HANDBOOK

Ideas, data and methods for the setup of the Water Balance Atlas of the Western Ukraine

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Content

1 Introduction

This document is one of the main outcomes of the project “Scientific Preparation of a Water Balance Atlas of Western Ukraine”, which was financed by the Federal Ministry of Education and Research, Germany and the Ministry of Education and Science of Ukraine. The main idea of the project is the establishment of the scientific and organizational basis for the setup of an atlas for Water Resources in the Western Ukraine. By means of workshops and scientific exchange the following aims were envisioned: 1) extension of the bilateral cooperation, 2) get an overview of the data situation, of the scientific and societal needs for meteorological, hydrological and landscape ecological research, 3) compare methods for data acquisition and processing, 4) facilitate the exchange of knowledge and ultimately 5) formulate a project proposal for the setup of a Water Resources Atlas of Western Ukraine. The handbook is the result of three workshops held in Germany and Ukraine, scientific stays of four Ukrainian scientist and intensive discussions via email.

The management of water resources is one of the measures needed for the protection of public wealth. The concept of an Integrated Water Resource Management (IWRM) is a widely accepted approach to deal with this topic on a catchment, regional or even national level. An analysis of the quantity and quality of water resources, their exposure to natural and anthropogenic factors is required to find appropriate measures for their conservation, protection and sustainable use. The planned atlas can serve as an information and analytical framework tool for the monitoring and management of water resources on a catchment or regional scale.

The mapping of surface and ground water, water bodies, processes caused by flowing water, factors and conditions for the formation of water has a long history, e.g. "Climatic Atlas of the USSR" (1960-1962), "Agroclimatic Atlas of the World" (1972), "National Atlas of Ukraine" (2007). The Hydrological Atlas of Germany (Hydrologischer Atlas von Deutschland, 2003) is a comprehensive atlas of both, groundwater and surface water resources, including a wide range of factors affecting the conditions of their formation, distribution, anthropogenic use etc. A digital application is available as well (www.bafg.de). A further example is the digital atlas “Geoecological Basin of Koropets”, which is prepared for publication and bases on maps of the scale 1:50.000 and aerospace information (Andreychuk, Kovalchuk).

To set up this handbook we followed this path:

1) Different study areas as target region were discussed: 1) Western Ukraine, 2) Cross-border river basins Western Bug, Dniester or Tisza and 3) Carpathian region. The regions have their specific water related problems. Some studies already exist, which could serve as a basis or starting point for the atlas. The region of interest for this handbook was defined as Western Ukraine, because no priority of the above mentioned areas could be identified.
2) The target group of the atlas was defined. It was agreed that the focus should lay on the general public and administrations. More details could be given in an annex or in digital format on a DVD.

3) We developed an overall concept and structure of the atlas that includes the knowledge about the societal needs, the data availability and data processing methods. The aim is to show recent changes in the natural conditions. Therefore, the climatic reference period 1961-90 and the recent period 1991-2013 will be analyzed. The consideration of the whole period is not possible for all themes, because data are hardly available. For example, for land cover/ land use specific dates will be chosen (e.g. 1991, 2000, 2010)
4) Finally, we defined the content of individual maps. The scale of the maps depends on the data availability, but should not be coarser than 1:1,000,000. Gridded maps will have a resolution of 3 x 3 km².

The core of the handbook is chapter 2. It describes the seven envisioned chapters including the single themes of each chapter. All themes are specified equally with the sub-chapters: A. Definition, B. Approach, C. Material, D. Final Product and E. Applicability.

2 Content of the Atlas

2.1 <u>Chapter 1: Natural and social conditions</u>

2.1.1 Topography

Author: Ivan Kruhlov

A. Definition

Topography comprises the relief features or configuration of an area. The synonyms are “relief” or “geo-relief”.

B. Approach

Topography can be traditionally represented by topographic contours (isohypses) or by raster. They can easily be transformed into each other.

Fig. 2.1-1: Digital elevation model (SRTM90) and further hydrographic features of the river basin Western Bug

C. Material

For the purpose of the “Atlas”, the topography map can be produced from a digital elevation model (DEM), such as SRTM (Jarvis et al. 2008), which exist for the entire world in a 90 m resolution and is freely available (http://srtm.csi.cgiar.org/).

More resolved DEM that originate from Ukrainian sources and cover large areas are not known. A Global Digital Elevation Model with a resolution of about 30 m is the product Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (http://asterweb.jpl.nasa.gov/gdem.asp), which as well is freely available.

DEM data should be checked on plausibility applying, e.g. GIS operations.

D. Final product

An exemplary map which contains the SRTM90 data is visible in Fig. 2.1-1.

E. Applicability

Most of the meteorological and hydrological processes show a clear dependency on the altitude. In many approaches this dependency is used as an explaining variable. For example, precipitation data can be regionalized using a elevation data in a regression approach.

Furthermore, other relief parameters like slope, aspect and geo-morphological forms can be calculated on the basis of a DEM.

2.1.2 Lithology

Author: Ivan Kovalchuk

A. Definition

The geological structure is the distribution of deposits and geological formations of different types in a particular area. The oldest rocks are involved in the structure of the crystalline basement of the Ukrainian Shield. They are represented by sedimentary complexes, sedimentary-volcanic, volcanic and metamorphosed formations as well as granitoid intrusions. These are Archean sediments. Their age is from 3.4 to more than 2.6 billion years (Paton et al. 2007).

Proterozoic sediments have an age of 2.6 billion vs. 570 million years. At that time the processes of granitization, basalt and granitoid plutonism were taking place. Platform mode was set throughout the Ukrainian shield in the late Proterozoic.

Above Proterozoic sediments mainly deposited Phanerozoic sedimentary strata are situated. They are divided into Paleozoic, Mesozoic and Cenozoic.

In the composition of the relief, mainly sedimentary strata of Cretaceous (145-65 million years), which are sandy-clayey in the Carpathians and carbonate facies on other territories, as well as Paleogene strata (65-23.3 million years) are included. They are found on a large part of the territory of Ukraine. Neogene (23.3-1.8 million years) deposits occur almost everywhere and are represented by clays, limestone and sandy-clayey rocks. In the

Carpathians there are igneous rocks. These sediments are covered by Quaternary strata (1.8 million years - nowadays). They are divided by genesis into marine, glacial, superficial, alluvial and others (Paton et al. 2007). Main part of the area is covered by loess and loess-type loams (depth of 5-40 m or more).

B. Approach

A wide spectrum of methods is used for the geological structure of the region's or river basin's visualization. Distribution of same-aged strata deposits are represented by qualitative background (color corresponds to the age of stratigraphic scale of sediments). Borders of uneven deposits are shown by linear signs. In addition, the sediments' age is shown with the help of alphanumeric codes. The method of linear signs is used to depict major disruptions of geological and phase boundaries as well as lines of geological cross-sections.

C. Material

As reference of information the National Atlas of Ukraine (Paton et al. 2007), data of SSPE "Geoinform", stock materials of geological expeditions, literature and regional atlases are used.

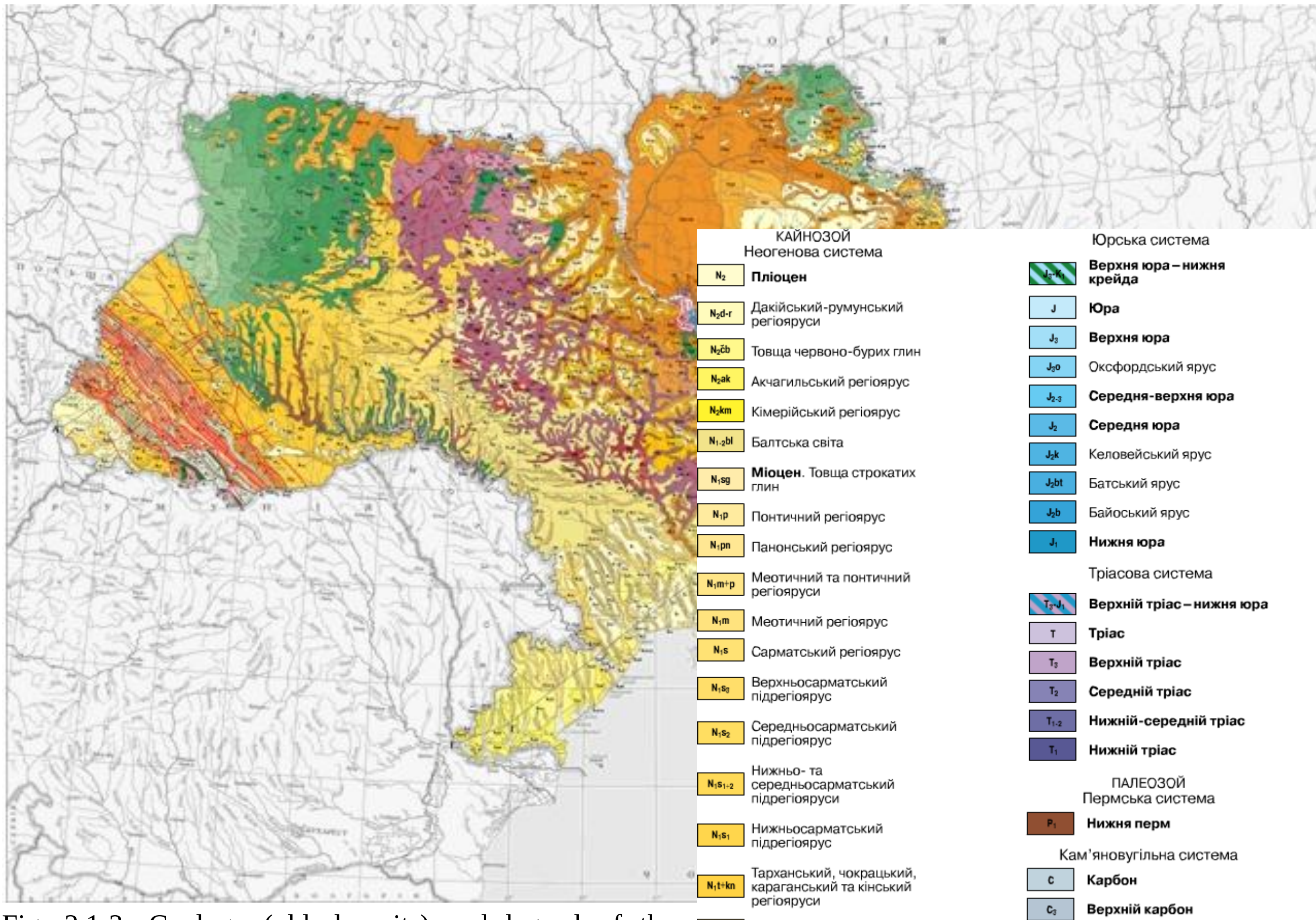


Fig. 2.1-2: Geology (old deposits) and legend of the geological map (fragment) (Paton et al. 2007)

D. Final product

The geological map (Fig. 2.1-2) shows:

1) Geographical distribution of uneven sediments
2) Types of deposits (sedimentary, igneous, metamorphic)
3) Sediment genesis (marine, alluvial, glacial, etc.)
4) Location of disjunctions, thrusts, flexures etc.
5) Properties of the sediments.

E. Applicability

A geological map of Pre-Quaternary sediments is the base for the creation of landscape maps, to determine the influence of lithology on runoff and filtration as a result of precipitation as well as for the formation and properties of soil, the spread and development of geological processes and so on.

2.1.3 Geology (Quaternary or Anthropogenous deposits)

Author: Ivan Kovalchuk

A. Definition

Anthropogene: the shortest among all geological periods - according to different data it began approximately 1.8 to 2.6 million years ago. By the decision of International Stratigraphic Comission (January 2008) Anthropogene is divided into the two epochs Pleistocene and Holocene.

Quaternary deposits: complex of geologic sediments, which are formed during the anthropogenous period of Cainozoic era. Quaternary deposits are spread out everywhere in Ukraine and are represented by marine (Black Sea and Azov Sea coasts), glacial (Northern part of Ukraine and the Dnipro river valley downstream to Dniprodzerzhyns'k), alluvial (deposits of the floodplains and terraces) and subaerial or subeolic (loess with buried soils) formations (Paton et al. 2007). Other genetic types are spread out fragmentary. Glacial deposits are represented by moraines, fluvio-glacial and lake-glacial sediments of two ice ages - Ok and Dnipro. Loess covers older deposits. Their thickness is from 5 up to 40 m and more. Concerning the granulometric composition they are presented by sands, gravel, shingle, boulders, clay, loams and peat. In the Pleistocenic as well as in other Quaternary deposits boulders, clays and loams are characteristic (they are called also moraine) since their genesis corresponds to the glaciers activity. Most typical rock of the Anthropogene in Middle Europe, especially in Ukraine, is carbonated loam - loess of yellow-pale color.

B. Approach

Different genetic types of the Quaternary deposits are visualized on the maps by the methods of qualitative background, areas, linear signs and point signs. Information is provided by the methods of field geological mapping, laboratory analysis of the sediments and remote sensing of the Earth's surface. Cartographic generalization depends on the map scale and mapping technologies (Fig. 2.1-3).

C. Material

To create a map of Quaternary deposits, different information are used: National Atlas of Ukraine (Kyiv, 2007 in Paton et al. 2007), information of geological institutions of Ukraine and regional atlases, monographs, scientific papers on Quaternary deposits studies.

Fig. 2.1-3: Quaternary deposits of Ukraine and legend of the map (fragment) (Paton et al. 2007)

D. Final product

Final product is a map of genetically different types of the quaternary deposits' distribution. As it is shown in Fig. 2.1-3, the distribution of different age and different genesis Pleistocene deposits is visualized by the methods of qualitative background and letter-number signs.

E. Applicability

The map of Quaternary deposits is necessary to evaluate their influences upon soil properties, ground water levels, exogenous processes development potential and other tasks.

2.1.4 Soil types

Authors: Filipa Tavares Wahren, Ivan Kruhlov, Maria Tarasiuk

A. Definition

In order to have a better understanding of the terminology *soil type* an insight into soil classification is needed. Soil classification is a tool for stratifying, generalizing, remembering, predicting, mapping and communicating information on soil resources for a specific purpose (Krogh, 2002). In the course of soil genesis characteristic soil horizons are formed which are diagnostic to distinct soil types, soil units or soil orders. Their name depends on the classification system in use (Ehlers and Goss, 2003). Geographic information about soils is often best communicated to land managers by means of a soil map. Generic soil maps convey the distribution of actual soil units, either homogeneous – pedotopes (Haase and Schmidt, 1970), or heterogeneous – pedochores (Miehlich, 1976). They are used to provide a general overview of natural conditions within the mapped area and to spatially interpret soil water properties, which are relevant for the estimation of water balance. There is worldwide a great demand for soil maps for all types of questions related to land planning and management.

B. Approach

Soil is perceived as a landscape feature, which has been continuously formed throughout the history of landscape development under the influence of other landscape properties (soil factors), such as:

- superficial geology,
- topography,
- climate,
- land use / land cover, incl. (semi-)natural biotic communities and human impacts

From this perspective, it is rational to consider soil and its properties as a key (central) component of a spatially-determined ecosystem (geo-ecosystem) (e.g., Gessler et al., 2000; Wilding and Lin, 2006; Siqueira et al., 2010; Umali et al., 2012). Soil maps can be drawn manually, when the boundaries between soil types revealed in soil pits are aligned with respective landform elements (concave/convex slopes of different inclinations, terraces, etc.) and land use patches (field, grassland, forest, etc.). In this context, a catena (Milne

1935) approach is one method of such a soil mapping, when a (limited) number of soil pits is available along a transect for a given area, covering typical sequences of landform elements and, possibly, land use/land cover types within the watershed. Then, obtained knowledge about the soil/landform/(land cover) relations within the typical transect is extrapolated onto a wider area (e.g., Landon, 1991; Moore et al., 1993).

It is possible to apply automated methods for the extrapolation of the soil information collected via field studies and for the creation of soil maps. In this case, digital elevation models (DEM) are processed in a geographic information system (GIS) to produce different topographic variables in order to derive the relations between soil properties and topography. Tavares Wahren et al. (2011) tested for the Western Ukraine a suitable approach of generating a new soil map by combining both field surveys and old soil maps containing gapped information and fuzzy logic. In this approach the available soil map, with a scale of 1:10,000, covered only around 40% of the study area. Most of the gaps occur in forested areas. However, the available soil map produced from conventional soil surveys, contains a wealth of information that serves as a starting point for predicting the soil distribution within the catchment.

The approach was built upon the idea that - if the relationship between each soil and its specific environment is known - a soil at a particular location within the landscape can be inferred by assessing the environmental conditions at that point.

C. Material

Soil maps for the Western Ukraine are available in different scales and formats from various sources. Most of them were produced in the USSR period. Detailed soil maps (up to 1:10,000 scale) have been produced for selected areas of limited scope – e.g. soil surveys for agricultural land reclamation projects in the scale 1:5,000 and 1:10,000 covering areas of hundreds to thousands ha. The maps are manually drawn upon topographic map sheets and have generally good quality. They are not published and are stored in the archives of land reclamation companies, such as "Lvivdiprovodgosp". Here, soil surveys of agricultural land (1:25,000) produced in the form of "wall maps" for some administrative regions are available. There is also a limited access to material, which belongs to the agricultural land planning institutions like "Zemproekt". Soil information is also sometimes included into large-scale (usually 1:25,000) forest inventory maps, produced by forestry planning institutions. The areal scope of these maps is selective and limited, and the access to the material is limited too. The most accessible is a 1:200,000 "overview" soil map of agricultural areas compiled on the basis of 1:25,000 soil surveys (Krupskyy, 1967). This map covers the whole country (but only agricultural areas), and is produced in two versions: on topographic map sheets in a scale of 1:200,000 and in the form of "wall" maps for administrative oblasts. Both versions have poor geometry – most likely due to inappropriate generalization techniques. These maps are also of limited access, but are available at different land management and research organizations. Here, also published small scale (1:1,000,000 and smaller) soil maps are available (e.g. Shabliy et al., 1989).

This brief overview of the available soil maps illustrates the shortage of soil information/data for Western Ukraine, which can only be used for appropriate spatial interpretation of soil water parameters on large and medium mapping scales. However, it is possible to improve the geometric accuracy of the available soil maps by aligning them with more accurate topographic geo-data derived from, for example, global DEM such as SRTM or ASTER.

D. Final product

One possible product is a soil type map. The different soil units are related, by means of the attributes related to a soil profile with respective diagnostic horizons. An example of such an end product is given in Fig. 2.1-4 .

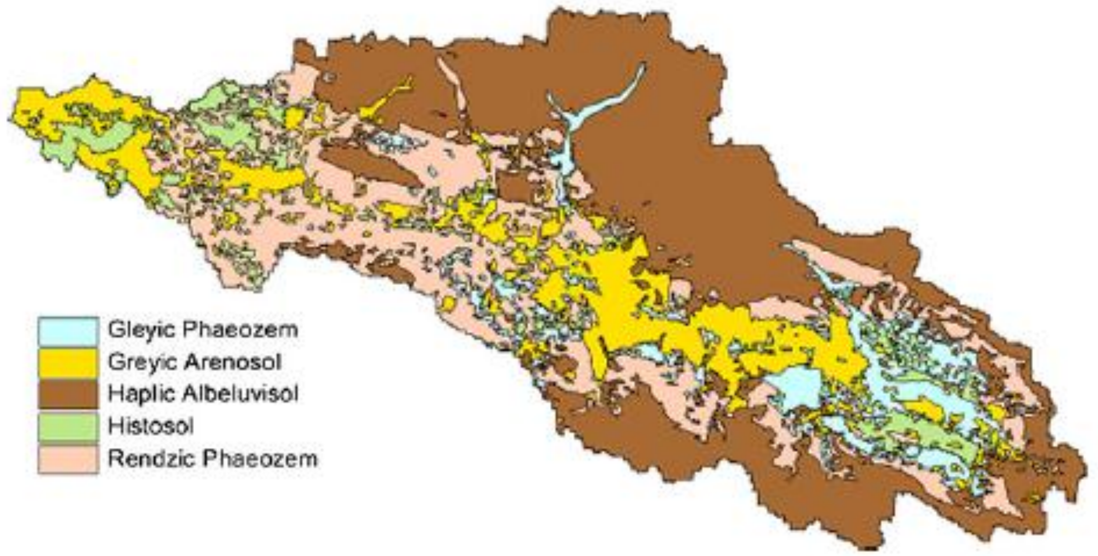


Fig. 2.1-4: Distribution of soil types over the Western Bug Headwater catchment (Tavares Wahren et al., 2011)

One other final product may be a pedo-geomorphic map that represents the distribution of dominant soil types, landforms, and superficial quaternary deposits (Fig. 2.1-5, Tab. 2.1-1). When appropriate, the number of the pedo-geomorphic classes can be decreased by merging the entries with similar attributes – e.g. classes 51 and 52 as well as classes 53 and 54 respectively, can be merged into two classes, or they can all be merged into a single super-class 50 (Tab. 2.1-1).

E. Applicability

Soil information is crucial for any water related investigation carried out. It is vital for modeling water resources management as well as for spatially based assessments.

The dataset of pedo-geomorphic units has a broad practical significance and can be used in several aspects, especially when supplemented with the land cover/land use information:

1. Spatial interpretation of soil water parameters
2. Delineation of hydrologic response units (HRU) for watershed modeling
3. Estimation and spatial interpretation of soil water erosion risk
4. Fulfill the role of a basic universal spatial unit for sustainable comprehensive land planning and integrated water resource management

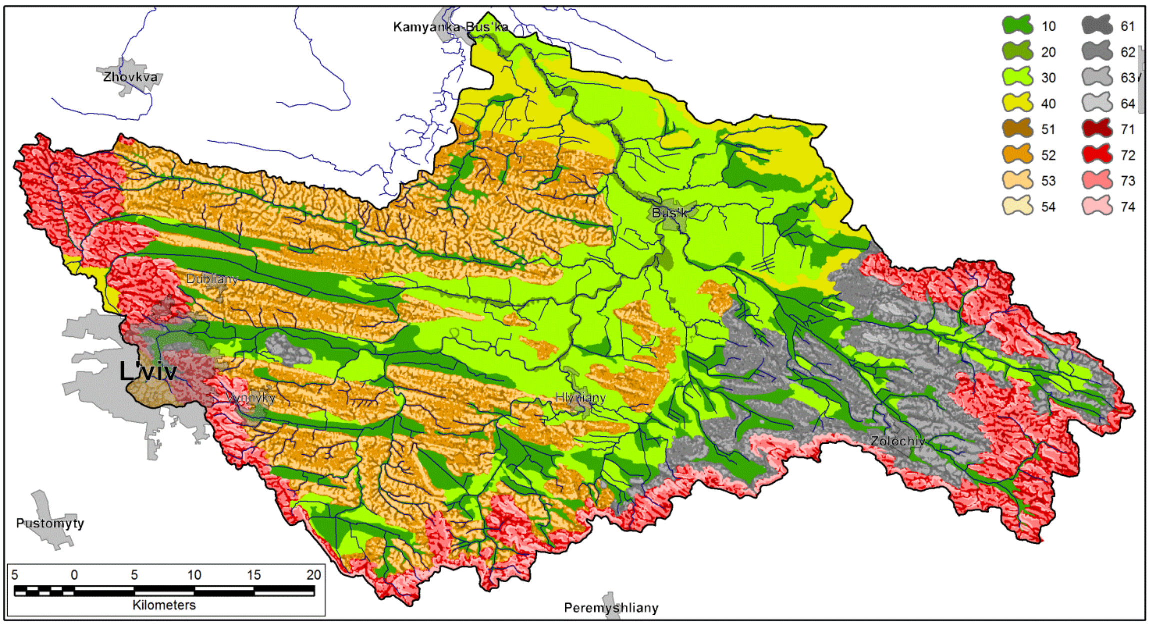


Fig. 2.1-5: Pedo-geomorphic units of the Upper Western Bug Basin (Legend in Tab. 2.1-1)

Tab. 2.1-1: Legend (attributes) of the UWBB pedo-geomorphic units

Id/ Class	Landform	Parent rock	Soil UA name	Soil WRB name
10	Alluvial valley bottoms	Al loam-clay & peat	Alluvial meadow & peat	Gleyic Phaeozem & Histosol
20	River floodplains	Al loam	Alluvial meadow	Gleyic Phaeozem
30	Low alluvial terraces	Al sand-loam & El marly debris	Alluvial meadow, alluvial sod & carbonated	Gleyic Phaeozem, Gleyic Arenosol & Rendzic Phaeozem
40	Low flat & wavy interfluves	Col sand & loesss-like loam	Sod weakly podzolised & grey forest	Greyic Arenosol & Haplic Albeluvisol
50	Medium wavy interfluves	Col loess-like loam	Grey forest & podzolised chornozemic	Haplic Albeluvisol & Chernozem
51	Gentle concave/foot slopes	Col loess-like loam	Dark-grey forest & podzolised chornozemic	Haplic Albeluvisol & Chernozem
52	Flat watershed surfaces & moderate concave slopes	Col loess-like loam	Dark-grey forest & podzolised chornozemic	Haplic Albeluvisol & Chernozem
53	Convex watershed surfaces & convex moderate slopes	Col loess-like loam	Grey forest	Haplic Albeluvisol
54	Steep slopes	Col loess-like loam	Grey forest	Haplic Albeluvisol
60	Medium & high wavy interfluves with steep inselbergs	El calcareous debris & El-Col sand	Carbonated & sod weakly podzolised	Haplic Albeluvisol & Rendzic Phaeozem

Id/ Class	Landform	Parent rock	Soil UA name	Soil WRB name
61	Gentle concave/foot slopes	Col loess-like loam	Dark-grey forest & podzolised chornozemic	Haplic Albeluvisol & Chernozem
62	Flat watershed surfaces & moderate concave slopes	El calcareous debris	Carbonated	Rendzic Phaeozem
63	Convex watershed surfaces & convex moderate slopes	El calcareous debris & El-Col sand	Carbonated & sod weakly podzolised	Rendzic Phaeozem & Greyic Arenosol
64	Steep slopes	El calcareous debris	Carbonated	Rendzic Phaeozem
70	High steep interfluves	Col loess-like loam & El sand/calcareous	Grey forest, sod weakly podzolised & carbonated	Haplic Albeluvisol & Haplic Arenosol
71	Gentle concave/foot slopes	Col loess-like loam	Grey forest	Haplic Albeluvisol
72	Flat watershed surfaces & moderate concave slopes	Col loess-like loam	Grey forest	Haplic Albeluvisol
73	Convex watershed surfaces & convex moderate slopes	Col loess-like loam	Grey forest	Haplic Albeluvisol
74	Steep slopes	El calcareous debris & El-Col sand	Carbonated & sod weakly podzolised	Rendzic Phaeozem & Greyic Arenosol

2.1.5 Land cover

Author: Cornelia Burmeister, Jochen Schanze

A. Definition

Land cover (LC) is the direct observable Earth surface including vegetation cover and man-made structures (Mimler, 2007; Verburg, van de Steeg, Veldkamp, & Willemen, 2009). Together with atmospheric and soil factors, it determines the processes of the hydrological cycle, e.g. evapotranspiration and infiltration.

B. Approach

Pattern recognition principles of remote sensing data use a variety of methods, e.g. visual interpretation of images; statistical classification methods like parallelepiped classification algorithm or maximum likelihood classifier; object-based classification including in a first step the segmentation process and then a rule-based decision tree based on information like shape and size; artificial neural networks; support vector machines, and so forth. The scope, aim, data availability and financial resources for software, data, and licenses determine the applied classification methods (Tso & Mather, 2009).

Besides the classification algorithms, the classification scheme with the descriptions and definitions of the land-cover categories plays a central role in the classification process. The requirements for a classification scheme are: compatibility between different regions,

consistency for different scales, sharp description and differentiation between the land-cover categories, and multi-user possibility (G. Meinel & Hennersdorf, 2002).
One widespread classification key in the European Union is the CORINE Landcover scheme (CoORdination of INformation on the Environment) which serves as a comparable land-cover data set for the member states (Bossard, Feranec, & Otahel, 2000; Umweltbundesamt & DLR-DFD, 2009). The scheme is divided into 3 hierarchical levels, whereupon the lower the level is, the coarser the scale is.
Multi-temporal satellite images present the state of the land-cover for different time steps across years or decades to analyze the land-cover change; inner-annual multi-temporal satellite images present different phenological growing states of the vegetation within one year, and enhance the accuracy concerning the spectral description of the land-cover categories and the differentiation, respective separation of the classes.
Ground truth data, such as topographic maps, aerial photographs, field surveys, are crucial for selecting training samples for the description of the land-cover classes and for the afterwards conducted accuracy assessment of the classification result.
Data sources for long term remote sensing are, first of all, the Landsat sensors which started imaging in the 1970ies (Cohen & Goward, 2004; Wulder et al., 2008) and the French Spot system (Système Pour l'Observation de la Terre, engl. System for Earth Observation), which was launched in the mid 1980ies. Nowadays, there are a lot of high resolution recording satellites like Ikonos, Quickbird, or Rapid Eye with a ground resolution up to less than a meter.
The recording of the spectral bands varies from one platform to the other. In general, every sensor records in the visible spectrum (blue, green, red) and the near infrared which is very important for classifying the vegetation.
Additional information is used to describe the land-cover classes, for instance the generation of the Normalized Difference Vegetation Index (NDVI), digital elevation model (DEM), or texture measures. Nevertheless, the already above mentioned ground truth data has to be taken within field surveys or from other data sources as for instance actual topographic maps.

C. Material

For a medium scale Landsat, data with a resolution of 30x30 m is accurate enough - if the classification should go into more detail, higher resolution satellite images are needed, e.g. RapidEye. For high-resolution data, an object-oriented classification method is the most appropriate, for Landsat data also a statistic-based classification fits.
Ground truth data has to be collected in the field or on high resolution data. The NDVI and DEM support the classification process by setting thresholds for e. g. vegetated and non-vegetated areas.

D. Final product

The final product is a land cover map with different land cover classes, e.g. settlements, arable land, forests, bogs, water bodies. When an object-based classification method is used, more land-cover categories could be detected: When a lot of ancillary data is available, more possibilities are available to detect more categories.
As an example the map of Western Bug is presented for the year 2010 (Fig. 2.1-6).

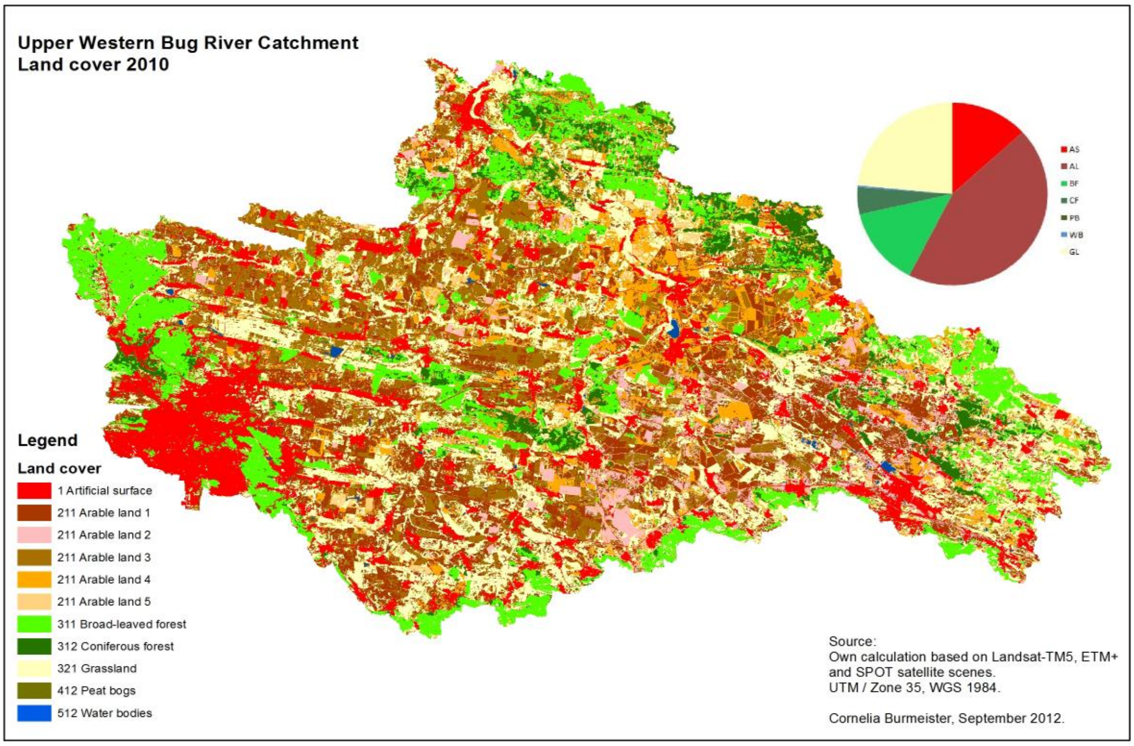


Fig. 2.1-6: Land cover of the basin Inflow Reservoir Western Bug

E. Applicability

Land-cover data is crucial for deriving the land use, also, it is useful for investigations or further modeling related for instance to evaporation or infiltration.

2.1.6 Land-use types

Authors: Cornelia Burmeister, Jochen Schanze

A. Definition

Land use is the result of human activities that utilize land cover for their own purpose (FAO & UNEP, 1999; Geist & Lambin, 2001, Verburg et al., 2009). Land use, such as management activities on grass land or arable land, has an impact on the water balance (surface runoff, evapotranspiration, etc.).

B. Approach

The land-cover and even more, the land-use patterns have an important impact on the processes of the water cycle, for instance leads an increase of the surface sealing to a lower infiltration and thus higher evaporation rates (Moore, 1981).

To derive land use, different data bases need to be considered. First of all, the land cover data is a base to identify land-use types (LUT), which are differentiated into urban structure types (UST) and vegetation structure types (VST). Urban structures, for instance, include block and building information by applying high resolution settlement classifications (Blum, Gruhler, & Thin, 2010) with the SEMENTA tool

(SettleMENTAnalyzer, (Gotthard Meinel, Hecht, & Herold, 2009)). The LUTs are further characterized by their physical or societal characteristics.

Parallel to the spatial analysis, the processes which are related to the water cycle have to be identified. Up to 20 processes are relevant to consider for urban and rural areas (Trümper, in preparation; Trümper, Burmeister, & Schanze, 2011), like for instance interception, evaporation, discharge, leaching, and so on. The identified land-use parameters of each water-related process, such as the amount of sealing, tree coverage or water consumption, are analyzed and determined with descriptive statistics. Furthermore, there are different types of linkages between the land-use parameters and the land-cover: 1) strong relation to land cover like for instance the soil sealing; 2) relation between land cover and natural or societal conditions like root length, which depends on the soil depth and management; and 3) independence to land cover like irrigation (Schanze, Trümper, Burmeister, Pavlik, & Kruhlov, 2012). Correlation between certain parameter values and the LUTs, which are investigated on test sites, will show the above mentioned relations and similar features (parameter values) can be clustered to a LUT.

Urban structure types are composed by the spatial urban structures and the relevant process related parameter values to ensure a data set, which is homogenous and consistent in appearance and properties. In open spaces (rural areas), the land-cover data is combined with geo data layers of the natural conditions and with management practices of vegetation structure types.

C. Material

Needed data are a land-cover map, statistics on water consumption, management (fertilizer) and own mapped statistics via field surveys.

D. Final product

Final product is a map with land use types and water-related parameters like percentage of soil sealing, water consumption, LAI etc. An Example can be shown for the upper part of Western Bug catchment for the year 2010.

E. Applicability

This analysis provides important input data for all types of hydrological models.

2.1.7 Ecoregions

Author: Ivan Kruhlov

A. Definition

Ecoregions are large ecosystems of regional extent (Bailey, 1983; Omernik, 2004). The terms “natural region” and “landscape region” (e.g., Isachenko, 1965) are synonymous to ecoregion.

B. Approach

The boundaries of ecoregions generally coincide with boundaries of oro-tectonic units – morpho-structures, which influence the evolvement of local landforms, the differentiation of topo-climate and hence, the distribution of soils and biotic communities (Bailey, 1983; Kruhlov, 2008). Thus, the spatial pattern of ecoregions is congruent with the pattern of regional geomorphic units. However, the map, or the geo-dataset of ecoregions, along with the geological-geomorphic characterization, include attributes about other ecosystem (landscape) components, such as dominant types of topo-climate, soils, and natural vegetation.

Ecoregions are usually delineated manually via an interpretation of topography and geological structures (Isachenko, 1965; Bailey, 1983). This procedure can be fulfilled directly using a GIS (Kruhlov, 2008).

For example, in the framework of the IWAS-Ukraine project, the ecoregions of the Upper Western Bug Basin were selected as oro-tectonic (morpho-structural) units via manual grouping of the landform type polygons inside the GIS. In turn, landform types were delineated via a manual interpretation of the SRTM DEM and its derivative features (surface inclination). The official map of Quaternary Deposits, with a scale of 1:200,000, was used as an ancillary source of information about the substrate. Some additional boundaries were drawn to indicate the limits of separate ecoregions. The published scheme of natural landscape units of Lviv Oblast (Mukha, 2003) was used as guidance. The ecoregions were assigned with individual names derived from existing regionalization schemes as long as available (Herenchuk, 1972; Mukha, 2003). The regions were typologically characterized according to geomorphic and geo-botanical features. Additionally, their association with larger macro-ecoregions (landscape provinces) was indicated (Fig. 2.1-7, Tab. 2.1-2).

C. Material

The SRTM and ASTER DEM data are available at the global scope, with a spatial resolution, which is sufficient for the delineation of ecoregions in the large-medium scale (approx. 1:100,000). As additional data sets, medium scale (1:200,000) maps of soils (Krupskyy, 1967) and Quaternary deposits can be used. They are available for the whole potential study area. Existing digital medium-scale datasets (Kruhlov et al., 2008; Kruhlov, 2008) as well as small-scale schemes (e.g., Herenchuk, 1972; Mukha, 2003) of the ecoregions of Western Ukraine can also be useful.

D. Final product

The geo-dataset of the UWBB ecoregions has the geometric accuracy of the SRTM DEM, which was used for its production (Fig. 2.1-7). Its attributes are represented in Tab. 2.1-2.

E. Applicability

The geo-dataset of ecoregions has a broad practical significance. In the first instance, it can be used for the delineation of large hydrological Response Units (HRU), which can be suitable for hydrological modeling at the scale of large basins. The dataset can also be utilized for the regionalization of environmental impact analyses and the integrated management of water resources.

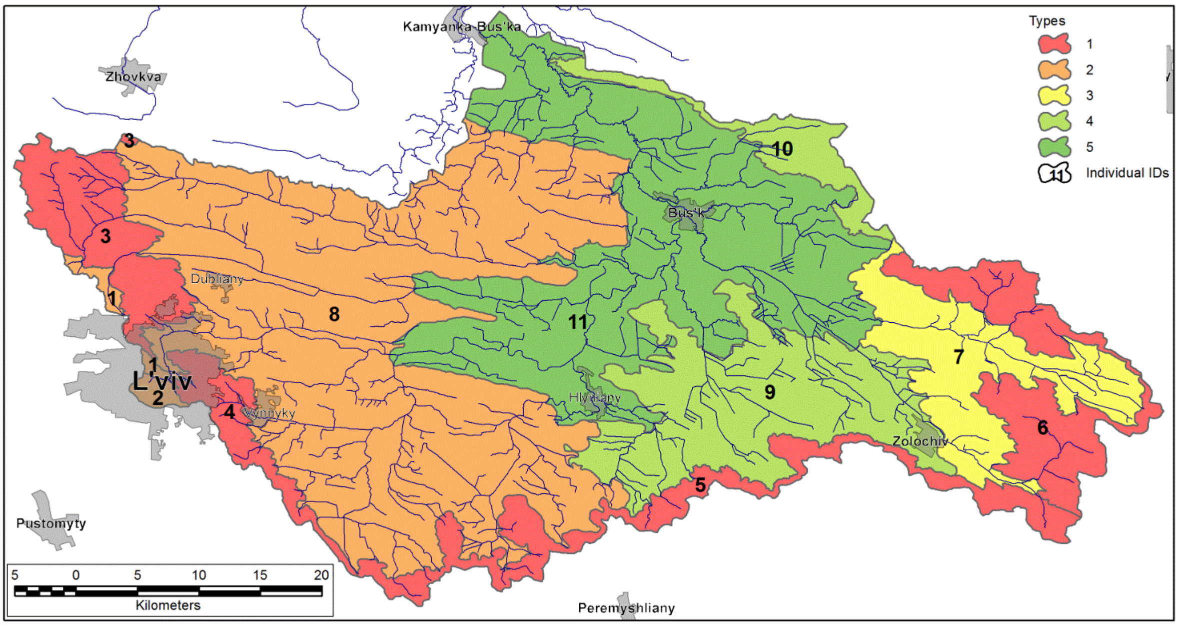


Fig. 2.1-7: Ecoregions of the Upper Western Bug Basin (Legend in Tab. 2.1-2)

Tab. 2.1-2: Ecoregions of the Upper Western Bug Basin (explanation for Fig. 2.1-7)

<table>
<tr><th>Id</th><th>Name</th><th>Type</th><th>Macro-ecoregion</th></tr>
<tr><td>1</td><td>Southern Roztocha Hills</td><td rowspan="2">Loess hills with beech forests</td><td>Roztocha Upland</td></tr>
<tr><td>2</td><td>Davydiv Hills</td><td rowspan="5">Podillia Upland</td></tr>
<tr><td>3</td><td>Holohory Hills</td><td rowspan="2">Loess hills with beech forests</td></tr>
<tr><td>4</td><td>Voroniaky Hills</td></tr>
<tr><td>5</td><td>Lviv-Lubin Plain</td><td rowspan="3">Wavy loess plains with oak forests</td></tr>
<tr><td>6</td><td>Lviv Plateau</td></tr>
<tr><td>7</td><td>Pobuzhia Ridged Plain</td><td rowspan="5">Male Polissia Depression</td></tr>
<tr><td>8</td><td>Zolochiv-Sasiv Hilly Plain</td><td>Erosional hilly plains with oak and beech forests</td></tr>
<tr><td>9</td><td>Krasne Plain</td><td rowspan="2">Erosional and loess plains with oak forests</td></tr>
<tr><td>10</td><td>Olesko Plain</td></tr>
<tr><td>11</td><td>Busk Plain</td><td>Alluvial plains with oak and alder forests</td></tr>
</table>

2.2 Chapter 2: Climate

General aspects:

Based on the recommendations of the International Meteorological Conference in Warsaw in 1933, climate is defined according to the average values of a suite of climatic parameters (temperature, precipitation etc.) measured over a 30-year interval. A 30-year interval is long enough to filter out any of the short-term inter-annual fluctuations and anomalies, but is also short enough to be used to reflect longer climatic trends (Guide, 2010). The period from 1961, January 1st to 1990, December 31st is the official normal period, which represents the current climate and is defined by the World Meteorological Organization (WMO). To acknowledge on-going climate change, other statistical characteristics are included, e.g. deviation to and with the period, trend, variation and extremes.

Different temporal aggregation levels are used to analyze the climate and climate change, respectively. Annual averages of climatic parameters are calculated over two different periods: 1961-1990 (reference period) and 1991-2010 (recent period). Additionally to the calculated annual averages of each climate period, the following seasons are used:

- Winter: December, January, February (DJF)
- Spring: March, April, May (MAM)
- Summer: June, July, August (JJA)
- Fall: September, October, November (SON)
- Summer half year: April to September
- Winter half year: October to March

2.2.1 Climate data monitoring network

Author: Yuri Nabyvanets

A. Definition

Climate data information is provided by measurement data of monitoring stations within the Ukraine. These stations record several climate variables such as solar radiation, temperature, humidity, precipitation, snow cover, wind and evapotranspiration. Additional observations are performed visually or by other methods. The snow depth for instance is investigated via field survey.

B. Approach

Meteorological stations are illustrated in a map using their geographical coordinates and GIS tools.

C. Material

In Tab. 2.2-1 the available climate stations and the parameters observed are summarized for districts in Western Ukraine.

Tab. 2.2-1: Data availability of meteorological parameters for the period 1961-2010

Stations	Solar radiation	Temperature	Humidity	Precipitation	Snow cover	Wind	Evapotrans-piration
Lvivska oblast							
Rava Ruska		+	+	+	+	+	+
Kamyanka Buzka		+	+	+	+	+	
Brody		+	+	+	+	+	+
Yavoriv		+	+	+	+	+	
Lviv		+	+	+	+	+	
Mostytska		+	+	+	+	+	
Drogobych		+	+	+	+	+	
Stryj		+	+	+	+	+	
Turka		+	+	+	+	+	
Slavske		+	+	+	+	+	
Ternopilska oblast							
Kremenets		+	+	+	+	+	
Ternopil		+	+	+	+	+	
Berezhany		+	+	+	+	+	
Chortkiv		+	+	+	+	+	
Zakarpatska oblast							
Velykyj Bereznyj		+	+	+	+	+	+
Nyzhni Vorota		+	+	+	+	+	
Nyzhnij Studenyj		+	+	+	+	+	
Mizhgirya	+	+	+	+	+	+	
Plai		+	+	+	+	+	
Uzhgorod		+	+	+	+	+	
Beregove	+	+	+	+	+	+	+
Hust		+	+	+	+	+	
Rahiv		+	+	+	+	+	
Ivano-Frankivska							
Dolyna		+	+	+	+	+	+
Ivano-Frankivsk		+	+	+	+	+	
Kolomyja		+	+	+	+	+	
Pozhezhevska		+	+	+	+	+	
Chernivetska oblast							
Chernivtsi		+	+	+	+	+	
Selyatyn		+	+	+	+	+	
Novodnistrovsk		+	+	+	+	+	+
Jaremtha		+	+	+	+	+	+

D. Final product

The final product is a map of the meteorological observation network, showing stations and respective tables which contain the station name and category, as well as types of observation and observation period.

E. Applicability

A map of the climate data monitoring network is useful for several tasks where climate data is required and the availability of data for an area of investigation needs to be examined.

2.2.2 Sunshine duration / Global radiation

Author: Thomas Pluntke

A. Definition

Solar radiation is the only relevant energy source for the Earth and its climate system. Global radiation is the total of direct solar radiation and diffuse sky radiation received by a unit horizontal surface.

The historically most common way to determine this input is to measure the duration of sunshine (SD) during a day. Global radiation (RG) can be derived from sunshine duration, e.g. applying the approach according to Ångström (1924).

B. Approach

Sunshine duration data will be tested on plausibility using the astronomical sunshine duration SD_0. Here, the observed sunshine duration data is plausible fulfilling the following condition: $0 \leq SD \leq SD_0$

Ångström approach to calculate global radiation from sunshine duration:

$$RG = RG_{ex} \cdot \left(a + b \cdot \frac{SD}{SD_0}\right)$$

$$SD_0 = \frac{24}{\pi} \cdot \omega_s$$

$$R_{ex} = \frac{24 \cdot 60}{\pi} \cdot S \cdot d_r \cdot [\omega_r \cdot \sin(\varphi) \cdot \sin(\delta) + \cos(\varphi) \cdot \cos(\delta) \cdot \sin[(\omega_r)]]$$

$$d_r = 1 + 0.33 \cdot \cos\left(\frac{2 \cdot \pi}{365} \cdot J\right)$$

$$\omega_s = \cos^{-1}(-\tan(\varphi) \cdot \tan[(\delta))]$$

$$\delta = 0.409 \cdot \sin\left(\frac{2 \cdot \pi}{365} \cdot J - 1.39\right)$$

a and b	empirical Ångstöm-coefficients
RG	Global radiation
Rex	extraterrestrial radiation
n	Sunshine duration
N	Maximal possible Sunshine duration
ω_s	hour angle at sunset
S	Solar constant (0,082 MJ/m²min)
d_r	inverse relative distance earth sun
φ	Geographical latitude of location
δ	Declination of the sun
J	Julian day of the year

The empirical Ångstöm-coefficients have to be estimated applying regression analysis at stations where global radiation and sunshine duration are measured.

C. Material

Daily sunshine duration data, measured with a sunshine autograph (heliograph), and global radiation, measured with a pyranometer, are available for the stations listed in Tab. 2.2-1.

D. Final product

Table or diagram (annual cycle) of the few stations that exist for the periods 1961-1990 and 1991-2010

E. Applicability

Global radiation and sunshine duration, respectively, are essential for the calculation of potential evapotranspiration rates and are needed as input to model the actual evapotranspiration. Furthermore, some snow and vegetation growth models need a radiation input as well.

2.2.3 Air temperature

Author: Thomas Pluntke, Sergej Snizhko, Oleksander Mkrtchian

A. Definition

For a climatic characterization of a region, areal information of the (yearly) mean, minimal and maximal air temperature (T), which is measured at 2 m height, is needed. Additionally to the defined seasons, the coldest (January) and hottest (July) month of an average year are usually used for the characterization of cold and warm seasons referring to the mean temperature (Snizhko et al., 2010) in Ukraine.

B. Approach

To calculate daily values the averaging method is applied, for which regularly daily temperature measurements on all of the meteorological stations are required. Here, eight

daily observations are used to calculate mean daily values, the daily maximum and minimum value. Since the statistical distribution of the temperature series is usually described by a normal distribution, arithmetically averaged values can be used.
Additionally, the plausibility of the temperature data is tested with the following conditions:

- $-89.9\ °C < T < 60.0\ °C$
- $T_{min} \leq T \leq T_{max}$
- not allowed to be repetitive for 5 days
- must be less than the long term average daily mean temperature for that calendar day + 5 times standard deviation and must exceed the long term average daily mean temperature for that calendar day – 5 times standard deviation

Required temporal data coverage for calculation of statistics:

- Missing values should be less than 10% of the values for a 30 year period, with maximal 10% missing days for a month.

Furthermore, homogeneity tests are applied, which is necessary to detect and eliminate systematic changes in the observations, which do not belong to the actual climate variation of an element (e.g. station relocation, changes of measuring devices, urbanization of the surroundings). If changes in exposure or instruments have occurred, a correction is needed to remove the non-climatic in-homogeneities, which may hide the true climatic signals and patterns. For this correction the graphic method of O. Drozdov (Kobysheva & Narovlyansky, 1978) is applied in Ukraine. A widely accepted approach in Germany is the application of relative tests, using a reference data series (main test: Alexanderson, 1986). The tests are executed on monthly or yearly time step to reduce temporal variability and thus, better identify in-homogeneities

Regionalization:

1. Approach

The following approach is based on one typical example which is also available for other climate variables. A Software package that can be applied is called InterMet. It was developed for automatic interpolation of meteorological variables (Hinterding, 2003). Static and dynamic non-stationarities in the investigation area are considered by so called homogeneity areas and by an adaptation of the interpolation model to the random field of each homogeneity area. Combination of static and dynamic non-stationarity leads to the homogeneity areas. Because all homogeneity areas are modeled separately, fuzzy methods are deployed in InterMet in order to avoid strong gradients along the borders of homogeneity areas. The experimental variogram is determined automatically, using the robust variogram estimator after Genton (1998). Subsequently, an exponential theoretical function is adjusted. Anisotropy occurs in hourly precipitation data, which is not considered in InterMet. Precipitation cells are frequently divided and modeled separately due to subdivision of the investigation area. Thus, anisotropic effects are reduced (Hinterding, 2003). Various linear kriging models are implemented and applied for homogeneity areas. The most adequate kriging model is automatically chosen, based on an analysis of the current event. If the correlation between precipitation and altitude of the gauge exceeds 0.5, kriging with external drift is used. Universal kriging is applied, if spatial (x, y) correlation exceeds 0.5. The maximum correlation coefficient determines the method of choice. Otherwise ordinary kriging is used.

2. Approach

Regression-kriging (RK) is a modern, statistically sound and effective method for the regionalization of spatially correlated data (Hengl et al., 2007). It allows accounting for both the spatial autocorrelation in climatic data and their relation with the auxiliary spatially distributed data. The latter can be associated with geographic effects like rain shades, cold air pools, warmth belts on slopes, etc. Spatially distributed data on altitude and topographic effects can be derived from free DEM data like SRTM DEM using open-source GIS software. RK is especially promising in cases where the data are too sparse to effectively apply kriging and other procedures that rely solely on spatial autocorrelation in the data. This is the case for the Ukraine. There are examples of successive applications of this method for the interpolation of climatic variables (Dryas & Ustrnul, 2007; Hengl et al., 2007; Tveito, 2008). Our studies proved the effectiveness of the RK method for the regionalization of annual precipitation (Mkrtchian, Shuber, 2011) and monthly temperature data (Mkrtchian, Shuber, 2009). The data requirements for the application of the RK regionalization method are point data of the required climatic element from climate stations (e.g. precipitation sums, mean temperatures, humidity, etc.), and a DEM (freely available 90 m SRTM is precise enough for the regionalization to 3x3 km resolution). To run the regionalization procedure, the open-source SAGA GIS, developed at the Department of Physical Geography, University of Göttingen can be used (Böhner et al. 2006). The final results are the required raster map of the predicted spatial distribution of the climate element, together with the raster map of the spatially distributed measures of the prediction error.

C. Material

Daily data of air temperature measured at 2 m height on the meteorological station of Ukrainian Hydro-meteorological Service network during the period 1961-1990 and 1991-2010 (Tab. 2.2-1). The following instruments are used (Palamarchuk & Shevchenko, 2012, Guidelines, 2011):

- a meteorological dry bulb thermometer TM-4-1 with a range of measurement from -35 ° C to +40°C and a meteorological dry bulb thermometer TM-4-2 with a range of measurement from -20 ° C to +50°C
- low degree thermometer TM-9-1 with a range of measurement from -60 ° C to +20°C and low degree thermometer TM-9-2 with a range of measurement from -70 ° C to +20°C
- meteorological minimal thermometer TM-2 with a range of measurement from -70 ° C to +20°C
- meteorological maximal thermometer TM-1-2 with a range of measurement from -20 ° C to +70°C

- registration of maximum and minimum daily temperatures is realized with the thermograph M-16-AC

D. Final product

The final product is a raster map of the mean air temperature with a resolution of 3x3 km covering the Ukraine. The final temperature maps are referring to the chosen two periods, while each period contains a mean temperature map of the year as well as winter and summer half year.

E. Applicability

Information about different temperature parameters is needed for estimations of evapotranspiration, the calculation of the water balance, snow modeling and plant growth.

2.2.4 Frost days

Author: Olga Shevchenko

A. Definition

A frost day is a day with a daily minimum air temperature below 0°C. It is used to characterize the thermal regime of a region. In contrast to mean or even maximum temperatures it reflects often the microclimate of the station.

B. Approach

The duration of frost day periods is calculated using daily minimum air temperatures for the whole year.

C. Material

Daily data of minimum air temperature measured at 2 m height at the stations in Tab. 2.2-1 is used. There are no measurements from automated instruments. Temperature measurements are carried out on all the meteorological stations eight times per day (00, 03, 06, 09, 12, 15, 18, 21 UTC).

Measured data are pre-processed taking into account instrumental and additional corrections. For the instrumental correction a specific table, containing values of adjustment is used. This correction is applied directly on the meteorological station. An additional correction is needed for the alcohol-in-glass thermometer. The adjustment value for the additional correction is calculated every month for each station and all alcohol-in-glass thermometers. Here, the difference between data measured by dry-bulb (mercury) thermometer and data measured by alcohol-in-glass thermometer (both measurements are taken at the same station at 00 and 03 UTC) is used. A further correction is taken into account at the data processing centers.

D. Final product

Final product is a map of the duration of the frost day period for the two agreed time-horizons.

E. Applicability

The information about the frost day period duration is important for snow modeling and is a relevant index for vegetation growth.

2.2.5 Relative humidity

Author: Olga Shevchenko

A. Definition

Humidity is the actual amount of vapor in a certain volume of air. Different parameters can be used to characterize the amount of vapor in the air: absolute humidity, relative humidity and partial pressure. The most common parameter is relative humidity. It is the percentage of the ratio between actual vapor pressure and saturation vapor pressure (maximum amount of moisture) depending on temperature.

B. Approach

The main method for measuring relative humidity, which is used in Ukraine, is the psychrometric method (Palamarchuk & Shevchenko 2012). A psychrometer consists of two mercury thermometers, a dry thermometer (used to measure the current air temperature t_1) and a wet thermometer. Evaporation from the wet thermometer lowers the temperature of surrounding air t_2 by the latent heat required for the liquid-to-vapor phase transition. The difference between the two temperatures (t_1 and t_2) depends on the air humidity. Evaporation increases with decreasing humidity or increasing saturation deficit, respectively, which causes an increase of the temperature difference between t_1 and t_2. Using this temperature difference as well as special psychometric equations or tables, the relative humidity can be determined. Relative humidity and temperature are measured at 2 m above ground level every three hours. It is necessary to correct the measured data according to the calibration certificate of the instrument.

Another approach is the sorption or hygrometric method. The hair hygrometer is the most common instrument based on this method. However, the hygrometric method is not as accurate as psychrometers. Nevertheless, it is used as the main method in winter, when the air temperature drops below -10°C (during this period the psychrometer cannot be used). For the remaining seasons, the hygrometer is used as additional instrument. Two months before the onset of freezing temperatures, both observations of hygrometer and psychrometer are detected to clarify the point when the hygrometer is needed.

C. Material

The data is measured at the meteorological station network of the Ukrainian Hydro-meteorological Centre since at least 1961. Here, psychrometers and hygrometers are the only non automated instruments used. Relative humidity measurements are carried out at all of the meteorological stations eight times per day (00, 03, 06, 09, 12, 15, 18, 21 UTC). For the territory of Western Ukraine, relative humidity is measured at stations listed in Tab. 2.2-1. The measurements are corrected regarding the instrumental error. Every thermometer is corrected according to the table of the instrument's corresponding calibration certificate.

D. Final product

Graphs of the annual cycle (together with precipitation and temperature) are envisioned for the most representative stations of the region.

E. Applicability

Relative humidity is important for agriculture, human comfort and is used for calculations of different meteorological parameters, such as potential evapotranspiration.

2.2.6 Precipitation

Author: Thomas Pluntke

A. Definition

Precipitation is the amount of condensed or sublimated atmospheric water vapor that falls under gravity. The main forms are rain, sleet, snow and hail. Precipitation is the main component of the water cycle. Therefore, areal information of precipitation is needed for the climatic characterization of a region.

B. Approach

Daily precipitation values are calculated as the sum of all daily measurements. The number of observations per day varies over time.

Plausibility test of raw data:

- $0 \leq P < 300$ mm/day
- not allowed to be repetitive for 10 days with an amount larger than 1.0 mm
- not allowed to be repetitive for 5 days with an amount larger than 5.0 mm
- dry periods receive flag = 1 (suspect), when the amount of dry days for the specific location exceeds a value of 14 times bivariate standard deviation

Testing homogeneity is similar to temperature. Here, the respective time period is crucial – homogeneity increases with duration, but much longer periods are needed for precipitation than for temperature.

Required temporal data coverage for calculation of statistics:
Missing values should be less than 10% of the values for a 30 year period, with maximal 5% missing days for a month.

Bias correction:

- corrected values should be applied for water balance calculations
- wetting and evaporation correction already applied to the archived data in the Ukraine (in contrast to Germany, where only uncorrected values are recorded)

- correction due to wind is necessary (Bogdanova et al. 2002):

$$P_{corr} = K \cdot (P_{obs} + \Delta P)$$

K Wind coefficient in dependency on temperature, wind speed, water and air pressure
ΔP wetting and evaporation correction (already applied to the archived data)

C. Material

Daily data is measured with a Tretyakov rain gage at 2 m height at the stations mentioned in Tab. 2.2-1.

D. Final product

The final product is a raster map of the precipitation sums with a resolution of 3x3 km covering the Ukraine. The final precipitation maps are referring to the chosen two periods, while each period contains a map of the precipitation sum for an average year, the four meteorological seasons as well as for the averaged winter and summer half year.

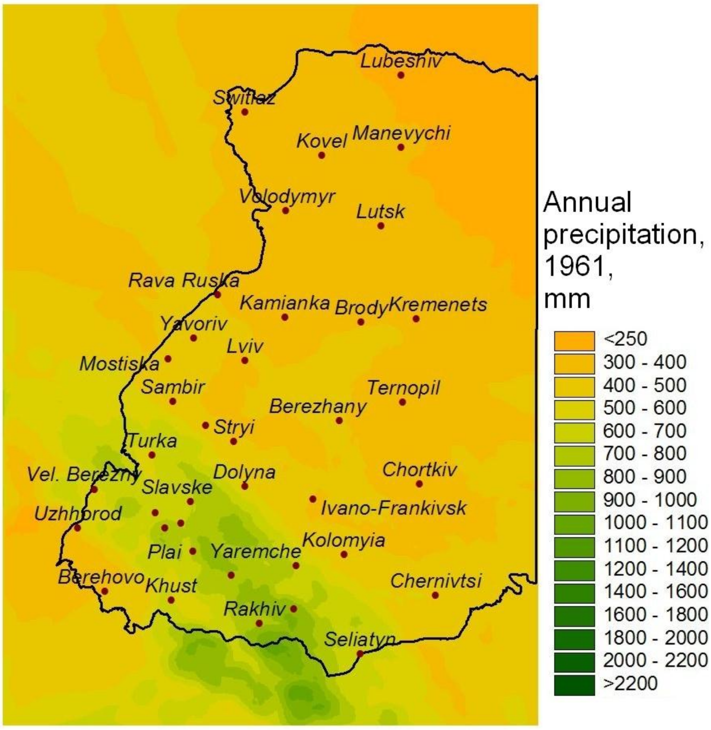


Fig. 2.2-1: Example map of the annual precipitation for the year 1961 in the area of Western Ukraine

E. Applicability

Precipitation is the main water input for all hydrologic processes in the catchment.

2.2.7 Snow cover

Author: Sergej Snizhko

A. Definition

Snow cover is the layer of snow laying on the surface of soil or ice. The snow cover is characterized by high reflectivity and has a significant influence on the climate. It is a crucial hydrological parameter in the global water cycle. Snow cover is directly influencing the dynamics of the global water cycle and controls climate through its effect on energy budget at the surface and lower atmospheric levels.

B. Approach

Observations of snow cover are made on a daily basis at the meteorological stations and periodically via field survey in natural landscapes. Snow depth, as the distance from the soil surface to the snow surface, is determined using fixed snow stakes.

Daily snow fall is observed at 6:00 a.m. Field surveys are undertaken periodically, every five days during winter season. A ten-day average of the snow depth is calculated for each meteorological station.

C. Material

Ten-day average snow depth values are available for each meteorological station mentioned in Tab. 2.2-1. Daily values of snow depth are available only in form of daily observations workbooks, which are mostly not digitized.

D. Final product

Map of duration of snow cover period and map of mean snow cover depth for the two agreed periods.

E. Applicability

Water reserves in form of snow cover are very important for hydrological calculations, especially for the assessment of water resources in river basins, forecasting of spring floods etc.

2.2.8 Wind

Author: Olga Shevchenko

A. Definition

Wind is the movement of air relative to the Earth's surface. Two wind characteristics are usually measured at meteorological stations: speed and direction. Wind speed units are meter per second, wind direction units are degrees azimuth.

B. Approach

Wind characteristics at Ukrainian meteorological stations are measured by non automated weathercock of Wild (standard) and optionally by automatic anemometers. Wind characteristics are measured in 10 m above ground level and are listed every three hours. Both of the wind characteristics are usually a 2 or 10 minutes-average representing the observation time, e.g. 06 or 09 UTC.

Measured characteristics are:

- mean wind speed at the observation time,
- mean wind direction at the observation time,
- maximum wind speed (wind gust) at the observation time
- maximum wind speed (wind gust) in the last 3 hours

To characterize the wind regime, the monthly or yearly average of wind speed and the prevailing wind direction for each station or region are calculated. So called "wind roses" are constructed to display prevailing wind directions combined with average wind speeds.

C. Material

The wind data is measured at the meteorological stations of Ukrainian Hydrometeorological Centre network (see Tab. 2.2-1 for Stations in Western Ukraine). Measurements of wind characteristics are carried out at all the meteorological stations eight times per day (00, 03, 06, 09, 12, 15, 18, 21 UTC).

D. Final product

Final product is a table of mean wind speed and wind roses for each station referring to the agreed periods. If areal information is envisioned, the setup of a wind model is needed.

E. Applicability

Wind characteristics are important for the estimation of evapotranspiration and the assessment of the energetic and damage potential of wind.

2.2.9 Potential Evapotranspiration

Author: Thomas Pluntke

A. Definition

The potential evapotranspiration is the possible evapotranspiration rate of a densely covered grass surface under current climatic conditions assuming an unlimited water supply. It normally sets the upper limit of the actual evapotranspiration and is one of the main climate characteristics of a region.

B. Approach

The FAO recommends the crop reference evapotranspiration ET_0 (Allen et al. 1994) as an international standard to replace the many empirical approaches to potential evapotranspiration. ET_0 is based on the Penman Monteith approach considering fixed boundary conditions: closed grass cover of 12 cm height, a defined aerodynamic resistance of 208·v_2 (wind speed at 2m height), no water shortage for plants, a surface resistance of 70 s/m and an albedo of 0.23.

Due to possible shortages of all the required meteorological variables at measuring stations, Wendling et al. (ATV-DVWK 2002) proposed an adjusted version for monthly values:

$$ET_0 = \frac{s}{s+\gamma} \cdot \left(0{,}65 \cdot \frac{RG}{L} + 0{,}25 \cdot n_M \cdot k\right) \cdot \frac{1}{1+0{,}00019 \cdot H}$$

$$L = (2.498 - 0.00242 \cdot T) \cdot 10^6$$

$$\frac{s}{s+\gamma} = 2.3 \cdot \frac{T+22}{T+123}$$

RG	mean monthly global radiation (J/m²)
T	mean monthly temperature (°C)
L	specific heat for evaporation of 1mm water (J/kg)
s	slope of the vapor saturation curve (hPa/K)
γ	psychrometer constant (0.65 hPa/K)
n_M	days of the month
k	coast factor (=1)
H	altitude (m) (for H > 600m: H=600m)

C. Material

Monthly data of air temperature measured at 2 m height and global radiation or sunshine duration are needed for the calculation.

D. Final product

Final product is a raster map with a 3x3 km resolution for yearly and seasonal sums referring to the agreed periods.

E. Applicability

Potential evapotranspiration is essential to calculate the climatic water balance, as an indicator for drought.

2.2.10 Actual Evapotranspiration

Author: Thomas Pluntke, Christian Bernhofer

A. Definition

Evapotranspiration is the sum of evaporation and plant transpiration from the Earth's land surface into the atmosphere. Evaporation accounts for the movement of water vapor to the air from sources such as bare soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through the stomata in its leaves. Interception is the evaporation from plant surfaces and is sometimes treated separately.

In contrast to potential evapotranspiration (ETP, ET_0), which is the amount of water that would be evaporated and transpired under the conditions of sufficient water availability, the actual evapotranspiration ETA considers the actual water availability (of the soil).

B. Approach

To get spatial values of ETA the results of a water balance model can be used. To set up such a model is a high effort, which is why more simple approaches are often used. In the Climate Atlas of Ukraine the method after Konstantynov (1963, 1968) is applied:

$$E = \frac{Eoi}{\bar{E} \cdot Ewon}$$

E	Evapotranspiration under optimal water availability
Eoi	Evaporation determined by the graphs of Konstantynov depending on temperature und absolute humidity
Ē	average seasonal value of evapotranspiration
Ewon	Ordinates of biological curves

The approach is used for the determination of monthly values and is based on the correlation between evaporation as well as air temperature and humidity. The values for the latter two factors are modified to consider the slowness of heat and moisture transfer from the active surface to a level of 2 m height during the daily and seasonal progression.

In Germany the method after Bagrov (1953), which was modified by Glugla et al. (2001), is widely used for the estimation of ETA. The meteorologically conditioned evapotranspiration from vegetated surfaces is calculated depending on precipitation (bias corrected), maximal evapotranspiration *ETmax* and an empiric parameter *n*. Land use dynamics is not considered in this approach. *ETmax* for a specific land use depends on the parameters f, f_H (a modification of ET due to orographic factors) and on the crop reference evapotranspiration (ET_0). The parameter *n* and *f* were determined from German lysimeter measurements and are therefore available for non-forested areas. Applying this approach for the Ukraine, an adaptation of the parameter is necessary. Calculations can be made for a snow free period. Further approaches are needed for snow, lakes and irrigation.

Alternatively, ETA is measured by micrometeorological methods (eddycovariance EC, Bowen ratio approach BR) or by estimates of the soil water budget from differences of soil water probes. EC is based on fast measurements of turbulent fluctuations of vertical wind speed and vapor concentration some meters above the active surface. It requires specific instruments and extensive post-processing of data. Yet, it is about to become a new standard for surface fluxes including CO_2, e.g. in the European ICOS (Integrated Carbon Observation System) network. BR is based on measurements of vertical gradients of temperature and vapor concentration some meters above the active surface, as well as on measurements of net radiation and soil heat flux. EC is applicable to all surface types including forests; BR works best for low plant canopies such as grassland or crops. Both methods yield ETA data at site level of high temporal resolution (e.g., half-hourly). In a bottom-up approach these values can be up-scaled to catchment level, either from multi-tower measurements or via modeling utilizing parameters derived from these ETA data. These methods will be covered by the next DWA (formerly DVWK) guideline to ET in 2014.

C. Material

Most of the data needed for the calculation are part of the atlas, namely precipitation, potential evapotranspiration, topography, land use and soil. Furthermore, lysimeter measurements of ETA are needed to modify the factors of the approach.

D. Final product

The result is a gridded map of ETA in a resolution of 3x3 km² referring to the agreed periods.

E. Applicability

ETA is the loss component of the water balance and is needed to determine the mean runoff height. It is also important for agricultural issues like irrigation.

2.2.11 Climatic water balance

Author: Thomas Pluntke

A. Definition

The climatic water balance CWB is an indicator used for the assessment of an areas' water yield. It is defined as the difference between precipitation and potential evapotranspiration referring to a certain period in mm per unit time. The climatic water balance is a normalized value which allows a comparison between different regions. The climatic water balance assumes positive or negative values, depending on precipitation and potential evapotranspiration depth. Hence, CWB indicates climate induced surpluses or deficits in the water budget and its regional distribution.

B. Approach

The climatic water balance is calculated using the equation below. The required precipitation depth needs to be bias corrected as shown in chapter 2.2.6. Potential evapotranspiration is calculated using the approach mentioned in chapter 2.2.9. It is recommended to use the crop reference evapotranspiration ET_0 (Allen et al. 1994), which is an international standard to replace the many empirical approaches to potential evapotranspiration and an independent value concerning the land use of an area. Nevertheless, it is necessary to keep in mind that ET_0 is not necessarily the maximum value for the evapotranspiration processes, since it refers to fixed boundary conditions according to a closed grass cover of 12 cm height.

$$CWB = P_{corr} - ETP$$

P_{corr} bias corrected precipitation
ETP potential evapotranspiration

C. Material

To calculate CWB climate data is required. Here, daily precipitation data measured with a Tretyakov rain gage at 2 m height at the stations mentioned in Tab. 2.2-1 is available. To calculate the crop reference evapotranspiration daily data of air temperature measured at 2 m height and global radiation or sunshine duration are needed.

D. Final product

Final product is a raster map with a 3x3 km resolution showing the annual depth of the climatic water balance referring to the agreed periods.

E. Applicability

CWB is used for the hydro-climatic characterization of a site and hence an important parameter for the water-management sector.

2.3 Chapter 3: Surface Water

2.3.1 Surface water monitoring network

Author: Yuri Nabyvanets

A. Definition

Hydrological observation is the observation of elements of the hydrological regime. The term "hydrological observation" is used to describe both actual observations and quantitative measurements. Actual observations are performed only visually without any measurements and are used to determine the activities related to the implementation of quantitative assessments (measurements) and for the characterization of hydrological phenomena and processes. Hydrological observations are performed at posts and stations according to official precepts.

A hydrological network is the totality of hydrological stations and posts that are based on established scientific principles within a certain area (river basin, administrative district) to study the hydrologic regime for daily systematic information about its current state.

B. Approach

Information on geographical coordinates of hydrological stations is used. Hydrological stations are depicted in an electronic map using GIS tools.

C. Material

The program of observations on hydrological (river/ gauging) stations originating from organizations of the Hydrometeorological Service (Ministry of Emergencies, Ukraine) is providing the needed input information. A fragment from the program is presented in Tab. 2.3-1.

Tab. 2.3-1: Program of observations at hydrological (river) stations from organizations of the Hydrometeorological Service (Ministry of Emergencies, Ukraine)

#	River	Station	Station code	Station category*1	Types of observations			
					water level	water discharge	solids discharge	water temp.
Volynski Hydrometeorological Service								
1	Vyshnya	Tvirzha	79720	I	+	+	-	+
2	Western Bug	Sasiv	79723	I	+	+	-	+
3	"	Kamyanka-Buzyka	79726	I	+	+	+	+
4	"	Lytovezh	79397	I	+	+	-	+
5	Poltva	Busyk	79747	I	+	+	-	+
6	Rata	Volytsya	79753	I	+	+	-	+
7	"	Mezhyritchya	79755	I	+	+	-	+
8	Svynya	Zhovkva	79757	I	+	+	-	+
9	Solokiya	Chervonograd	79761	I	+	+	-	+
10	Luga	Volodymyr-Volynsykyy	79763	I	+	+	-	+
11	Prypiaty	Richytsya	79361	I	+	+	-	+
12	"	Lyubyazy	79365	I	+	+	-	+
13	Vyzhivka	Ruda	79400	I	+	+	+	+
14	"	Stara Vyzhivka	79403	I	+	+	-	+
15	Turiya	Yagidne	79405	I	+	+	-	+
16	"	Kovely	79407	I	+	+	-	+
17	Stokhid	Malynivka	79416	I	+	+	-	+
18	"	Lyubeshiv	79424	I	+	+	-	+
19	Styr	Schurivtsyi	79473	I	+	+	+	+
20	"	Lucyk	79477	I	+	+	-	+
21	"	Kolky	79481	II	+	-	-	+
22	"	Mlynok	79485	I	+	+	-	+
23	Radostavka	Tryiytsya	79491	I	+	+	-	+
24	Ikva	Velyki Mlynivtcyi	79496	I	+	+	+	+
25	Goryny	Yampily	79513	I	+	+	+	+
26	"	Ozhenyn	79518	I	+	+	-	+

*1 Category I: meteorological and hydrological parameters: ice thickness, sludge ice, snow cover on ice, ice phenomena, aquatic vegetation, precipitation, water discharge, discharge of solids
Category II: as category I except water discharge and discharge of solids

Information about the geographical position will be used for the mapping of hydrological stations. An example of such information is presented in Tab. 2.3-2.

Tab. 2.3-2: Coordinates and elevations of the network of hydrological stations (Western region)

No.	Station	Elevation (m)	Geographical coordinates			
			latitude		longitude	
1	Sasiv	264	49º 52′ 42″	49,87833	24º 56′ 49″	24,94694
2	Kamianka-Buzka	206	50º 05′ 48″	50,09667	24º 22′ 26″	24,37389
3	Busk	212	49º 57′ 53″	49,96472	24º 36′ 27″	24,6075
4	Volytsia	202	50º 13′ 38″	50,22722	24º 06′ 35″	24,10972
5	Zhovkva	228	50º 03′ 10″	50,05278	23º 58′ 24″	23,97333
6	Chervonograd	193	50º 22′ 29″	50,37472	24º 14′ 07″	24,23528
7	Shchurivtsi	195	50º 16′ 15″	50,27083	25º 02′ 07″	25,03528
8	Triiytsia	206	50º 09′ 16″	50,15444	24º 46′ 09″	24,76917
9	Velyki Mlynivtsi	227	50º 07′ 22″	50,12278	25º 39′ 49″	25,66361
10	Ozhenyn	190	50º 25′ 35″	50,42639	26º 32′ 24″	26,54
11	Pyrohivtsi	274	49º 22′ 43″	49,37861	27º 15′ 40″	27,26111
12	Tiachiv	214	48º 00′ 20″	48,00556	23º 34′ 38″	23,57722
13	Vylok	118	48º 05′ 50″	48,09722	22º 50′ 24″	22,84
14	Ruska Mokra	552	48º 20′ 48″	48,34667	23º 54′ 27″	23,9075
15	Nyzhnii Bystryi	296	48º 21′ 08″	48,35222	23º 32′ 55″	23,54861
16	Dovhe	174	48º 22′ 01″	48,36694	23º 17′ 15″	23,2875
17	Shalanky	122	48º 15′ 01″	48,25028	22º 54′ 21″	22,90583
18	Svaliava	196	48º 33′ 10″	48,55278	22º 58′ 58″	22,98278
19	Mukacheve	122	48º 26′ 37″	48,44361	22º 43′ 05″	22,71806
20	Chop	101	48º 27′ 18″	48,455	22º 12′ 49″	22,21361
21	Turia Poliana	282	48º 41′ 57″	48,69917	22º 48′ 04″	22,80111
22	Simer	155	48º 44′ 03″	48,73417	22º 30′ 58″	22,51611
23	Lopushne	682	48º 38′ 41″	48,64472	23º 37′ 39″	23,6275
24	Luhy	604	48º 03′ 32″	48,05889	24º 25′ 02″	24,41722
25	Sambir	290	49º 30′ 21″	49,50583	23º 13′ 24″	23,22333
26	Rozdol	250	49º 26′ 20″	49,43889	24º 04′ 23″	24,07306
27	Zhuravlyne	241	49º 15′ 40″	49,26111	24º 17′ 22″	24,28944
28	Khyriv	351	49º 31′ 28″	49,52444	22º 48′ 48″	22,81333
29	Luky	269	49º 36′ 43″	49,61194	23º 23′ 30″	23,39167
30	Komarne	262	49º 37′ 23″	49,62306	23º 42′ 43″	23,71194
31	Verekhnie Synovydne	377	49º 06′ 30″	49,10833	23º 36′ 28″	23,60778
32	Rykiv	627	49º 02′ 24″	49,04	23º 07′ 40″	23,12778
33	Maidan	492	49º 09′ 58″	49,16611	23º 16′ 38″	23,27722
34	Myslivka	652	48º 47′ 36″	48,79333	23º 46′ 27″	23,77417
35	Zalishchyky	149	48º 38′ 03″	48,63417	25º 44′ 15″	25,7375
36	Perevozets	245	49º 04′ 42″	49,07833	24º 33′ 06″	24,55167
37	Bilshivtsi	221	49º 10′ 53″	49,18139	24º 44′ 14″	24,73722
38	Guta	641	48º 38′ 10″	48,63611	24º 12′ 44″	24,21222
39	Pidhaitsi	322	49º 15′ 47″	49,26306	25º 08′ 37″	25,14361
40	Koropets	206	48º 56′ 50″	48,94722	25º 10′ 41″	25,17806
41	Kaplyntsi	330	49º 32′ 57″	49,54917	25º 13′ 22″	25,22278
42	Buchach	271	49º 03′ 17″	49,05472	25º 24′ 10″	25,40278
43	Strilkivtsi	182	48º 46′ 18″	48,77167	25º 59′ 51″	25,9975
44	Volochysk	277	49º 31′ 51″	49,53083	26º 09′ 36″	26,16
45	Zavallia	141	48º 35′ 48″	48,59667	26º 20′ 17″	26,33806
46	Kuhaivtsi	243	48º 58′ 06″	48,96833	26º 21′ 47″	26,36306
47	Kupyn	235	49º 05′ 29″	49,09139	26º 34′ 24″	26,57333

No.	Station	Elevation (m)	Geographical coordinates			
			latitude		longitude	
48	Storozhynets	356	48º 08′ 59″	48,14972	25º 42′ 56″	25,71556
49	Liubkivtsi	227	48º 28′ 39″	48,4775	25º 21′ 54″	25,365
50	Kuty	333	48º 15′ 00″	48,25	25º 11′ 01″	25,18361
51	Verhovyna	601	48º 09′ 19″	48,15528	24º 51′ 14″	24,85389
52	Holozubyntsi	208	48º 50′ 23″	48,83972	26º 54′ 47″	26,91306
53	Zinkiv	202	49º 05′ 59″	49,09972	27º 03′ 40″	27,06111
54	Tymkiv	136	48º 47′ 41″	48,79472	27º 05′ 10″	27,08611

D. Final product

The final product represents a map of the hydrological observation network (stations) and tables containing a list of hydrological stations with their categories, types of observation and observation period. Examples of such a map are presented in Fig. 2.3-1 and Fig. 2.3-2. The structure of the resulting tables is presented in Tab. 2.3-3.

E. Applicability

The maps can be used to estimate the density of the hydrological observation network at the investigated water object and its adequacy for the performance of various hydrological calculations. The tables are useful to create a hydrological database with the aim of water balance calculations, description of water bodies' hydrological regime including temporal and spatial variability. The maps can also serve as a basis for pollution load calculations, the estimation of water quality and the vulnerability of the studied area to floods and flashfloods.

Tab. 2.3-3: Header of table describing hydrological observation network

#	River	Station	Station category	Observations type				Observation time series
				Water level	Water discharge	Sediments discharge	Water temp	

Fig. 2.3-1: Hydrological stations network of the Hydrometeorological Service of Ukraine

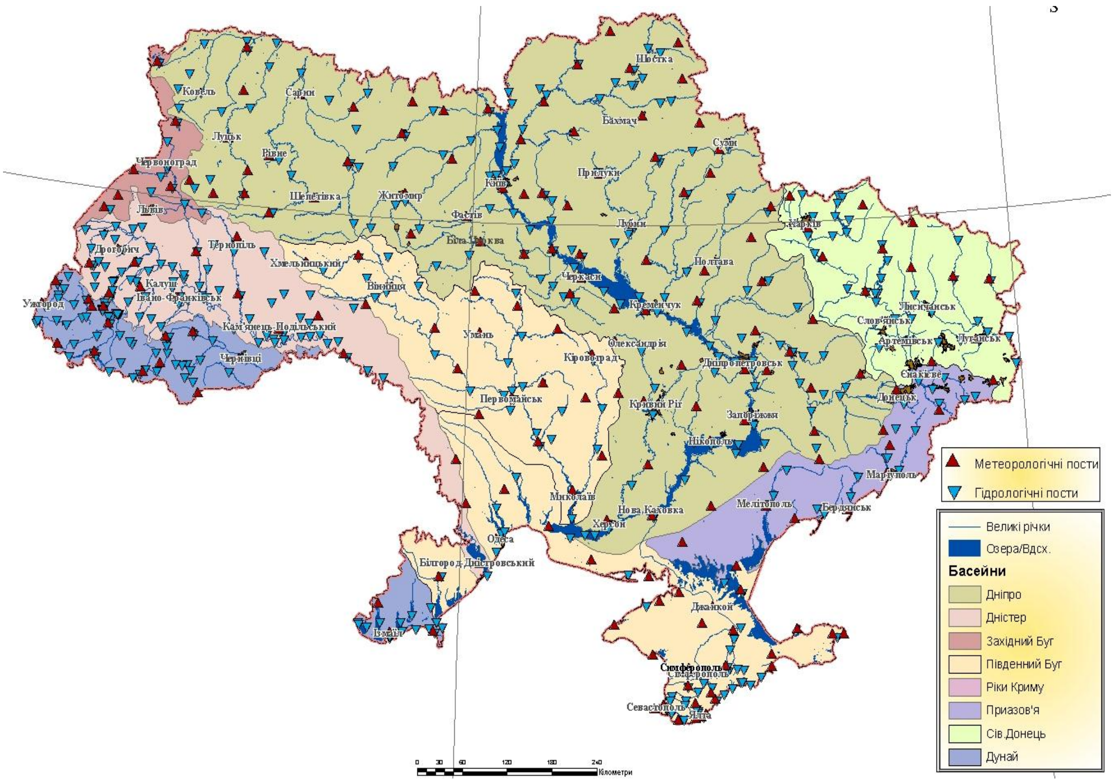


Fig. 2.3-2: Hydrological and meteorological stations network of the Hydrometeorological Service of Ukraine

2.3.2 Water reservoirs

Author: Victor Vyshnevski

A. Definition

Reservoirs are of great importance regarding the water management of a state. Furthermore they impact the water regime of rivers by different factors, such as water runoff, water temperature, sediment yield etc.

B. Methods

Reservoirs are shown in the majority of maps concerning different aspects: physiographic, economical and even political. There are special maps, where reservoirs are the main object of attention. Taking their importance related to different spheres into account, it is desirably to show as much as possible of the occurring reservoirs. The largest reservoirs (for example with the volume more than 50 or 100 million m^3) are usually shown in scale and marked with their names. The smaller ones can be shown by special signs - weirs for instance are corresponding to the shortest side of triangular symbol. Depending on the volume of the reservoir, three grades could be used: from 10 to 20 million m^3, 20 million to 50 million m^3 (100 million m^3) and up to 10 billion m^3. Depending on scale of the mapped region, there is a need to number all reservoirs or those with a volume more than 10 million m^3. A legend provides the main characteristics of the numbered reservoirs, such as name, area and the volume under the regular and operational level.

C. Material

The main source needed to create a map of reservoirs of the Ukraine is departmental material from the State Agency of Water Resources. According to the Agency, its total number is about 1100. To assume the exact number needed for an evaluation is problematic due to the fact that some reservoirs are under construction, while others (those which are silting significantly) are converted into ponds. The exact amount of data can be defined in the regional divisions of the Agency, each operating in a regional center.

D. Final Product

The cartographic basis for a map called "Reservoirs" is a map of the hydrographic network. Depending on the selected region, the mapping scales are 1:500,000, 1:1,000,000 or 1:2,000,000.

E. Application

The obtained maps primarily are needed for specialists working in the field of water management and land reclamation. In addition to that, such maps are of interest for local and state authorities.

2.3.3 Drainage and irrigation systems

Author: Victor Vyshnevski

A. Definition

Land drainage is a complex of hydro-technical facilities to decrease the water content in the soil. Main aims are the improvement of human living conditions and the productivity of agricultural cultures. In contrast to drainage, irrigation means an increase of the water content in the root layer of the soil to increase its fertility.

Drainage systems, such as open or tile drainage, lower the ground water level. The collected water is directed to rivers, lakes etc. by gravity or using pumps. Irrigation systems comprise facilities for the water abstraction and its transportation to the fields. The moistening of the root layer is realized by overhead irrigation, drip irrigation and other methods of watering.

The largest development of land melioration in Ukraine was implemented by state investments in the last third of the 20th century. During this time, the melioration systems were property of the state. Its management was carried out by the State Agency of Water Resources, Ukraine. The administration of rural land areas changed in the 21st century, where a large part of the facilities was determined as municipal property. Unfortunately, a large part of the state melioration network is dismantled. However, information about the area and condition of ameliorative lands should be obtainable by institutions of the State Agency of Water Resources of Ukraine.

B. Approach

Despite the extension of melioration in the Ukraine, mapping of ameliorative lands are comparatively weak developed. This can be partly explained by several reasons. One is the location of data at only one institute: the State Agency of Water Resources of Ukraine. Another problem is the above mentioned changes of rural land administration, for instance the partially transfer of ameliorative lands from state to municipal property. The third factor, which is connected to the latter, is to end up melioration on large parts of land. The current actual area of ameliorative land (both drained and irrigated) decreased essentially, compared to the year 1991.

Mapping of drained and irrigated lands has some specifics. The area of drained systems is small and consists usually of some hundreds of hectares. In some oblasts of the Ukraine there are more than 100 irrigation systems. The drainage systems, depending on the drainage type (open-, tile drainage or both), are mapped using different symbols. For large systems, the places where drained water is diverted into the river's network should be shown. Details such as name, area and year of construction can also be illustrated in tables.

Some of the irrigation systems in Ukraine are very large. Hence, mapping of main and distributive canals is obligatory. If possible, the location of large pumping stations should be mapped, as well as irrigated lands. Since there is a significant difference between the current area of irrigated lands and former times, it would be desirable to distinguish between the irrigated areas of different periods (end of 1980s with the largest development of irrigation facilities vs. recent state) using different colors. For the latest state, the utilization of air-borne photos is possible. During dry periods, irrigated land differs essentially from dry land, even in the visible spectrum. These differences are even larger using multispectral photos. Such photos could be used for the atlas to get an insight of the extent of irrigation and drained areas (Fig. 2.3-3).

C. Material

The main source of data to map ameliorative lands is the State Agency of Water Resources of the Ukraine. Another important data source to map irrigated lands is satellite photos.

D. Final product

The map "Meliorated Lands" is constructed using a special symbology and cartographic methods. The drained lands can be mapped by shades of a particular color, the irrigated by shades of another color. According to the spatial dimension of the selected regions, the scale of mapping should range between 1:500,000 and 1:2,000,000 (Fig. 2.3-4).

E. Applicability

The obtained maps are necessary for specialists in field of water management and irrigation and are of interest for local and state authorities.

Fig. 2.3-3: A satellite photo showing a part of Khersonskaja oblast. The green circles are irrigated land, which are watered by Frehat sprinkling machines

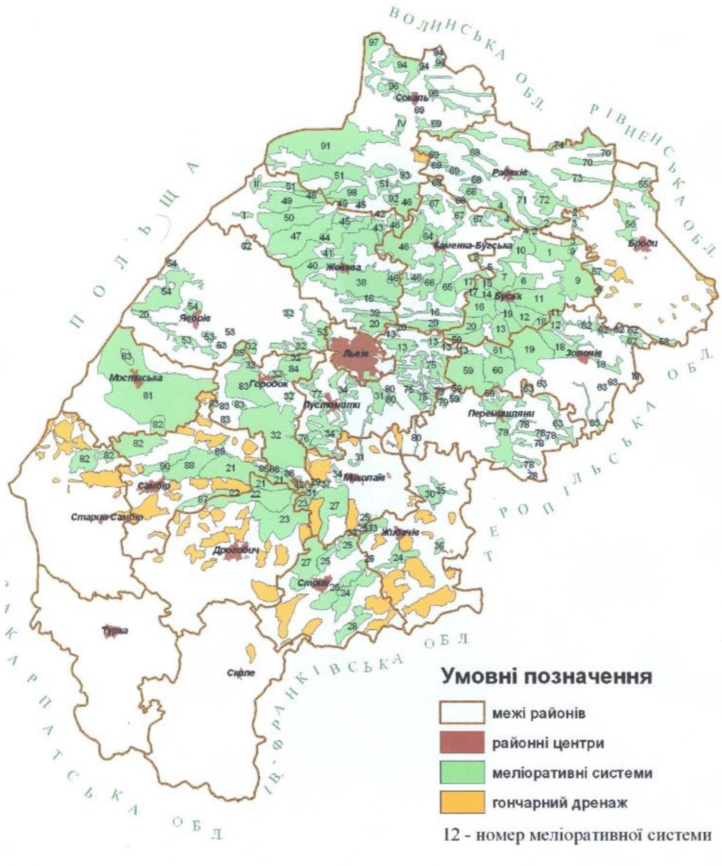


Fig. 2.3-4: Ameliorated lands of the Oblast Lviv

2.3.4 Mean runoff height

Author: Yuri Nabyvanets, Thomas Pluntke

A. Definition

Water runoff R is the amount of water which flows within the catchment area during a certain period of time, represented as a layer (in mm) uniformly distributed within the area. This mode of water runoff presentation can be applied to different time periods (day, month, season, year, multiyear period etc.) as well as to runoffs of different origins (surface, ground, spring, rain, glacier etc.).

B. Approach

1. Approach

The mean long-term runoff layer is calculated using bias corrected precipitation and actual evapotranspiration data. Runoff is composed of different components being dominant in particular time periods such as winter and summer half year, as well as meteorological seasons. Therefore, to address average catchment ETA, a long reference period is needed (30 years).

$$R = P_{corr} - ETA$$

P_{corr} areal bias corrected precipitation [mm]
ETA areal actual evapotranspiration [mm]

2. Approach

The mean annual long-term runoff layer *Y* of a catchment can be calculated as:

$$Y = \alpha_{mean} \cdot P \; [mm]$$

α_{mean} value of coefficient of annual surface runoff from the catchment
P mean long-term annual sum of precipitation (mm) which is derived using observation data of the nearest meteorological stations (considering special corrections), or a special map

The mean coefficient of the annual runoff related to the surface of a sub basin or the whole catchment α_{mean} is calculated according to the equation:

$$\alpha_{mean} = (a_1 \cdot f_1 + a_2 \cdot f_2 + \cdots + a_n \cdot f_n) \cdot \frac{1}{F}$$

α_1 α_2, α_n coefficients of the annual runoff from different surfaces of the territory (can be selected from special tables);
f_1, f_2, f_n areas of different surfaces (discharge forming complexes) of the studied territory (km^2). Areas are defined using maps with scales of 1:500 up to 1:5,000
F total area of delineated inner catchment (km^2)

For specific areas and discharge forming complexes, which represent natural but no modified surfaces (or nearly natural surfaces, depends on the point of view regarding direct runoff forming processes), the coefficients α correspond to the natural landscape of respective natural zones or river catchments.

C. Material

Maps of mean annual water runoff layers are developed on the basis of calculations depending on specific tasks for a given catchment. The database of precipitation observations for defined time periods and a certain territory serves as initial input information to calculate mean values of precipitation. Applying the first approach, calculations of actual evapotranspiration depending on land use and soil characteristics are needed (see chapter 2.2.10). The parameters needed for the second approach are derived from respective maps (area values) and respective issues of the State Water Cadastre.

D. Final product

Final product is a map of the mean annual long-term runoff layer for different basins. Values of runoff layer are presented by isolines or filled contours. Examples of such a map with different scales are given in Fig. 2.3-5 and Fig. 2.3-6.

E. Applicability

The map can be used as input information for water balance calculations and hydrological calculations with the aim to estimate preliminary the quantitative characteristics of water resources for a specific catchment or territory.

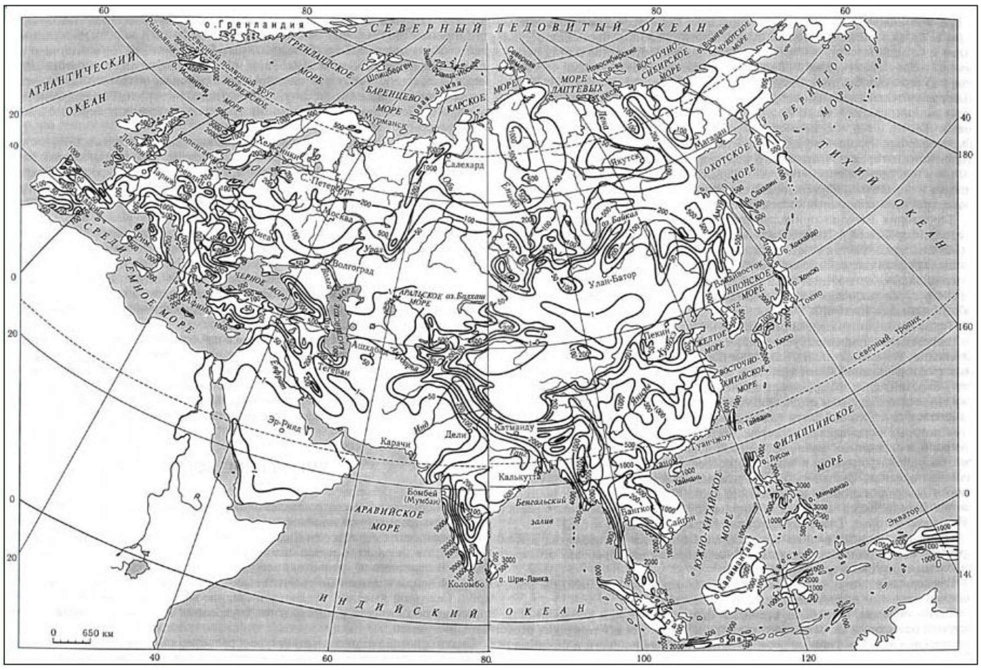


Fig. 2.3-5: Annual runoff layer of Eurasia

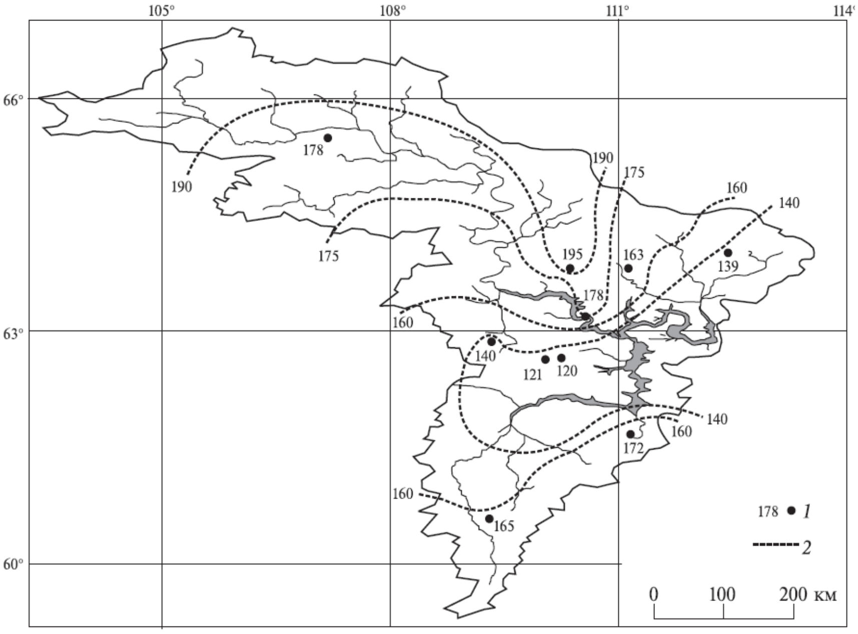


Fig. 2.3-6: Annual runoff layer for Vilyui Reservoir Basin

2.3.5 Long-term discharge and specific discharge

Author: Ivan Kovalchuk

A. Definition

The average long-term discharge refers to the water discharge of a river measured at a particular gauging station averaged over a long period T. The discharge dimension is declared as the volume of water that flows through a certain river profile within a given period of time, such as one year or one second.

An additional and widely used variable in hydrology is the discharge per unit area (or specific discharge), which is the ratio of a measured cross-section discharge (in meter per second) and the surface of the corresponding catchment area. Depending on the used discharge units, it has dimension $m^3/(s\cdot km^2)$ or $l/(s\cdot km^2)$. Generally, maps show the specific discharge, which allows a comparison between different river catchments. Thus, the specific discharge of a river basin depends on different factors such as geology, vegetation or precipitation of the area.

B. Method

The specific discharge can be shown in maps using the contour method. Initial information can be obtained by hydrological observations at gauging stations in (sub-) basins of different catchment size (Fig. 2.3-7).

C. Material

To create a map of the discharge per unit area one can use long-term observations of gauging stations. The generalization of data is provided by the Central Geophysical Observatory. This map in particular, can be found in Paton et al. (2007), as a further source Yatsyk et al. (1991) is used.

D. Final product

The final product is a map of the average discharge for the main rivers within the whole country or some regions. Isolines are drawn depending on the spatial variation of the minimum and maximum values of the specific discharge. As shown in Fig. 2.3-7, these values range from 0.1 to more than 30 $l/s\cdot km^2$. The largest averaged discharge per unit area, observed in Carpathian Rivers, is up to 30 $l/s\cdot km^2$ and more. In the Crimean Mountains it ranges from 2.0 to 25 $l/s\cdot km^2$, and in the uplands of the right bank of Ukraine the specific discharge ranges between 2.0 to 7.0 $l/s\cdot km^2$. The smallest values (less than 1.0 $l/s\cdot km^2$) are observed in the southern steppe regions of Ukraine and Crimea.

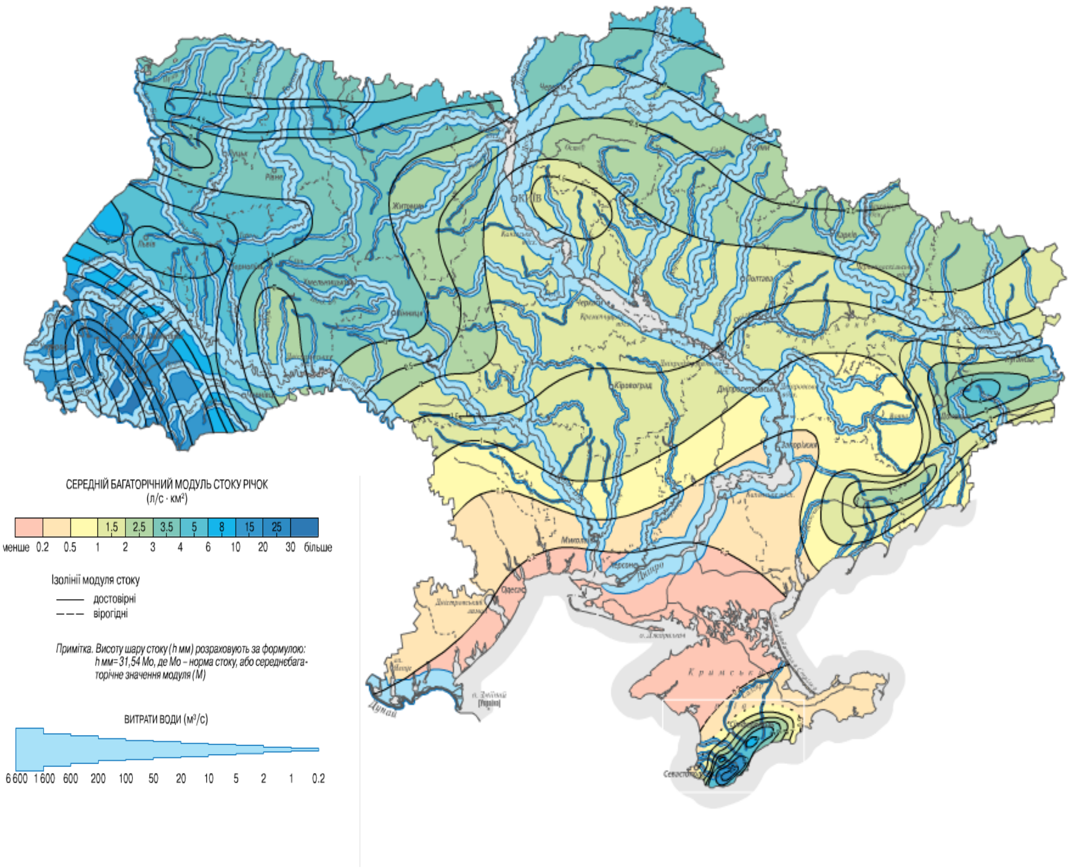


Fig. 2.3-7: Map of average long-term discharge and specific discharge for the Ukraine (l/s·km^2) (Paton et al. 2007)

E. Applicability

A map of the distribution pattern of the mean annual discharge offers valuable basis information on the availability of surface water for public, industrial, agricultural and private water consumption as well as for shipping. Furthermore, discharges of different intensities, such as high or low flows, are needed to calculate the discharge per unit area, which is important to make sub basins comparable.

2.3.6 Specific maximum flow

Author: Ivan Kovalchuk

A. Definition

The specific maximum flow is a concept that corresponds to the maximum water discharge of rivers, which are observed as a result of a melting snow cover (spring floods) or during heavy rainfall events. A map is a beneficial tool to give an overview about the flood vulnerability of different areas. The maps are created separately for maximum spring and rainfall floods using the corresponding discharge per unit area with the dimension m^3/(s·km^2) or l/(s·km^2).

Maximum flows represent a great threat to economic objects, settlements, communication systems and humans. A hydrologically dangerous maximum flow occurs in areas where rainfall floods and spring floods are formed simultaneously. That concerns first of all the Carpathian region, which partly covers Transcarpathian, Lviv, Ivano-Frankivsk and the Chernivtsi regions. Another flood vulnerable region is the area of the Western Bug basin and the area of the right tributaries of the Pripyat River.

The largest area of the Ukraine is affected by spring flood events with a probability of 1%, which corresponds to a specific maximum flow of 0.2 to 0.4 $m^3/(s \cdot km^2)$. The specific maximum flow in the Carpathian region ranges between 0.5 to 1.5 $m^3/(s \cdot km^2)$ and in the Crimean Mountains between 0.5 to 0.6 $m^3/(s \cdot km^2)$. For the Dnieper Lowland they are lower than 0.1 $m^3/(s \cdot km^2)$. The specific maximum flow of rainfall and snow-rainfall flood events with a probability of 1% is larger: the biggest area is covered by 0.2 to 0.5 $m^3/(s \cdot km^2)$. The Carpathian region is represented by 2.0 to 3.0 $m^3/(s \cdot km^2)$. High rates, up to 1.5 $m^3/(s \cdot km^2)$, of specific maximum flow are also observed in the Crimean Mountains. That underlines, that the specific discharge of flood events varies significantly between geographic areas. Hence, they can be described according to the major natural areas.

Zone of mixed forests

The water regime of rivers in this zone is characterized by prolonged spring flood events and relatively sparse summer and autumn rainfall floods. The spring flood begins in the first half of March and continues until the end of April. The maximum spring flood event is observed in the end of March or the beginning of April. The flood runoff layer is 40 to 80 mm, which is about 55% of the annual value. The specific maximum flow is 50 to 200 $m^3/(s \cdot km^2)$. The annual long-term water balance of this zone contains 690 mm precipitation, 110 mm runoff and 580 mm surface evaporation with infiltration.

Zone of deciduous forests

This zone represents the water regime of most of the rivers and is characterized by severe spring floods and low flow events, which are interrupted by summer-autumn and winter floods. Floods due to rainfall events are mostly lower than spring floods. The major river basins of this zone are the upper tributaries of the Pripyat, Dniester and Western Bug. Here, spring floods usually begin in early March, or sometimes in early February (Dniester). The end of the spring flood events are observed in the second half of April, or sometimes in the first half of May. The highest magnitudes of spring floods occur in the second or third decade of March (Dniester) and the beginning of April (tributary of Pripyat). The flood duration is about 1.5 to 2.0 months. The average water level rise is 20 to 90 cm per day. The greatest water level increase in small and medium-size rivers reaches 30 to 150 cm and 150 to 300 cm per day in large rivers. The average specific maximum flow is 3 to 4 $l/(s \cdot km^2)$. On the tributaries of the Dniester it can reach 4 to 6 $l/(s \cdot km^2)$, in upper regions of some Carpathian rivers 9.5 to 12.6 $l/(s \cdot km^2)$.

The forest-steppe zone

The water regime of rivers in this zone is characterized by spring floods and rare flood events in autumn and winter. The average duration of spring floods amounts to 40–50 days. Due to unstable winter, in some years no spring floods are observed. The flood runoff layer equals to 10–20 mm, which corresponds to more than half of the annual runoff the region. The greatest specific maximum flow in Western Ukraine is 300 l/(s·km^2). The annual long-term water balance of this zone contains 635 mm precipitation, 85 mm runoff and 550 mm surface evaporation with infiltration. The water balance components of the Siverskyi Donets River basin are different with 577mm precipitation, 57 mm runoff and 520 mm evaporation.

The steppe zone

The water regime of rivers in this zone is characterized by spring floods and rare flood events in autumn and winter. Due to the unstable winter in the Ukrainian steppe zone, no spring floods are observed. It lasts about 45 days. The flood runoff layer is about 16 mm, which corresponds to 65% of the zone's annual runoff.

B. Approach

Maximum discharges are measured by automatic hydrometric stations or temporarily on gauging stations using meters. Often the maximum discharges are obtained by extrapolation using the dependency between discharges and water level.

To estimate the maximum water discharge characteristics, data of hydrological observations, such as from gauging stations published in the handbook "Annual data on regime and resources of surface water" can be used. Maximum discharges are usually calculated by applying the well-known reduction equation, which is presented as an example in Gidrometeoizdat (1967). The analytical expression of the universal law of reduction, regarding for instance the relation between specific discharge and catchment area, reflects a decreasing specific discharge with increasing river basin area:

$$M_{max}{}^{(p)} = M_{max,200}{}^{(p)} \cdot \left(\frac{200}{F}\right)^n$$

$M_{max}{}^{(p)}$	probability p to exceed the specific maximum discharge of an area F [m^3/(s·km^2]
$M_{max,200}{}^{(p)}$	probability p to exceed the specific maximum discharge of an area of 200 km^2, [m^3/(s·km^2)
F	catchment area [km^2]
N	reduction degree

The index n varies for each territory of the Ukraine within a range of 0.4 to 0.8 for rainfall floods and 0.2 to 0.4 for spring floods (Paton et al. 2007, Gidrometeoizdat 1969). The specific maximum flow $M_{max,\ 200}$ is calculated for an exceeding probability p=1% according to the above mentioned equation:

$$M_{max,200}{}^{(p)} = M_{max}{}^{(p)} \cdot \left(\frac{F}{200}\right)^n$$

The maximum discharges of a river Q_{max} with a catchment area F, is determined using the following equation:

$$Q_{max} = M_{max,200} \cdot \left(\frac{200}{F}\right)^n \cdot F$$

C. Material

To map the maximum runoff, data of the Hydrometeorological Service of Ukraine, which is an institution of the Central Geophysical Observatory of Ukraine, can be used. These maps are also illustrated in Paton et al. (2007) and other sources.

D. Final product

The final product is a map of the specific maximum flow related to spring floods (Fig. 2.3-8) and heavy rainfall floods (Fig. 2.3-9). Isolines of the specific maximum flow are drawn at various intervals depending on the spatial variation of the smallest and largest values within the catchment. The largest specific maximum flows are observed in the Carpathian region with values up to 1.5 $m^3/(s \cdot km^2)$ and more. The specific maximum flow in the Crimean mountains is 0.3 to 2.0 $m^3/(s \cdot km^2)$, 0.1 to 0.5 $m^3/(s \cdot km^2)$ in the uplands and 0.05 to 0.4 $m^3/(s \cdot km^2)$ in the lowlands. The smallest values, less than 0.1 $m^3/(s \cdot km^2)$, are observed in the southern steppe regions of Ukraine and Crimea.

E. Applicability

Maps of the specific maximum flow are necessary to evaluate the risk of floods to economic objects.

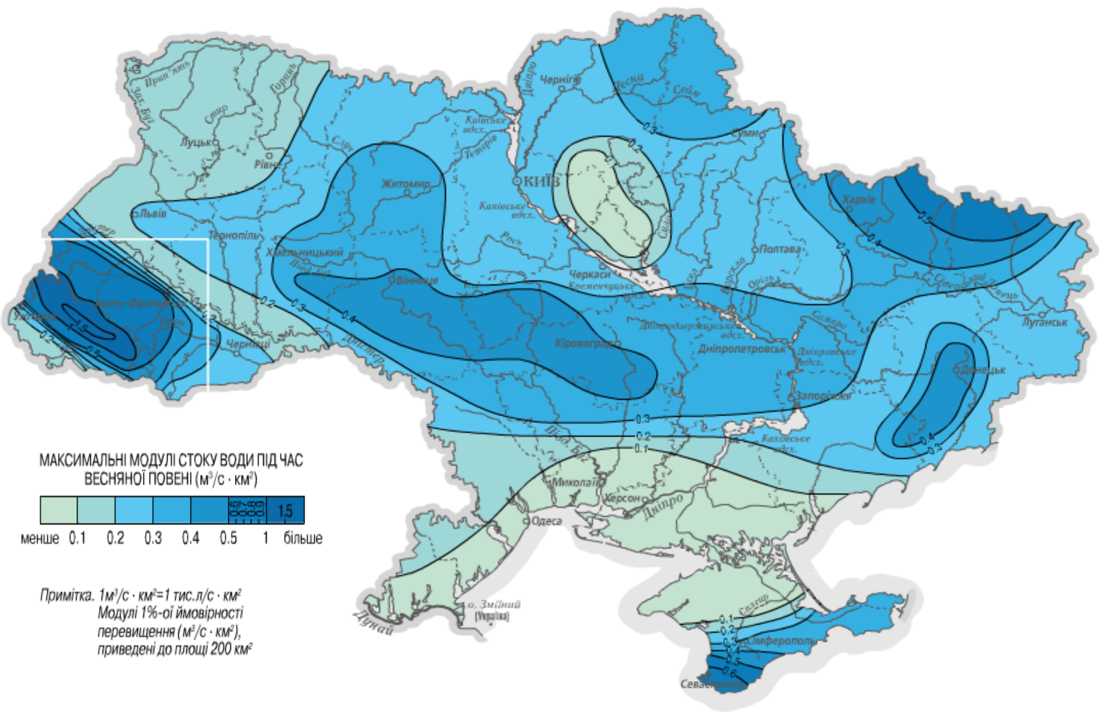


Fig. 2.3-8: Specific maximum flow $[m^3/(s \cdot km^2)]$ related to the spring flood events (Paton et al. 2007)

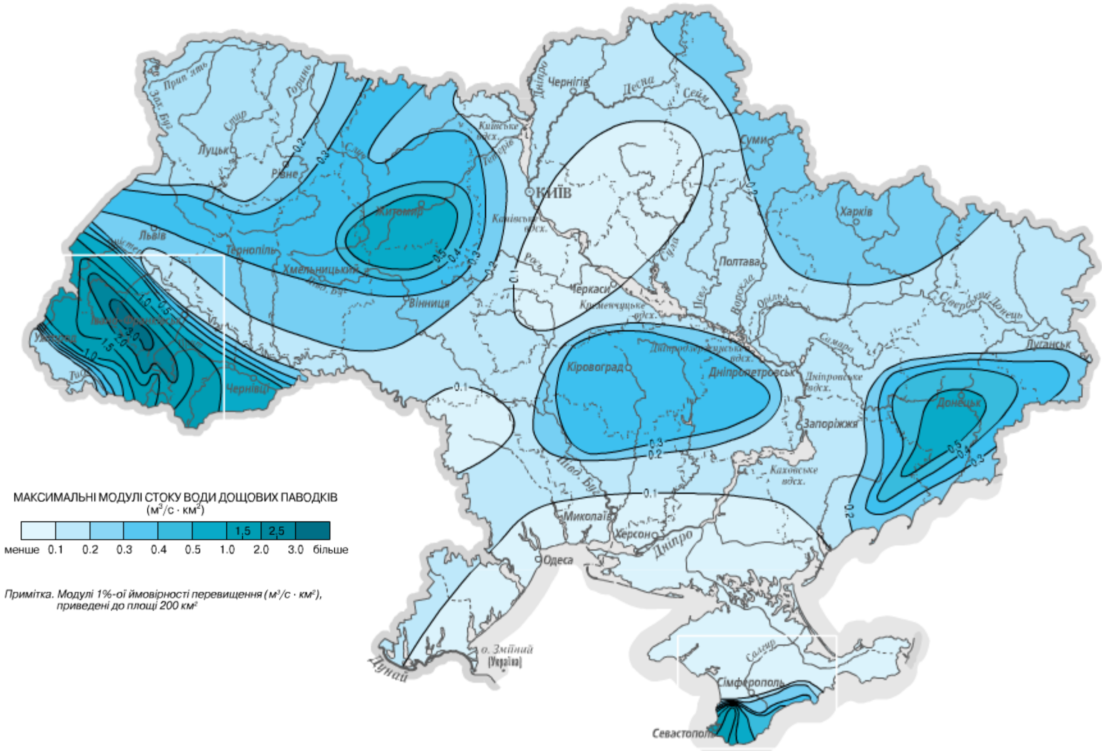


Fig. 2.3-9: Specific maximum flow [$m^3/(s{\cdot}km^2)$] related to rainfall flood events (Paton et al. 2007)

2.3.7 Specific minimum flow

Author: Ivan Kovalchuk

A. Definition

The minimum flow is the smallest river flow observed during a low flow period. As a rule it can be distinguished between average daily minimum and average monthly minimum discharge. In the last case, the lowest discharges for approximately 30 days of each calendar month are averaged. In addition, the average can also be calculated for winter and summer conditions or months. Another parameter of interest is the absolute minimum, which is defined as the smallest observed discharge within a period of interest. The minimum flow is calculated in relation to a probability of occurrence. The dimension of the minimum discharges is m^3/s or l/s. Generally, low flows are mapped as a specific minimum flow with a dimension of $m^3/(s{\cdot}km^2)$ or $l/(s{\cdot}km^2)$. Similar to the specific maximum flow, the specific minimum flow can be described according to the major natural areas.

Zone of mixed forests

Zone with a long duration of low flow events, summer one – low flows, winter one – moderate flows. The monthly averaged specific minimum flow is about 0.8 $l/(s{\cdot}km^2)$. Winter flows are higher than summer flows due to frequent snow melting events. The volume of the summer-autumn runoff is about 25% of the annual runoff; the amount for the winter months is about 20%.

Zone of deciduous forests

The period of summer-autumn low flows lasts from May to October/November and is often interrupted by rain floods.

Forest-steppe area

For this area, the flow limitation period is long and lasts from May to November. The specific discharge for the summer-autumn and winter period are similar with a value of 0.3 $l/(s·km^2)$. The runoff layer during the summer-autumn period is around 25 to 40% of the annual runoff and during the winter month about 10 to 15%. For catchment areas less than 15 km^2, drying and freezing of the rivers is observed.

Steppe zone

Here, summer-autumn low flows occur from March/April to November. The average specific minimum flow during the summer-autumn period is 0.1 $l/(s·km^2)$, and 0.3 $l/(s·km^2)$ during the period. The runoff during summer and autumn low flow period makes 25% of the annual runoff and during winter 10%. Many rivers dry up during the summer-autumn low period.

B. Approach

Minimum discharges are measured on gauging stations by the use of meters or by automatic hydrometric stations. Sometimes the discharges are obtained using dependencies with water levels. To estimate the minimum flows, characteristics of hydrological observations are used, such as data from gauging stations summarized in the handbook "Annual data on regime and resources of surface water", which is prepared to get print by the Central Geophysical Observatory. The determination of the estimated minimum water flow of rivers is realized in accordance to § 6.1, A.1-A.14 (Appendix A) of DBN V.2.4-X.

C. Material

To map the specific minimum river flow data of the Hydrometeorological Service, which is integrated in Central Geophysical Observatory of Ukraine, can be used. Such maps are illustrated in Paton et al. (2007), relevant studies such as Yatsyk et al. (1991) and others.

D. Final product

The final product is maps of the specific minimum flow either for particular basins or for the whole area of the Ukraine. Isolines of the specific minimum flow are drawn at various intervals depending on the spatial variation of the smallest and largest values within the catchment. These values range from 0.1 to 0.3 $l/(s·km^2)$ in the steppe zone to 0.8 $l/(s·km^2)$ in the area of mixed forests. The largest specific minimum discharges are observed in the Carpathian region. They reach 2.3 $l/(s·km^2)$ during the summer and 1 to 2 $l/(s·km^2)$ during the winter. In the Crimean mountains they vary between 2 to 5 $l/(s·km^2)$ in the uplands and 0 to 0.2 $l/(s·km^2)$ in the low lands. The smallest specific minimum flows are observed in the southern steppe regions of Ukraine and Crimea.

E. Applicability

Maps of the minimum flows are necessary for water management issues, for example to assess the possibilities of water abstractions for households and other stake holders. Furthermore, it is needed to calculate the so called ecological flow, which provides the ecological balance of the river.

2.4 Chapter 4: Soil water

2.4.1 Soil water parameters

Author: Maria Tarasiuk, Filipa Tavarez-Wahren, Stefanie Fischer

A. Definition

A lot of processes are influenced by the amount of water in the soil: soil temperature, diffusion of nutrients to plant roots, gas exchange with the atmosphere (evapotranspiration) and the speed with which the dissolved chemicals move through the root zone during rainfalls or irrigation. Generally, the water content of a soil is defined by its storage and percolation properties. Soil water, which is mainly absorbed due to precipitation or irrigation, can be classified by typical parameters, which are in turn characterizing the quality of the soil as a habitat for plants.

The hydraulic conductivity, as one example, is the ability of the soil to let water passing through it. It depends on the soil texture and the saturation of the soil. However, the ability of a soil to retain water can be described by different water-retention parameters, which can be derived from the water retention-curve in Fig. 2.4-1. Here, the relationship between the soil-water matric potential pF in hPa, representing the forces exerted by the solid matter in the soil, and the moisture content in Vol.-% are shown. The water retention curves characteristics differ for each soil type. The main typical indexes are field capacity FC, available water capacity aFC, permanent wilting point PWP and air capacity AC. Field capacity is the water content, which is hold in the soil against gravity with a matric potential greater 1.8.

The permanent wilting point is the lowest level of plant available water at which crops begin to wilt irreversibly when the corresponding amount of water falls below. This portion of water usually is held in fine pores with a corresponding pF-value of 4.2. Hence, the water which is available for plants to be soaked up by their roots is limited by the parameters field capacity and permanent wilting point, narrowing down a range of $1.8 \leq pF \leq 4.2$. The air capacity is equivalent to the air content at field capacity ($pF < 1.8$) when the moisture is relatively readily removed from the pores of the soil (BMU 2003).

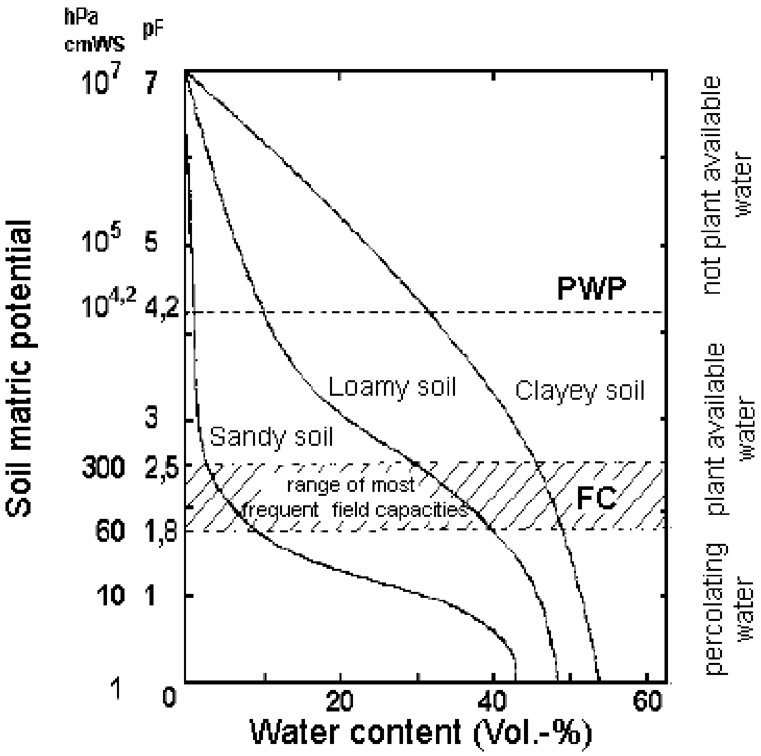


Fig. 2.4-1: Water retention curve (Scheffer & Schachtschabel 2008, edited)

B. Approach

The above mentioned parameters field capacity, available water capacity, air capacity and total pore space, which are indicators to describe the quality of the soil as a habitat for plants, can be estimated by pedotransfer functions (PTFs). PTFs represent relationships between soil hydraulic parameters and soil texture data such as soil texture class, bulk density and hummus content. Unfortunately, commonly available PTFs do not match the particle size classes of the Ukrainian texture scheme. Hence, the Ukrainian soil databases need to be converted from Katschinski's (1956) texture scheme to those ones used by the appropriate PTFs. The Bulgarian scientist Rousseva (1997) developed a procedure to transfer data between soil texture schemes that use different size ranges of the particle fractions. Here, in a first step the following exponential functions are used to fit the cumulative particle sizes. For fine textured soils, which are classified according to the USDA texture scheme of loam, silt and clay:

$$F_1(D) = \frac{a + (100 - a) \cdot D^n}{1 + b \cdot \exp(\mathbf{m} \cdot \mathbf{D})}$$

For coarse textured soils, which are classified according to the USDA texture scheme of sand, loamy sand, sandy loam, sandy clay and sandy loam:

$$F_2(D) = \frac{a + (100 - a) \cdot D^n}{1 + b \cdot \mathbf{D}^{\mathbf{m}}}$$

$F_1(D)$, $F_2(D)$	cumulative percentages of the particle size distribution (PSD) curve
D	log10 value of the particle size limits (1µm to 2000 µm)
a, b, m, n	fitted parameters

In a second step the found parameters are used to transform the PSD from Katschinski's (1956) texture scheme to texture schemes with alternative particle size limits by simple calculations using both equations.
Finally, the pedotranfer functions can be applied using several available approaches such as 1) Wösten et al. (1999), 2) Walczal et al. (2004) and 3) Zacharias & Wessolek (2007). Approach 1) developed PTFs for Europe using soil data from 12 European countries. Approch 2) was developed using soil data from Poland, predicting soil water contents at defined pressure head values. According to method 3) the PTFs were developed from soil data around the world (UNSODA and IGB-DIS soil data base), estimating the parameter of the van-Genuchten equation using only the amount of sand, silt, and clay, as well as the bulk density.

C. Material

To generate such maps, spatially distributed data about the soil classification (Chapter 2.1.4**Fehler! Verweisquelle konnte nicht gefunden werden.**) and soil texture is required. The soil texture data is available for some soil types in Ukrainian soil Atlas. There one can find information of sand, silt and clay particles content in each horizon, but based on Katchinski's classification. There are two ways to get needed information: to take new soil samples for further laboratory tests or to transform the data from Katchinski's tables into USDA triangle. Maps of soil classification are available for the Ukraine and gaps might be closed using the approach after Tavares Wahren et al. (2011) using additional land use data.

D. Final product

Final product are maps of the parameters field capacity, available water content (example in Fig. 2.4-2), air capacity and possibly mean annual percolation rates from the soil in accordance to soil type, landform and land use.

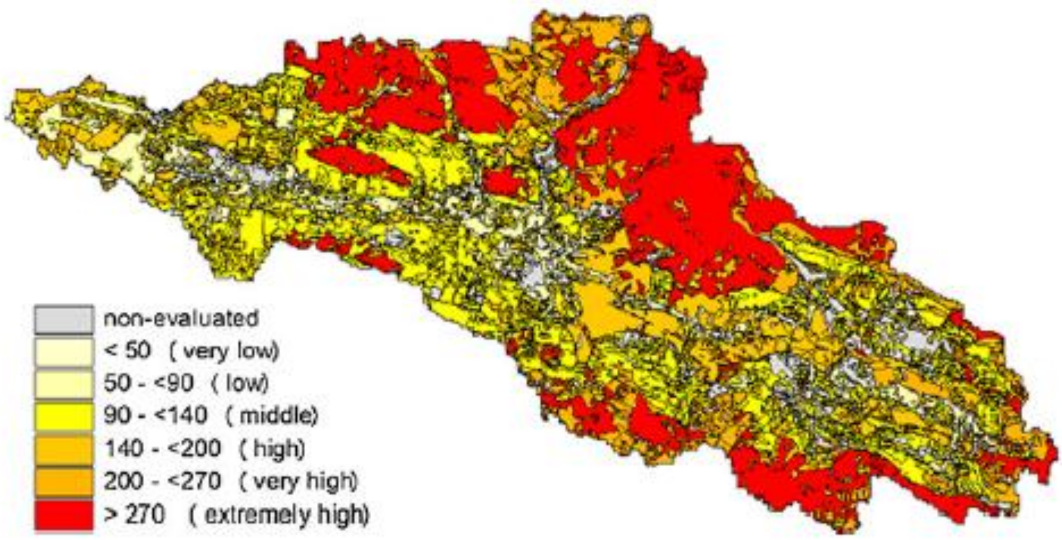


Fig. 2.4-2: Spatial distribution of plant available soil water, disregarding capillary rise of groundwater types over the Western Bug headwater catchment (Tavares Wahren et al. 2011)

E. Applicability

Soil-water characteristics and parameters are essential as an input for simple functional models, empirical nomograms and regression equations to estimate the mean annual rate of percolation. Knowledge about the soil-retention properties is basically of interest for flood or aquifer management. Additionally, it might be beneficial for the determination of the speed with which dissolved inorganic chemicals move through the soil in case of potential hazards.

2.4.2 Effective rooting depth

Author: Maria Tarasiuk, Filipa Tavarez-Wahren, Stefanie Fischer

A. Definition

The effective rooting zone is the soil section from the top of the surface to the potential depth to which plant roots can take up the maximum amount of plant available water during dry years. It is one of the main factors which are determining the quality of the soil as a suitable habitat for plants and crops. This in turn determines plant growth, evapotranspiration and crop yield.

B. Approach

The effective rooting depth can be estimated using the moisture distribution in a soil profile at the end of the growing period in markedly dry years at a site with a low water table (BMU 2003). Fig. 2.4-3 shows exemplarily that the effective rooting depth is approximately the point where the difference between actual soil water content and permanent wilting point (dotted area) equals the water content between filed capacity and actual water content (shaded area). However, this method requires various time-consuming and costly field measurements and laboratory tests, covering representative soil areas.

An alternative approach is the application of pedotransfer functions (PTFs), which enables an estimation of the effective rooting zone using empirical relations to particular soil characteristics. Additionally, there is a dependency between effective rooting depth and the plant species of an area. Therefore, a table containing the relation between effective root depth, soil texture and bulk density for root crops, cereal and grassland is given in Renger and Strebel (1980). A similar relation for the main land use types, including crops, grasses, conifers and broadleaves can be found in Boden (2005).

C. Material

To generate maps of the effective rooting depth, spatially distributed data about the soil classification and soil texture is required to apply the needed PTFs (Chapter 2.4.1). Additionally, land use data is required to apply the empirical approach after Boden (2005) or Renger and Strebel (1980).

D. Final product

Final product is a map of the effective rooting depth which contains implicitly information about the soil species and land use.

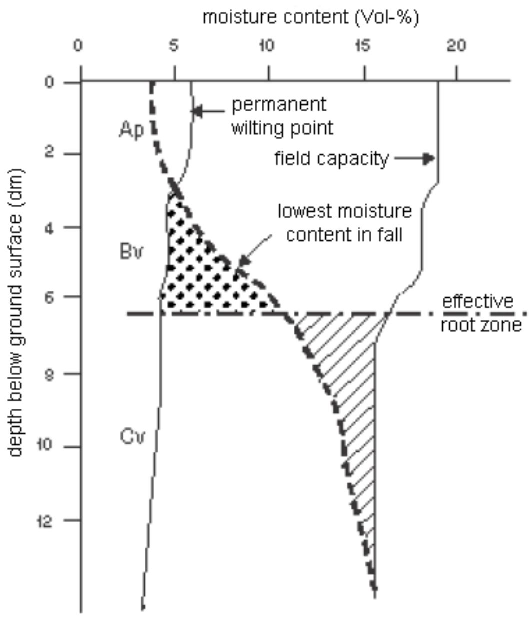


Fig. 2.4-3: Determination of the effective rooting depth using the parameters field capacity, permanent wilting point and the water content of a Eutric Cambisol from sandy sediments in the fall of a dry year (from Renger & Strebel 1980).

E. Applicability

Information concerning the effective root zone is an important input for models used to estimate the evapotranspiration loss per unit area. It also governs the growth and yield of a plant population.

2.5 Chapter 5: Ground water

2.5.1 Groundwater

Author: Ivan Kovalchuk

A. Definition

Groundwater: waters to be found in rocks of the upper part of the crust in liquid, solid and gaseous form. These parameters are displayed in geological maps. However, hydrogeological maps reflect the conditions of occurrence, distribution patterns and the formation of groundwater, as well as their qualitative and quantitative indicators. The maps are based on hydrogeological surveys (Bieleckyi, 2004).

Scales of hydrogeological maps can be divided into several groups: small-scale (less than 1:500,000), medium and large-scale (up to 1:200,000 and more). A special type of those maps is maps of the underground runoff, the groundwater resources or the hydrochemical regime of an area.

B. Approach

To map information on groundwater hydrogeological maps, a wide range of mapping methods is used: qualitative and quantitative background areas, linear signs, alpha-numeric indices, charts and localized diagrams etc. Using such an arsenal of cartographic symbols in maps, several categories can be displayed: types and groundwater supplies, hydrochemical properties, connection with surface waters, characteristics of the hydrogeological structure, potential pollution threats of different layers and other parameters.

C. Material

The following sources can be used as an information base: Paton et al. 2007, Bieleckyi (2004), scientific papers of Shestopalov et al. (2003), Shestopalov et al. (2009), Ohnyanyk (2000), data of the automated information system of the State Water Cadastre (Groundwater-UA, 2013), data of "Geoinform" and others.

The Ukraine is rich on groundwater resources with a significant amount of fresh water used for the water supply. In addition to that, almost all types of mineral waters are represented and some of them are unique (for example "Naftusja").

The main natural factors to determine the groundwater composition and distribution are: geographical, climatic, geological, tectonic, hydrogeological and biological (Babinets, 1961). Among these factors, the most important is the climatic one, which affects the groundwater recharge as well as the intensity of rock transformation (weathering). The hydrological impact on groundwater depends on the characteristics of the hydrographic network, which plays a significant role in the drainage properties of layers. The relief of an area is crucial for the formation of surface runoff and affects the water exchange between layers considerably. The biotic impact is the modification of water and rocks due to the influence of living bacteria and the conversion of organic matter.

The geological structure of an area; the conditions of occurrence, genesis and dynamics of layers as well as their interaction and connection with the surface water, the mineral composition of rocks and organic matter affect the chemical composition of groundwater. Therefore, the presentation and synthesis of hydrogeological information can be grouped into two types of zoning: 1) the fundamental components of regions (structural zoning of similar areas); 2) zones according to unity and orientation processes (functional zoning) (Shestopalov et al. 2003). As a basis for structural hydrogeological zoning, the principle of uniform conditions concerning the water exchange under natural conditions is applied. There are three taxonomic units of zoning: 1 – region, 2 – oblast, 3 - area.

According to the geological structure and the main features of water exchange in the Ukraine, five regions are allocated: I - Ukrainian Shield; II - Russian stove; III - Donetsk folded structure; IV - Carpathian folded structure; V - Crimean folded structure (Shestopalov et al., 2009). These regions include oblasts, which in turn include areas. Thus, the region Russian stove contains four oblasts or artesian basins, respectively: Volyn-Podolsk, Dnipro, Donetsk and the Black Sea.

The groundwater distribution in Ukraine is diverse due to the varying hydrogeological conditions of areas, such as a different age or composition of deposits, as well as other environmental key factors which contribute to the formation and distribution patterns of groundwater. The largest groundwater resources are located in the Dnipro Artesian Basin, which contains more than half of the operating water resources of Ukraine with an average specific discharge of 1.67 $dm^3/(s \cdot km^2)$. The second largest artesian basin is the Volyn Podilsk, which constitutes about 20% of all groundwater resources in the Ukraine (average specific discharge is 1 $dm^3/s \cdot km^2$). Less groundwater resources are located in the southeastern part of the Ukrainian Shield, in the Carpathians, the Donbass and in the southwestern part of the Black Sea Artesian Basin. Here, the specific discharge is lower than 0.1 $dm^3/(s \cdot km^2)$ and the operational resources are only used by individual wells, which flow rates range between 1 dm^3/s (most cases) to 10 dm^3/s (rare cases).

Investigations of underground flows are based on the study of their directions, where underground water flows from zones of water formation into adjacent distribution zones. This approach is widely used in the Ukraine to classify multiscale hydrogeological zones. First order geological structures of isolated groundwater-pools are characterized by a close trend related to the regional water cycle. Major regional "flows" of groundwater are occurring due to the presence of powerful regional drains, such as seas and main rivers as well as extended regions of high hydrostatic pressure, which mainly correspond to the watersheds located in the local uplands. Regions of high hydrostatic pressure have an impact on the formation of groundwater pressure, as well as the direction and speed of its movement. Thus, the hierarchy of zoning conditions determining the formation of underground drainage and natural groundwater resources - areas of intense and significant water exchange (depth in different regions - up to hundreds or thousands of meters) - is similar to the hydrological regionalization principles of the runoff. In particular, isolated pools of a runoff sea (regions) and the main rivers flowing into the sea (provinces) can be identified. The next level of zoning takes the hydrogeological conditions and trends of water exchange into account. According to the scheme of functional zoning, the territory of Ukraine can be characterized by two regions: Baltic (A), as well as Black and Azov (B). The selected regions contain provinces, which in turn contain districts corresponding to water-exchange basins of different ranks.

D. Final product

Final product are maps considering the topics "Ground waters of the Ukraine" (Fig. 2.5-1), “Hydrogeological regions of Ukraine” (Fig. 2.5-3) , "Groundwater monitoring network", "Underground flow and its distribution by basin", "Groundwater recharge" and "Quality (pollution) of groundwater". These maps should have a scale of 1:750,000 - 1:1,000,000 (in case of creating a regional atlas) and 1:200,000 - 1:500,000 (in case of creating an atlas on water basin scale).

E. Application

The maps can be used to:

- investigate the changes of quantity and quality of groundwater
- inform central and local governments regarding the state and prospects of groundwater use for water supply of settlements and separate regions
- plan and design geological, geotechnical, environmental and geological researches
- assess groundwater resources and develop long-term forecasts of groundwater changes
- evaluate the impact of groundwater on small rivers and on the spread of flood lands as well as settlements.

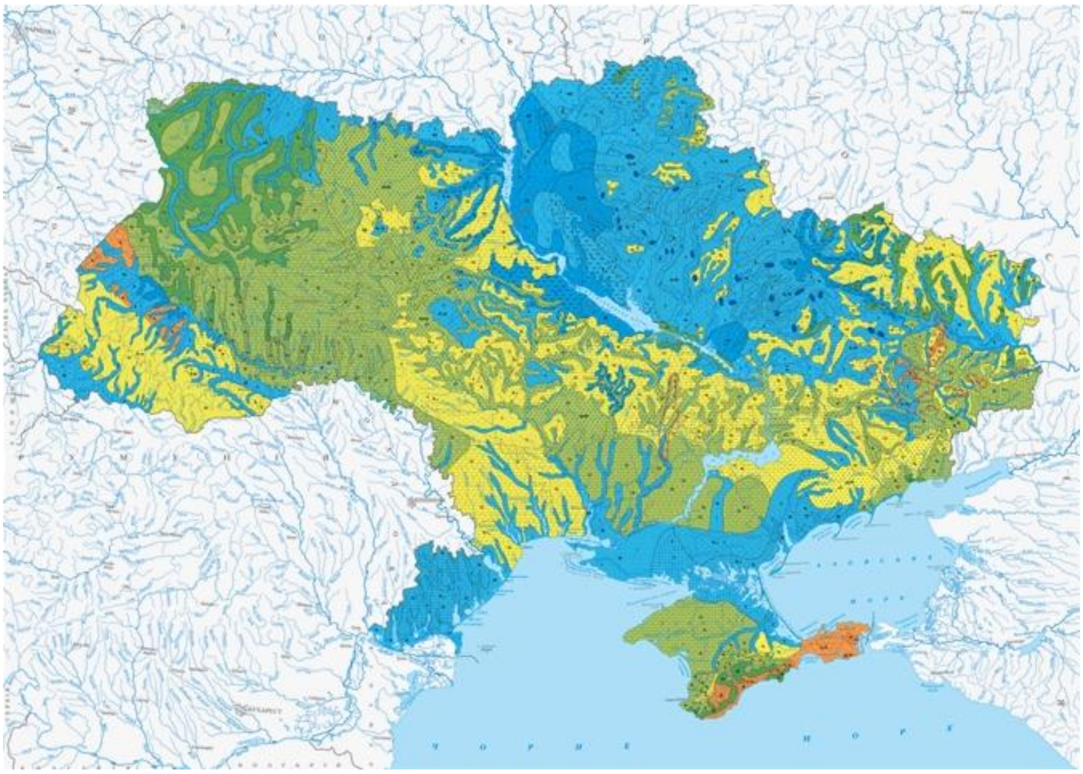


Fig. 2.5-1: Ground waters of Ukraine (Paton et al. 2007)

Fig. 2.5-2: Conventional symbols of the map “Ground waters of Ukraine” (fragment)

Fig. 2.5-3: Hydrogeological regions of Ukraine and their main horizons (Gkrmap 2013)

2.5.2 Groundwater recharge

Author: Thomas Pluntke

A. Definition

Groundwater recharge GWR is the part of precipitation that infiltrates into deeper soil layers, after actual evapotranspiration (ETA) and fast runoff components (R_D) are subtracted. Regarding the mean water balance as shown in the equations below, the long term average of groundwater recharge is equivalent to the baseflow (R_B) from the aquifer.

$$R = P_{corr} - ETA$$
$$R = R_D + R_B \quad or \quad R_B = R - R_D$$
$$GWR = R_B = P_{corr} - ET_a - R_D$$

GWR and R_B are given in mm per unit time, m^3 per unit time or liter per unit time.

B. Approach

Knowing the fact that GWR is equivalent to the baseflow, it can be determined using the runoff of an area. The total runoff can be subdivided into direct runoff (R_D) and baseflow (R_B). Here, the direct runoff is the sum of surface runoff, interflow and part of the groundwater flow. By contrast, the baseflow is the long-term, stable flow from the aquifer into a stream, even during dry periods. Hence, it is possible to determine R_B from a hydrograph of a gauging station, separating the discharge into its direct and base component. An additional parameter to determine GWR is the baseflow index BFI, which is the ratio between baseflow and total runoff. It can be calculated using the empirical

approach after Kille (1970), which sets the rate of groundwater recharge (or baseflow) equal to the reduced monthly mean low flow. Physically based procedures, such as the linear storage model DIFGA (Schwarze et al. 1999) supported the assumption of the Kille approach.
A more specific approach is using a regression analysis, where the influence of local factors to the groundwater recharge or BFI is considered. Such factors are the slope gradient of an area (influences the direct runoff component), drainage density (river network), land cover, field capacity and depth to the groundwater table.

C. Material

Depending on the chosen approach measurements of daily discharges and groundwater depths, as well as soil, land use and river network information are required.

D. Final product

Final product is a map of the mean annual groundwater recharge rates or the baseflow index for the Ukraine covering for example the climate normal period 1961 to 1990.

E. Applicability

Maps of groundwater recharge are of special interest for water resources management sectors, such as drinking water supply, irrigation or industries depending on water withdrawals.

2.6 Chapter 6: Water balance

2.6.1 Water intake

Author: Victor Vyshnevski

A. Definition

Water intake from surface and underground sources is an important factor, which impacts the resources river runoff and ground water. The official total water intake of Ukraine is about up to 14 to 15 km^3. About 80% of this volume is from surface sources, 14% from ground sources and 6% from sea water sources (previously from the Sea of Azov). The extraction of groundwater is related to mining activities. The current amount of extracted water is greater than the above mentioned volume due to the high quantity of small water users, which do not report the amount of water intake.

B. Approach

The mapping of surface and groundwater abstractions depends on the spatial dimensions of the selected regions. Considering the whole country, the use of circle diagrams is possible. In this case the diameter of the circle corresponds to the volume of water intake in separate administrative formations (for example – oblasts). It is possible to create a map for different river basins. Water extracted from surface resources can be represented by

arrows, originating from the corresponding rivers for instance. The dimensions of the arrows are related to the volume of surface water that is extracted. Here, it is advisable to use a numbering for the largest water intakes presented in a separate table.
The mapping of the groundwater extractions is more specific. The most common facility to withdrawal water are dug wells, their quantity in Ukraine consists of some millions. The most dug wells are located in the north and west of the country. In the South is a lack of groundwater supply due its bad quality and deep groundwater tables. Using this information, it is possible to produce a corresponding map showing the regions of easy groundwater-supply achievements, complicated and occasional ones (three gradations).

C. Material

The maps of surface and groundwater intakes are created using data of the State Agency of Water Resources of Ukraine. If available, the data can be applied regarding separate oblasts, rivers basins, water management districts and main users groups. The resulting maps could be related to the topics: "Water intake in the Crimea and oblasts", "The largest water intakes of Ukraine" and "Water intake by river basins".

D. Final product

The cartographical background for the map "Water intake in the Crimea and oblasts" is an administrative map of the Ukraine with a small quantity of cities. The maps "The largest water intakes" and "Water intake by river basins" are based on simplified maps of river networks. These maps are created for the whole country and separate regions (oblasts) determining the scale of mapping, which can be 1:500,000, 1:1,000,000 and 1:2,000,000.

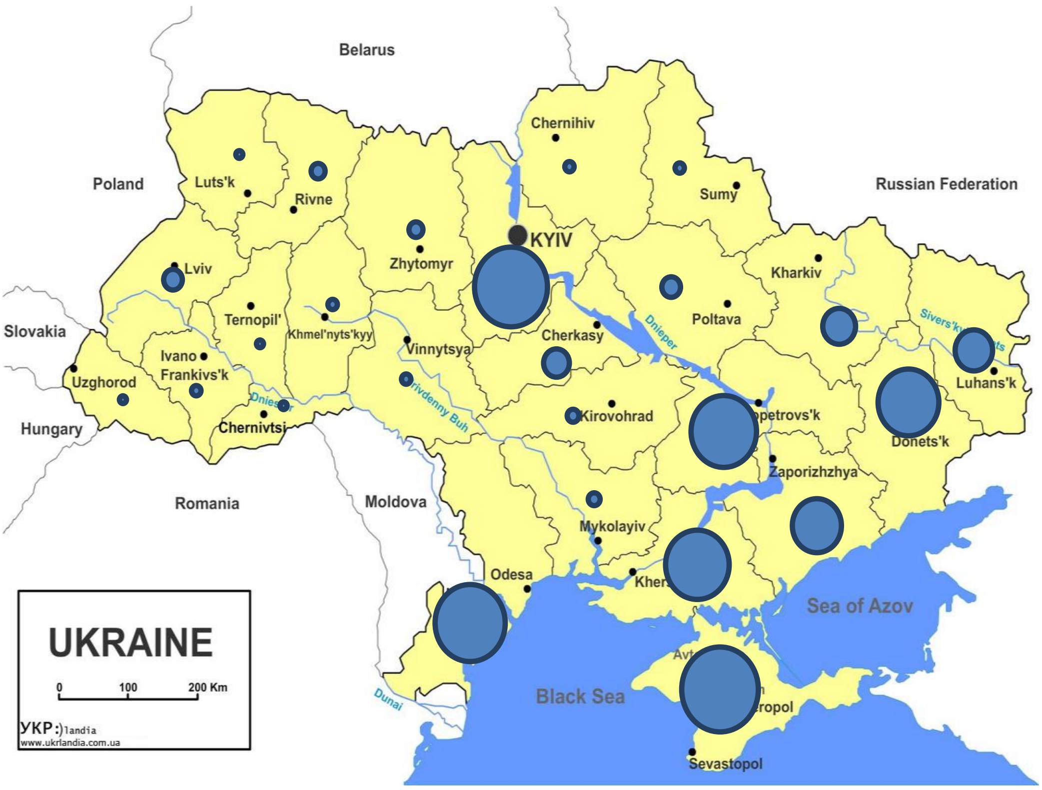


Fig. 2.6-1: Water intake in Ukraine by administrative oblasts (2011). The size of the dot in Kiev is equivalent to 1400 million m³ per year.

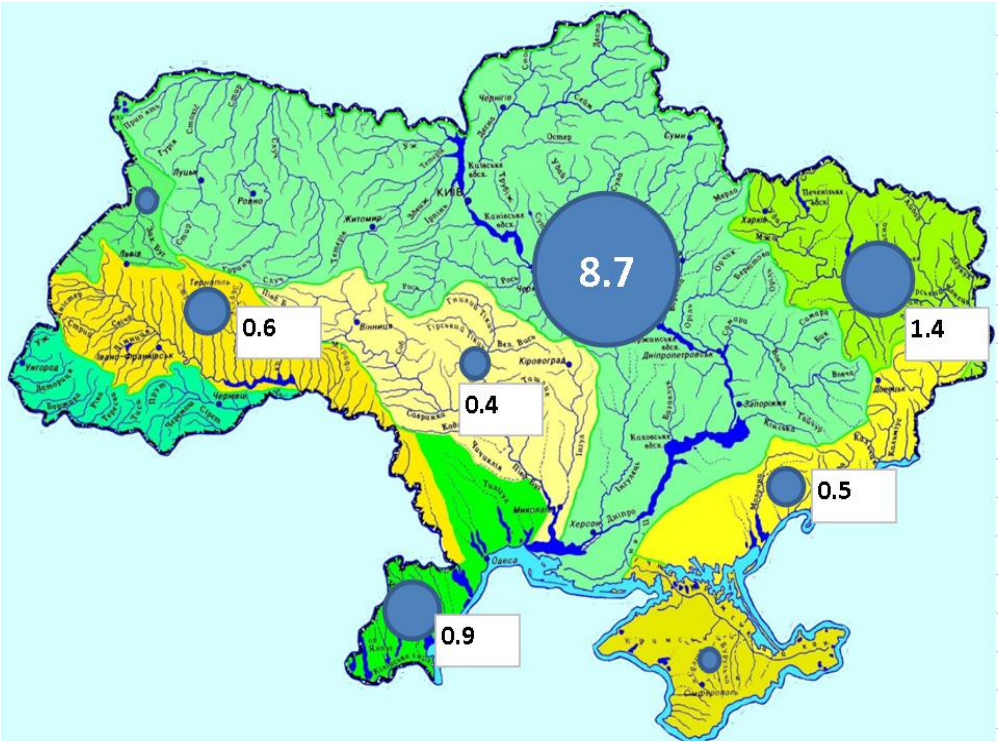


Fig. 2.6-2: Water intake (in billion m³) of the main river basins in Ukraine (2011)

E. Applicability

The obtained maps are necessary for specialists of the field water management and melioration. In addition to that, such maps are interesting for local and state authorities.

2.6.2 Waste water discharges

Author: Victor Vyshnevski

A. Definition

Discharge of waste waters is an important factor, which influences the water quality of rivers and even the volume of water runoff. Recently, the total volume of sewage from technical devices in the Ukraine consists of about 8.0 km^3. Depending on the degree of treatment, this volume can be divided into four groups:

1. without treatment → polluted
2. insufficient treatment → polluted
3. without treatment → meets the standard
4. with treatment → meets the standard

The majority of the total sewage volume (about half) is of the third category. This volume practically corresponds to the water, which is used in the cooling systems of thermal power plants. Untreated sewage is represented by 5% of the total sewage volume. Additionally, sewage can be classified by the type of water consumption, such as industry, municipal engineering or agriculture. Wastewater resulting from mining activities is a special case.

B. Approach

The mapping of wastewaters depends on the spatial dimension of the selected regions. Creating maps for the whole country, the use of pie charts is possible. In this case the diameter of the circle corresponds to the volume of sewage related to separate administrative formations (for example – oblasts). The pie chart is divided according to the degree of sewage treatment (without treatment, insufficient treatment etc.). A similar map can be created for different river basins. Additionally, discharge locations can be illustrated using arrows, which dimension depends on the volume of waste waters. Here, it is advisable to use a numbering for the locations or institutions producing the highest amount of wastewater or pollutants, which should be additionally presented in a separate table.

C. Material

The maps of wastewaters can be created using data of the State Agency of Water Resources of Ukraine. If available, the data can be applied for separate oblasts, rivers basins, water management districts and for main users. The resulting maps can be related to the topics "Waste waters in Ukraine", "Waste waters by rivers basins" or "Main places of water pollution".

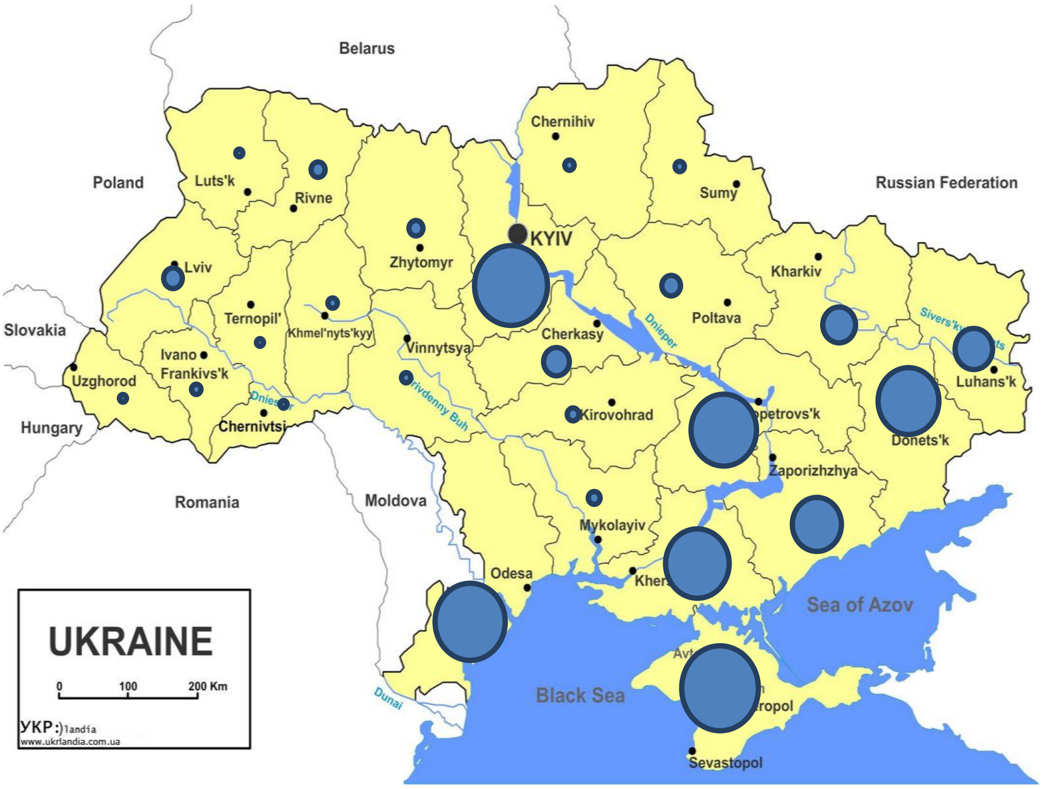


Fig. 2.6-3: Waste waters in Ukraine by administrative oblasts. The size of the dot in Kiev is equivalent to 1400 million m³ per year.

D. Final product

The cartographical background for the map "Waste waters in Ukraine" is an administrative map of the Ukraine with a small quantity of cities. The maps "Waste waters by rivers basins" and "Main places of water pollution" are created on a simplified map of river networks. These maps are created for the whole country and for separate regions (oblasts). Depending on that, the scale of mapping is determined to 1:500,000, 1:1,000,000 and 1:2,000,000.

E. Applicability

The obtained maps are necessary for specialists in the field of water management and melioration. In addition to that, such maps are interesting for local and state authorities and also for specialists in the field of environment protection.

2.6.3 Runoff balance

Author: Thomas Pluntke

A. Definition

The runoff balance is the quantification of water volumes that enter and leave an area above or under the ground. The components of the runoff balance are determined as long-term annual means. Besides the natural water balance (see chapter 2.3.4) anthropogenic interference (e.g. water extraction, water transfer) has to be considered. The runoff balance can be expressed as discharge in volume per unit time, or as runoff depth in mm per unit time, which is related to the balance area.

B. Approach

The basis is an analysis of long-term runoff data, which are referring close to the border of the area of examination. For areas with insufficient runoff data, the runoff is calculated by water balance modeling. Grid cell based runoff depth (corrected precipitation minus actual evapotranspiration) can be used to estimate the runoff balance as well.
The water yield is calculated from the difference between inflow and outflow of an area, plus or minus possible water gains or losses (water usage) and evaporation from the river itself.

C. Material

Required data are the observed discharge from respective gauging stations and water use information (e.g. water extraction, water transfer). In case of water balance modeling, topography, land cover, soil and further climatic data (temperature, humidity, wind and solar radiation) are required.

D. Final product

Final product is a map visualizing the spatial runoff balance, tables and diagrams that illustrate the in- and outflow, as well as water usage for the region of interest separated for catchments.

E. Applicability

The runoff balance is valuable information to quantify the water yield of politic or administrative areas. It is an important factor within the framework of long-term water management planning. Together with the water balance of a region it serves as a measure to estimate the renewable water resources.

2.6.4 Runoff coefficient

Author: Victor Vyshnevski

A. Definition

The map of the water balance is one of the most important maps in the Atlas of water balance. It reflects the proportion of water turning into a river flow corresponding to the quantity that fell as precipitation. The specified quotient is called "runoff coefficient". The runoff coefficient is determined using the just mentioned variables: precipitation and the amount of runoff related to a catchments surface (as layer flow, measured in millimeters). Depending on local conditions the values of the runoff coefficient ranges between 0 to almost 1.0.

B. Approach

There are already existing maps of the runoff coefficient reflecting the water balance. Here, the contour method is used, sometimes in addition with the method of qualitative background.

C. Material

A source to create relevant maps is hydrometeorological observations, although additional information is needed. There is a need of very careful calculations, which consider different conditions of an area, particularly for the mountains. Here, interpolation and extrapolation of available data is necessary. A map showing the water balance or runoff coefficient of a territory is based on detailed maps of precipitation and runoff layer.

D. Final product

A cartographic basis for this map can be administrative maps of the Ukraine with a small number of localities. Relevant maps should be created for the whole country. The mapping scale can range between 1:1,000,000 and 1:2,000,000.

E. Applicability

These are maps primarily needed for specialists in the sphere of meteorology and water management. In addition, maps of the water balance in relation to neighboring countries (see chapter 2.7.6) is interesting for public authorities.

2.7 Chapter 7: Ecological and water management aspects

2.7.1 Water temperature

Author: Victor Vyshnevski

A. Definition

The temperature of water is one of the most important parameters, which influences water quality, the living conditions of hydrobionts and also the opportunity to use water for human activities, particularly for recreation.

B. Approach

The water temperature depends on both natural conditions and human impact. In the first case, climatic factors play a significant role. Other natural factors are the inflow of ground water, the dimension of rivers and their altitude as well as the mixing of water. Human factors are the release of waste waters (here, water temperatures are mostly higher than under natural conditions) and also the creation of reservoirs.
Maps of water temperatures are available, for example in Paton et al. (2007). This map shows the water temperature as a column diagram for three months of the year.

C. Material

The data source to create a map of water temperatures can be observations of the network of the Hydrometeorological Service. There are a lot of measuring points, which are about 400 for rivers and 60 for reservoirs. It should be considered, that the temperature measurement is realized only twice a day at 8 am and 8 pm. Under these conditions the representation of the maximum temperature is not possible.

D. Final product

The most informative map is the mean July temperature, since the water temperature is highest but deficit of dissolved oxygen as well. The map shows temperature isolines for typical rivers, for some points the maximal observed temperatures can be added. There is no need to use the data just downstream of large reservoirs and in places of water release from thermal power plants. Additional information could be diagrams to illustrate the inter-annual changes of water temperature.
The cartographical background for the map "Water temperature in rivers in July" is a simplified map of the Ukrainian river network. These maps can be created for the whole country or for separate regions (oblasts), for which the scale of mapping can be 1:500,000, 1:1,000,000 and 1:2,000,000.

E. Applicability

Taking the fact of the large use of rivers for recreation into account, the obtained maps might be interesting for different population groups. Furthermore, the maps might be useful for specialists of water management, melioration and fishing.

2.7.2 Riverbed processes

Author: Alexander Obodovskiy

A. Definition

River bed processes are the phenomena occurring in a riverbed-floodplain-complex and are the result of interaction between flow and soil. Among the main factors of riverbed processes are riverbed forming discharges, riverbed deformations, river channel stability and types. These factors are responsible for the riverbed morphology. An important issue in riverbed research is the analysis of floodplain formation mechanisms. At the same time, riverbed processes assessment is of a great practical importance, since it is associated with stream usage and regulation.

B. Approach

There is still a lack of maps referring to riverbed processes. Some were created for the territory of a former Soviet Union and its European part. There are no such maps for the territory of the Ukraine. In order to create these maps, the following symbols should be displayed along river channels: riverbed type (symbols), riverbed deformations (symbols), assessment of the channel stability conditions of river sections (indexes, text), channel and floodplain width (linear notations). It is pertinent not to compose a map of riverbed processes for very small rivers, in particular for lowland conditions. A map about riverbed processes can contain several inset maps, such as those showing riverbed forming discharges and hydro-ecological conditions of a riverbed process. It can be displayed dividing the territory into areas.

C. Material

Main data sources for mapping are long-term research results of scientists from Taras Shevchenko National University of Kyiv and data of the State Hydrometeorological Service of Ukraine. The proposed name for such a map is “Riverbed processes” and the names for additional maps are “Riverbed forming discharges” as well as “Hydroecological conditions of riverbed processes”.

D. Final product

The map scale depends on the territory and can range between 1:250,000 and 1:4,000,000. For the inset maps a scale of 1:8,000,000, 1:12,000,000 can be used. Photos of various river channel types can also be placed at the map. A color scale is also important. “Cold” colors (blue, green) represent a dominance of natural conditions for riverbed processes, while “warm” colors (yellow, brown) are indicators for a huge anthropogenic pressure on the rivers.

E. Applicability

Maps of river bed processes can be useful for water management organizations, monitoring and environmental protection services as well as the water transport sector.

2.7.3 Water sheet and rill soil erosion

Author: Alexander Mkrtchian

A. Definition

Soil erosion is a process, whereby solid material washes off from the soil and gets into the stream network, ponds and lakes. Soil erosion rates define the amount of solid sediment that gets into streams, influencing their sediment balance and contributing possibly to their silting.

B. Approach

The RUSLE equation can be used to calculate the amount of soil loss. It consists of multiple variables describing basic factors, which determine the amount of soil loss per unit area. These factors are the erosive power of the rain (R), two relief parameters (LS), the soil erodibility (K), the degree of soil cover protection (C) and conservation practices (P):

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

The two latter factors could be omitted due to their complex spatial structure. When other factors except P are held constant, soil loss is directly proportional to the rainfall factor composed of total storm kinetic energy (E) multiplied with the maximum 30-min intensity (I30). While direct calculations are time consuming and laborious, there are several ways to obtain approximate values for the rainfall factor. The simplest is given in the following equation:

$$R = 0.0483 \cdot P^{1.61}$$

P is the average annual precipitation in mm (Renard, Freimund, 1994). The soil erodibility K-factor can be defined from soil texture data such as the percentage silt and sand, soil organic matter percentage, soil structure index and soil permeability index, which is obtainable using a nomogram (Wischmeier and Smith, 1978). LS can be calculated using a DEM and applying the RUSLE formula with the use of map algebra tools.

C. Material

Average yearly precipitation, soil map data with texture information provided for soil types and a DEM (e.g. SRTM 90).

D. Final product

The final product is a raster map of water erosion potential with a 3x3 km² resolution. If a basin map was produced for another subject (e.g. Chapter 2.3.2), it could be overlaid to produce a map of potential sediment load per basin.

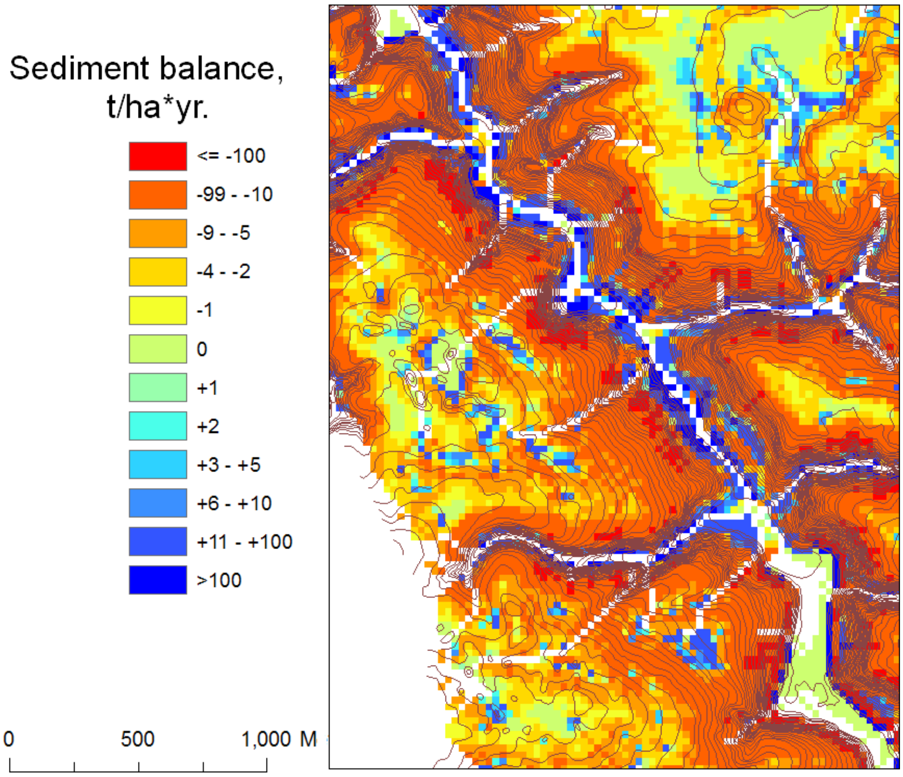


Fig. 2.7-1: Sediment balance (losses in red and surpluses in blue) for the area of Velyka Snitynka, situated in the Kiev region, Ukraine

E. Applicability

A map of the water erosion potential is essential to calculate the sediment load and balance, as well as the water pollution from watershed wash-out; to reveal areas, which are critical sources of sediment load and thus, need a particular conservation attention.

2.7.4 Water turbidity and sediment yield

Author: Victor Vyshnevski

A. Definition

Turbidity of water is an important factor affecting the management of rivers concerning the economic sector, particularly the regulation of flow and the supply of water for irrigation. Besides that, the turbidity of water significantly affects the suitability for the use of rivers for recreation purposes.

B. Approach

Maps of turbidity are available for instance in the National Atlas of Ukraine (Paton et al. 2007). Taking the wide range of turbidity into account (two or even more orders of magnitude) such maps are based on measured data and are presented with a specific symbology. Here, regions with different ranges of turbidity are indicated by different colors. The use of four or more gradations is possible: less than 20 g/m^3, 20 to 100 g/m^3, 100 to 500 g/m^3 and more than 500 g/m^3. The maps should only concern main or zonal rivers, not the small ones.

Taking a river’s regulation into account, corresponding rivers and regions should be marked by lighter contour lines and shading, respectively. In addition to that, the yield of suspended sediments can be illustrated by circles, which diameter corresponds to the yield of suspended sediments.

C. Material

The main source of information to create such a map is hydro-meteorological data. Information about the regulation of rivers can be obtained by relevant institutions, such as the State Agency of Water Resources in the Ukraine. The proposed title of the map is "Water turbidity and sediment yield".

D. **Final product**

The scale of the map depends on the size of the selected region and might range between 1:500,000, 1:1,000,000 and 1:2,000,000. Besides creating a map, blank spaces in the sheet can be used for photos showing several rivers in the period of flood observations. A brown color of water suggests high water turbidity. A graphic of the suspended sediment yield can be placed on the corresponding river, for example at a point located below newly created reservoirs. In that case, the chart shows the impact of reservoirs on sedimentation.

E. **Applicability**

The created map may be primarily of interest for the sector water management. In addition, it might be of common use, particularly for those who like to relax on rivers.

2.7.5 Hydro-morphological water quality

Authors: Alexander Obodovskiy, Zakhar Rozlach, Oksana Konovalenko

A. Definition

According to the main statements of the EU Water Framework Directive (EU WFD), the hydro-morphological assessment of rivers is an integral part to evaluate the ecological conditions of such water bodies. For its implementation, definite classes of the hydro-morphological status (from high to very bad) are determined. Moreover, the assessment of the ecological conditions and their components (biological, physico-chemical and hydro-morphological elements) is the basis for a river basin management plan, which should contain measures to sustain, preserve and improve the ecological conditions of all water bodies situated within a watershed.

B. Approach

Creating maps of the hydro-morphological status assessment is a new task. Some maps are available, such as for the territory of a river basin (Tisza basin) and for particular water bodies. Mapping the range of hydro-morphological conditions is performed using five colors. Boundaries of the hydro-morphological quality classes defined from the final score and its colors are given in Tab. 2.7-1.

Tab. 2.7-1: Delineation of hydro-morphological quality classes defined from the final score

quality class	Final score*	Color
1 – High	1.00 - 1.74	Blue
2 – Good	1.75 - 2.54	Green
3 – Moderate	2.55 - 3.44	Yellow
4 – Bad	3.45 - 4.24	Orange
5 – Very bad	4.25 - 5.00	Red

* Class boundaries are defined relative to the reference conditions

If a hydro-morphological assessment is based on contiguous survey, the whole river or water body is in a map is colored. Using single surveys to conduct a hydro-morphological quality assessment, the place of survey at the river or water body is indicated by appropriate colors, or the quality is indicated with circle diagrams.

C. Material

Main data sources for the mapping are field investigations, which were conducted by experts in hydro-morphological assessment. Such a research work is not done on the state level in Ukraine. There is no state hydro-morphological monitoring system as well. Several research projects for a hydro-morphological status assessment of the Carpathian Rivers were financed by the State Agency of Water Resources of the Ukraine.

D. Final product

The proposed name for such a map is "Assessment of the hydro-morphological status of rivers in a basin system". The recommended scale of mapping is 1:500,000. For certain water bodies (e.g. rivers in Uzh and Latorica basins in Carpathians) a mapping scale of 1:200,000 can be used. Free space of a map can be used for additional information, such as tables with quantitative indices of the hydro-morphological conditions. Besides that, the result of identification and typology of water bodies according to the standards of EU WFD can be displayed.

E. Applicability

Maps of the hydro-morphological status of rivers can be useful for water management organizations as well as monitoring and environmental protection services. Such maps are important for trans-boundary basins (especially with EU countries). It might be also useful for students, PhD-students, researchers, teachers, NGOs and all, who are not indifferent in the preservation of rivers.

2.7.6 Water protection measures, protected areas

Authors: Victor Vyshnevski, Ivan Kovalchuk

A. Definition

Protection of water bodies is realized by a system of measures for their conservation, particularly from siltation, excessive overgrowth and primarily from contamination.

Protection measures include a variety of activities: legislative, organizational, technical etc. A certain role plays the areas with enforced environmental protection, such as objects of the Nature Reserve Fund. Another important factor is the determination of water protection zones and coastal protection zones around rivers, reservoirs and ponds. Additional protection zones are sanitary zones near water intakes and around industrial facilities.

B. Approach

Maps of the Nature Reserve Fund generally exist. Most of them show the location of biosphere reserves, national parks and nature reserves. In particular, these maps are published in the National Atlas of Ukraine (2007), the Atlas of Teacher (2010), the atlas "Tour necklace Ukraine" (2011) and others. Usually, large areas are shown in appropriate scale, small areas are labeled by signs. Generally, large areas are illustrated by different backgrounds or cartograms, which show the proportion of the protected area related to the total area of the administrative region. Objects of the Nature Reserve Fund can be separated into the following categories: international, national and local importance.

According to the Water Code of Ukraine (1995, Articles 87–95), medium and large-scale maps of water protection zones and coastal protection zones along both banks of rivers and other water bodies can be provided. Depending on the size of the rivers and the area of reservoirs, the width of coastal protection zones range from 25 to 100 m.

C. Material

An informational source to create maps of nature protection areas is the Ministry of Environment and Natural Resources, which collects and summarizes corresponding information. A constantly changing quantity and status of the protected objects underlines the necessity to specify such maps. Taking into account that objects of the Nature Reserve Fund may have a different status, different names and content of maps can be proposed: "Protected areas", "Nature reserves", "National nature parks", "Ecological network", "Water protection zones and coastal protection zones" and so on.

D. Final product

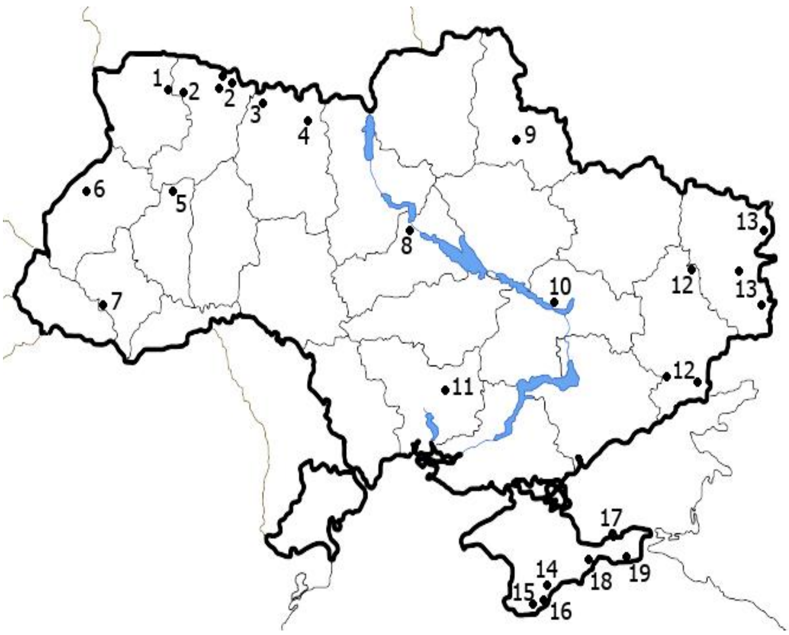
The mapping scale depends on the size of the selected region. It can range between 1:500,000, 1:1,000,000 1:2,000,000 etc. More information is given in case of numbering objects and summarizing the correspondent signatures and names in the outer margin of the map. Blank places can be used to add photos, for example of landscapes or typical representatives of protected flora or fauna. It is also possible to map some large scale objects, which belong to the most famous and most visited. Some examples of such maps are shown in Fig. 2.7-2 and Fig. 2.7-3.

E. Applicability

The created maps can be useful for the State Agency of Water Resources of Ukraine and its regional offices, as well as for the Ministry of Ecology and Natural Resources of Ukraine and its regional offices. In addition, these maps might be of interest for the State Agency of Tourism and Resorts, for teachers, students, or ethnographers.

1 Askaniya-Nova
2 Black Sea one
3 Danubian
4 Carpathian

Fig. 2.7-2: Location of biosphere reserves



1 Cheremsky
2 Rivnensky
3 Polessky
4 Drevlyansky
5 Medobory | 6 Roztochia
7 Gorgany | 8 Kanivsky
9 Michael virgin
10 Dnipro-Orilsky
11 Yelanetsky Step
12 Ukrainian Step
13 Lugansky | 14 Crimean
15 Yaltynsky mountain-forest
16 Cape Martian
17 Kazantyp
18 Karadag | 19 Opuksky

Fig. 2.7-3: Location of natural reserves

2.7.7 Potentially dangerous objects and water use risks

Author: Victor Vyshnevski, Ivan Kovalchuk

A. Definition

There are many factors which are a threat for water bodies such as rivers, reservoirs and lakes. First of all, a threat is a danger of chemical, radioactive and microbiological contamination. Objects causing a chemical contamination of water are chemicals, refineries, mining, iron and steel, paper manufacturing as well as the food industry. The contamination due to pollutants results from septic tanks, sludge ponds and pipelines transporting polluted water. Such cases of polluted water bodies already occurred. In particular, several accidents took place on gold mining in Romania. As a result of that, the Tisza River got polluted seriously. Radioactive contamination, which is the most dangerous threat, is caused by nuclear power plants and companies processing radioactive materials. An example is the accident at the Chernobyl nuclear power plant, which led to significant radioactive contamination of a large area including several water bodies. Threats due to microbiological contaminations can be caused by water supply companies including facilities treating sewage, which is released into water bodies and the corresponding transportation systems. Such accidents occurred even more than once. There is an additional risk regarding plants of the pharmaceutical industry. Another threat is related to agricultural enterprises, including large livestock complexes. The same can be said about the storehouses of pesticides, particularly those which have become unusable.

Besides those enterprises, transport represents an additional threat to water objects, caused by pipelines, railways and automobiles. Concerning pipeline transportation, the greatest threats are oil-trunk pipelines, which have large diameters (up to 1,000 mm and more) and cross the rivers. Pipelines, which represent the greatest danger in the Ukraine are for instance the ammonia pipeline, which crosses a big area of the country and ends up in the port "Southern" near to Odessa city.

B. Approach

Relevant maps showing in particular potential dangerous objects for rivers, reservoirs and lakes are practically absent. Till now there is lack of maps showing the risks in the sphere of water use. There are only small-scale maps illustrating the location of environmentally dangerous facilities in general, in particular for the air and surface water. There are maps "Industry", "Fuel industry", "Electricity", "Chemical and petrochemical industry", "Timber, woodworking, pulp and paper industry", "Food industry", "Pipeline", "Automobile transport", "Railway transport", "Pollution of surface water", "Air pollution" and others.

The main methods to create this map are the application of localized geometric and visual symbols, qualitative and quantitative background, as well as areas and so on. The informative content of the map will be greater in case of numbering dangerous objects and their explanation on sparse places of the outer map sheet. Blank places can be also used for photos of enterprises, which represent the largest threat to the environment (such as nuclear power plants, large industrial enterprises, etc.).

C. Material

A comprehensive source to create a corresponding map titled “Potentially dangerous objects for water bodies” does not exist. Nevertheless, the map can be created as a result of studies regarding the location of industrial and agricultural enterprises, their size and specialization of production. The important source of data might be maps of pipelines, roads and railway transport. Pipelines are also shown on large-scale topographic maps. Maps from "National Atlas of Ukraine" (2007, 2011) or the map “Environmental situation in Ukraine” might be useful. Additionally, there are several regional environmental atlases, such as “Environmental Atlas of the Southern Bug River Basin” (2009) and “Ecological Atlas of Kharkiv region” (2005).

D. Final product

The map scale depends on the size of the river basin or region to be illustrated. The scales can range between 1:500,000 to 1:2,000,000. Different industries should be shown by different signs. The size of signs should comply with the various powers of enterprises. The same applies to waste disposals, septic tanks, sludge ponds, etc.

E. Applicability

The created map can be interesting for workers in the sphere of environment and civil protection, as well as for the State Agency of Water Resources of Ukraine, or government authorities. Additionally, these maps might be interesting for educational institutions, students and public in general.

2.7.8 Recreational and touristic use of water bodies

Author: Victor Vyshnevski

A. Definition

Besides supplying water for the security of livelihoods, water bodies are used by the sectors rehabilitation, recreation and tourism. An appropriate use for rehabilitation and recreation purposes primarily depends on the size of the water bodies, their purity and temperature, as well as the presence of beaches and infrastructure. For tourism the presence of touristic objects, either created naturally or anthropogenic, is important. The latter includes for example monuments of history and architecture.

B. Approach

Appropriate maps of the recreational and touristic use of the water bodies do not exist. There are tourist maps of countries and regions, where some attention was paid to water bodies. Thus, in 2010 the Atlas "Touristic necklace of Ukraine" was published, where -among other things- touristic objects associated with rivers are presented.

C. Material

The informational basis for maps about the recreational and touristic use of water bodies can be the results of field studies, airborne photos or book- and internet resources. The proposed name of the map is "Recreational and touristic use of water bodies".

D. Final product

An administrative map can serve as a cartographic base. The final map scale depends on the size of the region and ranges between 1:500,000 and 1:2,000,000. The map should illustrate areas of rivers suitable for swimming, and the largest beaches. In the first case, three categories can be used considering the size of the water bodies, the water purity and the convenience of riverbanks for recreation: “quite suitable for recreation”, "relatively suitable for recreation" and "unsuitable for recreation". In the first two cases it is advisable to use conventional signs to illustrate the locations of the best equipped beaches.

The touristic component of the map contains appropriate districts for rafting and camping. Additionally, location of hotels, motels and other accommodation facilities for tourists should be included in the map. Other signs should show the location of museums, palaces, citadels, monuments of prominent figures etc. Besides, objects of protected areas, especially those related to water bodies could be illustrated. Blank spaces can be used to place photos of the most attractive objects.

E. Applicability

The map could be useful for regional planning, water management and public interests.

2.7.9 Mineral waters

Author: Ivan Kovalchuk

A. Definition

Mineral waters are natural underground waters, which have a therapeutic effect for humans, caused primary by their ion, saline and gas composition, a high content of active balneologic ingredients (Li, Sr, Ba, Fe, Mn, Br, J, F, As, etc.), or specific additional properties, such as radioactivity, temperature, structure of water, the reaction of water, pH number, redox potential Eh, etc. (Bieleckyi 2004, Geo-Kiev, 2013).

The Ukraine is rich of mineral water resources with different chemical compositions and balneologic effects on the human body. Mineral waters in the Ukraine are located in different depths and in sediments of different age. On the Ukrainian Shield they are found in depths less than 120 m below the surface. On the contrary, in artesian basins sometimes they are located in depths greater than 3000 m.

There are many classifications of mineral waters. The most recent one divides mineral waters into three categories: 1) mineral waters without specific components, 2) mineral waters with specific components, 3) mineral waters with specific physical properties (Shestopalov et al. 2003, Shestopalov 2009). Each of these categories is divided into a number of species. The first category identifies one species - water treatment composition of primary ions. In turn, this species is divided into further classes and subclasses concerning the composition of major ions: anions and cations. Here, the classes and subclasses are divided into groups of mineralization and (or) quantitative content of a specific component.

Those mineral waters, which balneologic impact on the body is determined by the composition and the ratio between the major components of water (sodium, calcium, magnesium, sulfate, bicarbonate and chloride) and their quantitative content (salinity), belong to mineral waters without specific components. According to the classification of mineral waters in the Ukraine, 25 types of mineral waters without specific components are identified, which in turn belong to 11 different classes (for anions), 7 subclasses (for cations) and 5 groups concerning the mineralization (from the low-mineralized type "Myrgorodska" to water of high mineralization like "Morshinska") (Shestopalov et al. 2003, Shestopalov 2009). The geological structure, lithology and other conditions determine the main features of the mineral waters without specific components for

different regions. Under these basic conditions, the map "Mineral waters without specific components" (Fig. 2.7-4) illustrates 19 areas, where mineral waters on the specifics of the major components are distributed within the main geological regions, similar to the selected map "Mineral water with specific components" in Fig. 2.7-5 (Shestopalov et al. 2003, Paton et al. 2007, Ohnyanyk 2000, Shestopalov 2009, Geo-Kiev, 2013).
Those mineral waters, which balneologic impact on the organism is determined by the content of specific bioactive components, are identified as "mineral waters with specific components." According to Shestopalov (2009), there are 9 kinds of mineral waters with specific components: 1) carbonated, 2) sulfide, 3) water enriched by organic matter, 4) boric, 5) siliceous, 6) arsen, 7) bromine and iodine, 8) polymetallic and 9) ferruginous waters. The third category refers to mineral waters with specific physical properties. There are three types: 1) radon waters, 2) waters, which therapeutic impact is related to their structure characteristics, such as pH, Eh and other physical parameters, and 3) thermal waters.

B. Approach

There are proposals for medium scale maps, which should illustrate:

1) Borders of artesian basins (Ukrainian Shield, Carpathian Mountains, Crimea, Donetsk folded structures), within mineral waters without specific components are formed, using linear way signs.

2) The variety of types and classes of mineral waters, using the method of qualitative background.

3) The variety of mineral waters with specific components, using methods of areas and signs.

4) The integrated map "Zones of Ukraine under the formation of mineral water" shows the borders of the largest mineral water zones (Ukrainian Shield, East European plate etc.). A map "Potential use of mineral waters of Ukraine", which reflects the untapped reserves of mineral waters, can be created as well. Furthermore, a series of maps related to "Mineral waters", "Hot Waters", "Therapeutic spa resources" could be prepared. These maps can be complemented by classification schemes of mineral waters, as well as other tabular and graphical information.

C. Material

To create the above mentioned maps, various information or data can be used: Paton et al. (2007), Bieleckyi (2004), Shestopalov (2009), Ohnyanyk (2000), data of the automated information system of the State Water Cadastre, or data of the Geological Sciences Institute of Ukraine and others.

D. Final product

The maps can show: 1) the distribution of mineral waters without specific components, 2) the distribution of mineral waters with specific components, 3) zoning of Ukraine in terms of the formation of mineral waters and 4) the potential use of mineral waters of Ukraine. The mapping scale is approximately 1:1,000,000.

E. Applicability

The maps can be used to:

- investigate changes in the intensity and use of mineral waters
- inform the central and local governments about the current situation and potential prospects of mineral waters use for drinking water consumption, spa etc.
- assess the mineral water resources, concerning the development of long-term forecasts of water use
- assess the human impact on the quality of mineral waters
- justify protecting measures for mineral waters against pollution and depletion

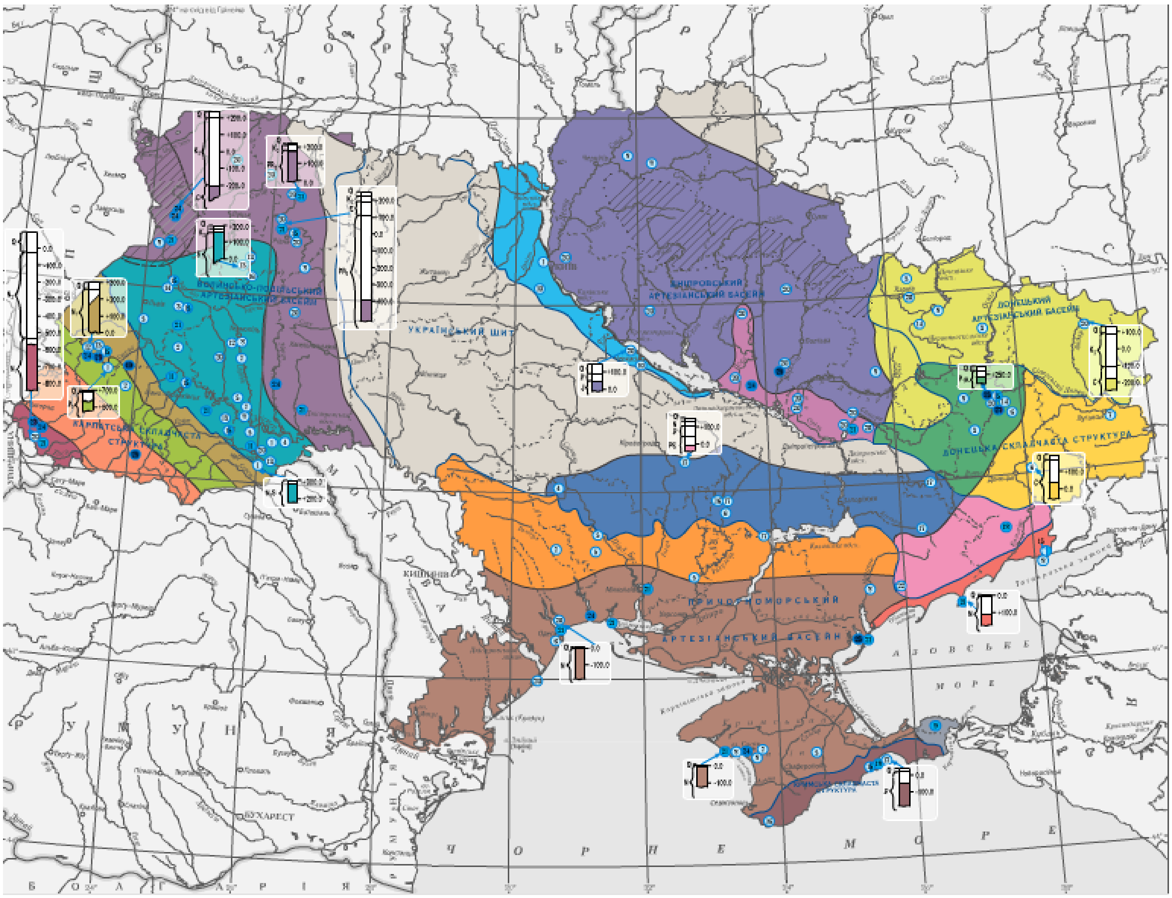


Fig. 2.7-4: Mineral waters without specific components (Paton et al. 2007)

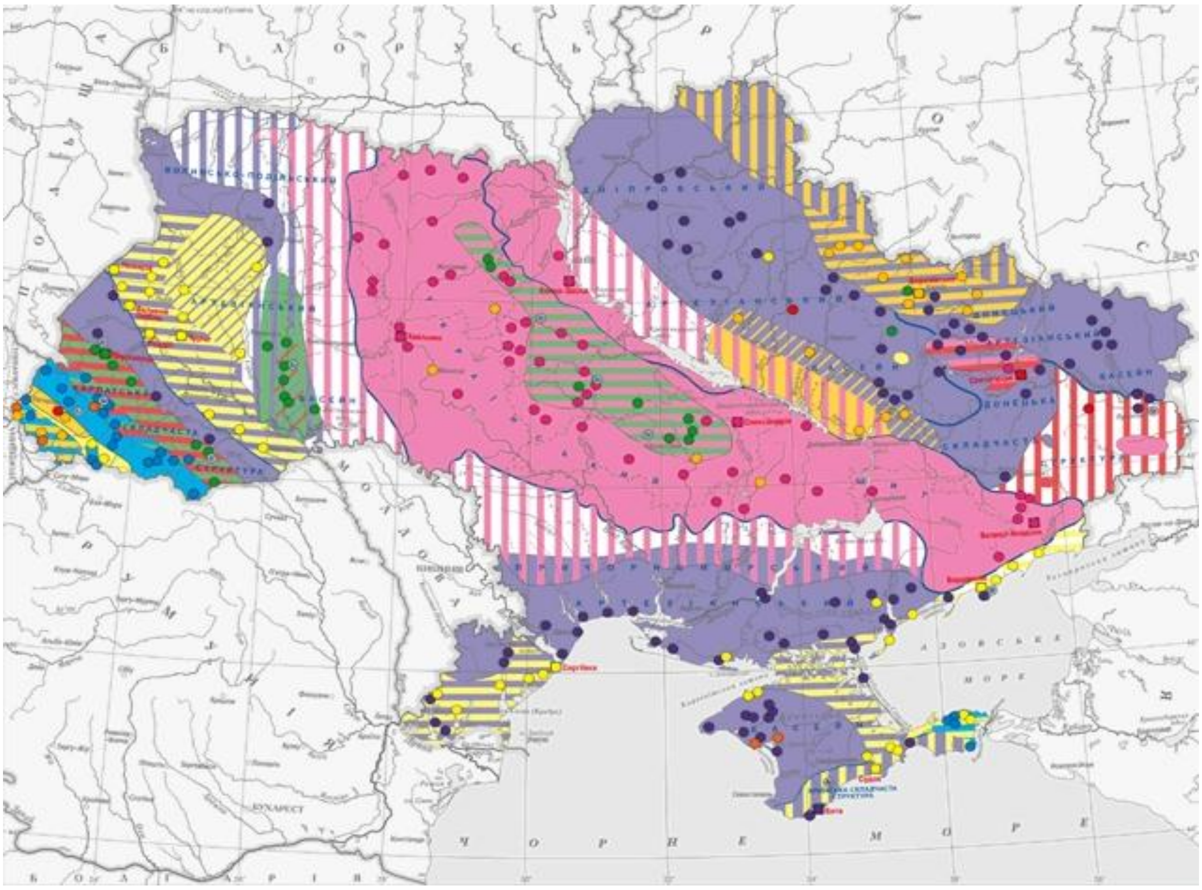


Fig. 2.7-5: Mineral waters with specific components

3 Cooperation partners

During the workshops the participants compiled a list of Institutions, which own or hold data that are needed for the atlas or have the scientific expertise to analyze them.

Tab 2.7-1 Institutions, which hold data and/ or have expertise in data analysis (responsible persons in parenthesis)

Meteorology/ Hydrology	**Soils**	**Land use/ Geography**	**General Aspects**
Ministry of Emergencies of Ukraine with Central Geophysics Observatory (Kosovets O) and Hydrometeorological Institute (Osadchyi V)		National Academy of Sciences of Ukraine Institute of Geography (Rudenko L)	State Scientific Production Center „Cartography“ (Sossa R.)
National Scientific Production Center „Nature“		Ministry of Agrarian Policy of Ukraine (Prysiazhniuk J)	Institute of Geodesy and Cartography (Karpinsky J)
The State Water Resources Agency of Ukraine	State Agency of Land Resources of Ukraine (Regional Institute of Land Resources)	State Scientific Production Center „Cartography“ (Sossa R.)	Institute of Water Problems and Melioration (Romashchenko M)
Ministry of Ecology and Natural Resources of Ukraine	National Universities in Kyiv, Lviv etc.	Scientific Center of Aerospace Research of the Earth (Kussul N)	State Statistics Committee of Ukraine
State Statistics Committee of Ukraine	NUBIP Ukraine		

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