be familiar with the water quantity and quality issues, water utilization, ecosystems needs, and function. Moreover, all the presented tasks are interconnected. However, to be considered in the reliable way many specialized works must be implemented. This material is focused on the river systems quantification

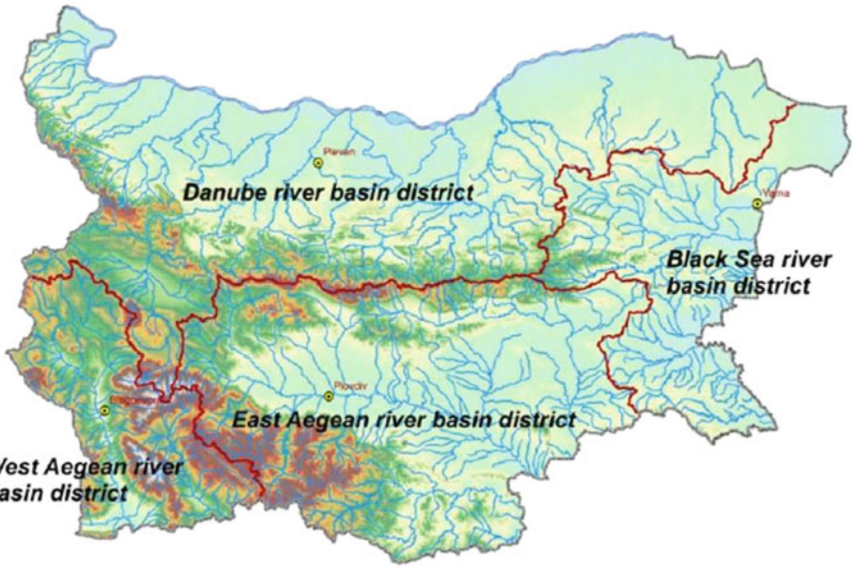


**Fig. 13.4** Bulgarian River Basin Directorates (RBMP 2016)

specifics. This includes both the river regime and extreme and risk events occurrences, as both issues are interconnected. For this purpose, the main connected basis is briefly presented with regard to the EU and Bulgarian experience in the area.

## 13.4 Bulgarian River Systems Regime

River systems behavior closely depends on various factors as local climate and topography, ground cover, existing soil type and connected physical properties and state, available artificial structures, etc. Presented issues are basic drivers for the water (hydrological) cycle that logically explain all the connected events. Atmospheric waters move by air currents before falling in precipitation form as drizzle, rain, snow, sleet, hail, etc. to water surfaces or land, forming there surface and subsurface flows. Part of surface waters flows in the form of surface runoff forming streams and rivers moving towards the sea. Part of runoff is filtered close to the surface forming soil moisture or groundwater discharge or stores into lakes, reservoirs or wetlands. Some waters infiltrates deep into the ground, moving along flow paths of varying length before reaching areas of discharge or store freshwater in aquifers for long periods of time. Groundwater moves slowly in contrast to surface runoff. Thus a clear differentiation of both physical processes is needed for proper evaluation and investigation of their impacts especially in case of their proper quantitatively description and understanding. Part of the groundwater form springs. Over a time period, water flows to the sea. Simultaneously processes as evaporation, transpiration, and sublimation runs allowing processes as condensation and water storage into the atmosphere. The water cycle adequately explains such water movements, and connected as a consequence of different occurring events. But to become reliable impression of importance is to account connected local specifics.

Bulgarian river systems include more than 325 small and large rivers. Respectively to the small territory in Bulgaria rivers are with small watersheds. Connected to the local topography rivers network is dense, especially in the mountain areas, but most of the rivers are short—229 rivers are less than 50 km in length, compared to 96—of more than 50 km in length. Mean drainage density in Bulgaria is 1.18 km/km$^2$. In mountain areas (Rila, the Balkan Mountains, Osogovo) it is more than 2 km/km$^2$, thus in some areas of the Danube Plain it is less than 1 km/km$^2$. With regard to the local conditions, the Bulgarian rivers flow to two main drainage basins—the Black Sea and Aegean. 57% of Bulgarian rivers drain to the Black Sea, and respectively 43% drain to the Aegean basin. Both basins are separated by the Balkan Mountain that, moreover, a natural climate border plays the role of a main drainage divide. Only 12% of the Bulgarian rivers flow directly to the Black Sea. The other part of the Black Sea drained rivers (45%) join the Danube River that flows to the Black Sea. All other Bulgarian rivers drainage to the Aegean Basin, outer to the Bulgarian territory, thus all of them are transboundary rivers.

For Bulgarian river systems, key formation role play both climatic and landscape factors. Landscape factors play serious role for the river systems networks formation. The existing topography, ground cover and its physical properties and state, available artificial structures and water transfers also predetermine the structure of the rivers network. From the climatic factors most significant are the precipitations (in liquid and solid form), surface temperature and evaporation.

Bulgarian rivers recharge is formed by two main sources—precipitations and groundwaters. There are rivers with snow-rainfall recharge. Such are the up-stream mountain rivers as Rila, Pirin, Balkan Mountains. They are characterized with significant recharge from the snow melting during the spring, and connected spring floods, summer, and winter regime is characterized by low flows. Other rivers are with rainfall—snow recharge. Such rivers are situated in the lower mountains as Predbalkan Mountain, Sredna gora, etc. Their spring recharges from snowmelt is not so indicative, while, normally summer and winter low flows occur. Some rivers are with typical rainfall recharge. Such rivers are situated near the south Black sea coastline, south of Rodiopes, etc. Their regime is forming mainly by the rainfall. There are rivers with karst groundwater recharge. Such rivers are situated in Dobruja, as Panega, etc. There are also some intermittent rivers. Some of them are situated in south Bulgaria, Dobruja, etc. As an illustration, following on Fig. 13.5 are presented the hydrographs of some of the Bulgarian rivers. They visualize the rivers monthly regime (Chilikova-Lubomirova et al. 2016).

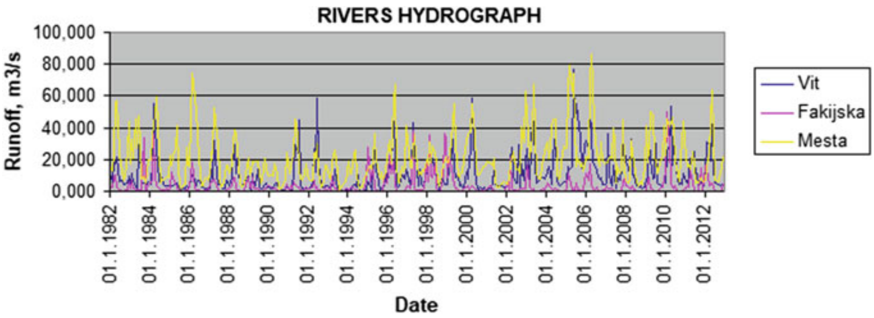


**Fig. 13.5** Rivers hydrograph (Chilikova-Lubomirova et al. 2016)

## 13.5 Extreme and Risk Events

Along with the regular river regime, there are some unusual events, often accompanied with harmful impacts to the rivers and connected artificial structures and ecosystems. Such water events are floods and droughts. In many cases, their occurrences tend to significant exposure and vulnerability, and adverse impacts as a consequence. Thus usually they are classified as extreme or risk events with strong attitude to the disasters. Their occurrence is strongly connected to the natural performance, but can be a result of anthropogenic works, or to both impacts. Thus during the process of their investigation, both nature and man activities must be properly accounted. For importance is to observe alterations in the connected physical systems behaviour and to account for the connected outer impacts, including climate change influences. This is connected to surveying of associated hazards and exposures, considering occurring or expected extreme or risk events. Risks of natural disasters in a very general sense is a combination of hazard and vulnerability (UN/ISDR-10-2007). Its proper consideration account all of the risk elements as follow:

**RISK = HAZARD * VULNERABILITY * EXPOSURE**

where:

Risk or Disaster risk represents the potential disaster losses or the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society. It is connected to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage;

Exposure—people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses;

Vulnerability—the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Such definition is punctual and comes to be clarified in the main water documents with regard to the main task connected to the risk managing and mitigation. This is well presented in the Flood Directive (2007) where: "flood risk" means "the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event".

In the context of drought (Blauhut and Stahl 2015), risk can be empirically estimated as the likelihood of impact occurrence. Drought risk is a combination of hazard and vulnerability, and managing risk requires understanding these two components and related factors in space and time (Chilikova-Lubomirova 2016).

### *13.5.1 Flood Events*

Flood events are well defined in the Flood Risk directive (2007). There "flood" is characterized as "the temporary covering by water land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems".

They are rapidly developed processes, in time of several minutes to several days, with the main cause of appearance—the abnormal amount of water. In most cases, the initial reason is connected to observed heavy precipitation or sudden snowmelt. Rivers connected structures operation or damages can also contribute to the flood occurrences. However, of importance are also the state of the river bed and channel, the river banks and floodplain with regard to connected aggradations or backwater effects. Aggradations are observed when the channel sediment volume is more than the flow can remove. In such cases sediment usually is deposit into the channel, making the existing river bed shallower, causing changes in the river channel gradient and decreasing flow velocities. Moreover, when reduced riverbanks are overtaken by the increase from floods discharges, overflow events can be observed even to slighter compared to the past conditions. Backwater effect occurs when the river flow meets obstructions that restrict its flow. Such effect can be observed in case of in-channel sediment deposits, river confluences, landslips of river banks, levees and dams, culverts, bridges, etc. In such cases river flow can break-through, creating a new channel or divert to an old one to bypass the deposited sediment.

When floods occur, it is distributed downstream as a wave. Observing it at a particular point, the water amount rises to a unique maximum (flood peak) over the overall normal flow (baseflow) and then recedes slowly. Such progress is presented in Fig. 13.6 (Chilikova-Lubomirova 2017).

In regards to the basic hydraulic principles, such flow can be considered as gradually varied unsteady flows, characterized by high temporal and spatial

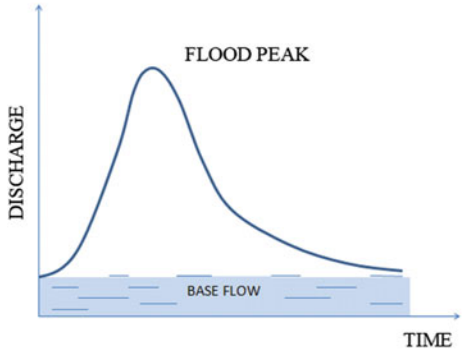


**Fig. 13.6** Flood wave propagation at a certain point of the river (Chilikova-Lubomirova 2017)

variations. In the basis of all flow descriptive models stay the Navier-Stokes equations (Jeppeson 1974; Popesku 2014; Lamb 1994; Lisev et al. 2013).

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+\rho g_x$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+\rho g_y \quad (1)$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+\rho g_z$$

where $u, v, w$, are the velocity components in regards to the rectangular coordinates $x, y, z$ and time $t$; p is the pressure, $\rho$ represents the density and $\mu$ represents shear viscosity.

They represent the balance of momentum. However, to estimate the flow with regard to practical solutions, additional data and information are needed. This information can be gain by the continuity equation and boundary data introduction. Such solutions can be obtained with the help of numerical modeling and computer simulations with regard to the adopted assumptions and initial conditions. For this reason, the following approaches are used in practice (Jeppeson 1974; Popesku 2014; Lamb 1994; Lisev et al. 2013):

(a) the method of characteristics
(b) the finite difference methods and
(c) the finite elements methods.

They are used for floods propagation characterization.

Considering the flood occurrence at a given point of importance is to investigate the event overflow over a specific threshold and connected recurrence intervals and probabilities of occurrences (Marchinkov 1973; Wilson 1980; Shaw 1994; WMO No. 1044 2010, Holmes and Dinikola 2010; Zeleňáková et al. 2017). For the purpose floods are characterized by the probabilities of occurrences connected to

**Table 13.3** Flood recurrence intervals and probabilities of occurrences (Chilikova-Lubomirova and Zaimes 2017)

| Recurrence intervals and probabilities of occurrences | | | |
|---|---|---|---|
| Recurrence interval, in years | The probability of occurrence in any given year | Percent chance of occurrence in any given year | Annual exceedance percentage |
| 100 | 1 in 100 | 1 | 1 |
| 50 | 1 in 50 | 2 | 0,50 |
| 25 | 1 in 25 | 4 | 0,25 |
| 10 | 1 in 10 | 10 | 0,10 |
| 5 | 1 in 5 | 20 | 0,05 |
| 2 | 1 in 2 | 50 | 0,02 |

the probability of the peak streamflow occurrence at a given location in any year. Connected thresholds are presented in Table 13.3.

Initial information for such studies are data obtained from the river gauging stations. In case of data absence for ungauged sites, regionalized streamflow statistics methods are used. Most commonly used methods are the:

(a) index-flood procedure,
(b) ordinary-least-squares regression procedure,
(c) weighted- and generalized-least-squares regression procedure and
(d) region-of-influence procedure.

Recently some methods using satellite images for floods events characterization are also developed. Of importance is to account that the flow at any particular point depends on local river bed and floodplain conditions with regard to the riverbed slope, floodplain shape, impoundments of streamflow, existing river regulation structures or reservoirs, water intakes and transfers, etc.

Flood events influence the associated river and floodplain conditions. Such influences can be positive, considering that the floodplain is watered and enrichment by the minerals from rivers sediments. However, they can also cause negative impacts, considering the severe outcomes and possible observed damages connected to the river segments and connected riparian zones, rivers and terrestrial ecosystems, existing artificial structures and economics. In some cases severe local areas and social disturbances are also observed; consequences as reduce agricultural production and damages connected to fences, farm buildings and houses, equipment and animals, roads, electricity, water supply and sewage infrastructure, communications, etc. Other related impacts can be connected to the evacuation of people and animals, people and animals victims, social disruption and financial costs. Their range closely depends on the severity of the flood. Thus the proper event characterization must account for them in the related assessment process.

In Bulgaria recently are observed floods with various consequences (Chilikova-Lubomirova 2017). Some are connected to extremely heavy precipitations that seriously impact on the existing infrastructure; others are as a result of the precipitations impacts on the existing infrastructure. For illustrative purposes following are presented some of the observed events.

Such event occurs in the Batulijska river watershed and connected areas in 2014, presented in Fig. 13.7.

Batulijska river average flow near Batulija village is 2,7 $m^3/s$. As a result of a heavy rainfall, its streamflow significantly increases in several hours. In some places, the water level raised up to 1 m. Large areas were flooded including river banks, streets, houses, a whole section of villages. Some infrastructure was destroyed such as roads, bridges, electric infrastructure while water supply was interrupted. On August 1st 2014 a state of natural disaster was declared in the area for the villages: Vlado Trichkov, Lukovo, Rebrovo, Batulija, Bakjovo, Ogoja, Jablanitza, Bukovetz, Tompsan, Redina and Leskov dol. Some of the connected consequences are presented in Fig. 13.8 (Chilikova-Lubomirova 2017).

Common consequences were observed after the severe flood damaging Varna area, Eastern Bulgaria, near the Black Sea, June 2014—illustrated in Fig. 13.9.

In Belosem village area, situated in Southern Bulgaria, Upper Thracian Plain, Sept. 2015 such events also occur—Fig. 13.10.

Floods caused by artificial structures disturbance as a result of heavy precipitations were observed in the Tzar Kalojan village area, Aug 2007 (Danube Plain); Biser village area, Feb 2012 (Southern Bulgaria), etc. Both floods were caused by caused by closely situated dams disturbance. As a result in the first case more than

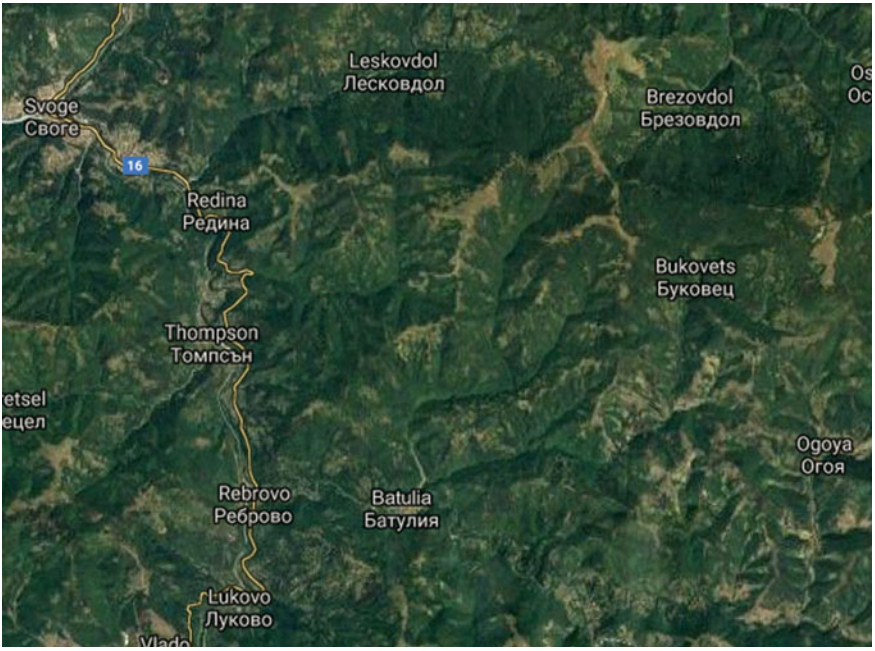


**Fig. 13.7** Batulijska River Location, Western Bulgaria, *Source* Google Map

**Fig. 13.8** Floods damages **a** Leskovska river, **b** Batulijska River area (Chilikova-Lubomirova et al. 2017)

**Fig. 13.9** Flood event in Varna area: **a** flood propagation, **b** flood consequences (Chilikova-Lubomirova et al. 2017)

1000 properties were affected, 21% of the properties significantly endangered or collapsed, about 70% of infrastructure collapse and eight humans lost their life. The second flood also caused significant damages, ten people lost their life. Some of damages are illustrated in Fig. 13.11 (Chilikova-Lubomirova 2017).

The last presented floods can not be identified as extreme events, but the main reason for their occurrence can be accepted as a result of extreme events.

**Fig. 13.10** Flood in Belozem, Southern Bulgaria, Sept 2015 (Chilikova-Lubomirova et al. 2017)

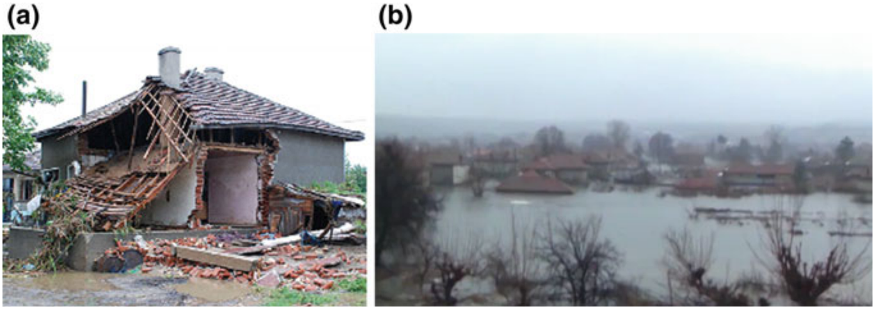


**Fig. 13.11** Floods resulting of artificial structures damages: **a** Tzar Kalojan village, Aug 2007, **b** Biser village, Feb 2012; (Chilikova-Lubomirova et al. 2017)

To mitigate such events with regard to the WFD (2000) and Floods directive (2007), following the preliminary flood risk assessments, the European Member States are required to prepare floods hazard and risk maps and Flood Risk Management Plans (FRMPs). For this purpose, all the four River Basin Directorates in Bulgaria also produced Flood Risk Management Plans, 2016–2021 (FRMP-DRBD 2016; FRMP-EARBD 2016; FRMP-WARBS 2016; FRMP-BSRBD 2016). They consider various aspects of water management including connected preventive, protective and preparedness works in six years period. For this purpose, various aspects of past flood events and areas with significant flood risk were considered. Such plans outline the main frame for future investments in the area for mitigation, preventive and preparedness works on a National level. In help, additional investigations are also conducted. They are connected to the possibility of additional measures providing (Chilikova-Lubomirova and Zaimes 2017; Zeleňáková et al. 2017; Ganová et al. 2017).

### 13.5.2 Droughts

Drought is a natural phenomenon that is characterized as "a temporary decrease of the average water availability due to e.g. rainfall deficiency. (http://ec.europa.eu/environment/water/quantity/about.htm)". It is a complex process connected both to meteorological, soil moisture and hydrological aspects of the water cycle, all observed as extreme events. With this regard usually following aspects or drought types are considered (Beran and Rodier 1985; COM 673 Final 2012; Merida et al. 2014; Chilikova-Lubomirova 2016):

- Meteorological or atmospheric drought, characterized as a prolonged period of precipitation deficiency, leading to hydrological imbalance or lower snowcaps, going along with high temperatures, high winds, low relative air humidity, increasing sunshine, low clouds cover, etc., causing serious effect on soil moisture and surface and subsurface waters.
- Agricultural or soil moisture drought, associated within periods with soil water deficiencies, causing plant water stress, reduced biomass and yield, and decreased recharge to surface and subsurface waters.
- Hydrological drought, considered as the abnormally low amount of water, affecting surface and subsurface water. It is associated with reduced streamflow, inflow to reservoirs, lakes, and ponds; reduced wetlands, and impacts on wildlife habitats.

As a consequence in many cases further stress to different sectors, the society and ecosystems are also observed. For this purpose, the problem is well considered by different practices, including water and climate change issues. The Intergovernmental Panel on Climate Change (IPCC) is focused on it as one of the recent challenges connected to observed extremes with impact on crop yields, general ecosystem functioning, water resources, and electricity production. The Water Framework Directive (2000) as main authoritative water addressed prescription of the EC and connected documents as: COM 673 Final 2012; Guidance document N24 2009 are also focused on it.

To clarify the problem with regard to river systems, various investigations were provided in time. And contrary to floods, which are simpler to be measured and quantified, droughts very often seem to retain qualitative connotations. In the past usually low flow were addressed to the problem. But accounting that low flow can represent a casual state of the river flow, to investigate the problem new approaches emerge. The basis was introduced stressing that there is a significant difference between streamflow drought and low flow: Low flow represents the lowest sustaining flow during base streamflow conditions. It is connected to the physical development of flow and represents the regime of a stream. It is connected to the average annual cycle of the streamflow, and the terms 'low flow period' and 'high flow period' are used to describe the normal annual fluctuations of streamflow linked to the annual cycle of the regional climate. For example in the Continental climate zone (representative for Bulgarian conditions) the regime of a stream can show one or more low flow and high flow periods during a year. Contrary the streamflow drought is more general phenomenon. It is addressed to prolonged untypical period, described by characteristics as duration, time of occurrence, starting and ending date, severity and minimum flow, when looking at the series in a specified period of time. Thus the particular low flow is a particular characteristic of drought, but not necessarily represents a drought. This very fine distinction between the two processes in many cases hampers both processes differentiation and properly investigation. In help of the practice various investigations recently were provided. One of the outputs was the drought indexes evaluation. For the streamflow drought investigation such opportunity provides implementation of the Standardized Runoff Index—SRI (Shukla and Wood 2008; Chilikova-Lubomirova 2013; Merida et al. 2014). It is a standardized evaluation of flow allowing accounting and grading its abnormal state. It is common to the Standardized Precipitation Index—SPI (McKee et al. 1993; Guttman 1999) and has common ground but in the process of evaluation the streamflow specifics are used for the index calculation. Evaluation scale proposed by the Expert Group on Water Scarcity & Drought, EC is:

(a) $-0.84 \geq SRI \geq -1.28$ corresponds to moderate drought;
(b) $-1.28 \geq SRI \geq -1.65$ corresponds to severe drought;
(c) $SRI < -1.65$ corresponds to extreme drought.

On this base, and on a monthly basis, some drought investigations were provided for some main Bulgarian rivers (Chilikova-Lubomirova et al. 2013, 2016). Rivers were selected with regard to investigate the possibility of streamflow drought occurrences diagnostics on the Bulgarian territory. For the purpose in the material are presented investigations connected to three different rivers, two of them: the Ogosta and Iskar Rivers are situated in neighboring watersheds in the Nort West Danube floodplain, and the third one—the Ropotamo River is situated near to the Black Sea. Investigations were provided with direct monitoring discharge data from the following monitoring points: Ogosta River—HMS 16850, Iskar River—HMS 18850, Ropotamo River—HMS 83620. Selected investigations present the drought diagnostics results for 2013 that can clarify the behaviour of rivers with different hydrological and hydro-morphological regime, flowing through different geographical, topological, climate, etc. conditions. The investigation results are presented in Table 13.4 and illustrated on Fig. 13.12.

Obtained results show that during the year streamflow drought was observed on the Bulgarian territory. For Ropotamo River moderate streamflow drought was identified for the months August and September. For Iskar River drought was identified as follow: severe drought—during months August and September and moderate drought—during the months from October to December. On the neighboring to the Iskar River, Ogosta River existence of a streamflow drought was not observed. Presented results can be interpreted as drought diagnostics results. They show that although Ogosta and Iskar rivers are rivers flowing in neighborhood watersheds, characterized by some common climate and meteorological, in some

**Table 13.4** SRI-1 values for the Rivers Ogosta, Iskar and Roporamo (Chilikova-Lubomirova et al. 2016)

| SRI-1 | Ogosta | Iskar | Ropotamo |
|---|---|---|---|
| | HMS 16850 | HMS 18850 | HMS 83620 |
| January 2013 | –0,451 | –0,697 | 0,029 |
| February 2013 | –0,461 | –0,562 | 0,837 |
| March 2013 | 0,197 | –0,086 | 0,639 |
| April 2013 | 2,075 | 0,582 | 0,682 |
| May 2013 | 0,463 | –0,706 | –0,075 |
| June 2013 | 0,147 | –0,752 | –0,306 |
| July 2013 | –0,010 | –0,251 | –0,597 |
| August 2013 | –0,334 | –1,312 | –0,841 |
| September 2013 | –0,445 | –1,455 | –0,863 |
| October 2013 | –0,382 | –1,111 | –0,527 |
| November 2013 | –0,434 | –1,170 | –0,596 |
| December 2013 | –0,397 | –1,142 | –0,793 |

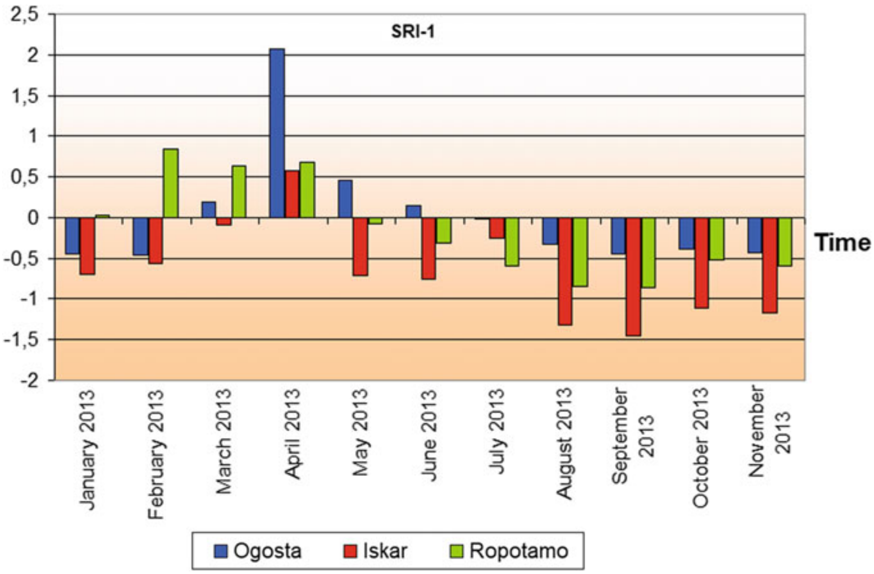


**Fig. 13.12** Monthly diagram of SRI-1 values for Ogosta, Iskar and Ropotamo rivers (Chilikova-Lubomirova et al. 2016)

cases conditions, they do not represent common drought behaviour. At the same time Ropotamo River, which flows in particularly different climate, meteorological and topographic conditions, with no connection to the previously presented rivers

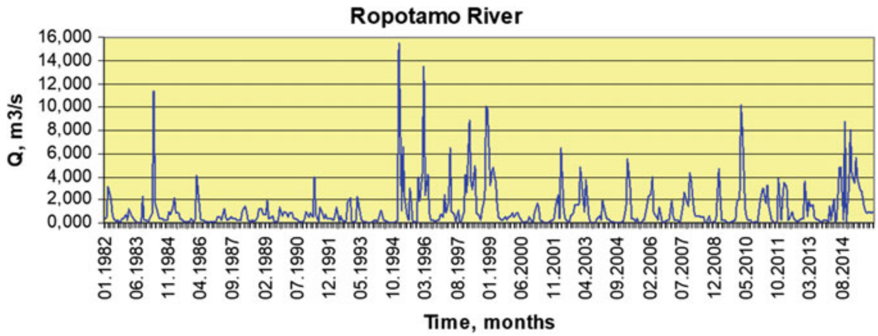


**Fig. 13.13** Ropotamo River, HMS 83620 (Chilikova-Lubomirova et al. 2016)

and their watersheds, drought events was also observed and occur. This once again confirms the spatial heterogeneity of the drought processes.

To clarify the drought process, some additional investigations connected to Ropotamo River were also provided. They aimed to investigate the River behaviour in time. For the purpose connected streamflow for the period of 1982–2015 was investigated. Its hydrograph is presented in Fig. 13.13 (Chilikova-Lubomirova et al. 2016).

Connected drought investigations were also provided by the implementation of the Standardized Runoff Index. Estimated SRI-1 values for the observed period are illustrated in Fig. 13.14 (Chilikova-Lubomirova et al. 2016).

Investigations show that during the period 1982–2015 there were observed cases with moderate, severe and extreme droughts. Such events generally occur during the summer time, in parallel with the low flow periods. Results show that there were observed some extreme droughts in 2009 and 2008, complemented by severe drought events that follow the drought genesis logics and connected recharge issues. Most significant detected drought periods cover 1982–1983, 1993–1994, 1997, 2001–2011. During the last pointed period, there were detected severe and moderate drought events that last in most cases from June to November. As most vulnerable can be specified August and September, but in some cases, July and October are also vulnerable to severe impacts. Investigations for the recent time periods confirm droughts occurrences during the August and September period. Results are presented in Fig. 13.15 (Chilikova-Lubomirova et al. 2016).

Presented approach was provided and can be implemented in future with regard to the WFD requirements for negative impacts mitigation instruments implementation, connected both to:

- general basin characterization under drought conditions;
- the river basin's experience on historical droughts;
- characterization of droughts within the basin;

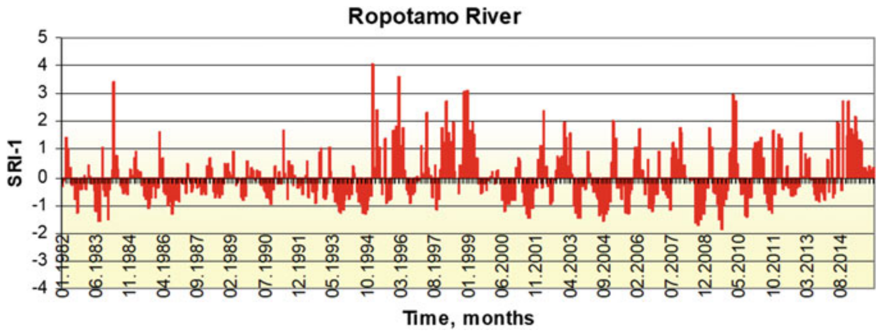


**Fig. 13.14** SRI-1 Ropotamo River, HMS 83620 (Chilikova-Lubomirova et al. 2016)

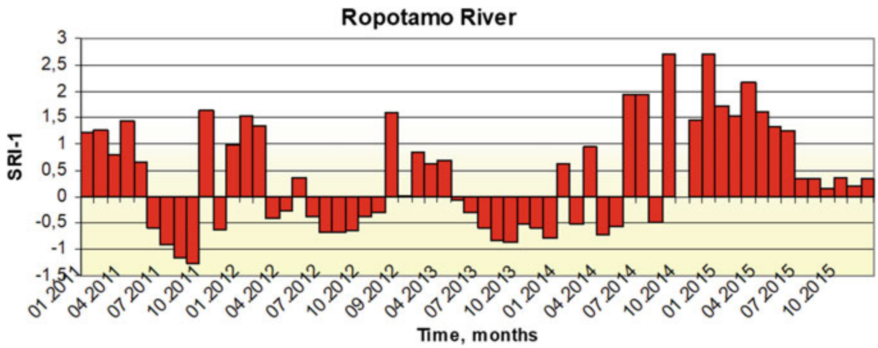


**Fig. 13.15** SRI-1 diagram for Ropotamo River, HMS 83620, 2011–2015 (Chilikova-Lubomirova et al. 2016)

- drought warning system implementation;
- program of measures for preventing and mitigating droughts linked to indicators systems.

Such investigations are important also considering the significant influences on the ecosystems. Drought, and low flows, in particular, associated to the very limited and scarce waters in rivers for sure impact on the aquatic and connected terrestrial organisms. For this purpose in Bulgaria, additional measures connected to their normal function are provided. They are connected to minimum permissible flow in rivers providing. This is regulated by the Bulgarian Water law (2015): For protection of aquatic ecosystems and wetlands, there shall be determined "a minimum permissible streamflow into the rivers"—Article 117 (1). With regard to §125 at the current stage, the minimum permissible streamflow in rivers shall be set at 10 percent of the mean multiannual run-off, but not less than the minimum average monthly water quantity with a 95 percent availability at the point of each facility for regulation of the streamflow or for water abstraction.

## 13.6 Conclusion and Recommendations

Bulgaria is a country with a dense river systems network, resulting of the topological specifics of the territory. It is influenced both by the Atlantic Ocean and Mediterranean Sea atmospheric circulation influences. As a result, five climate zones with Continental, Transitional, Continental-Mediterranean, Black Sea and Alpine climate specifics are formed. Such specifics directly impact the river systems hydrological regime and as result, rivers are characterized with periods of spring floods and summer and winter low flows, formed with regard to the precipitations and groundwater recharge.

As an European Community Member State Bulgaria accept and strictly implement in practice the EC legislation and connected practices. In help, main tools as River Basin Management Plans (RBMPs) and Flood Risk Management Plans (FRMPs) are elaborated. They account for the National and local specifics and the importance of regime and extreme events investigations. In help of the activity, various additional examinations are provided. For clarification purposes in the material briefly are presented main connected issues with regard to the Bulgarian topological, climate and hydrologic specifics. To better understand main considerations about the extreme events main analysis approaches are briefly presented. The main point is a description of water-related extremes: floods and droughts. For the purpose aspects connected to their theoretical base is briefly presented. And connected observed and investigated cases are also shown. Some floods and drought cases specification for the Bulgarian territory is used as an illustration. Briefly, the results of the connected analysis are also presented.

From the considered cases it can be concluded that on the Bulgarian territory both floods and drought events occur. They are irregularly distributed in space and time, showing various grades and emerging significant impacts in many cases. In recent years there were observed floods with very severe outcomes—some of them connected to significant damages concerning affected areas, households, infrastructure and economics, social and life lost. Considering the regime of the particular river their occurrences is not connected to the typical high flow conditions and can be connected to the particular weather events as it was presented with the selected for the illustration cases. Drought events were also observed. Their examination was provided to three Bulgarian rivers: the neighbour Watershed Rivers Iskar and Ogosta, and Ropotamo River that is situated in totally different from first two geographical, climatic and topological conditions. Presented results show the presence of drought events that are irregularly spread in time and space. Making a parallel between the observed rivers results it was proved that there is no connection between the observed drought events. To clarify the drought nature performance the results of additional time series investigation connected to the historic Ropotamo River streamflow droughts are also briefly presented. The result show that in many cases drought occurrences was observed during the low flow periods with a grade from moderate to extreme drought. Information about the most significant for the river drought periods is also presented.

All the material proved that extremes of appearance could be connected both to the particular climate and weather events, the existing topographic conditions and anthropogenic impacts. Of importance is to remark that the particular river bed conditions and connected watershed territory, land covering specifics, etc. also play a greater role. All this is connected to the related ecosystems that in case of extremes are of significant risk. To mitigate such outcomes various legislative and practical measures are implemented in practice. One of them is providing of specific water management measures, including ecosystems protection, briefly presented within the Bulgarian site. Another is initiation and performance of additional activities, based on the particular river basins studies and characterization. This course of interconnected implementation of legislative, theoretical and practical developments is the only way to guarantee best results are obtaining.

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