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MODEL GUIDELINES FOR RIVER BASIN MANAGEMENT PLANNING IN ARMENIA

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List of Acronyms

AED	Academy for Education Development
ASH	Armenian State Hydro Meteorological Service
AWSC	Armenian Water and Sewerage Company
BMO	Basin Management Organization
BPC	Basin Public Council
CTO	Cognizant Technical Officer
EIMC	Environmental Impact Monitoring Center
GOAM	Government of Armenia
GTZ	German Technical Cooperation Program
HPP	Hydropower Plant
IWRM	Integrated Water Resources Management
LGUs	Local Government Units
MNP	Ministry of Nature Protection
NGO	Non-Governmental Organization
NWC	National Water Council
PA	PA Government Services Inc.
PSRC	Public Services Regulatory Commission
RGF	Republican Geological Fund
RA	Republic of Armenia
RBM	River Basin Management
SWCIS	State Water Cadastre Information System
SCWS	State Committee on Water Systems
SEI	State Environmental Inspectorate
SHAEI	State Hygiene and Anti-epidemic Inspectorate
SNCO	State Non-Commercial Organization
USAID	US Agency for International Development
WRMA	Water Resources Management Agency
WUA	Water Users Association
WUP	Water Use Permit

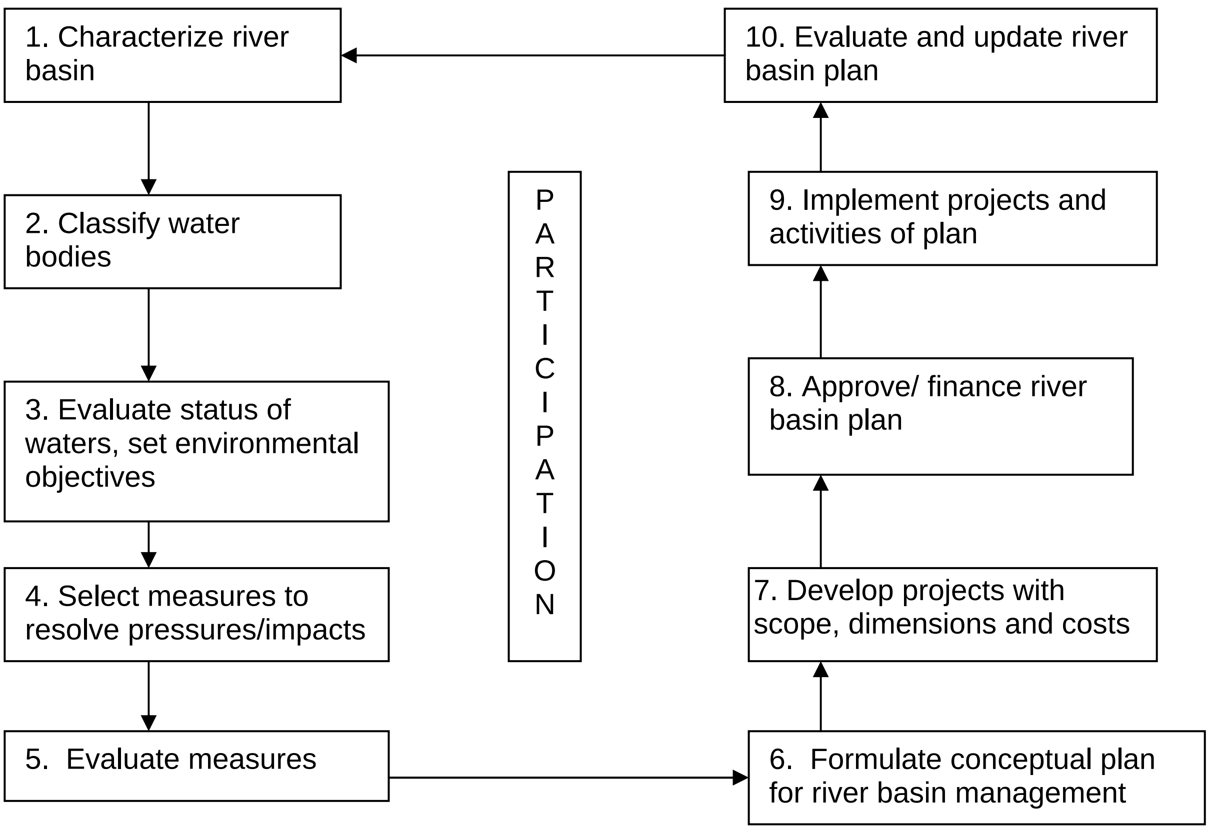
EXECUTIVE SUMMARY

This manual has been prepared by the USAID/PA Program for Institutional and Regulatory Strengthening of Water Management in Armenia and its subcontractor consortium of "Geocom Ltd." and "Kapan Communities' Union" NGO in collaboration with water sector stakeholders in Meghriget River basin. The purpose of these Model Guidelines for River Basin Management Planning in Armenia is to provide water management authorities with practical, user-friendly tools for development of river basin management plans in Armenia.

The guidelines are based on the concepts of integrated water resources management and adaptive management, and on the approach of the European Union Water Directive Framework. These concepts reflect the intent of Armenia's new Water Code adopted in 2002.. This Water Code requires the WRMA to prepare river basin plans to assure the long-term sustainable use of Armenia's water resources. These plans are meant to support adaptive management of water resources; in other words, they set appropriate environmental objectives for each basin, and encourage improvement of water quality and water quantity to meet those objectives, but they allow flexibility in the future use of water resources to support Armenia's economic development.

The guidelines proceed logically through a ten-step process of river basin planning. The process includes six data collection and analytical steps resulting in a river basin management conceptual plan. The final four steps explain in general terms the administrative process recommended for transforming that conceptual plan into a "projects plan"—a set of targeted projects which are approved, financed and implemented in the river basin.

The overall ten step process for river basin planning is presented below:



Step 1: Characterization, is a review of the physical, biological, geographic, social and economic and water use patterns in the river basin. Its provides data and maps, as well as background for next steps in planning. It includes analytical tools for development of a monthly water balance, and for flood estimation. It concludes with a description of water resource issues. The Characterization Synthesis Report for Meghriget River Basin illustrates how characterization should be done.

Step 2: Classification of water bodies includes delineation of water bodies and classifying them by type. Classification assigns each surface water body (stream, lake, canal, or reservoir) and ground water body (aquifer) to a category or type which has its own set of distinct, and ecologically appropriate environmental objectives. Categories are defined by ecological characteristics which determine what type of chemical water quality and aquatic life is found there under natural conditions—altitude, geology, size of stream, etc.—the system here is based on the Water Framework Directive. The first step in classification is delineation, or separation of water bodies into discrete units with similar characteristics. Certain types of man-made waters are known as highly-modified water bodies (canals, some reservoirs) because they cannot be expected to reach the same high environmental objectives as natural waters—these waters must be carefully separated from other water bodies. Armenia's Water Code also requires that water bodies be "classified" or described, according to a large set of criteria. This descriptive classification is complementary and parallel to the system described here.

Step 3: Evaluation and Setting Environmental Objectives includes several vital parts of the river basin planning process. Evaluation of status is the process by which Armenian standards are compared to the actual water quality and flow characteristics of a surface water body to determine whether it meets the requirements of human health and support for aquatic life. An index of water quality parameters is used, because biological data (recommended in Europe) is not available for Armenia. The water's status is ranked very poor, poor, satisfactory, good, and excellent. The environmental objectives, following EU Water Framework Directive, should support "good" status of waters. The environmental objectives (also called "targets") are set in order to measure the progress of improvement in water resources during a river basin planning period, usually a number of years. Environmental objectives are quantitative and can be measured by monitoring. Environmental objectives for surface waters include physical and chemical water quality, and maintenance of minimum ecological flows. For ground water, the key objectives are to maintain a balance of recharge and discharge from the aquifers, while remaining free of toxic contaminants.

Step 4: Pressure/Impact Analysis and the Selection of a program of measures is a type of problem-root cause-response analysis. Pressures are the socio-economic activities that can cause degradation of water resources, and impacts are the particular issues (e.g. type of pollution) they cause in waters. Measures are logical responses that relieve the pressure and remove the impact, in a sustainable way. Measures may take the form of policies (water permits, incentives), educational programs, or infrastructure investments. A this point in the basin planning process, the measures are preliminary, based on recommendations from technical specialists and water users.

Step 5: Economic and environmental analysis is applied to the program of measures, to determine which ones are acceptable at a environmental, social and particularly economic level, based on primarily qualitative and limited quantitative analysis. Prioritization of measures is done where multiple alternatives exist.

Step 6: Formulation of the River Basin Management Concept Plan is a summary of results from the steps two through five. The Concept Plan includes the delineation and classification of waters, the ecological status of waters, the environmental objectives for each water, the pressure/impact analysis, and the preliminary program of measures, with some prioritization of alternatives. The concept plan should display a long-term perspective on river basin improvements, at least ten years, preferably more. It is critical that this concept plan be widely discussed and accepted by key stakeholders, including local governments, major water user groups, and civil society leaders. Key potential implementers should commit to its basic priorities in writing.

Step 7: Development of projects, transforms the concept plan into a concrete set of projects with scope and dimensions, estimated costs, cost-benefit analysis, and institutional responsibilities. The projects plan is a specific proposal about how to put the concept plan into effect. It usually has a shorter time-frame (3-5 years) and is based on realistic budgets and implementation strategies. In order to complete a projects plan, the planning agencies like Water Resources Management Agency, must have "buy-in" from the key local agencies who have authority for implementation. Then the WRMA and collaborating agencies will invest in this stage, the studies and analysis needed to develop feasible projects which fulfill the river basin management concept plan.

Step 8: Approval of the River Basin Management Plan is an inter-institutional activity led by the Water Resources Management Agency. The approval process makes the river basin management plan an official priority of Armenian government, and qualifies it for government finance. But it is clear that the actual implementation of river basin management plans will be done by multiple agencies and perhaps civil society groups, working with independent finances, in coordination, and on complementary measures which are defined in the river basin plan. i

Step 9: Implementation of river basin plans is described in this section simply in terms of the proposed schedule for different stages of the river basin management planning process in Armenia. The river basin plans, once project development is achieved, are expected to last five years, but many projects will only be funded for a portion of this time period, and will require renewal. Therefore it will be necessary to coordinate the inclusion of river basin plan priorities into a variety of agency workplans each year. This coordination role is appropriate for the BMOs.

Step 10: Update of the River Basin Management Plan is required as new data is acquired and as project implementation monitoring and environmental status (water body status) monitoring progresses. Recommended data updates are outlined in this section.

Public participation is a vital part of river basin management planning, which is why the cycle of planning steps is depicted in the above diagram, with "participation" in the center of the cycle. Public participation refers to the involvement of all types of stakeholders in the river basin planning work, including WRMA and BMOs as leaders, but recognizing the key role of other national agencies, local governments, water user groups and civil society groups in the management of water resources. These stakeholders must be involved throughout the process, but particularly in key decisions such as: selection of principal water resource issues in the basin, setting environmental objectives, selecting preliminary measures, and approval of the basin concept plan. In fact, river basin planning can only be done effectively as a collaborative effort of multiple agencies. A guideline for participation is included in Section 5.2 of this manual.

Two intermediate planning products need to be produced prior to full development of the river basin management plan. Here we have included examples of these intermediate products. A river basin characterization synthesis report of the Meghriget is included as a summary of step one. A river basin management concept plan for the Meghriget River Basin is included in the document as an illustration of steps two through six.

River basin management planning is likely to be a major of activity of Armenian basin management organizations (BMOs) in coming years. Much of the basin planning work can and should be done by their staff, with assistance from WRMA central government staff. In some cases consultants or technical specialists from participating agencies may be used to develop certain parts of the basin plan.

More detailed versions of river basin planning guidelines are presented in the reports developed by Geocom Ltd., in EU Water Framework Directive implementation guidelines (www.ec.europa.eu/environment/water/water-framework/index_en.html) and in sources of literature noted in the chapter references.

INTRODUCTION TO RIVER BASIN PLANNING GUIDELINES:

These guidelines have been prepared to assist Armenia's Water Resources Management Agency (WRMA) in launching a national program of river basin planning in coordination with its Basin Management Organizations. Armenia has a new National Water Code, based on integrated water resources management principles. This Water Code requires the WRMA to prepare river basin plans to assure the long-term sustainable use of Armenia's water resources. These plans are meant to support adaptive management of water resources; in other words they set certain environmental objectives, but they allow flexibility in the future use of water resources. Their purpose is to assess current conditions of water resources, propose objectives which protect human health and aquatic ecosystems, develop programs to improve waters which do not meet objectives, and allow for the sustainable use of water resources by current users while providing clear guidance for future water use in responsible economic development.

The primary conceptual basis for this approach to river basin planning is the European Communities' Water Framework Directive. Armenia is not a member of the European Community, but it would like to make its water resources management programs compatible with European Community approaches. Therefore, this document draws heavily on the concepts of the Water Framework Directive (WFD), but it also modifies the EC approach, to be more compatible with Armenian reality. Certain aspects of the WFD have been greatly simplified or omitted in this approach. Information sources and technical capacities in Armenia are not at a sufficient level to apply the entire Water Framework Directive. But as technical capacities increase in Armenian agencies, the approach illustrated here can be modified to gradually incorporate more elements of the WFD, and more closely approach the EC model.

The approach to river basin planning in these guidelines is based on integrated water resources development (IWRM) concepts. Specifically, this approach integrates water quality and water quantity concerns, integrates surface water planning with ground water planning, integrates all water uses including ecosystem uses, integrates various distinct measures into the range of solutions considered (e.g., policy, education, and infrastructure), and integrates all the stakeholders into the planning process. Stakeholders includes national agencies, local governments, private industry, non-profit groups, water user groups and the general public.

This document visualizes a ten-step process of developing and implementing river basin plans. The first four steps are: 1) characterization of the river basin, 2) classification of water bodies, 3) setting environmental objectives, and 4) development of a pressure/impacts analysis and a proposed set of measures. These four steps are detailed and analytical, with specific techniques proposed, and illustrated with examples from the Meghriget river in southern Armenia. Step 5, evaluation of measures, is detailed but there is no illustration, as the Meghriget river basin work has not reached that stage yet. Steps six through ten are administrative and do not include illustrated examples: 6) Formulation of the river basin plan; 7) development of actions plans; 8) approval of the river basin plan; 9) updating the river basin plan, and 10) implementation schedules. A river basin characterization synthesis report and a draft river basin plan for the Meghriget are included as examples of intermediate products.

This set of guidelines is intended to be a flexible tool for the WRMA and BMOs to use in their river basin planning efforts. Experience will help them adapt these techniques and approaches, and the methods will certainly evolve with further use. It is hoped that this initial guidance will be both clear and practical in the short term, and provide a solid foundation for further improvements in the practice of water resource planning in Armenia.

STEP 1. RIVER BASIN CHARACTERIZATION

Introduction to Step 1: Characterization

River basin characterization is the first step in the river basin planning process. The purpose of the river basin characterization is to review the current economic, social, biological, physical, geographic and environmental conditions in a given river basin so as to reveal the river basin's major water resource management issues. Usually river basin characterization is done using existing data sources, in consultation with local stakeholders such as local governments. In areas where data is scarce, basin characterization also uses reconnaissance-level field measurements, remote sensing, and field interviews with stakeholders to develop basic physical, geographic, and socio-economic information.

This first step in the basin planning process describes the context of the most important water resource issues within the basin. Succeeding steps will delineate and classify the water bodies, determine their status, set the environmental objectives, diagnose the pressures (sources of problems) and their impacts, and propose measures to improve water management in the basin.

GUIDELINE 1.1: PHYSICAL-BIOLOGICAL-GEOGRAPHIC CHARACTERIZATION

1. Introduction:

***1.1 Purpose of this Guideline*:**

This guideline describes how to collect and organize the data pertinent to characterizing a river basin, as the first step in river basin planning. This work focuses on the local physical, geographic, and biological components of the basin that are important to understand the use and condition of water resources, such as climate, topography, geology, hydrology, aquatic biology and land use.

***1.2 Role of this Activity in River Basin Planning*:**

River basin characterization begins with a description of the river basin's physical and biological characteristics. It is important to define and quantify accurately the natural resources within the river basin, as this is the natural endowment which provides the context for economic development and potential use of those resources, particularly water resources. The land ownership and basic land use patterns are also defined in this section as these characteristics of human occupation of the river basin are also part of the context within which current development of water resources occurs.

2. Technical Approach to Inventory of Physical, Geographic and Biological Data

2.1 Methodology: Description and Justification:

The inventory of physical, geographic and biological data is primarily accomplished by research into sources of published information, including information published by local and national governments. Basin Management Organizations need to cultivate a close relationship with these organizations in order to facilitate the sharing of pertinent information.

2.2 Input Data Requirements:

Physical Data

The physical data include information about the climate, geology, soils, topography, hydrology, water quality, and hydrography of the river basin under study. These data must be extracted from existing records held by state institutions, academic institutes and local government agencies. Databases such as Armenia's state water cadastre information system (SWCIS) will be a key source of this information. This document includes references to particular data sets, with code numbers, in SWCIS.

The physical data will be downloaded from the SWCIS as data tables and maps. Geomorphic zones, soils, topography, climate zones and hydrography (rivers, lakes, reservoirs, major canals, aquifers) can be mapped for the entire river basin, on the same base maps at the same scales, to facilitate comparison of physical and geographic relationships.

Data on climate, hydrology, and water quality will be tabular data registered at particular long-term data collection points within each basin. If sufficient information on climate exists, then annual precipitation and temperature isohyets can be used to extrapolate climate characteristics across the entire basin in a map.

Biological Data

The biological data of interest includes information on the ecological zones present, natural vegetation (especially wetlands), and the principal fauna of the region, with particular emphasis on the aquatic fauna.

Maps of ecological zones or natural vegetation within Armenia can be modified to fit the river basin of interest. Simple tables that explain the principal (diagnostic) flora and terrestrial fauna species of each zone are sufficient; complete lists of fauna and flora are generally not useful. Information about important wetlands and their flora and fauna (for example, migratory wetland birds) is important, and references to specific studies on these topics should be included in the river basin characterization.

Aquatic fauna, especially native fishes and amphibians, are frequently well-known, and are important for establishing the ecological status of water bodies. Complete listings of species, their status, and even maps of their distribution within the river basin are often useful. Information on aquatic invertebrate fauna and aquatic flora is often difficult for non-specialists to interpret but studies done within the river basin should be referenced. Studies of aquatic invertebrate and aquatic flora as keyed to pollution or alteration of water bodies are especially important to cite, whenever they exist.

Geographic Data

The geographic data of interest within the river basin include maps of actual land use, including specific location and extent of irrigated areas and cultivated land, locations of intensive annual dryland
cropping, and locations of urban areas. These land uses, their distribution and extent, are extremely important to future understanding of water use and particularly water quality issues within the river basin.

Land ownership and management authority are very important aspects of river basin management, and should be mapped on the same scale as land use. Areas managed by private landowners, large corporations, national protected area authorities, military authorities or state governments should be clearly delineated on a map of the basin. These entities are key stakeholders in the management of the land and water within the basin.

2.3 Data availability and Data Collection—Where to Acquire Input Data

Much of the required data should be available through the State Water Cadastre Information System (SWCIS) and the Ministry of Nature Protection state agencies. Data which is prepared on a national scale should be useful as a first approximation, once it is clipped from GIS files to apply it to the river basin of interest. Other data, which is of a more regional scale, may be identified by each BMO, especially in working with the Marz government agencies. Where key data is not available for the river basin characterization, it is recommended to budget time and personnel for some field data collection as part of the river basin characterization process. This is especially important if there is a severe lack of water flow data and water quality data within the river basin.

2.4 Analysis for Characterization of Basin:

Physical-Geographic Characterization of Basin

The physical-geographic-biological characterization needs to start with identification of the river basin of interest, and a description of its LOCATION, HYDROGRAPHY, and TOPOGRAPHY, including appropriate maps. The following items should be included:

- General description of location, defined river basin by exact downstream point of discharge, and name its major upstream tributaries.
- Provide location map of river basin within Armenia
- Provide a general map of the river basin including: labeled rivers, lakes and sub-basin stream names; major towns: principal (national) highways; borders of Marz, and national border (if any).
- Prepare a Table of Hydrographic Data for the river basin, including for the entire basin, and each major tributary (more than 10% of basin area): Watershed area, maximum elevation, minimum elevation, length of channel, gradient, river network density.
- If possible, additional sample hydromorphic data on the main river channel of the basin should be included, for example depth, width, width/depth ratio, sinuosity (total length/straight line distance) and type of channel form (braided, meandering or straight), modifications that take place in-stream.
- Any natural lakes should be characterized as to area (hectares of km^2), maximum depth, average depth, and location (GPS) in a table.
- Topographic map of the entire basin, with a minimum of 100-meter contour intervals (depending on steepness of basin).

The physical-geographic characterization should also provide reference maps, and very brief descriptions of GEOLOGY, HYDROGEOLOGY and SOILS of the river basin, including:

- Geomorphologic map of basin, derived from national data.
- Geologic map of basin (rock types) with particular attention to limestone (calcium carbonate or “karstic”) types due to their hydrologic properties.
- Soil maps for the basin should be provided, but soils should be lumped into categories so that only 7-10 total types are shown (otherwise the maps become too difficult to interpret)
- Map of major known aquifers, if it exists
- Hydrogeologic map of the basin with major aquifers, springs and wells.

The physical-geographic characterization should also provide general data on CLIMATE, HYDROLOGY, and WATER QUALITY of the river basin. The following are the basic minimum data to be included:

- Monthly and annual precipitation averages for stations within the basin. If the basin is large, include stations from various elevations within the basin. If climate stations do not exist in the basin, use the nearest climate stations (of similar elevations and climatic zones) to lower and upper end of basin.
- Isohyet map of estimated average annual precipitation by elevation for basin.
- Annual snowfall averages for various elevations in the basin or in adjacent basins. It is important to understand the rainfall equivalent of snow, and the approximate percentage of annual precipitation that falls as snow. This data is taken from ArmStateHydromet.
- Monthly temperature means, minimums, and maximums for climate stations in the upper and lower end of the river basin (record altitude of station).
- If historical streamflow data exist for the basin, include tables of monthly average discharge, monthly minimum and maximum flows, and annual average discharge for ALL hydrologic stations within the basin (remember to reference the years data was collected for these averages, e.g. 1956-1988, and the altitude of station). This data is taken from ArmStateHydromet.
- If there is no historical streamflow data for the basin, include examples of historical monthly or annual streamflow averages, and monthly minimum and maximums, for nearest hydrologic stations within Armenia of similar altitude.
- Prepare a table calculating the monthly or annual average discharge per unit area of watershed for all hydrologic stations within the basin and nearby (e.g. $l/sec/km^2$)—this will be useful for estimating discharge from un-gaged sub-basins. This data is taken from hydrological stations.
- If no daily streamflow measurements are available for the basin or nearby, but some sporadic streamflow measurements exist, those should be included as examples, with

specific locations noted (GPS preferred). If possible, the BMO should measure, or ask the Marz Hydrologic service, to measure sample streamflows in January, April, June, and September in upper and lower basin to roughly characterize the hydrology of the basin.

- Although Step 3 of river basin planning, the Review of Status and Setting Water Resource Environmental Objectives, will be a more exhaustive look at water quality, it is very important to give an idea of water quality issues in this initial step of the characterization.
- If long-term water quality monitoring stations exist in the basin, a summary table and short description of water quality status for natural surface waters are useful. This should focus on identifying any parameters where current data exceed water quality standards.
- A brief text summary of any long-term or punctual water quality studies should be made, and even isolated water quality samples for rivers and lakes taken by university students, industries, or state agencies such as Environmental Protection Bureau, should be included in tables (with reference to national standards for each parameter).
- A very brief text description of important likely threats to water quality (large industries, large urban/municipal wastewater systems, municipal stormwater runoff) should be included, even if data do not exist.
- Water quality analyses for aquifers (well data) and springs/sources should be summarized in tables, with each well site separate, if any data exists.

Specific Data and Analyses for Biological Characterization of Basin

The biological characterization of the basin will focus on TERRESTRIAL ECOSYSTEMS or ZONES, WETLANDS, and AQUATIC SPECIES. The minimum data to be included should be:

- A map of the river basin with the principal national ecosystems delineated. These can be ecosystems, ecological zones, or natural vegetation types. An accompanying table which lists several typical dominant vegetation species for these ecosystems is sometimes helpful to the non-specialist.
- A map of important wetlands, including lakes, ponds, marshes, bogs or other wetland types identified within the river basin. If there is information on the area (extent) of these wetlands, it should be summarized as a table in the document.
- Prepare a list of native aquatic vertebrates which are present in the river basin (fish and amphibians)—this is very important for establishing ecological status of these waters. Consult the Institute of Hydroecology and Ichthyology of National Academy of Sciences in Yerevan. If sufficient data exists, a breakdown of native aquatic vertebrate species present in each major river/tributary of the basin is also useful. Even better is to prepare a map of the locations where key indicator native fish species are present in the basin (for example, native trout species).
- Tables of introduced fish species present in the basin are also of interest, although not of the same importance as native species for ecological characterization.
- Make text reference to studies of other aquatic species in the basin, including migratory birds (waterfowl), aquatic mammals, aquatic plants and aquatic invertebrates. Lists of these species are probably not necessary as they are difficult for non-specialists to interpret.

Specific Data on Geographic Characterization of Basin

Geographic characterization of the river basin will focus on ACTUAL LAND USE and LAND OWNERSHIP and LAND MANAGEMENT AUTHORITY that are aspects of great importance in river basin management. These aspects are crucial for understanding the possible impacts of the watershed lands on the water resource and the role of major stakeholders, respectively. Many other geographic aspects, for example location of particular water users, water permits, water infrastructure, etc. will be treated in another part of the characterization known as “water use characterization.” Specifically the river basin characterization should include:

- A detailed map of actual land use, based on GIS data, with a table summarizing the actual area devoted to each land use (in km^2 and as a percentage of the entire basin). It is important not to sub-divide the categories excessively for this exercise, as probably six to eight land use categories are sufficient, for example: irrigated agriculture, dryland agriculture, pasture/grasslands, forest (2 types maximum), shrublands, low-density urban residential (peri-urban), and high density urban-commercial-industrial. These categories are very important for judging relative pressures and impacts for water quality. If certain special land use issues, such as saline-sodic lands, are important in the river basin, specific maps can be included to indicate the location and extent of that issue.

- A detailed map of land ownership and management authority is extremely important, so that it is clearly understood who are the principal stakeholders and authorities in each sub-basin. Categories such as private ownership, village communal, corporations, state protected area or forestry areas, municipal or marz lands, or other similar categories are very useful, especially if they can be accurately mapped.

2.5 Type and Format of Output Data

Examples of River Basin Characterization Data (Tables)

HYDROGRAPHIC DATA TABLE FOR MEGHRIGET RIVER BASIN

Basin/ Sub-basin:	Watershed size (km^2)	Maximum channel elevation (m)	Minimum elevation (m)	Length of channel (km)	Gradient (m/m)
Meghriget/ entire					
Meghriget/Lichq					

HYDROGRAPHIC DATA FOR MEGHRIGET RIVER MAIN CHANNEL

Channel Reach:	Reach (km from mouth):	Maximum channel elevation (m)	Minimum elevation of channel (m)	Length of Reach (km)	Gradient (m/m)
Meghriget, upper					
Meghriget, upper					
Meghriget, middle					

AVERAGE MONTHLY PRECIPITATION IN MEGHRIGET RIVER BASIN (mm)

Station name/dates	Elev. (m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual (mm)
Lichq, 1956-99														
Meghri, 1949-2004														

MONTHLY STREAMFLOW MEAN, MIN/MAX IN MEGHRIGET RIVER BASIN (m^3/s):

Station name/dates:	Watershed area (km^2)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual (m^3/sec)
Meghirget/ Lichq, 1968-2002	21.0													
	Max													
	Min													
Meghriget/ Meghri, 1955-2005	274													
	Max													
	Min													

SUMMARY TABLE OF WATER QUALITY DATA FOR MEGHRIGET RIVER BASIN:

Water resource, Sampling Site:	N (number of samples, year dates)	GPS Location:	Parameters analyzed:	Parameters exceeding WQ Standards:
Meghriget -, Meghri	8, 2004-2005/IV	N40.847539 E 46.891341	BOD,NH3,Nox, TP,DO2, Cu,Pb	NH3
Site #2…..				

HYDROGRAPHIC CHARACTERISTICS OF THE RIVER BASIN:

River Name	Discharge point	Distance from the river mouth (km)	Length (km)	Average gradient %	Altitude of the river source	Altitude of the river mouth	Watershed area
Meghriget	Araks						
Nyuvadi	Araks						

Summary list of maps for physical-biological-geographic characterization

1) Location map for river basin (this could be obtained from hydrological stations).
2) Hydrographic map of the river basin (this could be obtained from hydrological stations).
3) General map of the river basin: tributaries, towns, highways
4) Topographic map of river basin, 100 m. contours
5) Geomorphologic map of river basin
6) Geologic (rock type) map of river basin
7) Soil map of river basin
8) Major aquifers (hydrogeologic) map of river basin
9) Isohyet map of estimated annual precipitation for river basin (this could be obtained from meteorological stations).
10) Ecosystem map of river basin
11) Map of wetlands (including lakes, ponds, marshes, bogs) in river basin
12) Map of actual land use in river basin
13) Map of land ownership/management authorities in river basin, saline soils
14) Protected Area map of river basin

Proposed Outline of Physical-Biological-Geographic Characterization

1. Physical Characteristics of Basin
    - 1.1 Climate: temperatures, precipitation, evapotranspiration
    - 1.2 Topography
    - 1.3 Geology

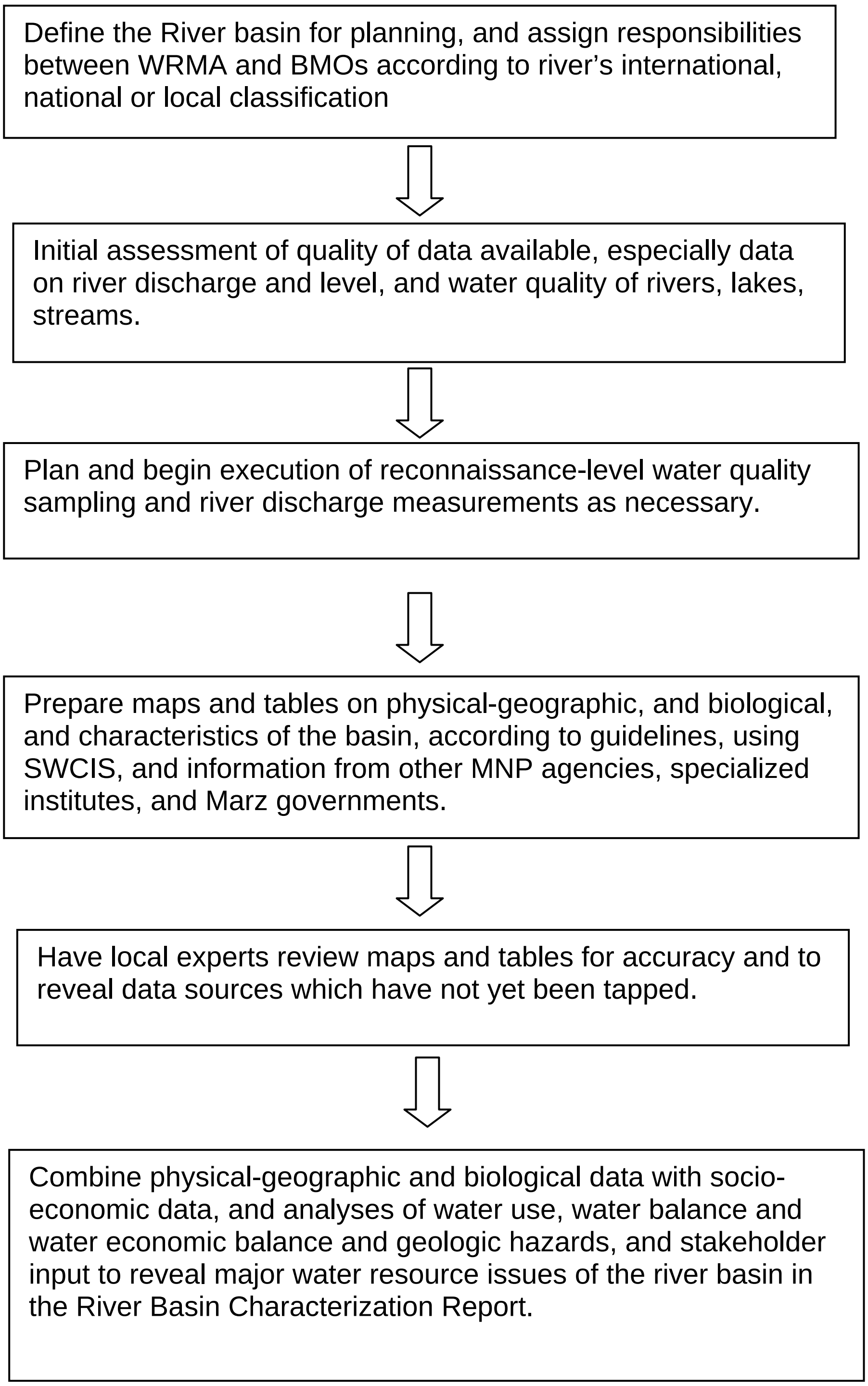
1.3.1 Geomorphology
1.3.2 Rock types and Mineral Resources
1.4 Hydrography and Hydrology
1.4.1 Surface Water Resources
*Sub-basin characteristics (altitude, length, size)
*Sub-basin water yields (average discharge)
*Description of lakes (sizes, depth, types)
*Surface water use (general description)
1.4.2 Groundwater Resources
*Aquifers (location, type, depth, geology, typical well yields)
*Springs, seeps, discharge areas
*Groundwater use (general description)
1.4.3 Water Quality
*Surface water
*Groundwater
1.5 Soil Resources

2. Biological Characteristics of Basin
2.1 Natural Vegetation and Ecosystem types
2.2 Terrestrial Plant and Animal Diversity
2.3 Aquatic Biodiversity (native fish, mollusks, crustaceans, etc.)

3. Geographic Characteristics
3.1 Land Use (actual and historical)
3.2 Land Capability Classification
3.3 Land Ownership Patterns (private, national, communal, local)
3.4 Protected Areas

4. MAPS

3. Diagram of Physical-Biological-Geographic Characterization Approach



4. Application of Method in Meghriget Basin:

River basin. A summary of this data is included in the Synthesis Report on Characterization of the Meghriget River Basin (after Section 1.7).

References:

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Syunik Marz Land Use Division, Management and Agricultural Departments, 2007, personal communication.

GUIDELINE 1.2: SOCIO-ECONOMIC CHARACTERIZATION

1. Introduction

1.1 Purpose:

This guideline describes the way to collect the type of data pertinent to characterizing a river basin, as the first step in river basin planning. This work focuses on the local social and economic situation which influences the quality and quantity of water in the basin.

1.2 Role of this Activity in River Basin Planning:

River basin characterization must include the status of social and economic development in the river basin. Socio-economic characterization includes a description of the pressures on water resources, including population, agricultural and industrial development, economic activity and infrastructure. These factors are the key drivers of how water is used in the river basin. Later in the river basin plan this information will be used to inform the pressures and impacts analysis.

2. Technical Approach

2.1 Methodology

The inventory of social and economic data is primarily accomplished by research into sources of published information, including information published by local and national governments. Basin Management Organizations need to cultivate a close relationship with these organizations in order to facilitate the sharing of pertinent information.

2.2 Input Data for Social and Economic Inventory

Social Data

The social data includes information about the population, its demographics, historical land use and water use, health and education status, and general infrastructure of the river basin under study. These data should be extracted from existing records held by state institutions, academic institutes and local government agencies, as well as from field interviews. The national census data is a key source of information on social conditions.

In many cases it is necessary to complement the existing data sources with field data gathered by a "participatory diagnostic team." In remote areas where population is dispersed, and the census data is not sufficiently detailed to explain the status of small villages, one or more professionals familiar with the area should visit the villages to gather information firsthand. Professional sociologists or anthropologists are generally most adept at gathering this information, using structured informal interviews, focus groups, and interactive exercises, such as Participatory Rural Appraisal (PRA).

Participatory data collection usually focuses on adult leaders of villages, including elderly residents with long history in the area. The type of data of most interest is information about historical land and water use, such as changes in agricultural or forestry exploitation, changes in availability or quality of water resources, historical changes in point of diversion or exploitation of water resources.

This type of "participatory" data collection is of great utility in understanding local perceptions of water resources, enriches the understanding of historical land use and water uses that continue to affect the resources today, explains the relationship of local economies to water resources, and facilitates an accurate identification of key water resource issues in the area. Social contacts with local leaders made at this early stage will be invaluable in later development of the basin management plan.

Some data on the social situation can be expressed using maps, such as population density maps, village maps, or infrastructure maps of railroad, secondary road and forest road maps, and electrical generation systems.

Economic Data

The economic data of interest is that which helps explain the patterns of water use, runoff and wastewater discharge in a river basin. This includes data on employment, income, and land and water use in agriculture, forestry, mining, manufacturing, construction, trade and service industries. This information should be gathered from economic development agencies, local governments, the census, and directly from interviews with representatives of key industries in the river basin.

In many river basins, agriculture is a predominant land use. Agricultural land use tends to affect the water resources substantially, therefore documenting patterns of agricultural land use is important. Maps of specific agricultural land uses are useful, if they exist, although annual crops vary dramatically year-to-year in many places. Long-term perennial crops like orchards, viticulture, etc. can be mapped, and distinguished from annual cropland under irrigation and annual crops under dryland cultivation. Livestock production zones, especially intensive medium- to large-scale production systems like hog farms, dairies, and poultry houses can have major impacts on water quality, and should be mapped.

Agricultural economic information, especially quantitative information on annual use of fertilizer and pesticide inputs to distinct crops, is useful, due to the potential for major effects on water resources. Although government agencies may have this data, in many cases it is necessary to seek information directly from farmers and agricultural input suppliers in the river basin.

Information on the quantitative output of forestry, mining, manufacturing, and food processing in the river basin is an important indicator of potential generation of wastes which can affect water resources. Data on historical economic activities with a large potential impact on water resources, such as historical mining, should be collected. Maps of the location and extent of historical mining, especially surface mining of coal, phosphorus, gold, or other metals should be generated.

The potential impact of certain small-scale trades and businesses on water resources should not be under-estimated, and data on their number and location should be collected. Small businesses with major documented impacts on water quality include gas/diesel fuel outlets, car washes, mechanic shops, metals (welding/plating) shops, dry cleaning and laundries, among others.

2.3 Data availability and Data Collection—Where to Acquire Input Data

Much of the required data will be available through the 2005 national census, the economic development offices of the Marz, Agriculture ministry, industry and trade organizations, and the Ministry of Nature Protection state agencies. Geographical data which is prepared on a national scale should be useful as a first approximation, once it is clipped from GIS files to apply it to the river basin of interest. Other data, which is of a more regional scale, may be identified by each BMO, especially in working with the Marz government agencies. It is recommended to budget time and personnel for some field data collection as part of the river basin characterization process. This is particularly important for certain types of social and economic data (see above) which is difficult to obtain without interviews.

2.4 Analysis and Mapping

Analyses for Social Characterization of Basin

The social characterization should focus on the demographics and land use history of the river basins' population. The following items should be included:

- Map of all inhabited areas of the river basin (villages, towns and cities expressing relative population size).
- Map of population density in rural areas of the river basin.
- Table of total population for the river basin, broken down by sub-basins.

- Map of social infrastructure, including: roads, railroads, water supply systems, power generation facilities and distribution networks
- Table of data on age distribution and life expectancy.
- Table of data on causes of mortality/morbidity
- Table of data on the incidence of major diseases, especially water-borne diseases (diarrehea), or diseases caused by aquatic vectors (mosquitoes).
- Data on immigration and emigration rates for the rural and urban sectors of the river basin population.
- Data on literacy rates, and educational level of population.
- Text description of historical settlement and land use patterns in the distinct sub-basins (forest-clearing, road-building, etc.)
- Text descriptions of historical changes in water use, water availability and water management as explained by informants in villages.
- Map of key social infrastructure, including all roads, railroads, potable water systems, electrical generation and distribution systems (irrigation infrastructure will be mapped in a distinct section to be described in "water use characterization.")

Analyses for Economic Characterization of Basin

The economic characterization should focus on the employment, income and water resource impacts of distinct sectors of the economy in the river basin.

The following specific data should be collected and analyzed:

- Map of crops in hectares for the river basin (by sub-basins if the basin is large)
- Map of large and medium-size dairy, poultry and pig farms
- Map of major forestry of the basin and roads crossing those
- Map the location of the major current and historical mining sites in the basin, with product (metals, coal, etc.).
- Map the gravel, quarries, aggregate, lime, and cement industries in the basin.
- Prepare a table on the employment and income statistics by sector in the basin.
- Map the agricultural production districts, and the key cropping systems in the basin, especially perennial and annual systems and irrigated areas.
- Develop a table explaining area in hectares of each major crop within the basin (by sub-basins if the basin is large).
- Data on livestock census, by species (cattle, hogs, sheep/goats, horses, poultry), within the basin.
- Map the intensive medium- to large-scale dairies, hog farms, and poultry farms in the basin.
- Develop tables on the annual fertilizer, manure, and pesticide inputs, per year, per hectare, for all major crops in the river basin.
- Map the major forestry production zones of the basin, and the forest road densities (kilometers of forest road per km^2) in these zones.
- Develop data tables on the approximate annual production of forestry and paper, mining, manufacturing and food processing industries in the basin.
- Inventory, or make approximate estimates of the small businesses with potential for major water resource impacts, including gas/diesel fuel outlets, car washes, mechanic shops, metals (welding/plating) shops, dry cleaning and laundries, with location by sub-basin.

2.5 Type and Format of Output Data

Examples of Social/Economic Characterization Data Tables

POPULATION OF MEGHRIGET RIVER BASIN:

Sub-basin:	Sub-basin Size (km^2):	Total Population:	Population Density (per/km^2):
Meghriget (total)			
Lichq			
Tashtun			
Karchevan (Agarak)			
Shvanidzor			
Etc……………			

EMPLOYMENT AND INCOME STATISTICS FOR MEGHRIGET RIVER BASIN: (developed from 2005 census data):

Economic Sector:	Total Employment:	Percentage of Total employment:	Average annual income (ad):
Agricultural Production			
Forestry			
Mining			
Government			
Trade/Commerce			
Manufacturing			
Service			
Etc………………			

AGRICULTURAL CROP AREA IN MEGHRIGET RIVER BASIN:

Cropping system:	Hectares:	Average Production (kg/ha)
Wheat		
Forage crops		
Pomegranate		
Potatoes		
Mixed vegetable crops		
Grapes		
Mixed fruit crops (peach/apricot/)		

Examples of Maps for Socio-Economic Characterization

1) Map of inhabited areas (all villages, towns, and cities) in river basin.
2) Map of population density of the river basin.
3) Map of infrastructure: roads, railroads, potable water systems, hydropower and other electrical generation systems, pipelines, etc.
4) Map of major industrial zones and concentrations of small businesses
5) Map of agricultural production zones
6) Map of medium- and large-scale dairies, feedlots, hog farms, poultry farms
7) Map of the forestry production zones with forest road density
8) Map of the current and historical metals mining sites in river basin
9) Map of current and historical non-metalic mining (incl. gravel, etc.)

Proposed outline of Socio-economic Characterization

1. Demographics
   - 1.1 Population and Demographic Growth
   - 1.2 Age Structure and Life Expectancy
   - 1.3 Immigration and Emigration
   - 1.4 Population Density

   1.5 Population Growth Forecasts

2. Health and Education
   2.1 Water and Sanitation Facilities and Citizen Access
   2.2 Health, Mortality, Morbidity
   2.3 Public Health Facilities and Access
   2.4 Literacy and Educational Status
   2.5 Schools and Universities

3. Economy
   3.1 Description of Major Sectors of Economy
   3.2 Employment and Income by Sector
   3.3 Production by Sector (Mining, refining, manufacturing, forestry, etc)
   3.4 Forecasts of Industrial Growth
   3.5 Inventory of major and minor industrial sites
   3.6 Inventory of Small businesses with water resource impacts
   3.7 Agricultural Production by Sub-sector
   3.8 Irrigated and Dryland Crop Acreage
   3.9 Livestock Census (types, number, management systems)
   3.10 Fisheries (wild caught and fish farming)
   3.11 Agricultural Inputs/Hectare/Crop
   3.12 Forecasts of Agricultural Growth
   3.13 Examples from Meghriget with MAPS/TABLES

4. Cultural/Historical Aspects of River Basin
   4.1 Historical Settlement and land use
   4.2 Historical water and resource use organizations and trends
   4.3 Culturally important uses of water and aquatic species

3. Diagram of Social/Economic Characterization Approach

Define the River basin for planning, and assign responsibilities between WRMA and BMOs according to river's international, national or local classification.

↓

Initial assessment of quality of data available. Budget for data collection process, including participatory diagnostic. Schedule **participatory work** (can be simultaneous to physical-biological-geographic characterization).

↓

Plan and begin execution of **participatory diagnostic interviews** or PRA sessions with rural village leaders, with farmers, and rural industries.

↓

Prepare maps and tables on social and economic characteristics of the basin, according to guidelines, using SWCIS, and information from other MNP agencies, Agriculture ministry, specialized institutes, and Marz governments.

↓

Have local experts review maps and tables for accuracy and to reveal data sources which have not yet been tapped.

↓

Combine **socio-economic data,** with physical, biological, and geographic data, and analyses of water use, water balance and geologic hazards, and stakeholder input to reveal major water resource issues of the river basin and document them in a River Basin Characterization Report.

4. Application of Method for Meghriget River Basin

A summary of this data is included in the Synthesis Report on Characterization of the Meghriget River Basin (after Section 1.7).

References:

GUIDELINE 1.3: WATER USE CHARACTERIZATION

1. Introduction:

1.1 Purpose of this guideline:
This guideline describes the way to collect water use data pertinent to characterizing a river basin, as the first step in river basin planning.

1.2 Role of this activity in river basin planning:
The water use characterization is a key part of the river basin characterization process. Water use, combined with hydrology, is the main factor affecting water supply and water quality. Addressing issues in water supply and water quality requires a detailed understanding, and quantification of existing water use. The water balance, and later, the pressures and impacts analysis, will use the water use information to calibrate those analyses.

2. Technical Approach to Inventory of Water Use Data

2.1 Methodology: Description and Justification
The inventory of water use data is primarily accomplished by research into sources of published information, including information published by local and national governments. Basin Management Organizations need to cultivate a close relationship with these organizations in order to facilitate the sharing of pertinent information.

Input Data Requirements
Water use data includes all withdrawal, use and wastewater discharges in a basin, as well as in-stream water uses. It is most logical to collect and organize water use data by economic sector, with the following being the principal sectors of interest:

- Municipal and Domestic Water Use and Wastewater Discharge
- Irrigation Water Use
- Industrial Water Use and Wastewater Discharge
- Recreation, Fisheries and Ecological Water Uses
- Hydropower Use

Each use sector will be treated separately in this characterization.

Municipal and Domestic Water Use and Wastewater Discharge
The municipal and domestic water use and wastewater discharge data is information about the quantity and quality of water diverted from surface waters or abstracted from groundwater to provide domestic and municipal water supplies, as well as the information on the quality, quantity and fate of the wastewater discharged from the same communities. This information is often managed by the health and sanitation departments of local governments or private water providers.

This information should be collected from local governments and private water suppliers, and checked against water use permits. Many small villages have rudimentary water supply systems with little data, and may not have water permits. The veracity of the data for these systems should be checked during field visits (this can be combined with field work done to characterize socio-economic data for the community). Information on number and status of latrines, sewage collection and wastewater treatment can be gathered from census data and/or local health officials or interviews with village leaders.

In some areas disposal of solid waste by dumping into rivers is common. A survey of household solid waste disposal practices, even an informal survey with village leaders, is useful to understand the potential impact of this practice on water quality.

Irrigation Water Use

Irrigation water use (and agricultural water use in general) is frequently the largest water use in a basin, and must be carefully quantified if basin water balance is to be understood. In some areas, surface water irrigation systems can be very complex, with a labyrinth of canals and drainage systems. In many cases, especially in more remote areas, little actual data on flows are measured or registered. In each case substantial effort must be devoted to understanding irrigation water use.

Irrigation withdrawals from surface water and groundwater must be quantified for all major irrigated farming areas in the river basin. State agricultural agencies, irrigation system managers, and irrigators' organizations may have the necessary data: quantified withdrawal data for different seasons, efficiency data on water conveyance and on-farm irrigation, etc. But in many cases it will be necessary to go to the field and make measurements or estimates of water diversion and efficiency. One of the most useful techniques is "synoptic" flow measurements, where many different sites in a basin are measured on one day to develop a better understanding of the proportion of water in each part of the water balance equation. This requires good flow measurement equipment, capable personnel and good logistical organization.

Consumptive use of water by crops can be estimated using standard references (already prepared for Armenia) if the actual area of each crop is known. The return flow of irrigation water to drainage systems, rivers, sumps and deep percolation is another aspect where good data are usually hard to find. However, it is very important to estimate the proportion of diverted or pumped water which directly or in-directly returns to the surface water system downstream.

Industrial Water Use and Discharge

Some small industries use the municipal water supply for their activities; but the focus here is on larger industries which have their own withdrawal points for water supply. In most cases these industries should have water use permits which quantify the water withdrawn, and provide some quality guidance on wastewater discharge.

For the purposes of a river basin plan, it is advisable to do enough field data collection to confirm that the quantities listed on water permits are good estimates of actual industrial use. Water permits often do not have a required amount of wastewater discharge, so it is difficult to estimate the amount of wastewater and the pollutant loads in wastewater. Reconnaissance-level sampling for this kind of wastewater data may be required to orient the river basin plan.

Recreational, Fisheries and Ecological Uses

Recreational, fisheries and ecological uses of water, such as in-stream flow, and maintenance of water levels in lakes and wetlands, are an important aspect of flow and especially water quality concerns in many basins. It is useful to describe and quantify, if possible, the characteristics of flow and water quality in specific areas of the river basin that have a high-value use for recreation or fisheries or other ecological aspects.

Hydropower

Hydropower uses river water by passing it through turbines to generate electricity. Hydropower facilities often store water so that power generation can respond to varying demand for power during the day and between seasons—large hydropower facilities can radically change river flow patterns.

Normally the only consumptive use of water by on-line hydropower facilities is due to excess evaporation from water stored behind dams. However, some hydropower facilities, depending on their type of construction, may involve diverting large quantities of water out of a river to a generation site located far downstream, where it is returned to the stream after passing through the turbines. In this case, the alteration to flow in that segment of stream or river immediately below the diversion can be quite dramatic.

It is important to describe the impact on flow in the river basin caused by hydropower facilities—changes in seasonal hydrograph, and daily variation in releases from storage reservoirs, for example.

2.2 Data availability and Data Collection—Where to acquire input data

Much of the required data should be available through the Basin Management Organization's water permit system, 2005 national census, the economic development offices of the Marz, Agriculture ministry, industry and trade organizations, and the Ministry of Nature Protection state agencies. Geographical data which is prepared on a national scale should be useful as a first approximation, once it is clipped from GIS files to apply it to the river basin of interest. Other data, which is of a more regional scale, may be identified by each BMO, especially in working with the Marz government agencies. It is recommended to budget time and personnel for some field data collection as part of the river basin characterization process. This is particularly important for certain types of data (see above) that are difficult to obtain without interviews or field sampling.

2.3 Analyses for Characterization of Water Use

Municipal Water/Wastewater

- Map of key sanitation infrastructure, including all potable water systems, wastewater treatment and solid waste handling and disposal sites.
- Data table detailing the existing potable water systems in the basin, water use in m^3/day, served population, type of water source, year of construction, etc.
- Data table on efficiency of water delivery at sample municipal systems (taking into account known and estimated losses)
- Data table on existing municipal wastewater treatment systems, including type of system, population served, year of construction, etc., daily volume of discharge, operating status.
- Estimate or inventory of on-site sewage disposal systems (septic systems) in the basin.
- Estimate of coverage of latrines or other types of on-site sanitary systems in villages.

Survey of solid waste disposal practices, focusing on use of waterways for isposal.Irrigation

- Map of the location of all major irrigation districts in the river basin, including major infrastructure (reservoirs, major diversions, large canals).
- Data on irrigation storage volumes in all reservoirs in the basin.
- Data table on the size (in users and hectares), of distinct irrigation districts, annual volume of water diverted or withdrawn, source waters, and the responsible management authorities.
- Data table on the approximate mix of crop types, predominant irrigation system types (flood, furrow, sprinkler, etc.), estimated efficiency of irrigation, and estimated annual consumptive use of water in each irrigation district.
- If appropriate, data on water quality effects of irrigation, especially salinization of surface waters in downstream areas.

Industrial Water and Wastewater

- Data table of all major industrial (including mining) water users in the basin, with the date of their water permit, location of withdrawal and annual withdrawal volume.
- Data table on all the major industrial water users with wastewater discharge in their water permits, estimated volume of annual discharge, and points of discharge.
- Data table reviewing the principal parameters of concern in each wastewater discharge permit.
- Data table on actual water quality in wastewater discharge for each major industrial facility, according to official measurements.
- Map of all industrial water/wastewater permits in the basin, with reference to codes in tables above.

Recreation, Fisheries and Ecological Water Use

- Map of areas intensively used for water-based recreation, especially swimming
- Data table of sample water quality measurements (especially micro-biological parameters) for intensively-used recreation areas
- Map of native fish diversity (areas with 1, 2, 3 or >3 native species still present) in the river basin, to indicate important sites for conserving aquatic bio-diversity
- Data table on annual take of commercial fisheries (if any) including species, and location

- Map of location of significant lakes, ponds, and wetlands, with code indicating their protection status.
- Text explaining the general water requirements for maintenance of existing wetland areas in the river basin.

Hydropower Water Use

- Data table explaining the location, size, reservoir storage capacity (if any) and ownership of hydropower facilities in the river basin.
- Data table explaining the monthly withdrawal of water for all hydropower facilities which withdraw water from a stream (off-stream generation).
- Data displaying daily variation in discharge from hydropower reservoirs.
- Data displaying annual variation in discharge from hydropower reservoirs.

2.4 Type and Format of Output Data

Examples of this approach to river basin characterization: water use

MUNICIPAL WATER USE:

Sub-basin:	Potable water Systems:	Population Served:	Volume extracted (m^3/day)	Source type:	Since Year:	Operator:
Meghriget (total)	Meghri town			River		
Lichq	Lichq village			Spring		
Tashtun	Tashtun village			River		
Agarak	Agarak town			Wells		
Shvanidzor	Shvanidzor village			Sub-surface springs		
Etc……………						

MUNICIPAL WASTEWATER SYSTEMS:

Sub-basin:	Location:	Population total:	Percent Population on sewer:	Daily discharge volume (m^3):	Type/status of ww treatment:
Meghriget	Meghri town				Oxygenated lagoon/non-functional
Lichq	Lichq				N.a.

SANITATION INFRASTRUCTURE: LATRINES AND SEPTIC SYSTEMS:

Sub-basin	Population total:	Percent Population without sewer:	Number of Latrines/% coverage of unsewered areas:	Number of septic systems with drainfields:
Meghriget				
Lichq				

IRRIGATION RESERVOIRS IN RIVER BASIN:

Sub-basin:	Name of reservoir:	Year constructed:	Total storage volume (m^3):	Dead storage volume (m^3):	Total volume available for irrigation (m^3):	Operator (agency):

Proposed Outline of Water Use Guideline:

1. Water Use by Sector (Urban, Industrial, Agricultural)
    *Surface Water Use (Percentage by sector, Withdrawals and Efficiency)
    *Groundwater Withdrawals (Withdrawals and Efficiency)
    *Recreation, Fisheries and In-stream Uses
2. Inventory of Water Withdrawal Permits
3. Estimates of non-permit water use
4. Inventory of Wastewater Discharges
5. Hydraulic Infrastructure--Capacities, condition, losses
    *Reservoirs
    *Irrigation Diversion and distribution systems
    *Hydropower Facilities
    *Potable Water Systems
    *Wastewater Treatment Systems
6. Water Demand Projections
7. Maps and Tables

3. Diagram of River Basin Characterization Approach (Water Use)

Define the River basin for planning, and assign responsibilities between WRMA and BMOs according to its international, national or local classification.

↓

Initial assessment of quality of data available. Budget for data collection process, including participatory diagnostic and additional field sampling. Schedule **sampling and participatory work** (can be simultaneous to physical-biological-geographic) characterization).

↓

Plan and begin execution of **sampling and participatory diagnostic interviews** with industries, rural village leaders, and with irrigator organizations.

↓

Prepare maps and tables on **water use characteristics** of the basin, according to guidelines, using SWCIS, field data, and information from other MNP agencies, Agriculture ministry, specialized institutes, and Marz governments.

↓

Have local experts review maps and tables for accuracy and to reveal data sources which have not yet been tapped.

↓

Combine **water use data** with **socio-economic data,** with **physical, biological, and geographic data**, water balance and geologic hazards, and stakeholder input to reveal **major water resource issues of the river basin.**

4. Application of Method to Meghriget River Basin

IRRIGATION DISTRICTS DATA:

Sub-basin:	Name of district:	Area under irrigation (ha)	Volume of water diverted (annual M3)	Sources of water	Number of irrigators:	Operator (agency):
Agarak	Agarak Irrigators	200	4.5 MM3	Araks river (pumped)	55	Agarak irrigators association

INDUSTRIAL WASTEWATER DISCHARGERS:

Sub-basin:	Name of Discharger:	Daily discharge Volume (m3):	Receiving water:	Key parameters:	Type/status of ww treatment:
Meghriget	Lichvaz Gold Project-Iberian Resources	5000	Meghriget river	Copper, pH, sulfate, turbidity	Tailings Pond with sub-drain

List of Maps for Water Use Characterization

1) Map of key sanitation infrastructure, including all potable water systems.
2) Map the location of all major irrigation districts in the river basin, including diversion, withdrawal, and storage sites.
3) Map of all industrial water/wastewater permits in the basin.
4) Map of areas intensively used for water-based recreation, especially swimming and boating
5) Map of location of significant lakes, ponds, and wetlands, with code indicating their protection status.

Proposed Outline of Water Use Characterization

1. Water Use by Sector (Municipal, Irrigation-Agricultural, Industrial, Recreation-Fisheries, Hydropower)
    - Surface Water Use (Withdrawals and Efficiency)
    - Groundwater Withdrawals (Withdrawals and Efficiency)
    - Recreation, Fisheries and In-stream Uses
2. Inventory of Water Withdrawal Permits
3. Estimates of non-permit water use
4. Inventory of Wastewater Discharges
5. Hydraulic Infrastructure--Capacities, condition, losses
    - Reservoirs
    - Irrigation Diversion and distribution systems
    - Hydropower Facilities
    - Potable Water Systems
    - Wastewater Treatment Systems
6. Current Water Supply Stresses and Conflicts
7. Water Demand Projections

5. Application of Method to Meghriget River Basin:

A summary of initial analysis of this data is included in the Synthesis Report on Characterization of the Meghriget River Basin (after Section 1.7).

References:(includes personal contacts)

GUIDELINE 1.4: CALCULATION OF WATER BALANCE

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to present a feasible method for calculation of water balance in river basins, which among other advantages, will also provide an opportunity to decision makers in the water sector to issue water use permits based on reliable information. Several works on water balance have already been implemented in Armenia. One of the main advantages of this guideline is that it also proposed a method for calculation of water balance for ungauged river basin. In addition, a special computer program has been developed for calculation of water balance.

1.2 Role of this Activity in River Basin Planning

Calculation of water balance for river basin has an important role in river basin planning, and should be done as part of basin characterization. The water balance analysis is critical for understanding the relationship between water availability and water use in the basin. In the case of Armenia, monthly water balances are important to understand seasonal water shortages. Particularly, it provides for issuing water use permits based on reliable information, as well as defining realistic objectives for river basin management and maintenance, and thus, identifying necessary implementation measures for achieving the environmental objectives of a river basin plan.

2. Technical Approach

2.1 Methodology: Approach and Justification

Water balance is a relation of water inflow, outflow and accumulation (change of storage) in any river basin or water object in a given period (year, month, decade and other). The method is based on the following: the difference of the volume of water inflow and the volume of water outflow in any watershed area should be equal to the change in water quantity (increase or decrease in volume stored) within the given watershed area. The water balance quantitatively represents water circulation in nature, particularly the critical relationship between precipitation, evaporation and runoff.

The differentiated equation for calculating multi-year average water balance in the Republic of Armenia has the following form:

$$X=Y+E=Y_{riv}\pm Y_{deep}+E,$$

where X is atmospheric precipitation, Y is the river flow, E is total evaporation, Y_{deep} is the deep flow (deep percolation).

2.2 Input Data Requirement

The following data is required to input for calculating water balance: topography, atmospheric precipitation, temperature, total evaporation and river flow for gauged basins. As for deep flow, it is calculated using the remnant of water balance (difference of climatic flow (precipitation minus evaporation) and river flow). Topography is needed because precipitation and temperature vary dramatically with altitude, but in predictable ways. Therefore, precipitation and temperature inputs are distributed according to altitude zones, usually be 1000-meter vertical increments (1000-2000 meters, 2000-3000 meters, etc.)

In Armenia, the majority of annual river flow is generated by spring snowmelt at higher elevations, therefore the topographic form of a basin is a critical factor in understanding how much runoff will be generated.

For ungauged basins, it is necessary to have mean precipitation and minimum, mean and maximum temperature data, and solar radiation, from which it is possible to calculate evapotranspiration and river flow. For the examples shown in Armenia, mean monthly data is used.

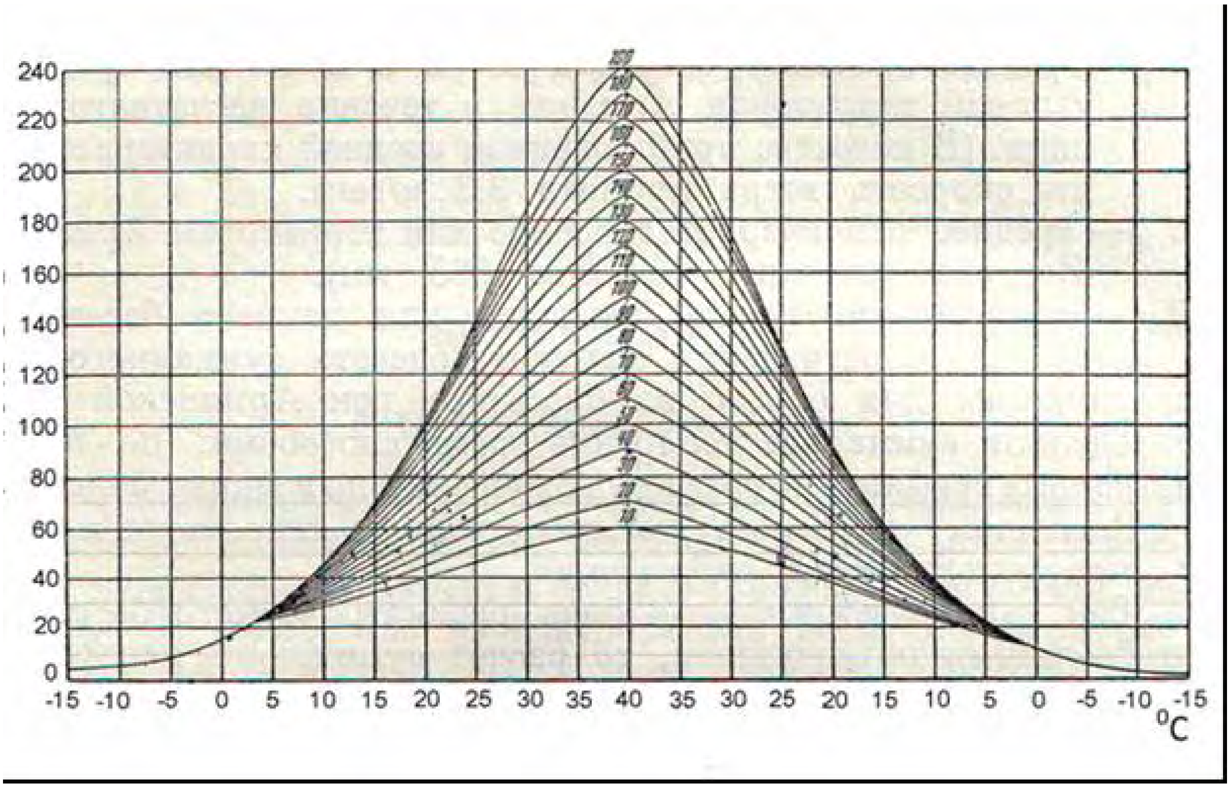
The interactive computer program developed as part of this Guideline has databases for precipitation by altitude, temperature by altitude, and solar radiation for Armenia, therefore that input data is already provided.

2.3 Where to Acquire Input Data

Topographic data for each river basin should be available from topographic maps. Separate each altitudinal zone (0-1000 meters, 1000-2000 meters, 2000-3000 meters, and 3000-4000 meters) on the topographic map and calculate the surface area of each zone (in km^2). This is more easily done with a Geographic Information System, but it can be done by hand if necessary.

In order to determine atmospheric precipitation in each river basin it is necessary first of all to use data presented in the table of Appendix 6.1. The table shows the list of meteorological stations for calculating the average monthly precipitation in the river basin. Appendix 6.2 presents the calculation scheme for observation points to be used and river basins. Thus, from Appendix 6.1 and Appendix 6.2 we select the calculation meteorological stations, after which the average monthly atmospheric precipitations are taken in mm for the selected stations, as presented in Appendix 6.3.

In order to calculate the total evaporation for gauged basins it is suggested to use the method proposed by Valesyan. For that, first of all, average monthly air temperatures are obtained for all altitude zones of the river basin (see Appendix 6.4), and then the following graph, developed by V. Valesyan is used:



River flow is calculated using data from hydrological observation points.

As of calculation of water balance for ungauged river basins, a special interactive computer program has been developed for that purpose. In order to calculate the water balance it is necessary to input into the program the required data, after which the program automatically makes corresponding calculations, as a result of which water balance for ungauged river basins is obtained.

The following data are required to enter in the input data section of the program:

- name of the river basin,
- river basin area divided according to the following altitude zones: <1000m, 1000-2000m, 2000-3000m and >3000m,
- average monthly precipitation for each altitude zone,
- minimum, average and maximum monthly air temperatures for all altitude zones, for which the publication "Reference Book on the Climate of USSR, Volume 16, Air and Soil Temperature" can be used, and
- radiation, value of which is constant for a given month (ungauged basins method). For ungauged basins, the data for radiation was taken from FAO, 1998, "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements," FAO Irrigation and Drainage Paper 56, Rome, (Hargreaves method), http://www.fao.org/docrep/X0490E/x0490e00.HTM

2.4 Explanation of Analysis Procedures

A special interactive computer program has been developed for calculation of water balance. Detailed explanation of analysis procedures is provided in Appendix 6.5 of this guideline.

2.5 Type and Format of Output Data

The water balance for gauged basins is presented as a monthly balance of precipitation, evaporation (evapotranspiration), river flow, and deep flow (percolation). Due to the nature of the snow-melt dominated hydrologic cycle in Armenia, the precipitation inputs and the sum of evaporation, river flow and deep flow outputs do not balance on a monthly basis---snow accumulates in winter, and river flow peaks as snowmelt proceeds in spring. The final water balance is annual: total precipitation input equals the sum of evaporation, river flow and deep flow each "water year." A water year is calculated from October to September, because that way the whole winter snow/spring snowmelt cycle is included in a single year. A sample of the output table is presented below:

Table 1 – Sample output table

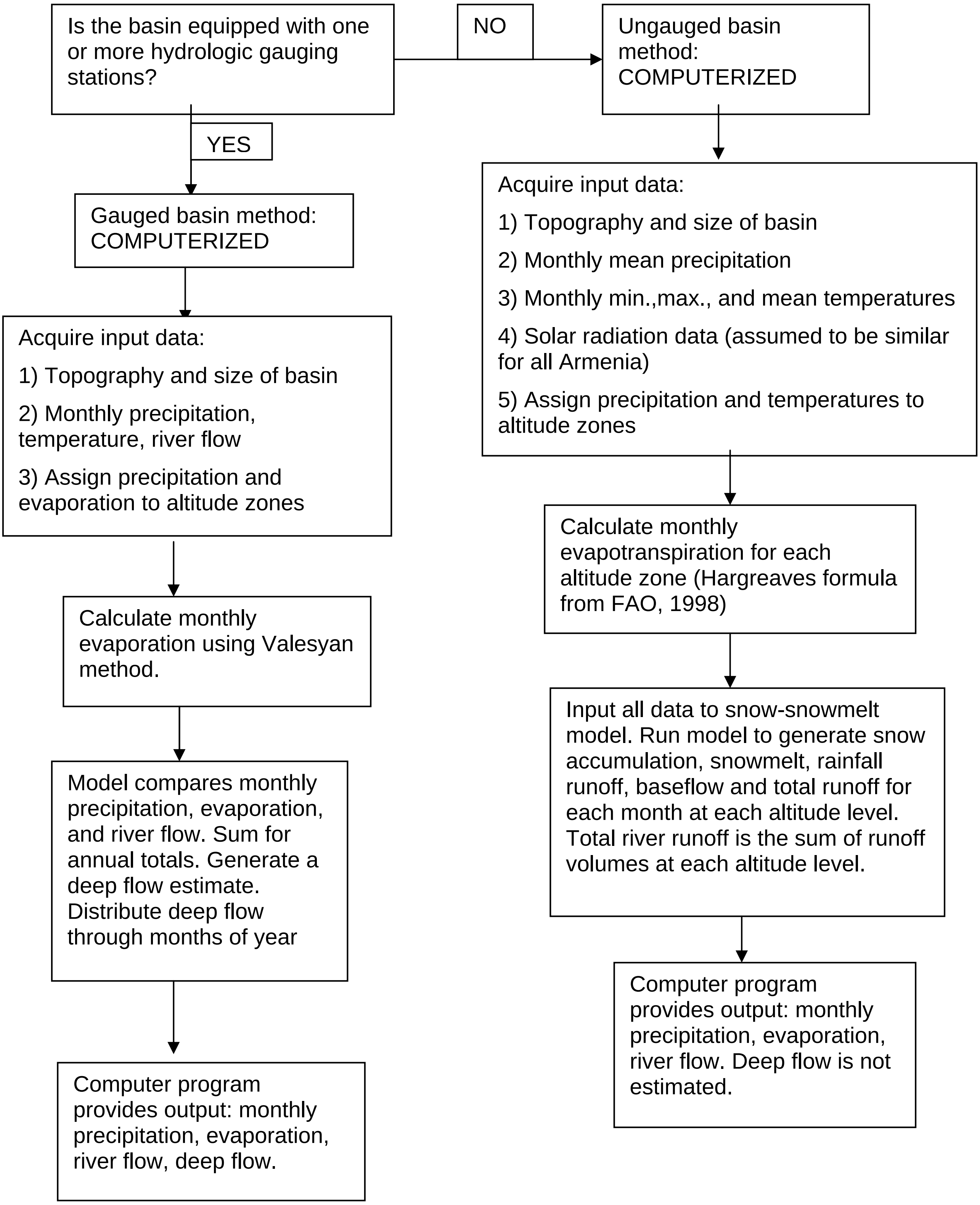
Month	Precipitations, mln. m^3	Total evaporation, mln. m^3	River flow, mln. m^3	Deep flow, mln. m^3
	X	E	Y	Y_{deep}

The ungauged basin method is similar, but the deep flow is not calculated. As a result of application of these methods the water balance for the river basin is obtained in mln. m^3 and also millimeters of water over the basin area, which are presented for each month, and for the year.

2.6 Computer Programs or Other Aid Tools

For calculation of water balance a special interactive computer program has been developed. After entering the required input data the program provides methods for automatically calculating the water balance both for gauged and ungauged river basins. Details of the computer program are presented in Appendix 6.5 of this Guideline.

3. Flow Chart of Water Balance Calculation Methods



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

In order to calculate water balance of Meghriget River basin it is necessary to divide the basin according to hypsometric altitudes. Afterwards, for each altitude zone corresponding input data needs to be inserted into the computer program. After inputting the required data into the computer program the monthly water balance of the river basin is obtained by computerized calculations, based on one of two methods: simple water balance for gauged basins, and a snow/snowmelt model for ungauged basins.

4.2 Examples of Input Data (Tables)

The following data is used as input data for calculation of water balance of Meghriget River basin: area of the basin according to hypsometric altitudes, use meteorological observation points, average monthly temperature in Meghriget River basin by altitude zones, as well as natural river flow of Meghriget River basin. After inputting the above-mentioned data the computer program calculated the water balance for the river basin.

Table 2 - Meghriget River Basin by hypsometric altitudes (1000 m intervals)

Altitude (m)	Area (km^2)	% of total area
<1000	19.54	5.8
1000-2000	183.33	54.5
2000-3000	102.97	30.6
>3000	30.63	9.1
Total	336.47	100.0

Table 3 - Used meteorological observation points from nearby areas of Armenia:

Observation Point	Absolute Altitude, m
Meghri	627
Qajaran	1842
Vorotan mountain pass	2031
Aragats high mountainous	3227

Table 4 - Average monthly air temperature in Meghriget River basin according to altitude zones

Alt./month	1	2	3	4	5	6	7	8	9	10	11	12
0-1000	1.6	3.5	8.0	14.1	18.8	23.1	26.3	25.8	21.4	15.3	9.2	4.0
1000-2000	-3.4	-1.5	2.0	8.1	12.8	17.1	20.3	20.8	16.4	10.3	4.2	-1.0
2000-3000	-8.4	-6.5	-4.0	2.1	6.8	11.1	14.3	14.8	10.4	5.3	-0.8	-6.0
>3000	-13.4	-11.5	-10.0	-3.9	0.8	5.1	8.3	8.8	4.4	-.07	-6.8	-11.0

Table 5 - Values of average monthly evaporation in Meghriget River basin according to altitude zones, in mm (calculated by Valesyan method)

Altitude zone, m	Area, km^2	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
<1000	19.54	20	22	30	43	53	62	44	45	40	38	22	17
1000-2000	183.33	12	17	19	33	50	53	44	44	38	30	19	12
2000-3000	102.97	6	8	10	20	27	40	40	40	31	22	13	8
>3000	30.63	4	5	7	10	18	27	27	27	19	14	4	2

Table 6 - Natural flow of Meghriget River Basin (actual flow adjusted due to withdrawals and return flows)

Month	Natural flow, mln. m^3	Flow in the lower section of the river basin, mln. m^3	Water intake from river, mln. m^3	Volume of water return flow after water use, mln. m^3
	Y	Y_i	Y_a	Y_b
I	2.39	2.36	0.04	0.01
II	2.58	2.57	0.01	0.00
III	5.01	4.98	0.04	0.01
IV	14.83	14.54	0.36	0.07
V	19.93	19.49	0.55	0.11
VI	21.69	21.07	0.77	0.15
VII	12.12	11.61	0.64	0.13
VIII	4.48	4.04	0.55	0.11
IX	2.59	2.38	0.26	0.05
X	2.7	2.67	0.04	0.01
XI	2.96	2.95	0.01	0.00
XII	2.63	2.62	0.01	0.00

4.3 Examples of Output Data (Tables)

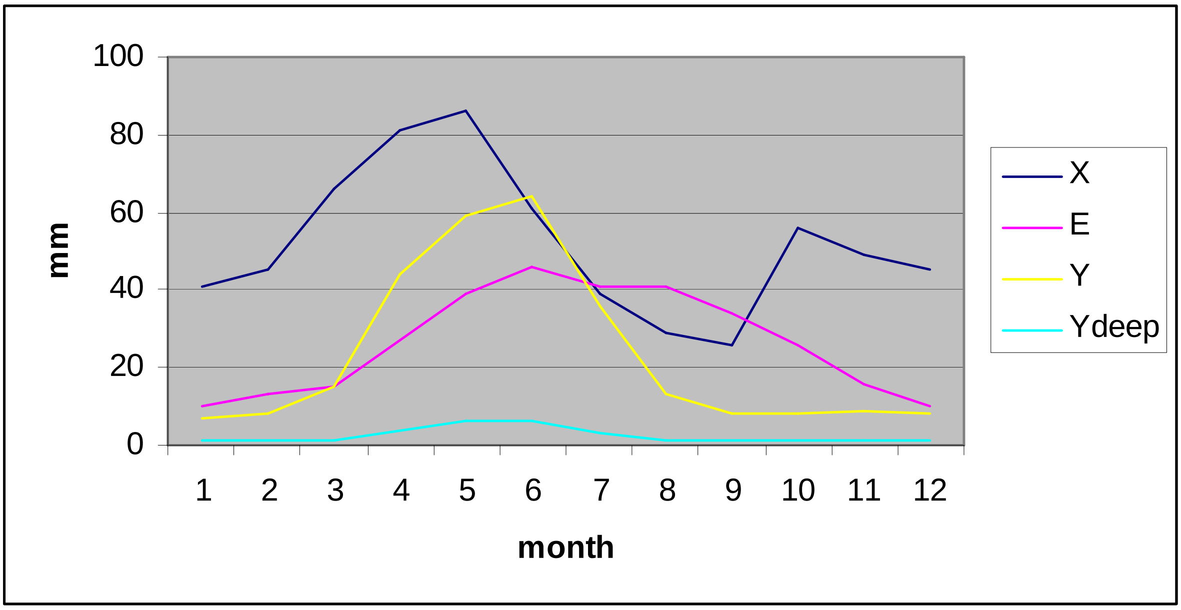
As a result of project implementation the water balance of Meghriget River Basin by months will be obtained as output data.

Table 7 - Water balance of Meghriget River Basin, Calculated using river gauge data, mln m^3

Month	Precipitations, mln. m^3	Total evaporation, mln. m^3	River flow, mln. m^3	Deep flow, mln. m^3
	X	**E**	**Y**	Y_{deep}
I	13.64	3.33	2.39	0.22
II	15.31	4.39	2.58	0.24
III	22.07	5.13	5.01	0.47
IV	27.12	9.02	14.83	1.39
V	28.96	13.16	19.93	1.87
VI	20.55	15.53	21.69	2.04
VII	13.10	13.77	12.12	1.14
VIII	9.72	13.79	4.48	0.42
IX	8.69	11.45	2.59	0.24
X	18.96	8.77	2.7	0.25
XI	16.37	5.31	2.96	0.28
XII	15.26	3.36	2.63	0.25
Total	209.75	107.01	93.91	8.83

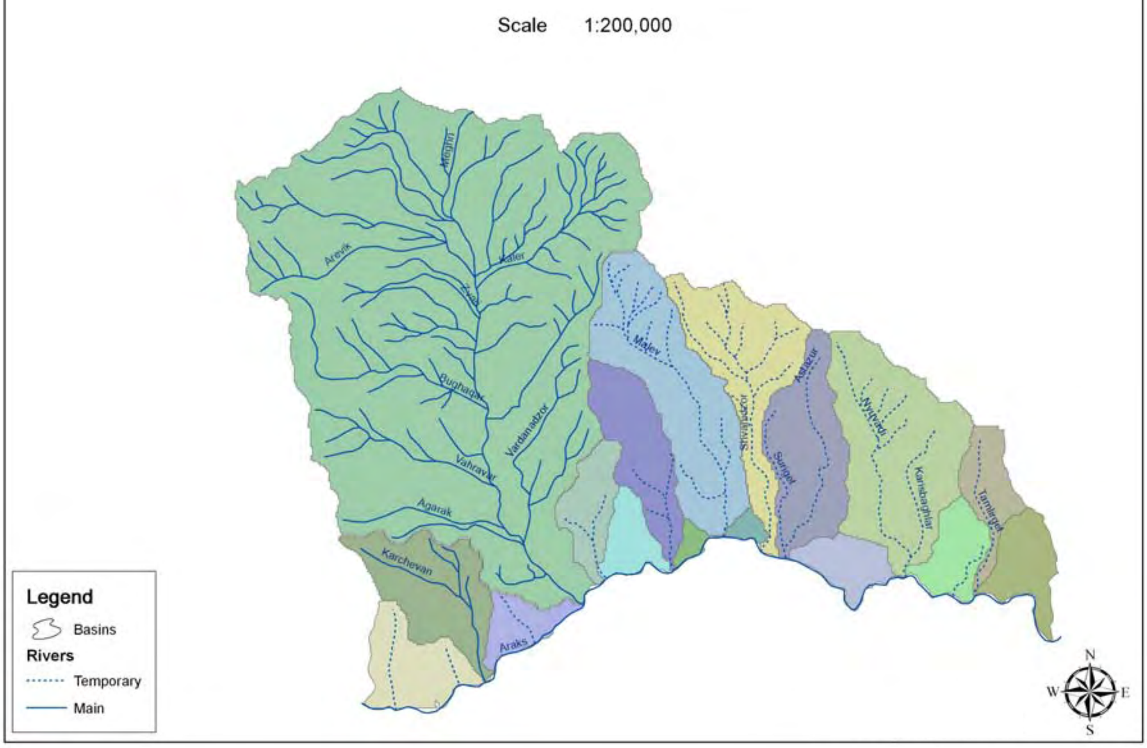
Table 8 - Water balance of Meghriget River Basin, Calculated using river gauge data, mm

Month	Precipitation, mm	Total evaporation, mm	River flow, mm	Deep flow, mm
	X	E	Y	Y_{deep}
I	41	10	7	1
II	45	13	8	1
III	66	15	15	1
IV	81	27	44	4
V	86	39	59	6
VI	61	46	64	6
VII	39	41	36	3
VIII	29	41	13	1
IX	26	34	8	1
X	56	26	8	1
XI	49	16	9	1
XII	45	10	8	1
Total	624	318	279	27

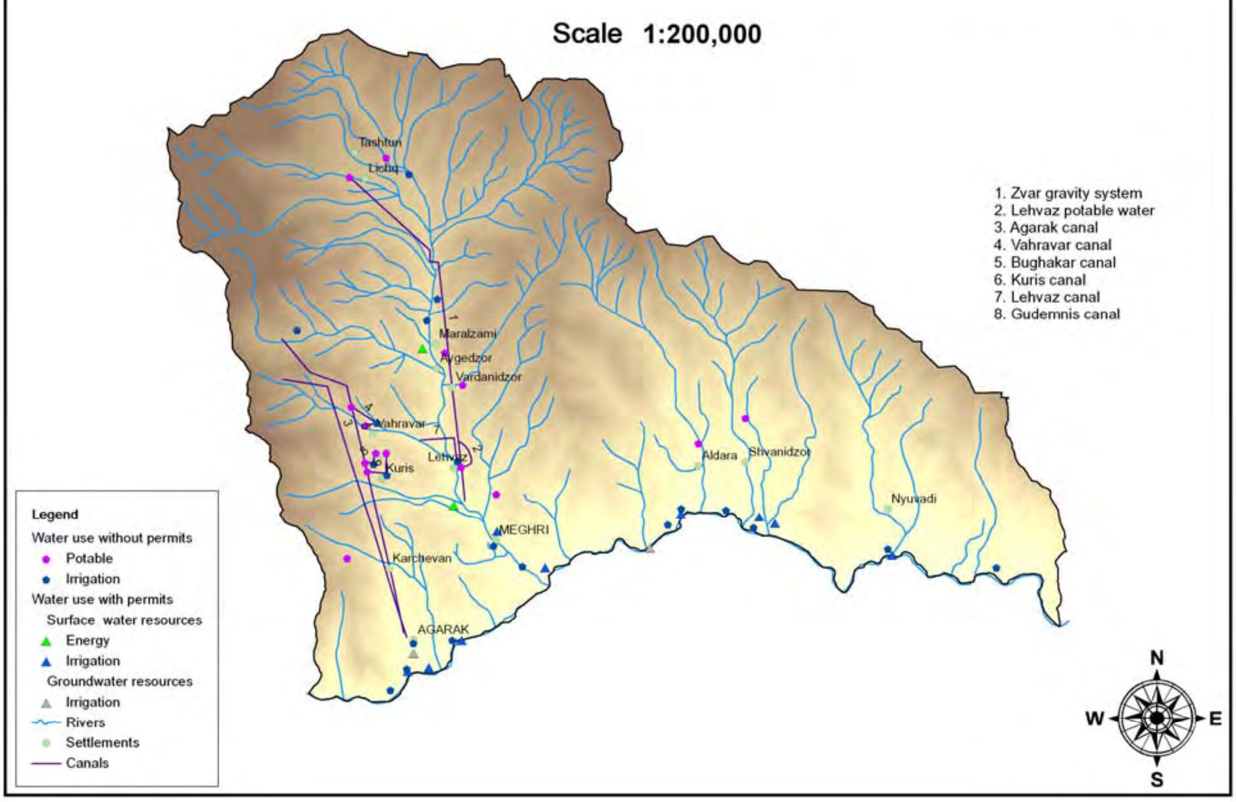


4.4 Maps of Application of the Method

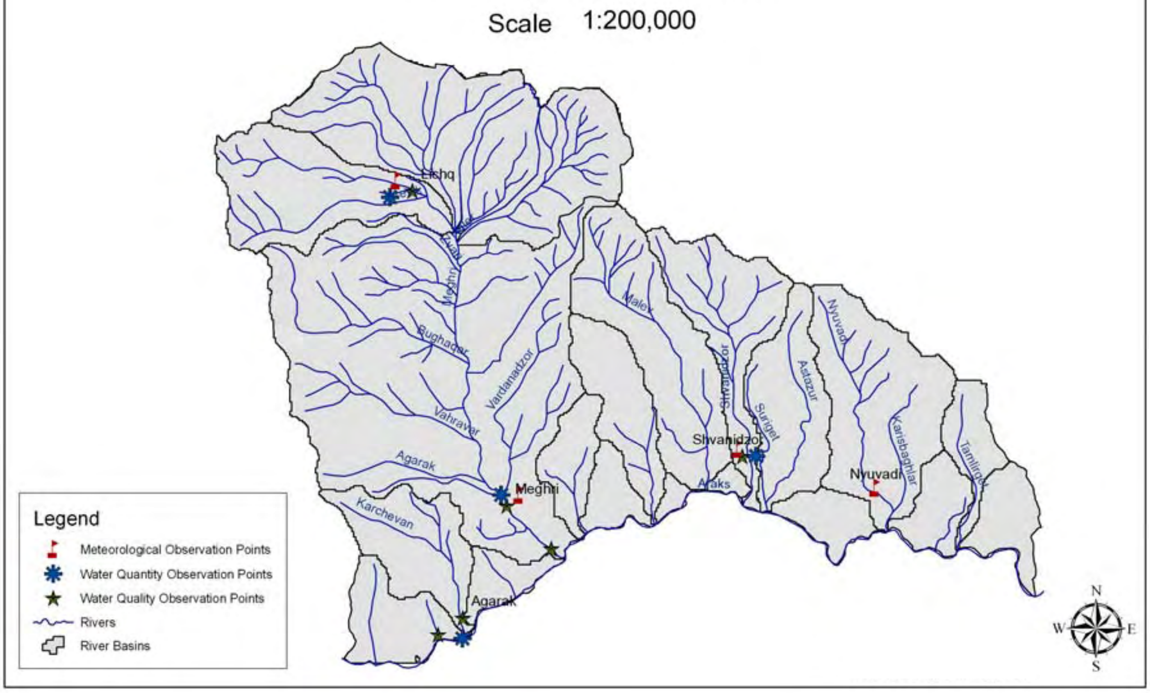
Map of Meghriget River and Small Tributaries of Araks River



Water Use Within Basins of Meghriget River and Tributaries of Araks River



Meteorological, Water Quantity and Water Quality Observation Points in Meghriget River Basin



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6. Annexes

Appendix 6.1 - Meteorological stations of Armenia, their altitude, as well as proposed calculation region

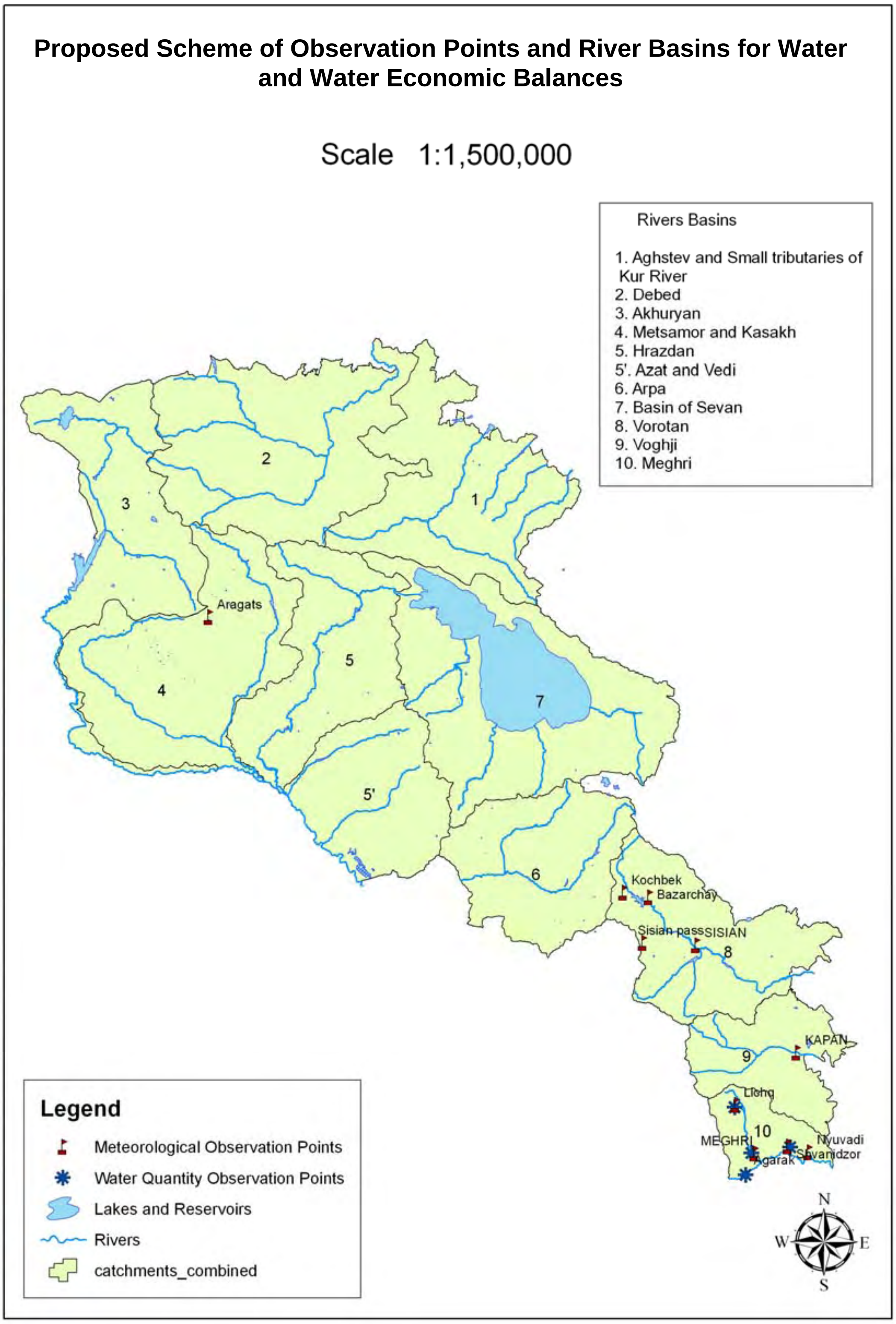
No.	Station	Altitude, m	Hydrological Region	River Basin	Calculation region *
1.	Aygedzor	740	I	Tributaries to Kura River	1
2.	Haykavan	1600	II	Akhuryan	3
3.	Amasia	1876	II	Metsamor	3
4.	Amberd	2074	II	Hamberd	4
5.	Hanqavan	1992	III	Hrazdan	5
6.	Aparan	1889	II	Kasakh	4
7.	Aragats high mountainous	3227	II	Hamberd	4
8.	Ararat	1256	V	Vedi	5'
9.	Areni	1009	VI	Arpa	6
10.	Armavir	861	II	Metsamor	4
11.	Artashat	829	V	Azat	5'
12.	Artik	1724	II	Akhuryan	3
13.	Akhurik	1470	II	Akhuryan	3
14.	Ashotzq	2015	II	Akhuryan	3
15.	Ashtarak	1090	II	Kasakh	4
16.	Bagratashen	450	I	Debed	2
17.	Unnamed mountain pass	2122	V	Vedi	5', 8
18.	Berd	717	I	Tributaries to Kura River	1
19.	Vanadzor	1376	I	Pambak	2
20.	Vorotan mountain pass	2031	VII	Vorotan	6, 9, 10, 8
21.	Gavar	1961	IV	Vagaraget	7
22.	Garni	1422	V	Azat	5'
23.	Garnahovit	2169	II	Karkachun	4, 3
24.	Goris	1493	VIII	Vorotan	8
25.	Gyumri	1525	II	Akhuryan	3
26.	Daranak	1915	IV	Sevan	7
27.	Jajur railway station	1792	II	Akhuryan	2, 3
28.	Jermuk	2064	VI	Arpa	8
29.	Dilijan	1254	I	Aghstev	1
30.	Yeghvard	1336	III	Kasakh	4
31.	Yeratmber	3101	III	Hrazdan	Applies to all
32.	Yerevan, Arabkir	906	III	Hrazdan	5
33.	Yerevan, agro	942	III	Hrazdan	5
34.	Yerevan, Erebuni	1316	III	Hrazdan	5
35.	Yeghegnadzor	1267	VI	Yeghegis	6
36.	Ijevan	732	I	Aghstev	1
37.	Kajaran	1842	VII	Voghji	9
38.	Kapan	705	VII	Voghji	9
39.	Martuni	1945	IV	Sevan	7
40.	Masrik	1940	IV	Masrik	7
41.	Meghri	627	VII	Meghriget	10
42.	Odzun	1127	I	Debed	2
43.	Paghakn	2005	II	Akhuryan	3

No.	Station	Altitude, m	Hydrological Region	River Basin	Calculation region *
44.	Pushik mountain pass	2066	I	Pambak	2
45.	Hrazdan	1765	III	Hrazdan	5
46.	Sevan, hydromet station	1936	IV	Sevan	5
47.	Sevan, lake	1913	IV	Sevan	7, 5
48.	Semyonovka	2104	IV	Dzknaget	1, 5, 7
49.	Sisian	1580	VIII	Vorotan	9, 10, 8
50.	Sisian mountain pass	2380	VIII	Vorotan	2
51.	Spitak	1552	I	Pambak	2
52.	Stepanavan	1397	I	Chqnagh	3, 4
53.	Talin	1582	II	Mastara	2
54.	Tashir	1507	I	Tashir	5'
55.	Urtzadzor	1064	V	Vedi	5
56.	Fontan	1800	III	Hrazdan	4
57.	Tsaghkahovit	2099	II	Kasakh	7
58.	Chambarak	1853	IV	Getik	1
59.	Shnogh	660	I	Debed	2
60.	Shorzha	1922	IV	Sevan	7
61.	Nerqin Shorzha	2365	IV	Sevan	7
62.	Yangh	2334	IV	Sevan	7

* Notation

1	Aghstev and tributaries to and Kura
2	Debed
3	Akhuryan
4	Metsamor (including Kasakh)
5	Hrazdan
5'	Azat and Vedi
6	Arpa
7	Sevan basin
8	Vorotan
9	Voghji
10	Meghri

Appendix 6.2 – Proposed calculation scheme of use for observation points and river basins



Appendix 6.3 - Quantity of multi-year average monthly precipitation recorded in meteorological stations, mm

No.	Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	Aygedzor	18	24	38	53	85	86	43	40	33	45	27	18
2.	Haykavan	18	20	19	39	74	45	26	20	24	28	19	16
3.	Amasia	42	50	48	78	107	84	52	41	31	47	49	55
4.	Amberd	57	62	68	80	97	54	30	20	23	52	50	61
5.	Hanqavan	51	56	69	94	121	100	62	41	37	61	57	50
6.	Aparan	45	56	66	83	88	90	75	51	35	52	57	53
7.	Aragats high mountainous	77	82	109	123	114	81	61	50	38	81	95	89
8.	Ararat	16	19	24	34	38	24	7	8	7	22	22	16
9.	Areni	26	30	40	53	45	34	13	9	10	30	23	28
10.	Armavir	17	20	23	32	45	24	12	8	9	27	18	15
11.	Artashat	16	16	23	28	34	18	7	5	7	20	18	15
12.	Artik	22	28	41	69	94	85	42	37	27	54	34	26
13.	Akhurik	19	26	28	52	88	62	39	36	23	42	28	19
14.	Ashotzq	28	34	33	61	101	88	50	43	31	43	39	35
15.	Ashtarak	26	30	34	51	58	32	18	11	11	36	28	30
16.	Bagratashen	21	29	39	52	76	80	46	36	35	38	30	19
17.	Unnamed mountain pass	46	53	65	83	85	45	18	15	13	43	37	50
18.	Berd	22	27	37	50	73	67	41	29	35	43	28	17
19.	Vanadzor	18	25	36	63	96	95	58	43	32	47	33	19
20.	Vorotan mountain pass	46	53	75	94	105	72	53	36	31	69	43	50
21.	Gavar	19	24	36	41	73	74	53	51	38	38	28	27
22.	Garni	35	41	55	75	82	42	16	11	15	41	38	37
23.	Garnahovit	24	30	48	80	112	89	55	36	30	56	34	26
24.	Goris	35	42	75	95	112	99	51	53	61	74	47	34
25.	Gyumri	24	29	32	61	86	72	45	33	20	40	29	24
26.	Daranak	17	24	28	43	60	68	49	33	31	42	30	24
27.	Jajur railway station	28	30	40	69	102	83	44	34	30	45	36	33
28.	Jermuk	63	73	84	102	95	71	40	29	23	72	53	73
29.	Dilijan	23	33	47	67	107	104	67	53	40	53	40	23
30.	Yeghvard	33	37	42	62	63	39	19	12	14	41	34	36
31.	Yeratmber	79	84	99	93	90	71	46	33	34	63	70	69
32.	Yerevan, Arabkir	29	38	41	51	60	29	14	9	9	32	30	26
33.	Yerevan, agro	24	26	33	41	48	23	13	9	9	31	24	26
34.	Yerevan, Erebuni	22	25	30	37	44	21	9	8	8	27	23	23
35.	Yeghegnadzor	33	36	45	59	60	46	21	17	15	40	29	35
36.	Ijevan	24	34	43	64	97	91	51	42	38	52	35	21
37.	Kajaran	47	54	88	104	96	66	27	20	31	61	57	54
38.	Kapan	28	32	60	80	96	68	31	30	43	55	40	27
39.	Martuni	25	34	45	59	73	67	34	31	30	46	32	28
40.	Masrik	19	23	30	44	64	71	48	33	28	47	28	24
41.	Meghri	16	16	35	42	49	31	10	10	13	30	23	15
42.	Odzun	21	29	37	61	94	103	61	47	39	42	30	18
43.	Paghakn	28	40	39	65	110	81	56	52	33	34	33	36
44.	Pushkin mountain pass	35	47	65	86	136	112	70	68	50	64	46	33
45.	Hrazdan	54	60	64	87	100	64	40	24	28	62	57	53
46.	Sevan hydrometerological staion	26	33	43	68	96	81	46	33	33	51	35	26
47.	Sevan, lake	16	23	33	60	87	78	44	33	25	49	31	18
48.	Semyonovka	36	49	62	86	112	105	69	46	42	66	56	40
49.	Sisian	16	23	35	53	69	54	26	15	19	39	25	19

No.	Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
50.	Sisian mountain pass	47	62	72	99	104	70	40	26	33	63	51	65
51.	Spitak	14	18	26	51	78	80	44	35	29	42	26	16
52.	Stepanavan	22	34	41	71	123	126	75	57	41	49	34	20
53.	Talin	26	30	38	56	79	54	31	22	17	39	26	23
54.	Tashir	20	30	38	68	125	127	83	55	46	44	30	20
55.	Urtzadzor	26	32	40	53	55	35	13	12	10	35	32	27
56.	Fontan	43	53	60	92	100	59	36	22	23	66	59	53
57.	Tsaghkahovit	19	27	40	61	82	74	64	53	26	49	33	16
58.	Chambarak	22	30	43	60	98	95	63	45	40	58	41	26
59.	Shnogh	19	28	35	53	75	82	47	39	32	38	27	15
60.	Shorzha	14	19	27	47	72	69	51	38	27	44	26	18
61.	Nerqin Shorzha	26	33	43	53	68	91	67	46	34	49	34	39
62.	Yangh	23	24	41	61	78	62	32	28	22	44	36	27

Appendix 6.4 - Average monthly air temperatures

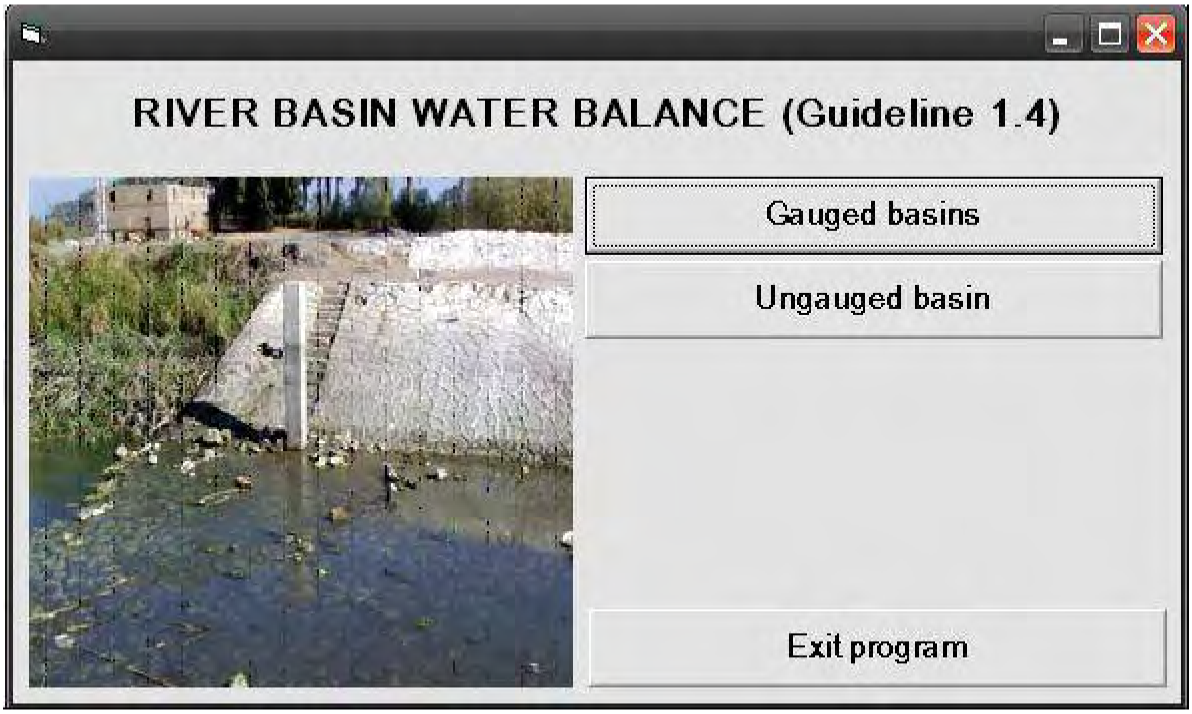
No	Station	Alt., m.	River Basin	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	Amasia	1876	Metsamor	-8.9	-7.2	-2.9	4	9.1	12.7	16.4	16.1	12.6	6.6	0.4	-5.6
2.	Amberd	2074	Hamberd	-7.4	-6.1	-1.5	4.6	9.6	13.8	18.1	17.8	13.9	7.1	1.3	-4.3
3.	Hanqavan	1992	Hrazdan	-7.8	-6.6	-2.7	3.5	8.4	11.5	14.9	14.5	11.1	5.6	0.5	-5
4.	Aparan	1889	Kasakh	-9.1	-7.8	-2.7	4.5	9.5	13.1	16.9	16.5	12.7	6.3	0.5	-5.6
5.	Aragats high moutain	3227	Hamberd	-12.6	-11.8	-9.9	-4.9	-0.5	3.9	8.9	8.8	5.1	-1.2	-6.8	-10.4
6.	Ararat	1256	Vedi	-3.4	-0.6	6.4	13.2	18	22.3	26.4	25.5	20.8	13.3	6.3	0.5
7.	Areni	1009	Arpa	-2.5	-0.3	5.6	12	17	21.1	26.2	25.6	20.9	13.4	6.7	0.8
8.	Armavir	861	Metsamor	-4.5	-1.5	5.4	12.5	17.3	21.6	25.6	24.7	19.7	12.3	5.6	-0.2
9.	Artashat	829	Azat	-3.4	-0.8	6.1	12.9	17.6	21.6	25.5	24.4	19.7	12.7	5.9	0.4
10.	Artik	1724	Akhuryan	-7.4	-5.8	-0.7	6.3	10.9	14.5	18.6	18.2	14.4	8.1	2	-4.1
11.	Ashotzq	2015	Akhuryan	-12.1	-10.9	-5.6	2.4	7.7	11.1	14.6	14.2	10.5	4.3	-1.8	-8.4
12.	Bagratashen	450	Debed	0.1	1.5	5.9	11.6	16.3	20.2	23.3	22.4	18.4	12.6	6.9	2.4
13.	Unnamed mountain pass	2122	Vedi	-7.1	-6.2	-2.2	4	9.1	13.6	18	17.8	14.1	7.3	1.2	-4.2
14.	Berd	717	Tributaries to Kura	0.4	1	4.7	10.6	15.4	19.3	22.5	21.5	17.6	11.6	6.9	2.7
15.	Vanadzor hydro-met st.	1376	Pambak	-3.1	-2	1.9	7.7	11.9	15.1	18.2	17.6	14.4	8.7	4.1	-0.3
16.	Vorotan mountain pass	2031	Vorotan	-8.7	-7.9	-4.4	1.2	6.4	10.3	13.2	12.9	10.4	4.6	-0.5	-6
17.	Gavar	1961	Gavaraget	-7.2	-6.8	-2	4.3	9	12.4	15.7	15.3	11.9	6.5	1.1	-4.1
18.	Garni	1422	Azat	-4.9	-3.2	2.4	8.9	13.7	17.9	21.8	21	16.6	9.9	4.1	-1.8
19.	Garnahovit	2169	Karkachun	-7.2	-6.6	-2.9	3.2	8.4	12.1	16.4	16.4	12.8	6.3	0.8	-4.6
20.	Goris	1493	Vorotan	-0.9	-0.4	2.7	8.3	12.5	16	18.8	17.8	14.3	9.2	5.6	1.8
21.	Gyumri	1525	Akhuryan	-9.2	-7.4	-0.8	6.7	11.4	15.3	19.5	19.1	15	8.2	1.6	-5
22.	Jajur railway station	1792	Akhuryan	-7.4	-6.2	-1.5	5.2	10	13.5	17.1	16.8	13.5	7.5	1.4	-4.5
23.	Jermuk	2064	Arpa	-7.7	-6.5	-2.4	3.6	8.7	12.7	16.3	16.2	12.9	6.3	0.7	-4.8
24.	Dilijan	1254	Aghstev	-1.8	-1.1	2.3	7.9	11.7	15	18.3	17.5	13.9	8.6	4.5	0.6
25.	Yeghvard	1336	Kasakh	-5.2	-3.1	2.8	9.3	14.1	18.5	22.5	22.2	18.3	11.3	4.7	-1.3
26.	Yeratmber	3101	Hrazdan	-12.8	-12.5	-9.9	-4.5	0.2	4.7	8.6	8.9	5.4	-1	-6.3	-10.7
27.	Yer., Arabkir	906	Hrazdan	-3.2	-1	5.1	11.6	16.3	20.6	24.6	23.9	19.8	12.8	6.6	0.5
28.	Yer., agro	942	Hrazdan	-4.1	-1.7	5.3	12.1	16.9	21.5	25.6	24.9	20.3	12.9	5.9	-0.5
29.	Yer., Erebuni	1316	Hrazdan	-3.5	-0.9	5.9	12.7	17.4	21.9	25.8	25.3	20.7	13.3	6.5	0.4
30.	Yeghegnad zor	1267	Yeghegis	-3.7	-1.8	4	9.8	14.9	19.6	23.9	23.4	19.7	12.2	5.8	0.3
31.	Ijevan	732	Aghstev	0.9	1.6	5	10.7	14.9	18.6	21.9	21.1	17.4	11.5	7.1	3.4
32.	Kajaran	1842	Voghji	-2.3	-2.5	0.6	6.9	9.9	13.7	16.7	15.9	13.2	7.6	3.7	-0.3
33.	Kapan	705	Voghji	0.6	1.9	5.6	11.8	16.3	20.3	23.6	22.8	18.7	12.6	7.6	2.9
34.	Martuni	1945	Sevan	-5.8	-5.8	-1.5	5.1	9	13.1	16.4	15.9	13	7.8	2.6	-2.7
35.	Masrik	1940	Masrik	-8.6	-8.3	-2.8	4.4	9.3	13	16.5	16	12.6	6.6	0.9	-5.2

No	Station	Alt., m.	River Basin	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
36.	Meghri	627	Meghriget	1.6	3.3	8.2	14.1	18.8	23.1	26.3	25.4	21.2	14.7	9.5	4.7
37.	Odzun	1127	Debed	-1.1	-0.5	3.2	8.8	12.8	16.2	19.4	18.7	15.2	9.8	5.7	1.6
38.	Paghakn	2005	Akhuryan	-11.8	-10.9	-5.4	2.3	7.7	11.1	14.6	14.1	10.3	4.4	-1.2	-8.1
39.	Pushkin MP	2066	Pambak	-6.6	-6.1	-2.8	2.9	7.3	10.3	13.3	12.7	10	5.3	0.7	-4
40.	Hrazdan	1765	Hrazdan	-7.6	-6.1	-1.2	5.3	10.3	13.9	17.4	16.5	13.4	7.1	1.4	-4.2
41.	Sevan, station	1936	Sevan	-8.1	-7.3	-2.9	3.8	8.7	11.8	15.8	15.5	12.3	6.1	0.6	-5.2
42.	Sevan, lake	1913	Sevan	-5.8	-5.7	-2	3.9	8.7	12.7	16	15.7	12.8	7.5	2.3	-2.9
43.	Semyonovka	2104	Dzknaget	-7.3	-7.1	-3.3	2.7	7.2	10.5	13.6	13.1	10.2	5.3	0.4	-4.6
44.	Sisian	1580	Vorotan	-4.5	-3.3	1	6.8	11.3	15	18.2	17.5	13.9	8.2	3.1	-1.8
45.	Sisian M/P	2380	Vorotan	-8.4	-7.7	-4.2	1.3	6.2	9.9	12.9	12.6	10	4.6	-0.6	-6
46.	Spitak	1552	Pambak	-4.4	-3.7	0.6	6.7	11.1	14.4	17.8	17.3	14	8.7	3.3	-1.6
47.	Stepanavan	1397	Chqnagh	-3.8	-3.2	0.9	7.1	11.2	14.3	17.4	16.7	13.4	8.1	3.4	-1.2
48.	Talin	1582	Mastara	-5.6	-4.2	0.9	7.4	12.1	16.3	20.6	20.3	16.4	9.4	3.2	-2.6
49.	Tashir	1507	Tashir	-4.7	-4.2	-0.3	5.9	10.9	13.2	16.1	15.4	12	7	2.6	-2
50.	Urtzadzor	1064	Vedi	-3.5	-1.4	5.3	11.9	16.5	20.7	24.8	24	20.1	13.1	6.4	0.2
51.	Fontan	1800	Hrazdan	-6.7	-5.4	-0.5	5.7	10.6	14.3	17.8	17.6	14.4	8.1	2.5	-3.6
52.	Chambarak	1853	Getik	-5.1	-4.7	-1.3	4.6	9	12	14.7	14.2	11.2	6.4	2.1	-2.6
53.	Shnogh	660	Debed	1	1.8	5.5	11.4	15.8	19.4	22	22.5	17.9	12.3	7.3	3.2
54.	Shorzha	1922	Sevan	-4.7	-4.9	-1.4	4.6	9.6	13.5	17.1	16.8	13	8.2	3	-1.9
55.	Yangh	2334	Sevan	-8.7	-8.1	-4.4	1.6	6.8	10.7	14.4	14.1	11	4.9	-0.5	-5.9

Appendix 6.5 – Detailed description of the computer program for calculation of river basin water balance

The work starts from the main menu window. It consists of two large sections:

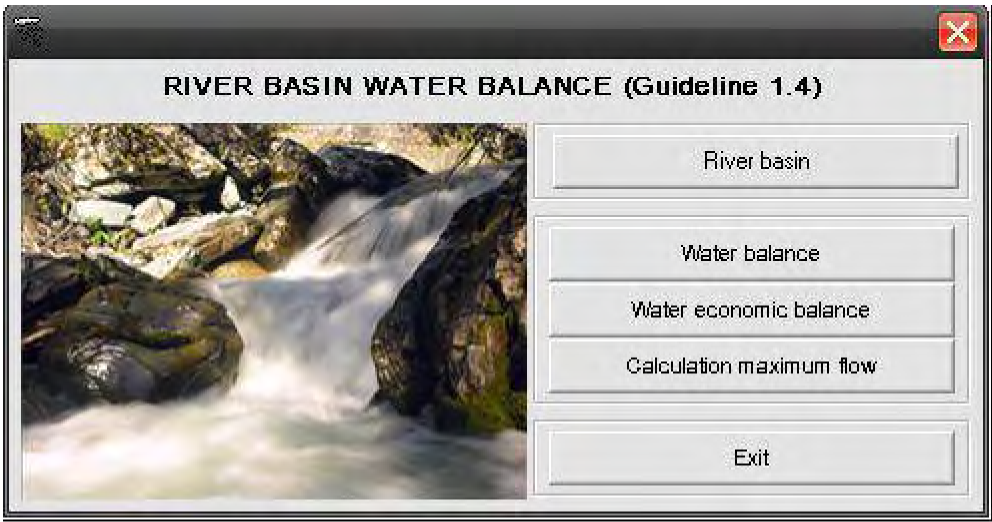
1. Gauged river basins,
2. Ungauged river basins (picture 1).



Picture 1

First it is necessary to select the section "Gauged river basins". A window with 4 functional buttons opens:

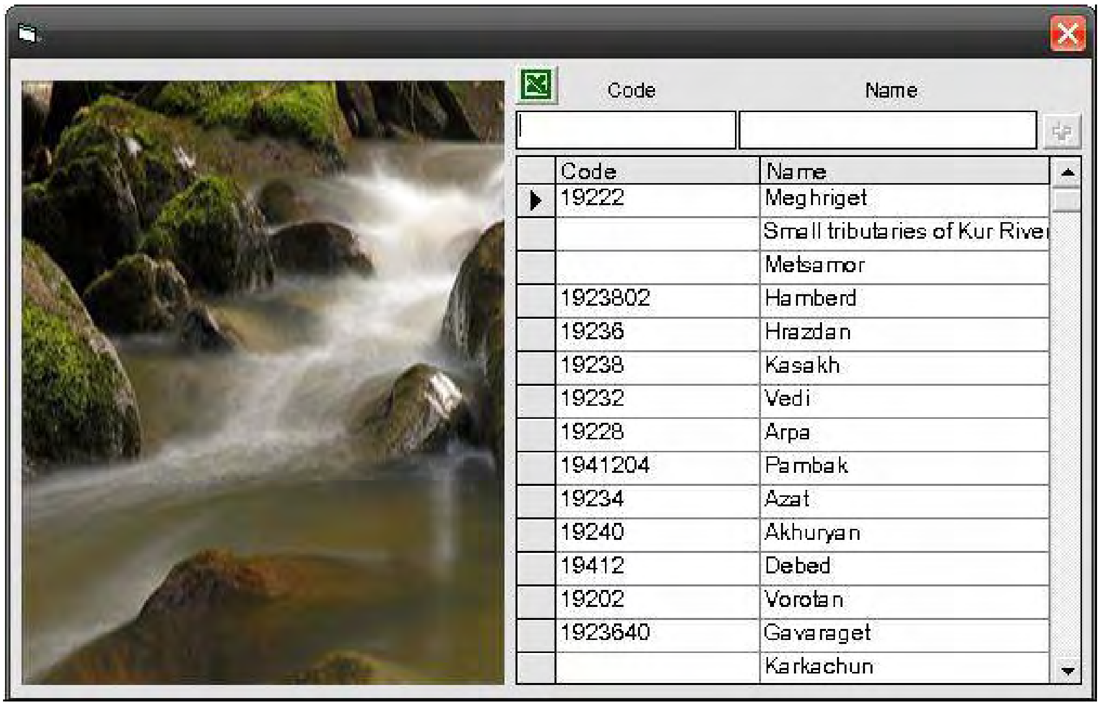
1. River basin,
2. Water balance,
3. Water Economic balance,
4. Maximum flow calculation (picture 2).



Picture 2

6.5.1. River basin

By pressing the river basin button, a window is opened which allows inputting, deleting or revising the name and code of the river basin. Data from the section “River Basin” is used in all sections of the program. Before making calculations for any river basin it is necessary to make sure that it is inputted correctly in the “River Basin” section. If not, such data should be inputted (Picture 3).



Picture 3

6.5.2. Water Balance

In order to obtain water balance it is necessary to separate hypsometric zones of the river basin, calculate atmospheric precipitation, evaporation, river flow. These calculations are implemented through the corresponding buttons presented below (Picture 4).

Picture 4

6.5.2.1. Hypsometric zones

In the section “River Basin” the list of all river basins is presented. Before selecting any basin it is necessary to input the ranges of its altitude zones. “Beginning of altitude” is the minimum altitude, and “Ending altitude” is the maximum altitude of the river basin. For example, beginning altitude for the interval 1400-1600m will be 1400m, and ending altitude will be 1600m. In the next step it is necessary to input in the column “Area” the area of the river basin within the range of 1400-1600m. By pressing the button “+” the inputted data are added to the table. Following the same logic we will input the entire area of the river basin with 200m intervals (picture 5).

Picture 5

6.5.2.2. Calculation of atmospheric precipitation

a. Meteorological observation points

It is necessary to input the name of the observation point, its absolute altitude and multi-year average monthly precipitation in mm. By pressing the button “+” meteorological observation point data will be recorded in the database (Picture 6).

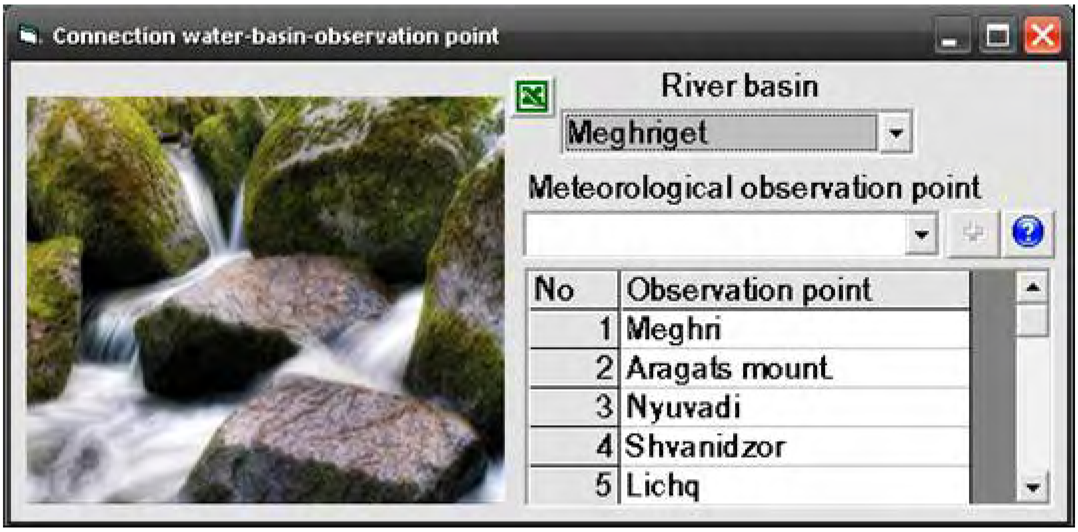
Quantity of average monthly precipitation (mln. m3)

Observation point	Altitude	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Meghri	627	16	16	35	42	49	31	10	10	13	30	23	15
Nyuvadi	600	17	17	29	43	52	31	14	9	11	23	26	14
Shvanidzor	640	17.9	24.2	34.3	45.5	46.8	33	19.8	5.7	18.9	26.9	25.8	16.3
Lichq	1769	55	62	94	97	101	60	20	15	22	55	57	41
Kaler	2000	29	34	54	78	78	49	20	19	29	39	34	24
Bazarchay	2031	33.9	53.8	64.2	75.4	50.3	68.7	52.1	34.7	27.7	51.3	43.2	39.6
Kochbek	2387	34.5	61.9	87.2	112.9	101.4	76.6	99	60.9	30.9	84.3	45.7	48.5
Tchambarak	1853	22	30	43	60	98	95	63	45	40	58	41	26
Aygedzor	740	18	24	38	53	85	86	43	40	33	45	27	18
Berd	717	22	27	37	50	73	67	41	29	35	43	28	17
Haykavan	1600	18	20	19	39	74	45	26	20	24	28	19	16
Amasia	1876	42	50	48	78	107	84	52	41	31	47	49	55
Armavir	861	17	20	23	32	45	24	12	8	9	27	18	15
Amberd	2074	57	62	68	80	97	54	30	20	23	52	50	61
Aragats	3227	77	82	109	123	114	81	61	50	38	81	95	89
Hanqavan	1992	51	56	69	94	121	100	62	41	37	61	57	50
Eratmber	3101	79	84	99	93	90	71	46	33	34	63	70	69
Yerevan, Arabkir	906	29	38	41	51	60	29	14	9	9	32	30	26
Yerevan, Agro	942	24	26	33	41	48	23	13	9	9	31	24	26
Yerevan, Erebuni	1316	22	25	30	37	44	21	9	8	8	27	23	23

Picture 6

b. Connection water basin-observation point

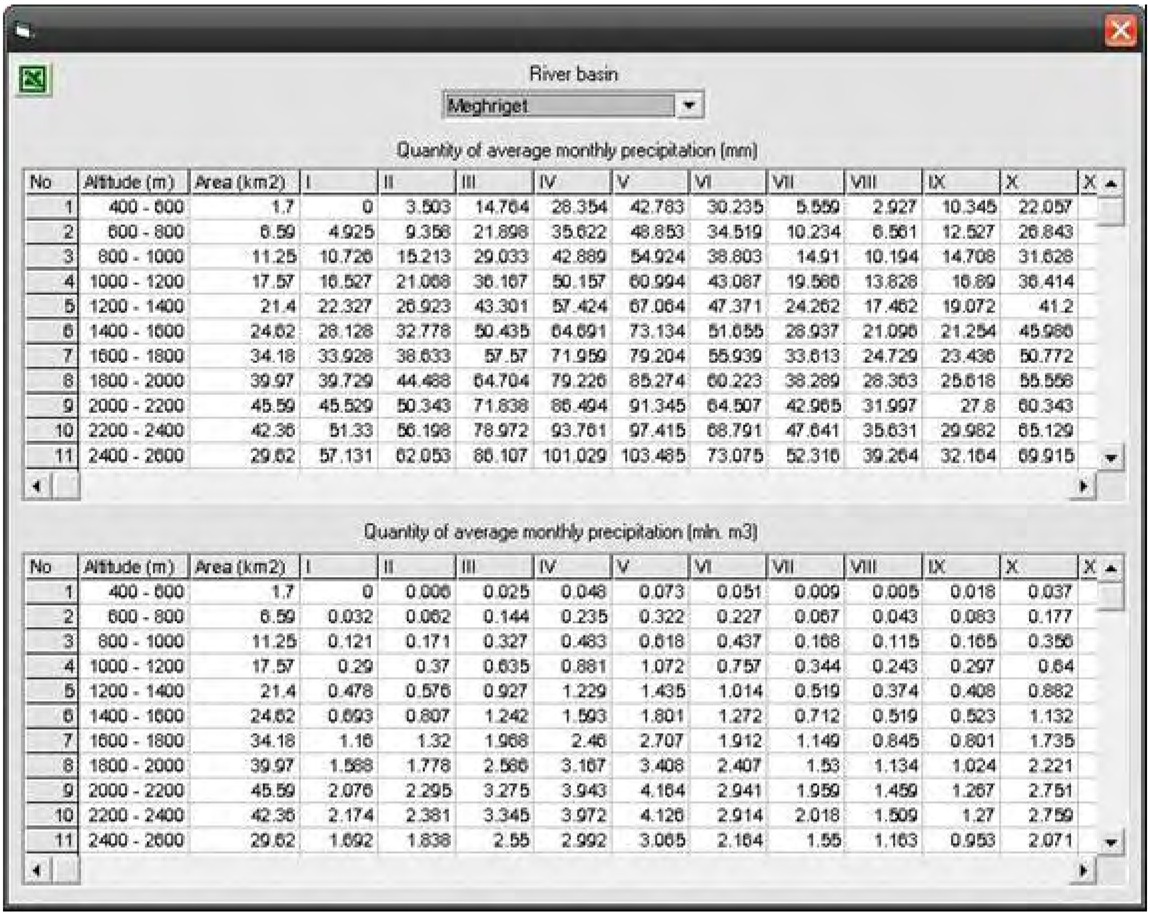
In order to get a connection it is necessary to press the button "Water-basin-observation point" in the window "Water balance", as a result of which the auxiliary window presented in Picture 6 is opened. The river basin and its corresponding meteorological observation points are selected in that window. These data will be used for calculation. By selecting the observation point and pressing the button "+" the given observation point is added in the database. In order to make proper selection it is necessary to the the sign "?". By pressing it a table is opened, which mentions the application of the given observation point for river basins (Pictuer 7).



Picture 7

c. Calculation of atmospheric precipitation

In order to make the calculation it is necessary to press the button “Calculation” in the “Water Balance” window. By selecting the necessary river basin the program brings the quantity of average multi-year monthly precipitation in mm (as well as in mln. m^3) according to hypsometric zones (Picture 8).


River basin

Meghriget

Quantity of average monthly precipitation (mm)

No	Altitude (m)	Area (km2)	I	II	III	IV	V	VI	VII	VIII	IX	X	X
1	400 - 600	1.7	0	3.503	14.764	28.354	42.783	30.235	5.559	2.927	10.345	22.057	
2	600 - 800	6.59	4.925	9.358	21.898	35.622	48.853	34.519	10.234	6.561	12.527	26.843	
3	800 - 1000	11.25	10.726	15.213	29.033	42.889	54.924	38.803	14.91	10.194	14.708	31.628	
4	1000 - 1200	17.57	16.527	21.068	36.167	50.157	60.994	43.087	19.586	13.828	16.89	36.414	
5	1200 - 1400	21.4	22.327	26.923	43.301	57.424	67.064	47.371	24.262	17.462	19.072	41.2	
6	1400 - 1600	24.62	28.128	32.778	50.435	64.691	73.134	51.655	28.937	21.096	21.254	45.986	
7	1600 - 1800	34.18	33.928	38.633	57.57	71.959	79.204	55.939	33.613	24.729	23.436	50.772	
8	1800 - 2000	39.97	39.729	44.488	64.704	79.226	85.274	60.223	38.289	28.363	25.618	55.558	
9	2000 - 2200	45.59	45.529	50.343	71.838	86.494	91.345	64.507	42.965	31.997	27.8	60.343	
10	2200 - 2400	42.36	51.33	56.198	78.972	93.761	97.415	68.791	47.641	35.631	29.982	65.129	
11	2400 - 2600	29.62	57.131	62.053	86.107	101.029	103.485	73.075	52.316	39.264	32.164	69.915	

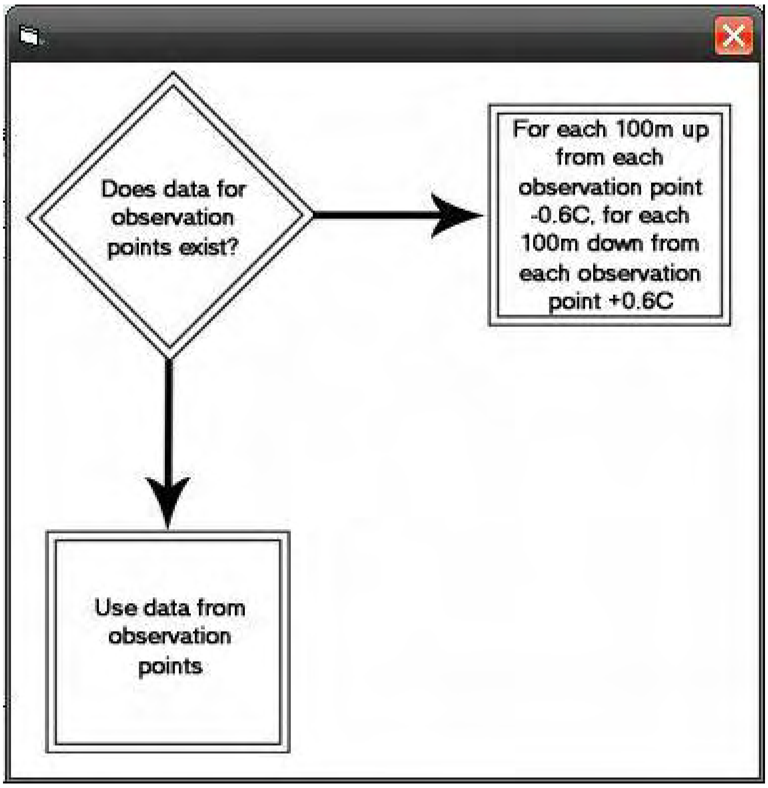
Quantity of average monthly precipitation (mln. m3)

No	Altitude (m)	Area (km2)	I	II	III	IV	V	VI	VII	VIII	IX	X	X
1	400 - 600	1.7	0	0.006	0.025	0.048	0.073	0.051	0.009	0.005	0.018	0.037	
2	600 - 800	6.59	0.032	0.062	0.144	0.235	0.322	0.227	0.067	0.043	0.083	0.177	
3	800 - 1000	11.25	0.121	0.171	0.327	0.483	0.618	0.437	0.168	0.115	0.165	0.356	
4	1000 - 1200	17.57	0.29	0.37	0.635	0.881	1.072	0.757	0.344	0.243	0.297	0.64	
5	1200 - 1400	21.4	0.478	0.576	0.927	1.229	1.435	1.014	0.519	0.374	0.408	0.882	
6	1400 - 1600	24.62	0.693	0.807	1.242	1.593	1.801	1.272	0.712	0.519	0.523	1.132	
7	1600 - 1800	34.18	1.16	1.32	1.968	2.46	2.707	1.912	1.149	0.845	0.801	1.735	
8	1800 - 2000	39.97	1.588	1.778	2.586	3.167	3.408	2.407	1.53	1.134	1.024	2.221	
9	2000 - 2200	45.59	2.076	2.295	3.275	3.943	4.164	2.941	1.959	1.459	1.267	2.751	
10	2200 - 2400	42.36	2.174	2.381	3.345	3.972	4.126	2.914	2.018	1.509	1.27	2.759	
11	2400 - 2600	29.62	1.692	1.838	2.55	2.992	3.065	2.164	1.55	1.163	0.953	2.071	

Picture 8

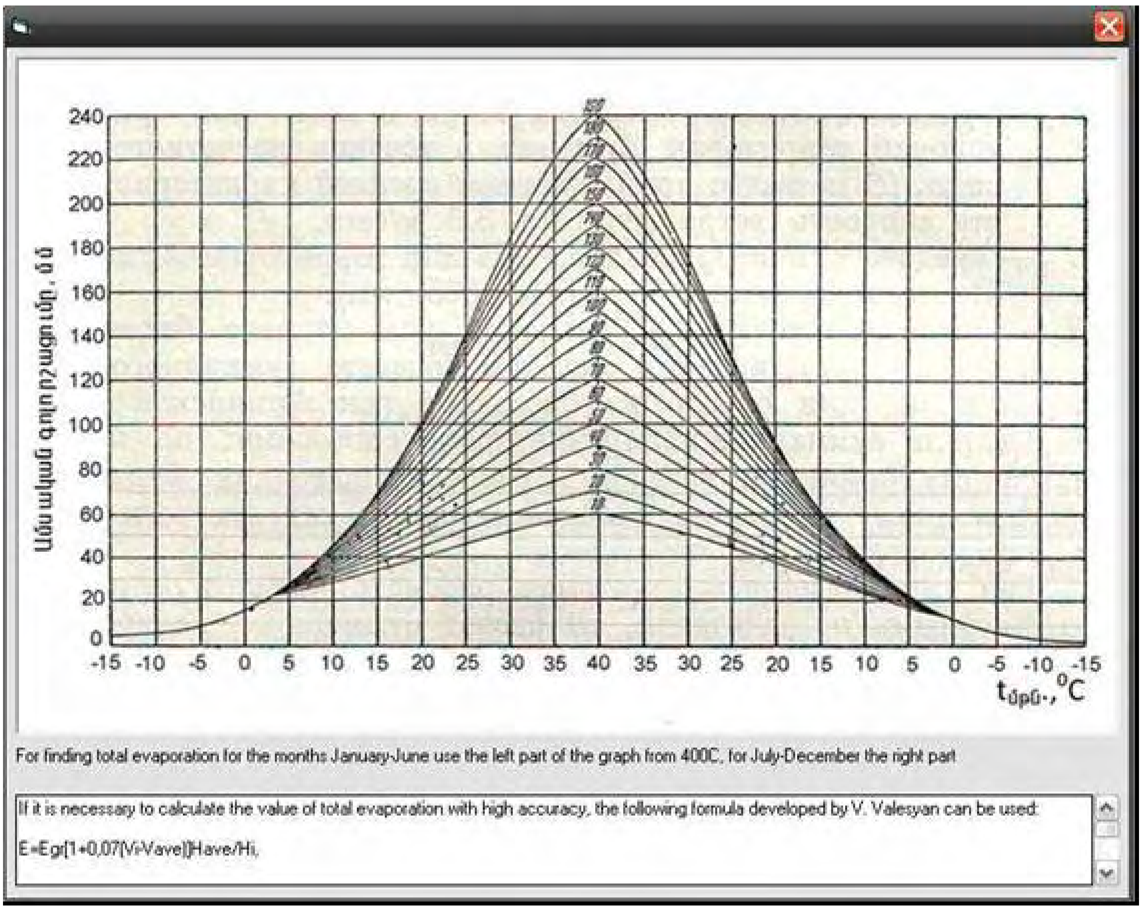
6.5.2.3. Calculation of evaporation

As the first step of calculation it is neccesary to press the button “Calculation of Evaporation” in the window “Water Balance”. A window is opened, where it is necessary to select the required river basin. The section “Explanation” (Picture 9) represents the consecutive steps in case of presence or absence of meteorological observation point.

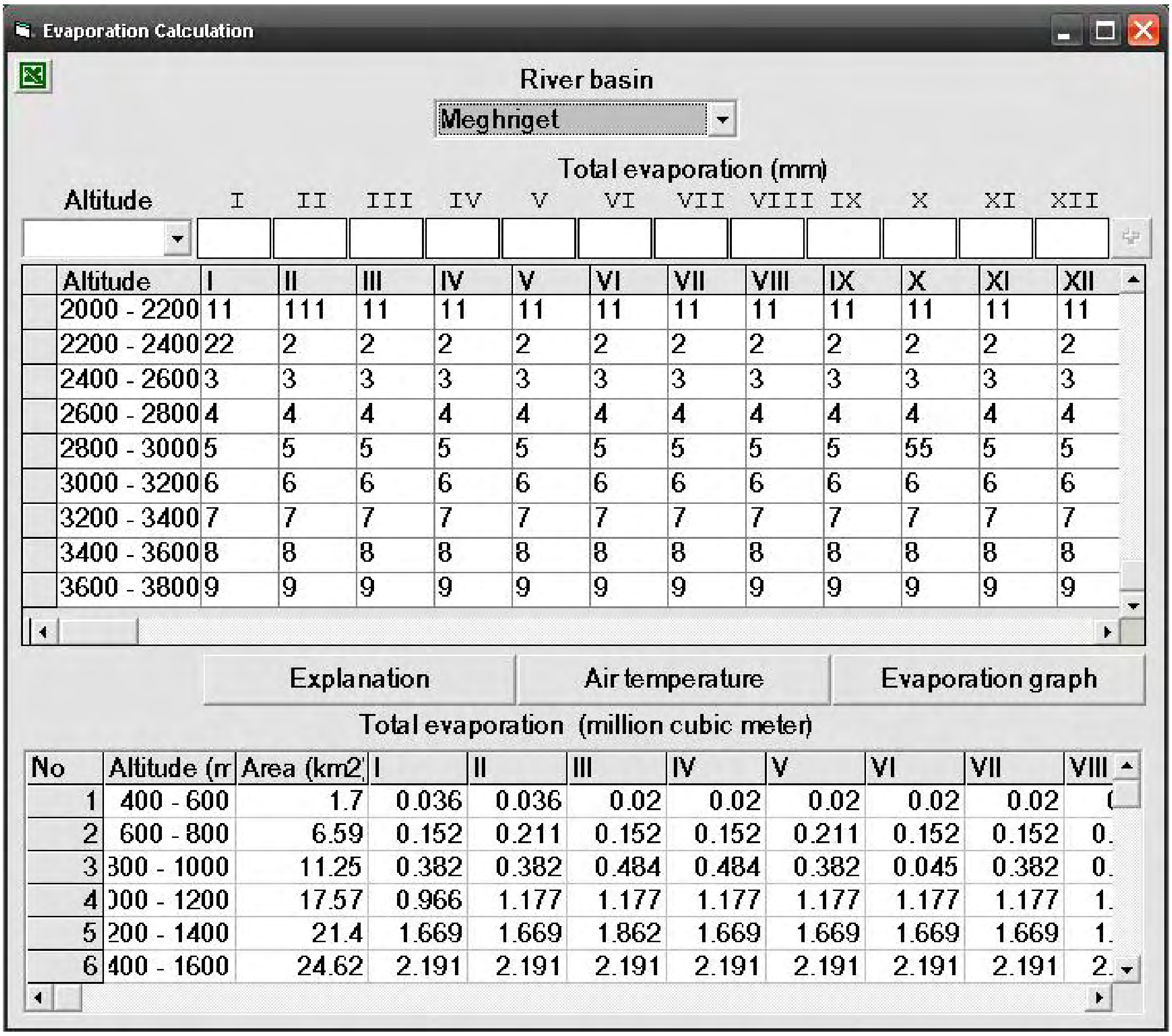


Picture 9

From the evaporation graph (Picture 9.1) according to monthly precipitation and temperature the value of monthly evaporation is decided (Picture 9.2).



Picture 9.1



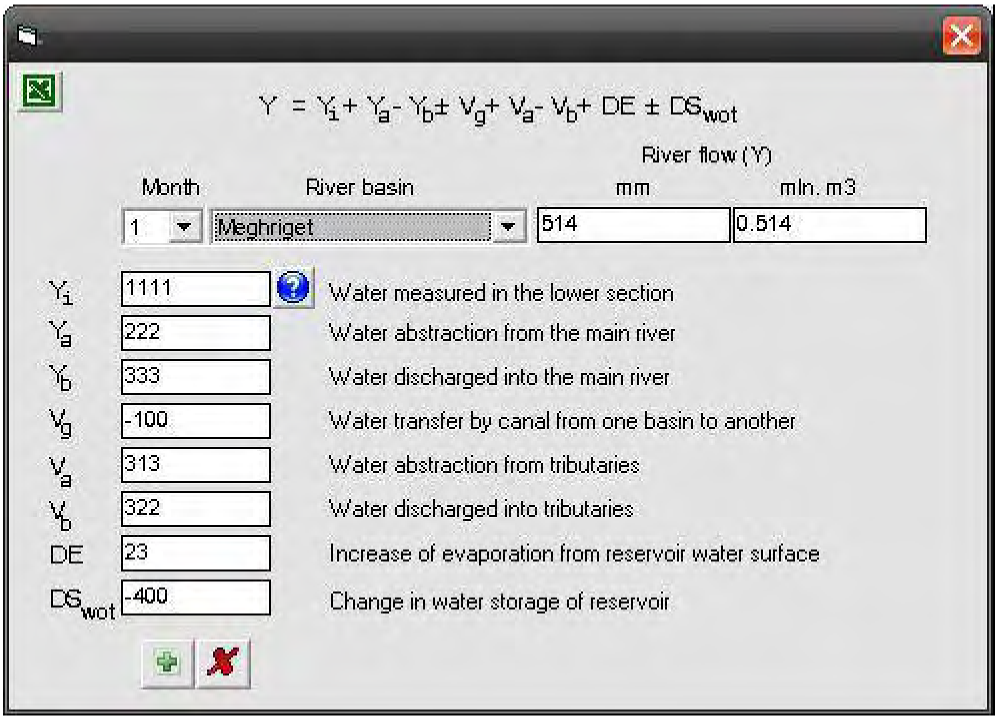
Picture 9.2

6.5.2.4. Calculation of river flow

In order to make calculation it is necessary to press the “River flow” button in the “Water Balance” window. A window is opened, where, first of all, it is necessary to select the month and river basin, for which the river flow will be calculated (Picture 10). The formula for calculation of river flow is the following:

$Y=Y_i+Y_a+Y_b \pm V_g+V_a-V_b+DE \pm DS_{res}$

Y_i – is the flow measures in lower section of the basin,
Y_a – water abstration from the main river,
Y_b – water discharged into the main river,
V_g - water transfer from one canal to another,
V_a – water abstraction from tributaries,
V_b – water discharging into tributaries
DE – increase of evaporation quantity from the reservoir water surface,
DS_{res} – change in the storage of water in reservoir (Picture 10).

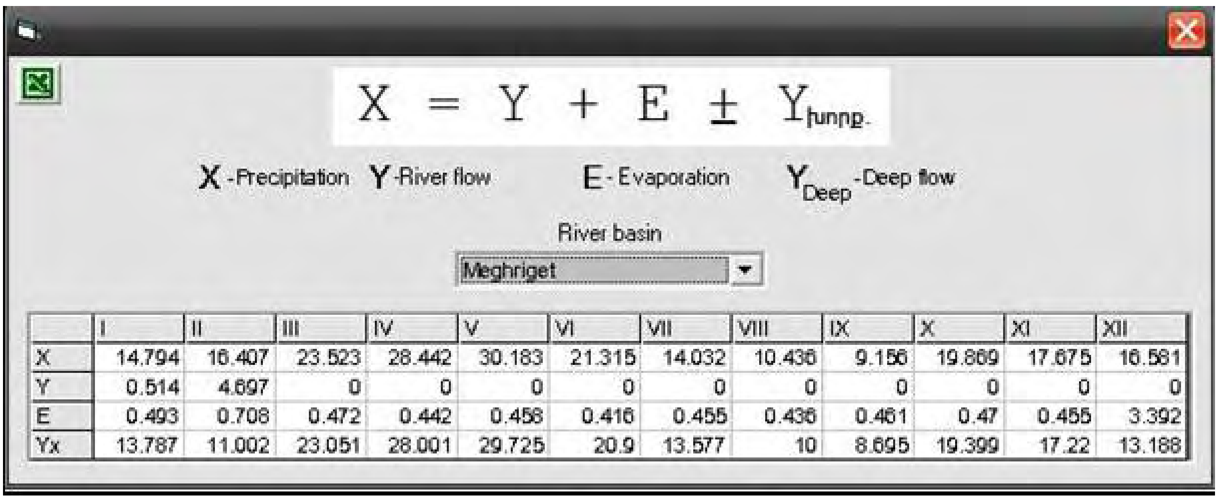


Picture 10

By pressing button “?” the table of multi-year average monthly discharge in all hydrological observation points of the Republic of Armenia is opened. By filling the table and pressing the button “+”, the value of calculated river flow (Y) in mm and in mln. m^3 will be calculated.

6.5.2.5. Water balance

By pressing the button “Water balance” in the window “Water calculation” a window is opened, where the results of calculated in the previous sections precipitation (X), river flow (Y) and evaporation (E) are inputted (Picture 11), and the value of deep flow is observed from their difference.

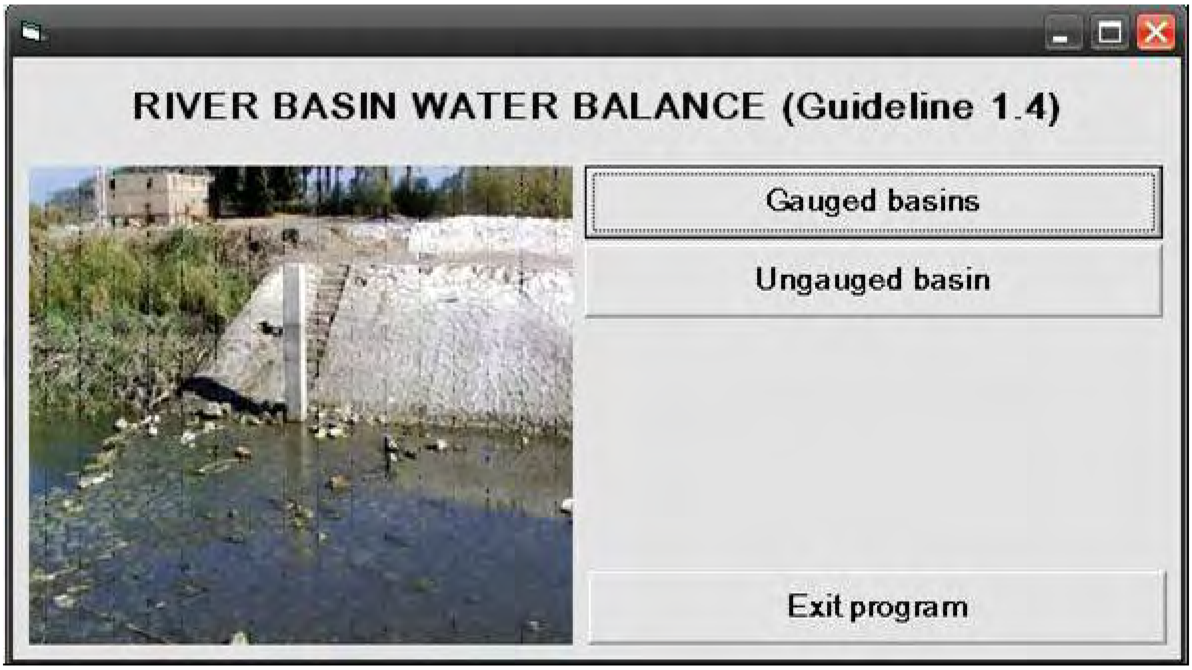


Picture 11

6.5.2.6. Water balance of ungauged basins

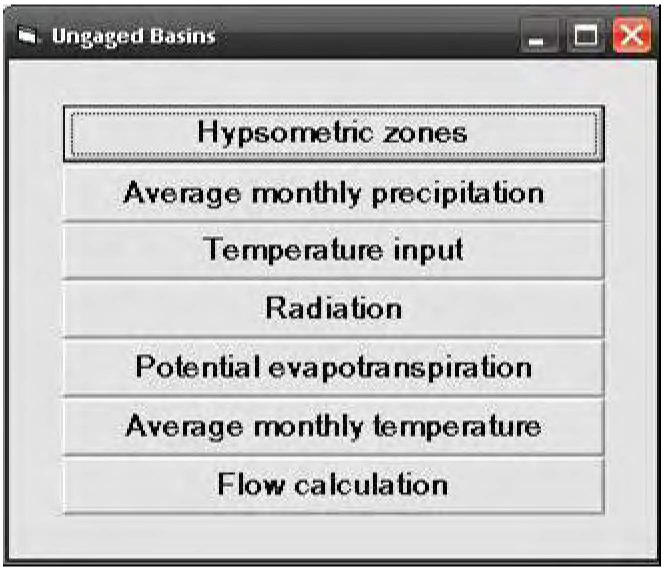
This part of the program is anticipated for calculating water balance in ungauged river basins.

For that purpose, from the main menu it is necessary to select the window "Ungauged River Basins" (Picture 12).



Picture 12

By pressing the button "Ungauged river basins" a window is opened as presented in Picture 13, where it is necessary to make appropriate actions in order to receive the river flow in the basin.

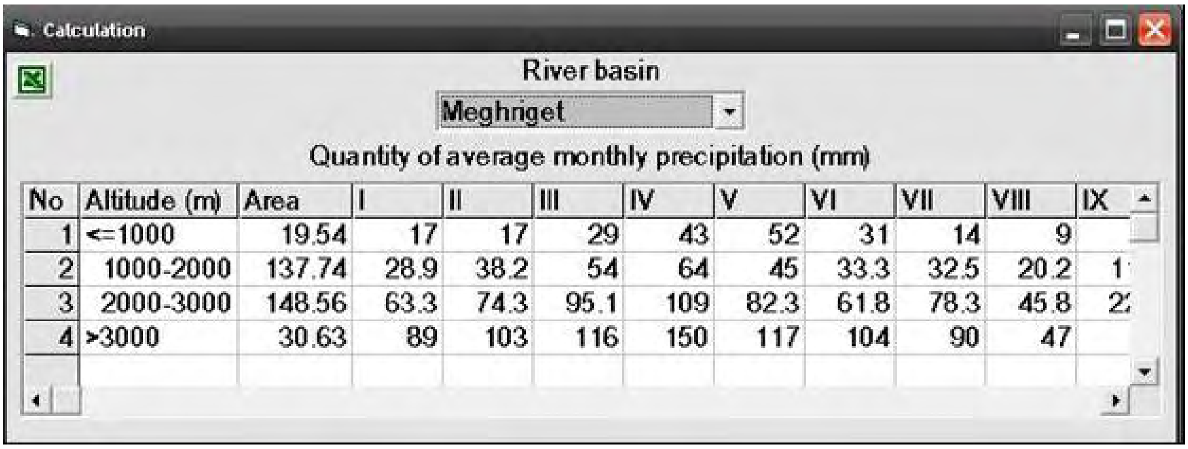


Picture 13

1. Hypsometric zones: In the section "River basin" the list of all river basins inputted in the program are given. Before selecting any river basins it is necessary to input the boundaries of hypsometric zones: 0-1000m, 1000-2000m, 2000-3000m, 3000-4000m. The areas of corresponding hypsometric zones should be inputted as well (Picture 14).

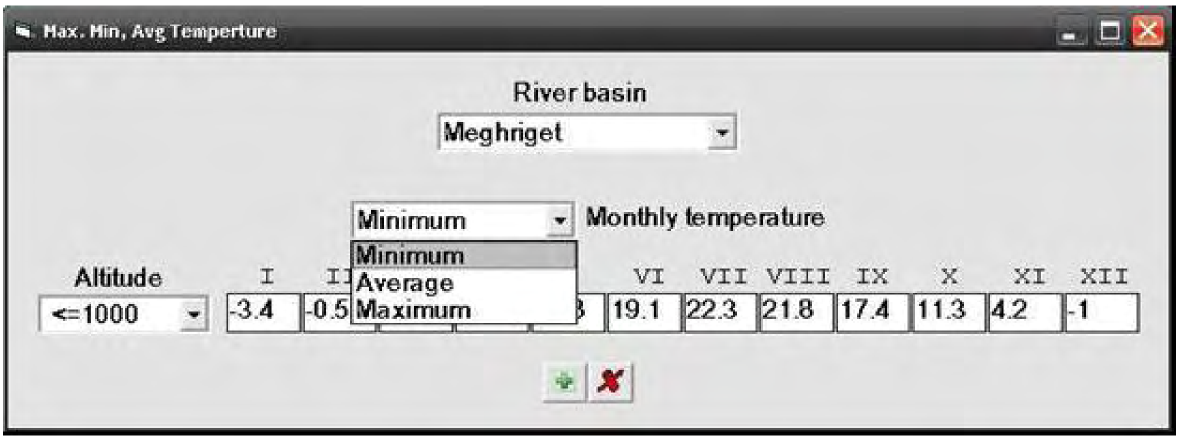
Picture 14

2. Average monthly precipitation: Here it is necessary only to select the river basin, and the values of atmospheric precipitations are inputted in the first section of the program ("Gauged river basins") due to the connection between water basin-meteorological observation points (Picture 15).



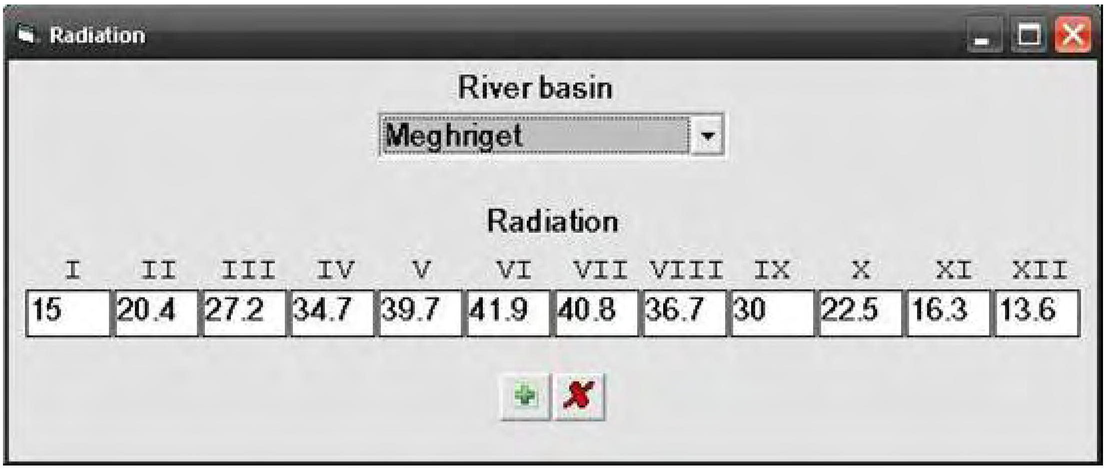
Picture 15

3. Air temperature input: It is necessary to select the river basin and for each altitude zone input the minimum, average and maximum monthly temperatures (Picture 16). For air temperature data it is suggested to use the publication "Reference book on the climate of USSR, Volume 16, Air and Soil Temperature".



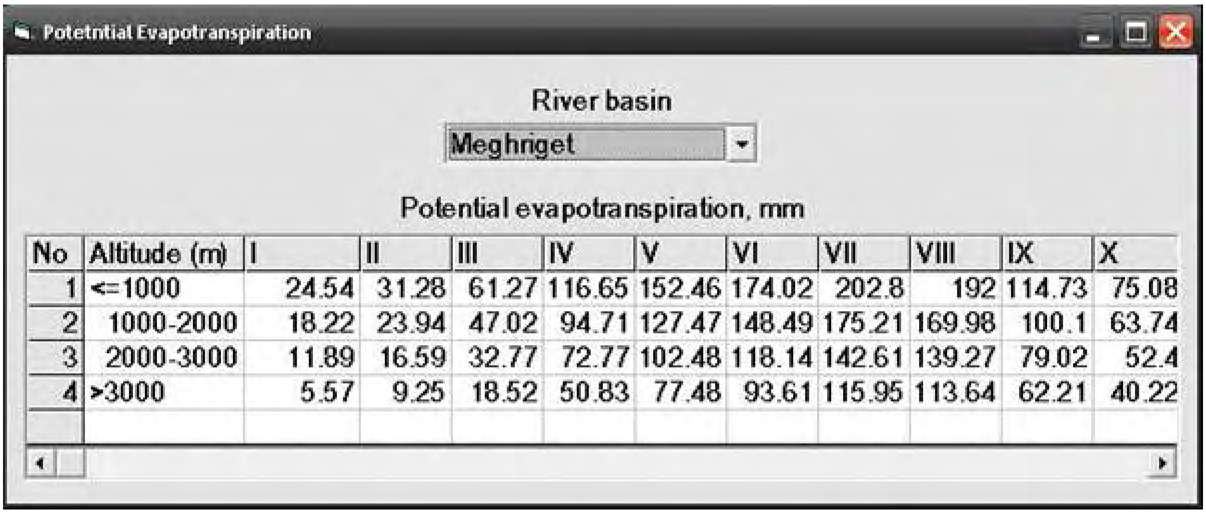
Picture 16

4. Radiation: It is necessary to input the radiation value for each month, which is constant for the entire territory of Armenia (Picture 17).



Picture 17

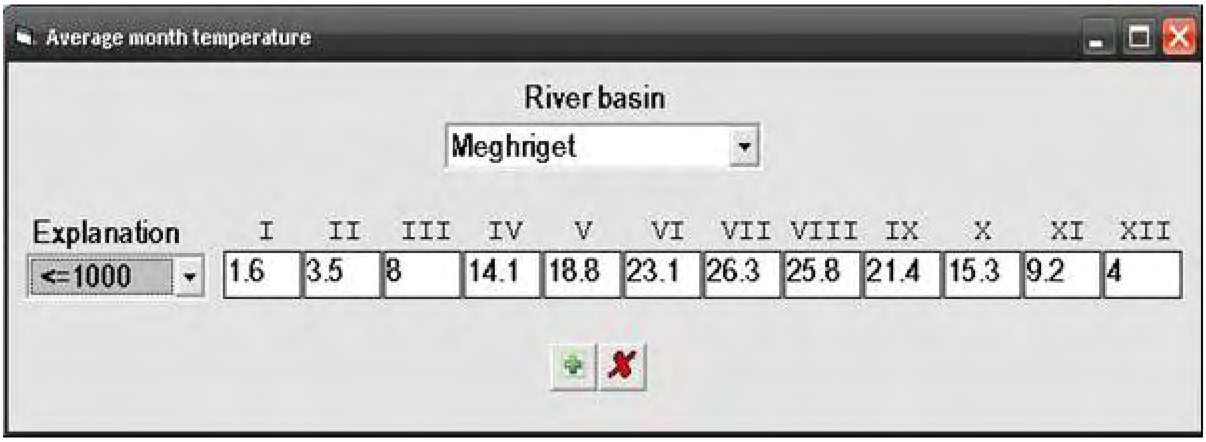
5. Potential evapotranspiration: Based on the average, minimum and maximum monthly temperature values and radiation inputted in the previous sections, and using the Hargreaves formula: $((PET)_m=0.0023*(T_m avg+17.8)*sqrt\ (T_m max-T_m min)*Ra_m)$, the program will calculate the potential evapotranspiration for all zones (Picture 18). This is the method recommended by the FAO for estimating evapotranspiration in their Irrigation and Drainage Paper No. 56 (1998).



No	Altitude (m)	I	II	III	IV	V	VI	VII	VIII	IX	X
1	<=1000	24.54	31.28	61.27	116.65	152.46	174.02	202.8	192	114.73	75.08
2	1000-2000	18.22	23.94	47.02	94.71	127.47	148.49	175.21	169.98	100.1	63.74
3	2000-3000	11.89	16.59	32.77	72.77	102.48	118.14	142.61	139.27	79.02	52.4
4	>3000	5.57	9.25	18.52	50.83	77.48	93.61	115.95	113.64	62.21	40.22

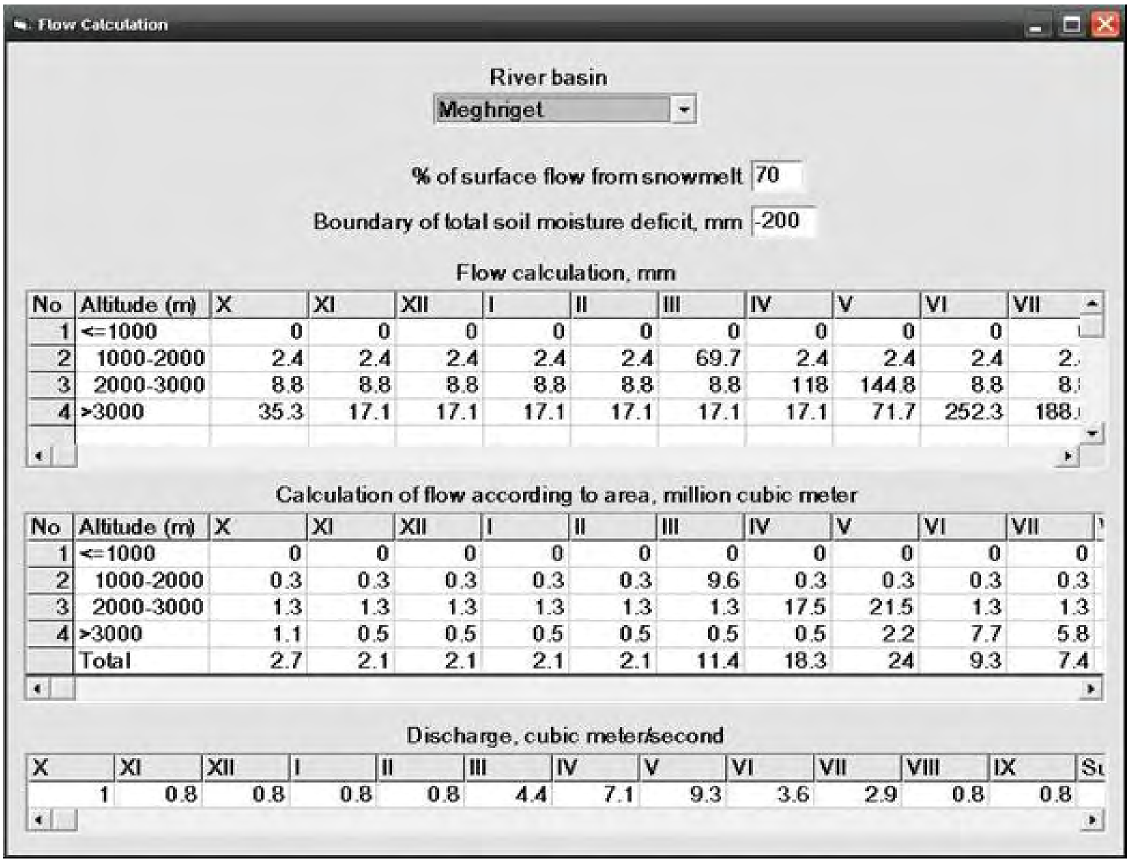
Picture 18

6. Average monthly temperature: It is necessary to input average monthly air temperature data for each altitude zone (Picture 19).



Picture 19

7. Calculation of flow: By selecting the river basin, based on the inputted data in the previous sections here the monthly and annual flow values are calculated for each altitude zone and for the entire basin. Snowmelt is calculated by a simple degree-day model, with 2mm of melt for every degree above zero each day as the default value. The program assumes that 70% of the snowmelt turns immediately into a surface flow, and 30% infiltrates, then flows sub-surface to form baseflow distributed throughout the year. It also assumes that the default value of the soil moisture storage is 200 mm. However, both these values can be changed. Total flow is the sum of rainfall runoff (if soil moisture deficit is zero), snowmelt, and sub-surface base flow each month. At first, the flow values for a unit area of altitude zone are calculated, which are then summed with corresponding areas at each altitude zone. Also, the average monthly and average annual discharges are calculated (Picture 20).



Picture 20

GUIDELINE 1.5: CALCULATION OF WATER ECONOMIC BALANCE

1. Introduction

1.1 Purpose of this Guideline

Water economic balance is the comparison of water resources and calculated water demand in the given territory or region. The calculated comparison defined the extent of water resources satisfying the demand, as well as the surplus or deficit of water resources due to spatial and temporal variations.

The purpose of this guideline is to present the method for calculation of water economic balance as well as its application, which will provide possibility to define the surplus and deficit of water in any calculated section. Naturally, such information will serve as the basis for provision of water use permits.

1.2 Role of this Activity in River Basin Planning

The role of calculation of water economic balance is significant in river basin planning. It is considered as one of the important steps in river basin planning. Particularly, water economic balance provides a possibility to issue water use permits based on reliable information, as well as to define realistic objectives for river basin planning. Hence, based on the objectives set, it will be possible to identify corresponding measures for proper maintenance and management of water resources in the giver river basin.

2. Technical Approach

2.1 Methodology: Approach and Justification

As input elements (supply) of water economic balance the following parameters are considered: river flow, dynamic storage of groundwater resources, static storage of groundwater resources, return flows after water use and water from previously drained agricultural lands. As output parameter (demand) of water economic balance water supply and other water demand are considered, including natural and economic factors. It should be mentioned that the input and output elements of the water economic balance should have spatial and temporal correspondence.

The negative value of water economic balance shows the extent of water deficit in the given segment.

In each selected time segment water economic balance in the river basin is defined by the following formula:

$B=R+U-\Delta U-I+I_r-T\pm\Delta V$,

where B is the result of the balance (balance difference) through which a certain element of the balance is defined more precisely, R is the water inflow from the upper segment, river flow, which represents a sum of the water resources of upper segment and calculated flow, U is the groundwater resources in the given basin, if such resources are included in the total water use (this amount cannot exceed the approved deposit storage of groundwater resources), ΔU is decrease of the river flow due to groundwater use, I is water abstraction or intake for the river basin, I_r is water return after water use, T is the required transit from the lower section of the basin (environment flow), and ΔV is the outflow (+) or inflow (-) from reservoir, including water loss from reservoir (evaporation, filtration).

2.2 Input Data Requirement

For calculation of water economic balance it is necessary to have the following data: water flow from upstream water-economic junction (river flow), underground waters, total water abstraction, water return after use, ecological flow, as well as the outflow (+) or inflow (-) from reservoirs in the section.

2.3 Where to Acquire Input Data

The method for calculation of river flow is described in the guidelines on “Calculation of Water Balance”, which is mostly based on hydrological observations. For the sections where there are no hydrological observation points, the assessment is done using various forms of calculations.

Total guaranteed reserve in 34 groundwater main deposits in 12 groundwater and surface water basins of the Republic of Armenia compose approximately 102.27 m^3/sec, which is being used for drinking, irrigation and other economic purposes. Information about the deposits is available from the publication “UNDP/GEF. “Main Deposits, Useful Storage and Current Conditions of Groundwater in the Republic of Armenia”, "Reducing Transboundary Degradation in the Kura-Aras River Basin" 2006”.

Total water intake I includes water abstraction for drinking-household supply, industrial water supply and irrigation purposes. Drinking-household water supply data can be obtained from the 5 water supply operating in the countries or the State Committee on Water Systems. As for the communities with self-supply, the daily drinking-household water demand is assumed 200/liters/person, whereas if the community has drinking water use permit, the data can be taken from the permit conditions. Data on industrial water supply can be obtained from the water use permit conditions issued by the Water Resources Management Agency of the Ministry of Nature Protection of Armenia. While calculating the irrigation demand, it is suggested to take into account the manual on “The Irrigation Norms and Regimes of Agricultural Plans for Irrigative Soil in the Republic of Armenia - Manual”, developed in 2007 by the Water Problems' Institute.

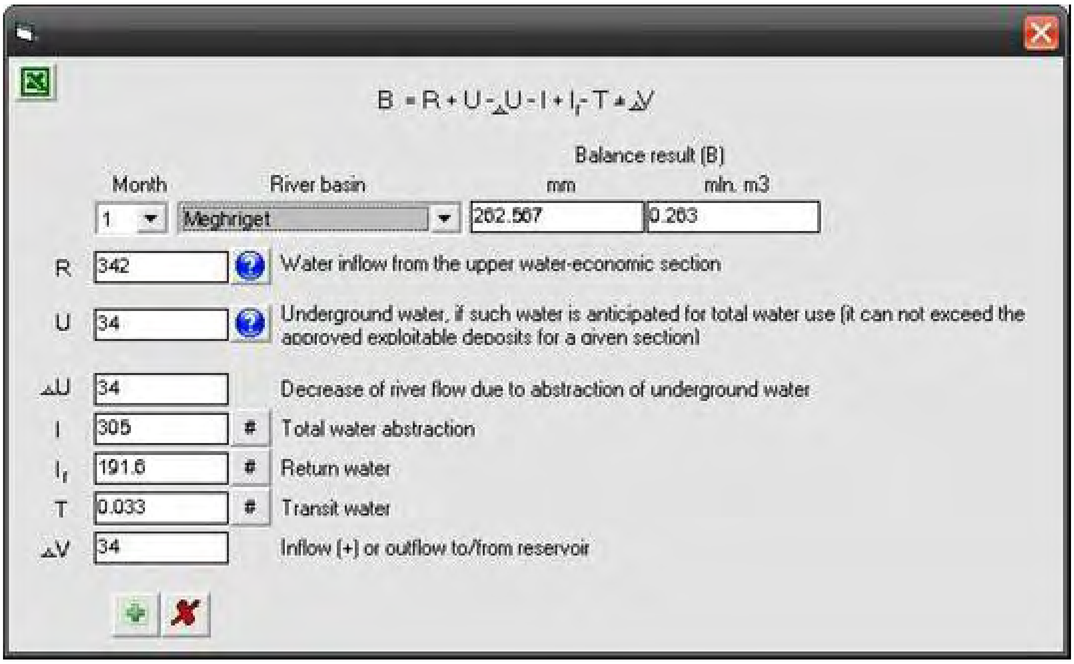
In order to calculate the water return after use, it is suggested to take into consideration the research conducted by the Water Problems Institute (Chilingaryan L., Mnatzakanyan B., Torgomyan M. 1999. Armenia’s Rivers and Lakes as Source of Irrigation; Yerevan, Agrogitaspyur, No. 10.). According to the research conducted by the Water Problems Institute approximately 20% of the water used for irrigation purposes is being returned after use, and for industrial water use the corresponding volume is 70%. In order to get more accurate information water use permit conditions can also be studied, if for the given water use a corresponding permit is provided.

As for ecological flow, it is easily calculated using the guideline on “Setting Ecological Flow” developed within USAID Water Program. According to the guideline the ecological flow is determined as 75% of the average flow of 10-day minimum flow during water low-flow period.

2.4 Explanation of Analysis Procedures Using Computer Program

A special computer program has been developed for calculation of water economic balance. After inputting required data the program automatically calculates the water economic balance in the giver section of the river basin.

In order to prepare the water economic balance it is necessary to press the button “Water Economic Balance” from the “Main Menu” window. Then a window is opened, where first of all the river basin and corresponding month (for which it is necessary to calculate water economic balance) should be selected (Picture 1).



Picture 1

The formula of water economic balance is the following: B = R+U-ΔU-I+Ir-T+ΔV, where

R – is the water flowing from the upper water economic connection. By pressing the sign “?” a hint will be opened. According to the hint if there is hydrological observation point, then it is necessary to take a look at the table of hydrological observation point data. If not, it is necessary to take the river flow component of the upper water economic connection (Y), already calculated in water balance,

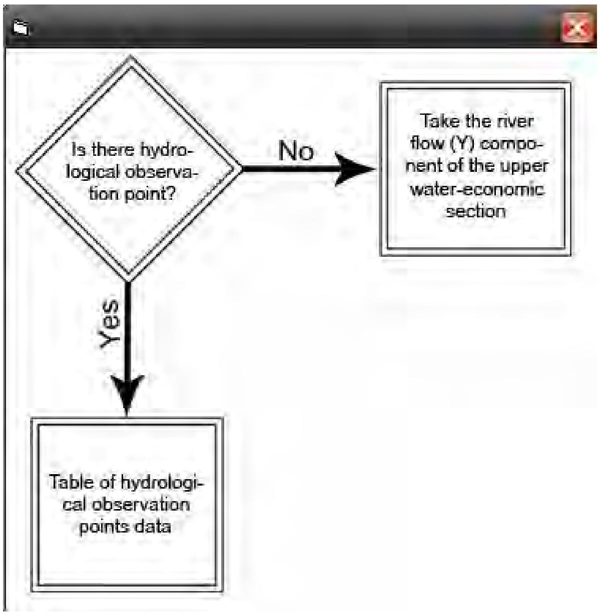
U – Underground waters, if such water is not anticipated for use in the total water intake (it cannot exceed the approved exploitable resources of underground waters in the given section). By pressing the sign “?” a table is opened, where information on underground waters is included.

ΔU – Decrease of river flow due to consumption of underground waters,

I – Total water intake, which consists of 3 components - $I_{dr.}$, $I_{ind.}$, I_{irr} (Picture 2).

Picture 2

For each component of water abstraction there is a sign “?”, by pressing which a hint on that particular water intake type appears (Picture 3).

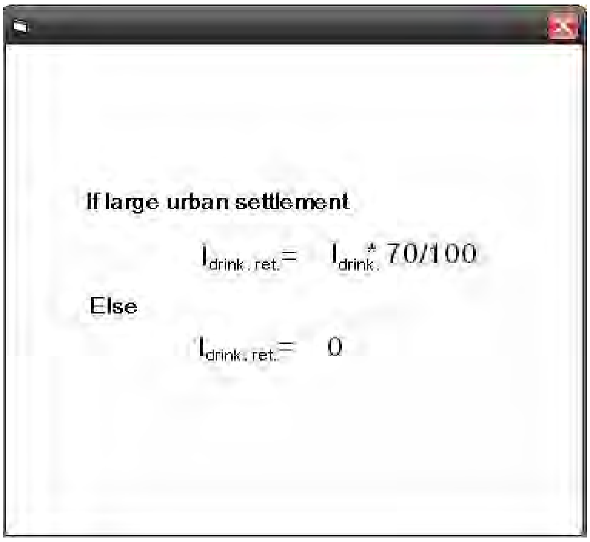


Picture 3

I_r – Return water, which also consists of 3 components – $I_{dr\ ret}$, $I_{ind\ ret}$, $I_{irr\ ret}$ (Picture 4).

Picture 4

Calculation method for each component has its explanation, which is provided by pressing the sign "?"(Picture 5).



Picture 5

It should be noted that by large urban settlement it is meant that there is a water discharge system. In this case the volume of water return on average composes 70%.

T – Transit water is calculated according to the guideline on “Setting Ecological Flow”.

ΔV – Inflow (+) or outflow (-) to/from reservoirs. Inflow or outflow to/from reservoir is filled with its corresponding sign in the box ΔV of the window “Water Economic Balance” (see Picture 1).

By filling in and calculating this component and pressing the button “+” the result of water economic balance (B) will be provided in mm and in mln. m^3 (see Picture 1).

2.5 Type and Format of Output Data

The application of the computer programs results in provision of water economic balance in mm and mln. m^3 for each month. The balance is presented in tabular format, which is possible to transfer into the software Microsoft Excel and Microsoft Word.

3. Diagram of Approach

The flow-chart of simplified approach for calculating water economic balance, as well as corresponding steps of the method are included in computer program. For the user it is only required to input the required data, after which the calculations are done by the program automatically, as the result of which water economic balance is obtained.

4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

Since there are no reservoirs and main groundwater deposits in Meghriget River Basin, as well as there are no guaranteed groundwater storages, then while calculating the monthly water economic balance of the basin the following formula will be used:

$B=R-I+I_r-T$,

where B is the result of the balance (balance difference) through which a certain element of the balance is defined more precisely, R is the water inflow from the upper segment, river flow, which represents a sum of the water resources of upper segment and calculated flow, I is water abstraction or intake for the river basin, I_r is water return after water use, and T is the required transit from the lower section of the basin (environment flow).

Taking into consideration the above-mentioned method and using the computer program developed for that purpose the water economic balance of Meghriget River Basin is obtained for all months.

4.2 Examples of Input Data (Tables)

The average monthly river flow in Meghriget River Basin is presented in table below:

Table 1 – Average Monthly River Flow in Meghriget River Basin

Month	River Flow, mln. m^3
I	2.36
II	2.57
III	4.98
IV	14.54
V	19.49
VI	21.07
VII	11.61

Month	River Flow, mln. m^3
VIII	4.04
IX	2.38
X	2.67
XI	2.95
XII	2.62

Water abstraction demand (in mln. m^3) for drinking-household, industrial and irrigation uses in Meghriget River Basin is presented in table below:

Table 2 – Water Abstraction Demand in Meghriget River Basin

Month	Drinking-household	Industrial	Irrigation	Total
I	0.231	0.012	0.04	0.283
II	0.231	0.012	0	0.243
III	0.231	0.012	0.05	0.293
IV	0.231	0.012	0.42	0.663
V	0.231	0.012	0.69	0.933
VI	0.231	0.012	1.22	1.463
VII	0.231	0.012	1.34	1.583
VIII	0.231	0.012	0.91	1.153
IX	0.231	0.012	0.30	0.543
X	0.231	0.012	0.05	0.293
XI	0.231	0.012	0	0.243
XII	0.231	0.012	0	0.243
Annual	2.77	0.14	5.02	7.93

Water return (in mln. m^3) after use for drinking-household, industrial and irrigation purposes is presented in the table below:

Table 3 – Water Return after Use

Month	Water return after use for industrial purposes	Water return after use for irrigation purposes	Total water return
I	0.0084	0.008	0.0164
II	0.0084	0	0.0084
III	0.0084	0.01	0.0184
IV	0.0084	0.084	0.0924
V	0.0084	0.138	0.1464
VI	0.0084	0.244	0.2524
VII	0.0084	0.268	0.2764
VIII	0.0084	0.182	0.1904
IX	0.0084	0.06	0.0684
X	0.0084	0.01	0.0184
XI	0.0084	0	0.0084
XII	0.0084	0	0.0084
Annual	0.1	1	1.1

The ecological flow of the river basin is presented in the table below:

Table 4 – Ecological Flow of Meghriget River Basin

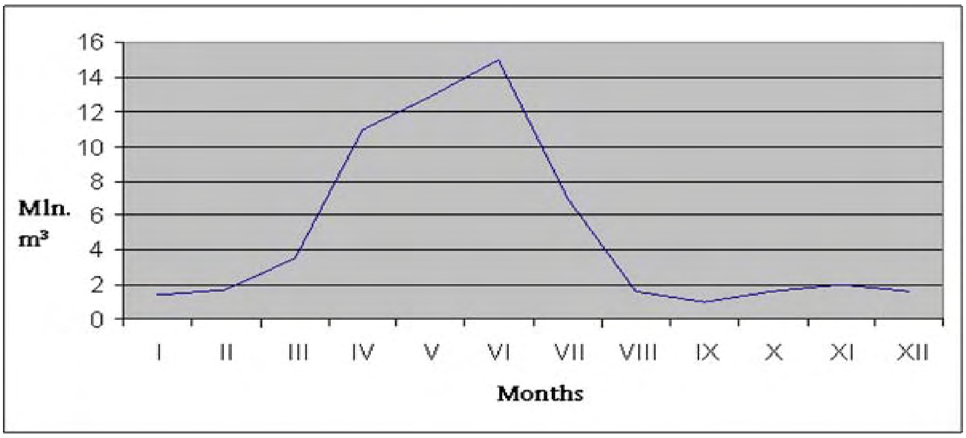
Month	Ecological Flow, mln. m^3
I	0.67
II	0.60
III	1.20
IV	3.01
V	5.80
VI	4.85
VII	3.36
VIII	1.45
IX	0.86
X	0.74
XI	0.67
XII	0.74

4.3 Examples of Output Data (Tables)

The table below represents the monthly water economic balance in mln. m^3.

Table 5 – Water Economic Balance of Meghriget River Basin

Month	Balance, mln. m^3	River Flow, mln. m^3	Water Abstraction, mln. m^3	Water Return, mln. m^3	Ecological Flow, mln. m^3
	B	R	I	I_r	T
I	1.43	2.36	0.28	0.02	0.67
II	1.74	2.57	0.24	0.01	0.60
III	3.51	4.98	0.29	0.02	1.20
IV	10.96	14.54	0.66	0.09	3.01
V	12.91	19.49	0.93	0.15	5.80
VI	15.01	21.07	1.46	0.25	4.85
VII	6.95	11.61	1.58	0.28	3.36
VIII	1.63	4.04	1.15	0.19	1.45
IX	1.05	2.38	0.54	0.07	0.86
X	1.66	2.67	0.29	0.02	0.74
XI	2.05	2.95	0.24	0.01	0.67
XII	1.65	2.62	0.24	0.01	0.74
Total	60.55	91.28	7.9	1.12	23.95



5. Bibliography

Armenia Ministry of Agriculture, “The Irrigation Norms and Regimes of Agricultural Plans for Irrigative Soil in the Republic of Armenia - Manual”, Yerevan 2007

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Chilingaryan L., Mnatzakanyan B., Torgomyan M. 1999. Armenia’s Rivers and Lakes as Source of Irrigation; Yerevan, Agrogitaspyur, No. 10.

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GUIDELINE 1.6: CALCULATION OF AQUIFER BALANCE

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to present the method for calculation of aquifer water balance and to present its application. Calculation of water balance for hydrogeological structures is done based on assessment of input and output of waters to and from an aquifer. As a result, underground water resources are assessed, and possibilities of obtaining sustainable water yield from those structures are described.

1.2 Role of this Activity in River Basin Planning

The European Union Water Framework Directive provides guidance on integrated water resource planning, including the integration of surface water and ground water resources planning. The basic principle is that aquifers must be managed for good chemical status (no pollution), and for a balance between recharge and withdrawal, so that the long-term water yield is sustainable. Assessment of water balance for aquifers in a given river basin provides a possibility to obtain necessary information on potential underground water resources in the river basin, and based on it, to estimate long-term sustainable water yield to support economic development, as well as implement optimal distribution of underground waters. Once the status of an aquifer's water balance can be assessed, then reasonable environmental objectives for that aquifer can be developed.

2. Technical Approach

2.1 Methodology: Approach and Justification

The annual water balance of water bodies (aquifers) is calculated for assessment of underground water resources. The latter ones are assessed through a general formula for basin water balance and through hydrodynamic method or Darcy's formula. Through the general formula for water balance underground waters for the entire basins in mountainous river basins are assessed, which have local distribution. Through the hydrodynamic method the underground waters of inter-mountain deposits are assessed, including water bodies in narrow river valleys.

In order to assess aquifer balance through the general method for annual water balance it is necessary to calculate the area of the given river basin, precipitation and evaporation, discharge of underground water sources in the river basin (springs, qyuhrizes, boreholes), as well as natural multi-year discharge of the river in the calculation profile. The difference of precipitation quantity and river discharge and evaporation sum represents the deep flow component of underground waters (recharge). Part of the river flow is composed of discharged components of underground waters – spring and drainage flows, the value of which corresponds to the lowest discharge of the river (also known as base flow).

In order to assess underground water resources through hydrodynamic method (Darcy's formula) it is necessary to know the profile of the water body (length and capacity), filtration coefficient (transmissivity) of water bearing rocks and hydraulic gradient. The Darcy formula is Q=KiA, where Q is the flow, K is the filtration coefficient, I is the hydraulic gradient (m/m), and A is the cross-sectional area of the discharge area of the aquifer.

2.2 Input Data Requirement

For assessment of underground water resources through the general method of water balance the following information is necessary:

- Topographic map of the river basin with contour lines, precipitation and evaporation izolines.

- Multi-year (not less than 10 years) river natural discharge in the profile bounded the calculation river basin.
- Underground water resources of the given river basin and their discharge.
- Discharge of irrigation and drinking water supply captures.

For assessment of resources through hydrodynamic method the following information is necessary:

- Hydrogeological map and profiles (not less than 10), which include hydro-isolines.
- Storage capacity and dimensions of aquifer.
- Fluctuations of underground water level during the year (if available).
- Filtration coefficient in various sections of aquifer (according to calculation profile).
- River discharge in the upper and lower sections of the deposits (if there is river in the given deposit).

2.3 Where to Acquire Input Data

Data on water balance of aquifers are available from publications of the Hydromet Service and from the Republican Geological Fund. Assessment of quantity of precipitation and evaporation should be done according to the maps of the mentioned parameters, which are composed by the Department of Geography of the Institute of Geology of the National Academy of Sciences of Armenia in 1990.

Hydrogeological data (maps, profiles, various graphs, hydrodynamic parameters and others) are available from Republican Geological Fund.

2.4 Explanation of Analysis Procedures in Calculation of Aquifer Balance

Assessment of water balance of aquifers is carried out by different methods using the following sequential steps.

A. General formula method for calculation of water balance:

1. Indicate isohyps (contour line) on 1:200000 scale topographic map for every 400 m (400 m, 800 m, 1200 m and so on).
2. Locate on the same map isolines for annual precipitation and evaporation.
3. Separate the positive balance zone, where the quantity of precipitation exceeds evaporation.
4. Calculate the areas bounded by the iszlines of neighboring river basins, evaporation and precipitation izolines.
5. Calculate the quantity of precipitation and evaporation using the above-mentioned areas.
6. Add the quantity calculated by separate areas, which will results in overall precipitation in the given river basin.
7. Add the quantity of precipitation calculated by separate areas, which will results in overall evaporation in the given river basin.
8. Calculate the natural discharge of river through added the actual discharge and discharge of water abstractions.
9. Calculate the annual river flow volume.
10. Add evaporation and annual river flow.
11. Deduct from overall quantity of precipitation the sum of evaporation and annual river flow. The results will provide the deep flow component, also known as aquifer recharge.
12. In order to assess the overall resources of underground waters it is necessary to compare the value of deep flow component to multi-year minimum discharge (base flow) of river. They should be comparable quantities (order of magnitude).

B. Hydrodynamic method:

1. Collection of data on hydro-geological boreholes in the given territory, including the hypsometric altitude of borehole mouth, lithological profile, depth of water body location,

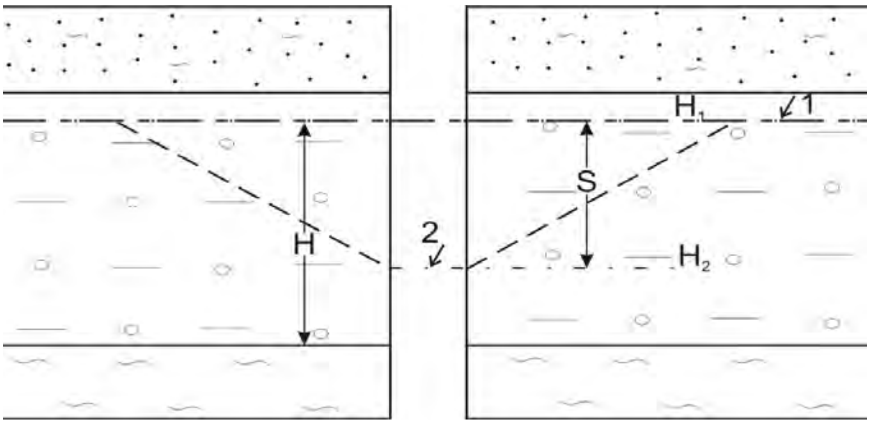
regeneration level of underground waters, as well as filtration coefficient of water bearing rocks.
2. Location of boreholes on the maps of scale 1:25000 and more.
3. Calculate the level of restored underground waters in boreholes.
4. Compose underground waters isolines similar to topographic isolines.
5. Compose hydro-geological profiles according to hydro-isolines maps following the directions of flow indicated by hydro-isolines (this will give hydraulic gradient).
6. Underground water resources are calculated by Darcy formula using the composed profiles and filtration coefficient taken from geologic archive materials. Darcy formula is as follows: Q=KFY, where F-is the cross-sectional area or product of aquifer thickness and width dimensions perpendicular to direction of flow K is the filtration coefficient (according to archive materials for that type of geology), Y is the hydraulic incline, which is defined similar to topographic slope, presented in the hydro-isolines map.
7. Water resources calculated according to separate sections of the given hydro-isoline are then summed up, which results in overall underground water resources of the given territory.

The allowable level (S) of lowering water level during exploitation of boreholes must compose the 0.5-0.6 part of the capacity (aquifer thickness) of water bearing body:

S=(0.5-0.6)H.

If the depth of aquifer is 30m, then the allowable level of lowering should not exceed 18m.
The necessary parameters for deep wells are provided below:

Scheme 1



Notation:
1. (H_1) Static level of underground waters from the Earth's surface (m)
2. (H_2) Dynamic level of underground waters or exploitable level of waters (m)
$S=H_1-H_2$, represents the allowable lowering of water level in boreholes (m)
H – Capacity (thickness)of aquifer (m).

2.5 Type and Format of Output Data

Water resources calculated through the general water balance formula are summarized in a table, the form for which is provided below:

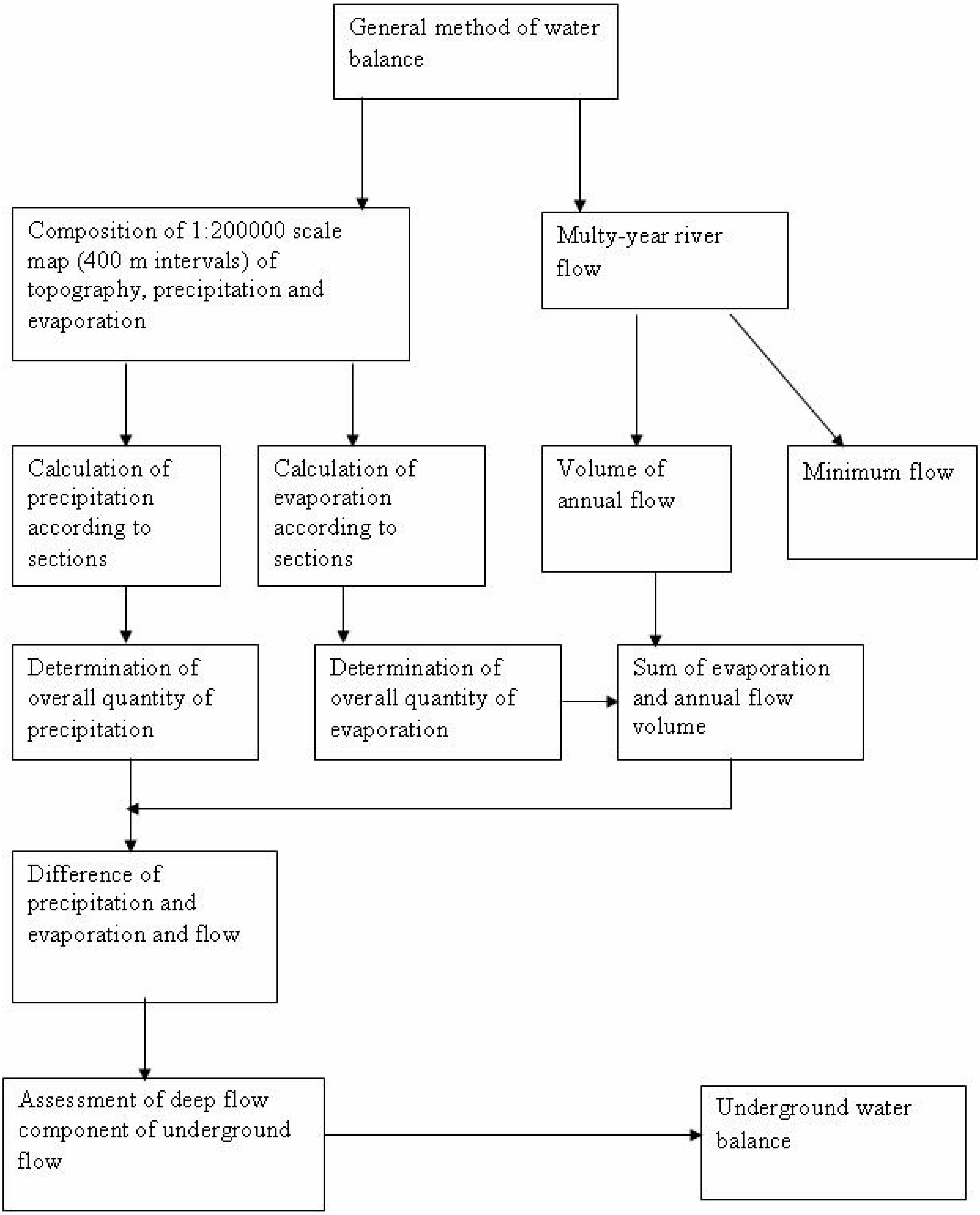
Table 1 – Sample output table

Underground flow, m^3/sec				**Water Balance, mln. m^3/year**					
Total	**of which**			**Precipitation**	**Evaporation**	**Spring flow**	**Drainage flow**	**Deep flow**	**Surface flow**
	spring	**drainage**	**deep**						

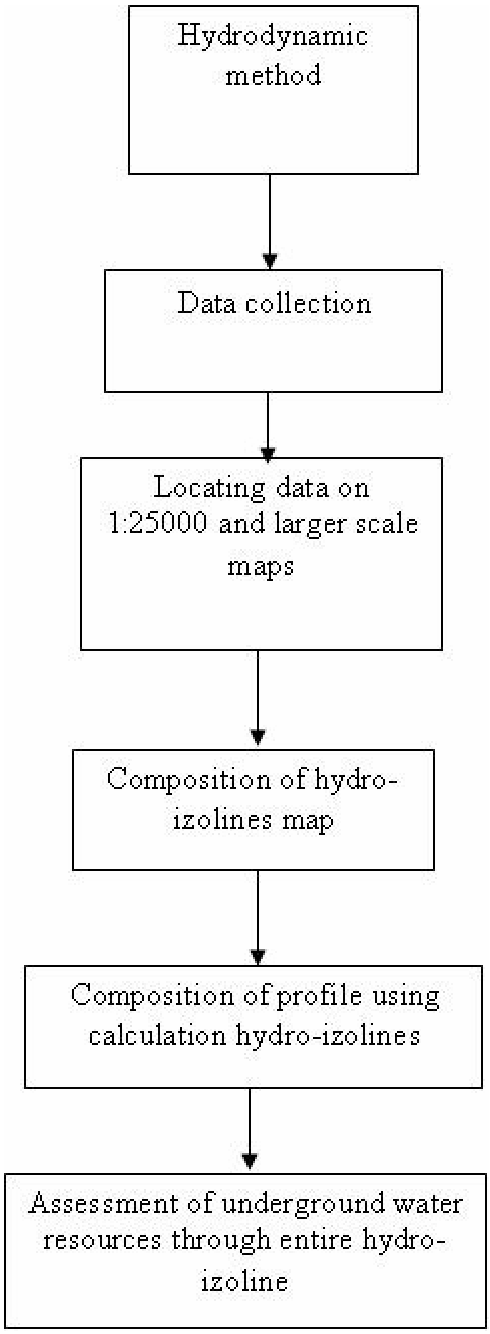
Water resources calculated through a hydrodynamic method are given in numbers, where only the deep flow component is calculated.

3. Diagram of Approach

Method A



Method B


Hydrodynamic method
Data collection
Locating data on 1:25000 and larger scale maps
Composition of hydro-izolines map
Composition of profile using calculation hydro-izolines
Assessment of underground water resources through entire hydro-izoline

4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

From the above-mentioned, two proposed methods for calculation of underground water resources in the general formula for calculation of water balance are applicable in Mehgriget River basin. The hydrodynamic method, which is methodically alllowable for the lower section water bodies of Meghriget and Karchevan, is currently impossible to apply due to absence of required data from wells.

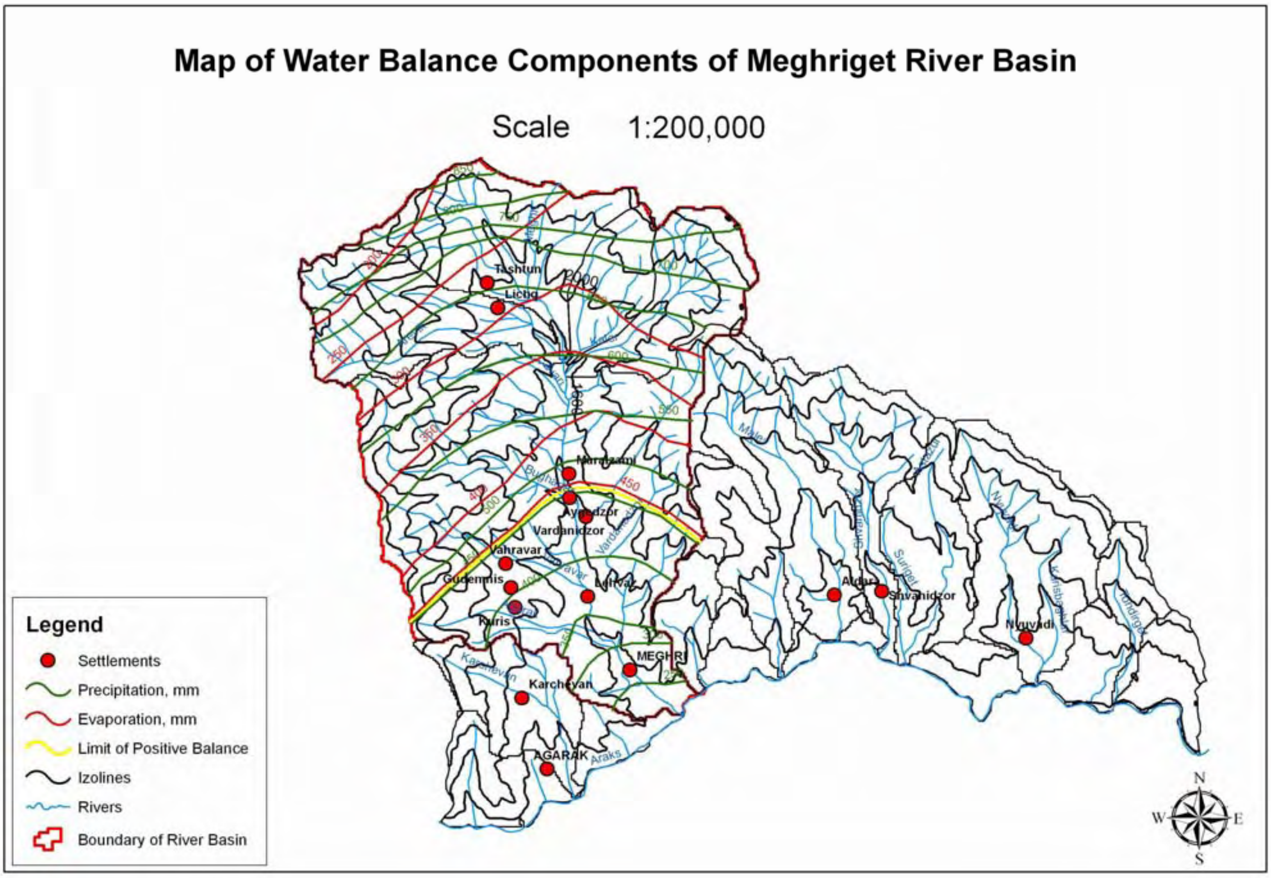
While applying the general formula for annual water balance method it is necessary to use 1:200000 scale maps of precipitation and evaporation together with the topographic izolines. The positive balance zone includes hypsometric altitudes above 1400m. This is why the evaoiratuib and precipitation are determined for the areas of the following altitudes: above 2000m, 2000-1600m and below 1600m. The average natural discharge of Meghriget is determined according to 1953-1962 annual hydrological publications. The lowest discharge of 0.94 m^3/sec. corresponds to the minumim discharge of river in the above-mentioned period. Discharge of springs has been determined using data from Republican Geological Fund. The drainage flow has been determined as difference of lowest discharge and springs discharge. Deep flow has been determined as difference of total precipitation and evaporation and average annual river flow.

Thus, the overall volume of discharge of underground water resources in Meghriget River basin is assessed as the sum of spring, drainage and deep flows 0.94 m^3/sec. (table 3).

4.2 Examples of Input Data (Tables)

Table 2 – Sample input table

Data type	Proposed use
1. Precipitation 2. Evaporation	Hydrological Atlas, 1990, Map 2.3
3. River discharge 4. Discharge of irrigation capture structures	Annual yearbooks of Hydromet Service
5. Discharge of springs	Republican Geological Fund
6. Description of wells and hydrodynamic parameters	Republican Geological Fund
7. Topographic maps of scales 1:25000 and 1:200000	Specialized organizations



4.3 Examples of Output Data (Tables)

Table 3 - Underground water resources of Meghriget River basin (according to hydrological observation point in c. Meghri)

Hypso-metric altitude	**Area of positive balance zone, km^2**	**Precipitation**		**Evaporation**		**Drainage flow of springs, mln. m^3/year**	**Surface flow, mln. m^3/year**	**Deep flow, mln. m^3/year**
		mm	**mln. m^3 /year**	**mm**	**mln. m^3 /year**			
Above 2000 m	34	850	28.9	(244)	88.3			
2000-1600 m	178	700	124.6	(305)	54.3			
Below 1600	66	500	33.0	(346)	22.8			
Total	278		186.5		85,4	54*18	41*58	-5,3

Notation: Underground water resources of Meghriget River Basin are composed of the sum of drainage flow and deep flow (54,18+5,3=59,8 mln. m^3/year or 1,89 m^3/sec.).

Table 4 - Underground water resources of Meghriget River basin

Underground flow. m^3/sec., according to importance				Water balance, mln. m^3 year (multi-year average data)					
Total	including			Precipitation	Evaporation	Spring flow	Drainage flow	Deep flow	Surface flow
	spring	drainage	deep						
0.94	0.4	0.38	0.16	186.4	85.4	28.35	25.83	5.3	41.58

5. Bibliography

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GUIDELINE 1.7: CALCULATION OF MAXIMUM FLOW (FLOODS)

a. For Gauged Basins
b. For Ungauged Basins

1. Introduction

1.1 Purpose of this Guideline

Thus purpose of this guideline is to briefly present the method for calculation of maximum discharge for (a) gauged basins, having long-term data series, and (b) ungauged basins. The guideline also explains the role and importance of calculation of maximum discharge in river basin planning, as an input to evaluation of flood risk, as well as its practical implementation and application example.

1.2 Role of Calculation of Maximum Flow in River Basin Planning

Calculation of maximum discharge, and associated flood risks, is a part of the characterization phase of river basin planning. The maximum discharge is often associated with flooding and mudflows, which impose significant damage on economies and populations located in a river basin. Hence the calculation of maximum discharges for different probabilities of occurrences is important for determination of frequency of repetition of the above mentioned threats. Calculation of flood risk is an important part of planning, particularly land-use planning, transportation planning, urban planning (stormwater) and planning of agricultural investments and hydraulic infrastructure in general. Flood control structures can alter the hydrology and morphology of river systems, and hence their hydro-morphological status, a key point of water body evaluation in the European Union Water Framework Directive.

2. Technical Approach

2.1 Methodology: Approach and Justification

a. Variation of maximum discharge values in different years is due to numerous factors, which makes it necessary to apply the methods of mathematical statistics in calculating maximum annual flows of different probabilities of occurrences (Sokolovski D., River Flow, Leningrad, 1983). Probability of occurrence of annual flow is the average number of years, represented in percentage, during which the annual flow will be equal to or greater than the given value of the flow.

In case of the existence of sufficient long-term data series it is suggested to do the calculation of maximum discharges using the curves of probabilities of occurrences, which show the probabilities of such cases in percentage (when the value of the given discharge will exceed the values of the observed series). While calculating the parameters of the curve of probability of occurrence the hydrological values are observed in the form of statistical series, sorted according to values in descending order. The curves of probabilities of occurrences are empirical and theoretical. Taken into consideration those curves, the maximum discharges of different probabilities of occurrence can be calculated using graphical-analytical and moments' methods (Luchsheva A., Practical Hydrology, Leningrad, 1983). This guideline finds it appropriate to use the graphical-analytical method for calculation of maximum discharges of different probabilities of occurrences.

b. In case of absence of observation series the maximum flow is calculated with a sufficient level of reliability using the Armenian maps of flow module isolines.

2.2 Input Data Requirement

a. The multi-year series of annual maximum flow is being used in these calculations.

b. For ungauged river basins it is necessary to use the maps of maximum flow module isolines.

2.3 Where to Acquire Input Data

a. The multi-year maximum flow series can be obtained from ArmStateHydromet.

b. It is necessary to use the corresponding maps of Republic of Armenia Hydrological Atlas (Hydrological Atlas of Armenia, Yerevan, 1990). From the atlas the maps of maximum flow module isolines of required probabilities of occurrences are given in maps No. 30, 31, 32, 33, 34.

2.4 Explanation of Analysis Procedures

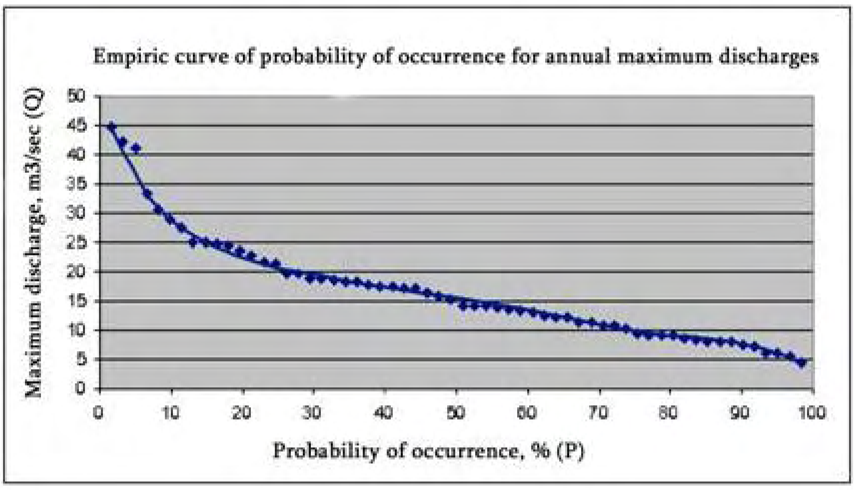
a. The purpose of calculation is to define the probability of repitition (probability of occurrence) of observed maximum discharges. The multi-year series of annual maximum flows is being used for calculation, which should be not less than 25 years.

1. The series should be sorted in descending order and probability of occurrence of each member of the series should be calculated. As a result of this operation we will obtain the probability of occurrence (P) for each of the observed maximum discharges. It is being calculated using the formula: P=(m/(n+1))100%, where m is the sequential number of the series member, n is the total number of series members. A table of the below-mentioned format is composed:

Table 1 – Structure of table sorted in descending order

m	Year	Maximum flow, m^3/sec	Maximum flow in descending order, m^3/sec	P=(m/(n+1))100%

2. Based on data from the 4th and 5th columns of the table the empiric curve of probability of occurrence is composed. It is possible to determine the empiric value of maximum discharge of any probability of occurrence using the curve.



The next steps of calculations calculate the theoretical curve of probability of occurrence and construct the theoretical curve of probability of occurrence.

For calculation of theoretical probability of occurrence the following parameters are being used: deviation (S) of empiric series, asymmetry coefficient (Cs), Foster coefficient (Φ), average square deviation (σ), average arithmetic value of theoretical curve ($Q_{a.a.}$), and variation coefficient (C_v).

3. Deviation (S) is calculated using the following formula:

$S=(Q5\%+Q95\%-2*Q50\%)/(Q5\%-Q95\%)$,

where Q5%, Q50%, Q95% are empiric curves of maximum discharges of correspondingly 5, 50, 95% probabilities of occurrences. These values are taken from the empiric curve of probability of occurrence.

4. Taking the value of deviation coefficient from the Foster table (Luchsheva A., Practical Hydrology, Leningrad, 1976, Appendix 3, page 431) it is necessary to find the value of asymmetry coefficient (C_s) of the empiric curve, as well as Foster coefficients (Φ5%, Φ50%, Φ95% and Φ5%-Φ95%) which will be used in further calculations.

5. Using the Foster coefficients, first of all, we will calculate the average square deviation σ of the empiric curve with the help of the following formula:

$\sigma=(Q5\%-Q95\%)/(\Phi5\%-\Phi95\%)$.

The average square deviation shows the level of dispersion of the members of the empirical series as compared to the theoretical average.

6. It is necessary to calculate the average arithmetic value of theoretical series:

$Q_{a.a.}=Q_0-\sigma*\Phi50\%$.

The average arithmetic value of the empirical series and the theoretically calculated value might differ from each other. If the difference satisfies the following condition $(Q_{a.a.}-Q_0)<0.02*Q_{a.a.}$, then the theoretically constructed curve is acceptable.

7. In order to obtain the maximum flows of the theoretical curve of probability of occurrence it is necessary also to calculate the variation coefficient C_v.

$C_v=\sigma/Q_{a.a}$.

8. Having those values and using the Foster annexes the following table is completed.

Table 2 – Table for construction of theoretical curve of probability of occurrence

P	0.01	1	5	20	50
Φ					
$\Phi*C_v$					
$K_h=1+\Phi*C_v$					
$Q_h=K_h*Q_0$					

The first row of the table represents the values of probabilities of occurrences in percentage.

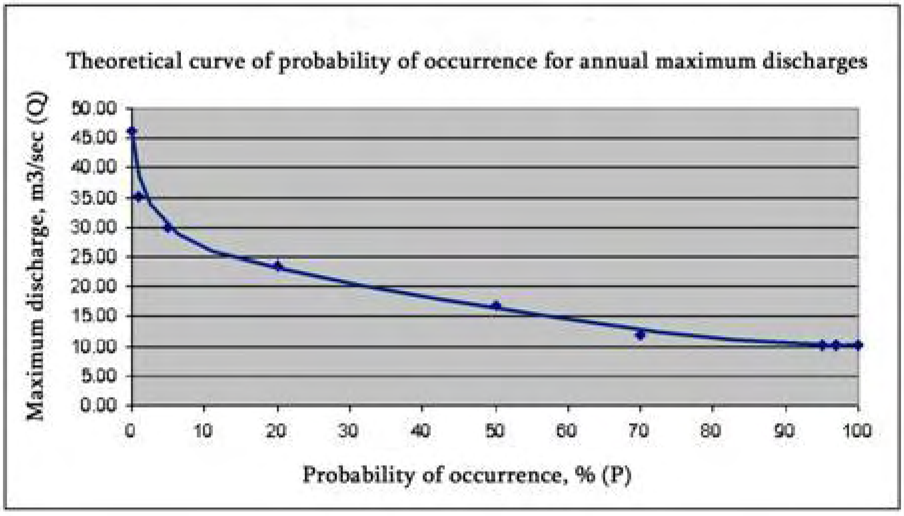
The second row is filled taking from the Foster table the values of 0.01, 1, 5, 20, 50% probabilities of occurrences for deviation coefficient (S) of the empirical curve.

In order to fill in the third row, it is necessary to multiple all the values of the second row correspondingly by C_v.

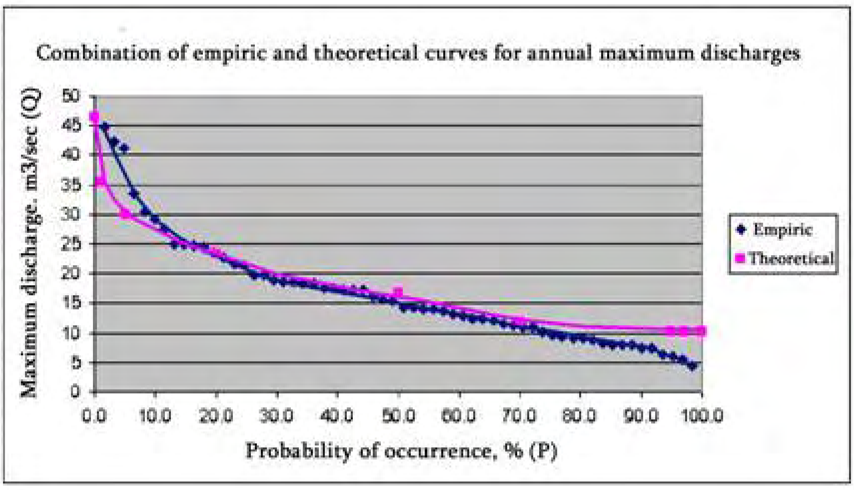
In the fourth row, 1 is added to all the values of the third row, since the values presented in the Foster table are given by deviations from 1.

The fifth row represents the theoretical maximum discharges. In order to obtain the values of the fifth row it is necessary to mutiple the values of the fourth row with the average arithmetic of the empirical series.

9. The theoretical curve of probability of occurrence is obtained using the first and fifth rows of the table.



10. With the last step it is necessary to combine the empirical and theoretical curves of probabilities of occurrences (Luchsheva A., Practical Hydrology, Leningrad, 1983).



b. Using the corresponding maps from Hydrological Atlas it is necessary to calculate the maximum discharge module for each river basin through the following formula:

$M= [((M_1+M_2)/2)*F_1+((M_2+M_3)/2)*F_2+\ldots+((M_n+M_{n+1})/2)*F_n\ldots] /F$,

where M_1, M_2,…, M_n,…are the maximum discharge module isolines, F_1, F_2,…, F_n,…are the areas bounded by two neighboring izolines, and F is the total area of the river basin. The efficient way for calculating the areas is the application of GIS, i.e. digitalization of maximum discharge module isolines and automated calculation of the areas. Transfer from maximum discharge module to maximum discharge is done using the following formula: Q=M*F/1000, where Q is the maximum discharge, M is the discharge module, and F is the area of the river basin.

2.5 Type and Format of Output Data

a. Output data represent tables and curves for statistical method.

b. Output data represents tables in MS Excel format for ungauged basins.

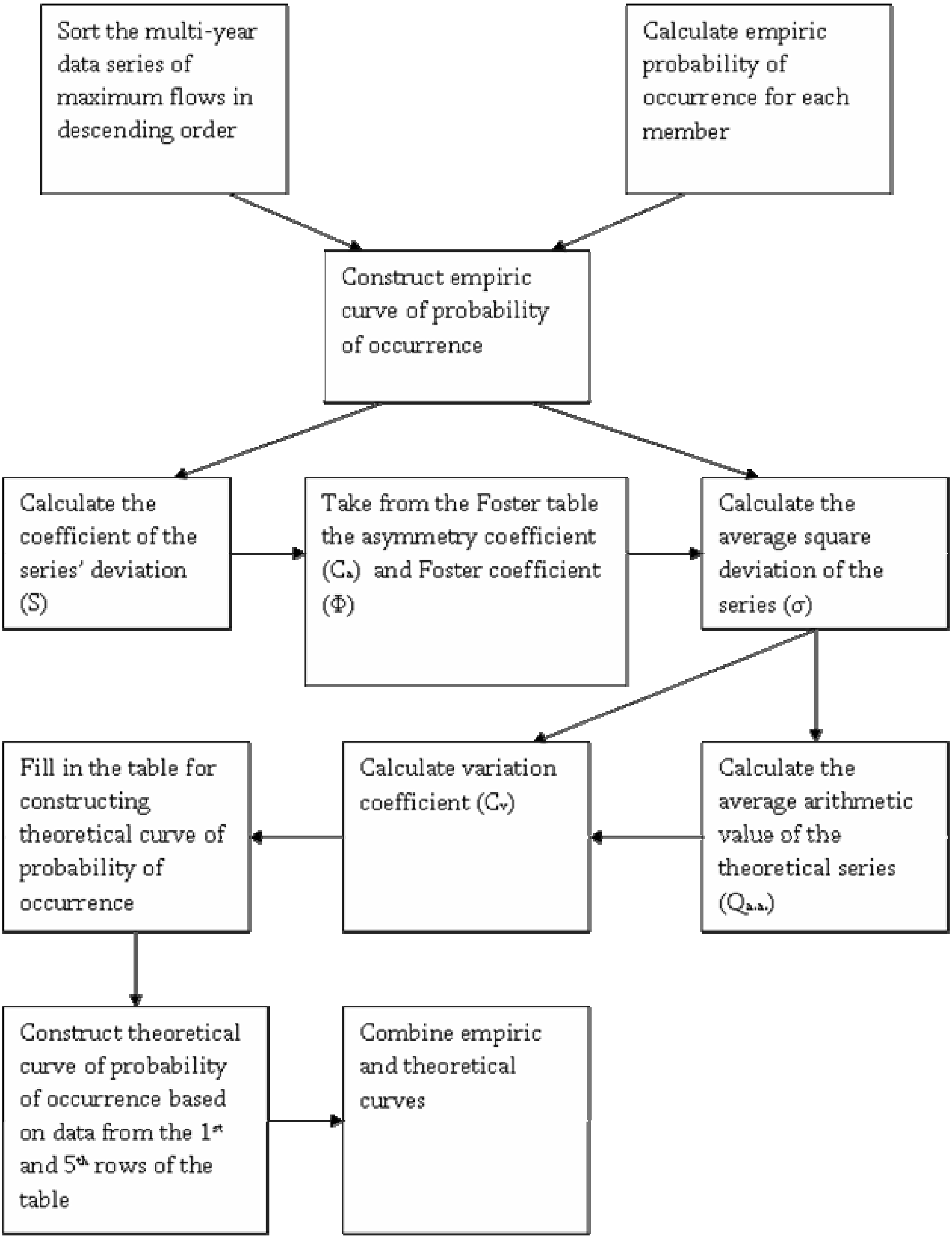
2.6 Computer Program or other Aid Tool for Calculation of Maximum Flow

a. The computer program on “River Basin Water Balance” includes a section on “Calculation of Maximum Discharge”, which provides for a possibility to automatically calculate maximum flows of different probabilities of occurrences. It is only necessary to input the multi-year series of maximum discharges and make simple computer operations. Parallel to the compute program a user's manual has been developed, which described the operations step by step.

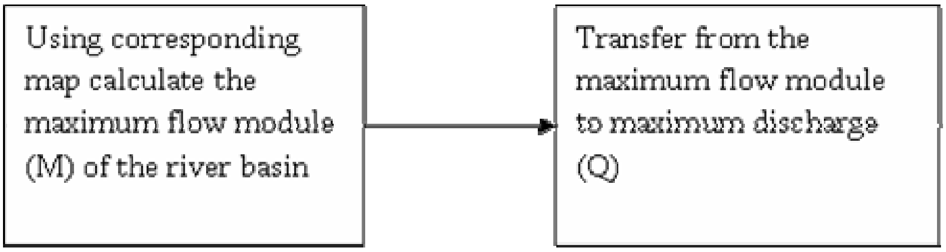
b. For ungauged river basins there is no special computer program for calculation of maximum discharge. However, the calculation of maximum discharge can be done through digitizing the maps of maximum flow module izolines, using ArcGIS 9.x software and implementing corresponding operations in GIS environment. Afterwards, the results data can be exported to MS Excel, where the corresponding calculations can be done.

3. Diagram of Approach

a. For Gauged Basins



b. For Ungauged Basins



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

a. The series of maximum discharges for 61 years recorded in Meghriget-Meghri hydrological observation point is taken. This series is sufficient for calculation of annual maximum discharges for different probabilities of occurrences using the graphical-analytical method described in section 2.4.

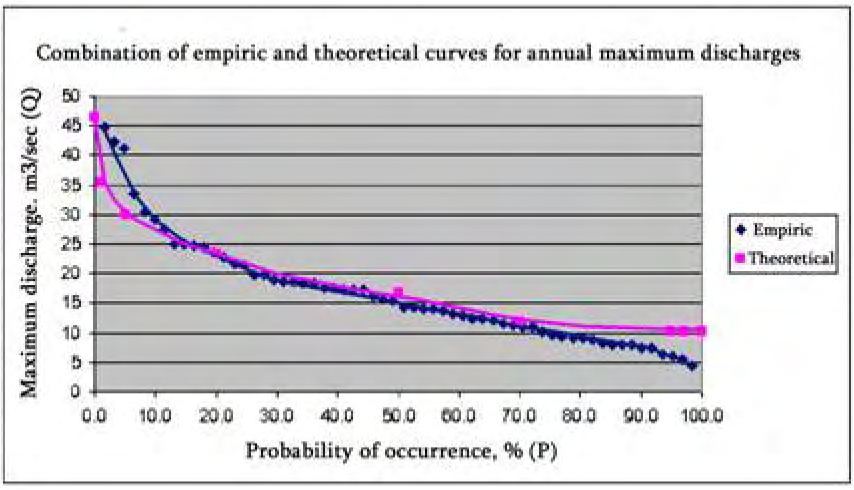
1. The series is sorted in descending order and the probability of occurrence (P%) for each member of the series is calculated.

Table 3 – Probability of occurrence of members of series

m	Year	Maximum flow, m^3/sec	Maximum flow in descending order, m^3/sec	P=(m/(n+1))100%
1	1945	8.7	87.5	1.6
2	1946	25	44.7	3.3
3	1947	9.1	42.3	4.9
4	1948	8.03	41.2	6.6
5	1949	7.55	33.4	8.2
6	1950	8.02	30.5	9.8
7	1951	9.06	29	11.5
8	1952	17.5	27.4	13.1
9	1953	18,3	25	14.8
10	1954	17.3	24.99	16.4
11	1955	41.2	24.6	18.0
12	1956	87.5	24.5	19.7
13	1957	21.5	23.5	21.3
14	1958	17.7	22.8	23.0
15	1959	18.4	21.7	24.6
16	1960	21.7	21.5	26.2
17	1961	10.2	19.8	27.9
18	1962	5.45	19.7	29.5
19	1963	33.4	19	31.1
20	1964	19.8	18.8	32.8
21	1965	19.7	18.7	34.4
22	1966	13.7	18.4	36.1
23	1967	18.7	18.3	37.7

m	Year	Maximum flow, m^3/sec	Maximum flow in descending order, m^3/sec	P=(m/(n+1))100%
24	1968	14.1	17.7	39.3
25	1969	42.3	17.5	41.0
26	1970	15.4	17.4	42.6
27	1971	6.2	17.3	44.3
28	1972	44.7	17.2	45.9
29	1973	19	16.3	47.5
30	1974	13.9	15.7	49.2
31	1975	12.5	15.4	50.8
32	1976	29	14.3	52.5
33	1977	16.3	14.2	54.1
34	1978	27.4	14.1	55.7
35	1979	11.4	13.9	57.4
36	1980	10.9	13.7	59.0
37	1981	14.2	13.3	60.7
38	1982	13	13	62.3
39	1983	30.5	12.5	63.9
40	1984	14.3	12.3	65.6
41	1985	22.8	12.2	67.2
42	1986	15.7	11.4	68.9
43	1987	11.4	11.4	70.5
44	1988	24.5	10.9	72.1
45	1989	6.03	10.9	73.8
46	1990	17.4	10.2	75.4
47	1991	10.9	9.5	77.0
48	1992	13.3	9.3	78.7
49	1993	24.6	9.1	80.3
50	1994	23.5	9.06	82.0
51	1995	9.5	8.7	83.6
52	1996	18.8	8.33	85.2
53	1997	12.3	8.03	86.9
54	1998	8.33	8.02	88.5
55	1999	7.95	7.95	90.2
56	2000	7.3	7.55	91.8
57	2001	4.5	7.3	93.4
58	2002	12.2	6.2	95.1
59	2003	24.99	6.03	96.7
60	2004	17.2	5.45	98.4
61	2005	9.3	4.5	100.0
n=61				

2. Using the fourth and fifth columns of the table the empiric curve of probability of occurrence is constructed. It is easier to construct the curve, as well as conduct follow-up calculations using the MS Excel software:



3. Calculation of deviation coefficient:

The following values are taken from the empiric curve: Q5%=29.82, Q50%=16.80, Q95%=3.77. Afterwards, those values are plugged into the formula for calculation of deviation coefficient:

S=(Q5%+Q95%-2*Q50%)/(Q5%-Q95)=0.

4. Calculation of average square deviation:

From Foster table it is necessary to take the values of Φ5%, Φ50%, Φ95% and Φ5%-Φ95%. The average square deviation (σ) is calculated using the following formula:

σ=(Q5%-Q95%)/(Φ5%-Φ95%), σ= 7.94.

5. Average arithmetic value of the theoretical series:

$Q_{a.a.}=Q_0-σ*Φ50\%$, $Q_{a.a.}$=16.80.

The average arithmetic value of the series and theoretically calculated value can be different from each other. The difference should satisfy to the following condition: ($_{a.a.}-Q_0$)<0.02*$Q_{a.a}$. According to calculations (16.8-16.8)<0.02*16.8. Since 0<0.34, then the calculation is correct.

6. Calculation of variation coefficient:

$C_v=σ/ Q_{a.a.}$, C_v=0.47.

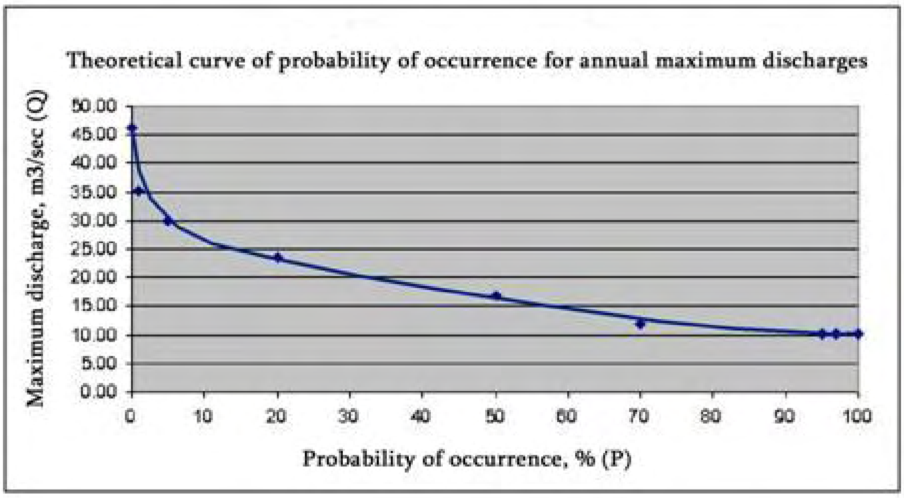
7. After completing the above-mentioned calculations, the table below is filled in:

Table 4. Completed table for construction of theoretical curve

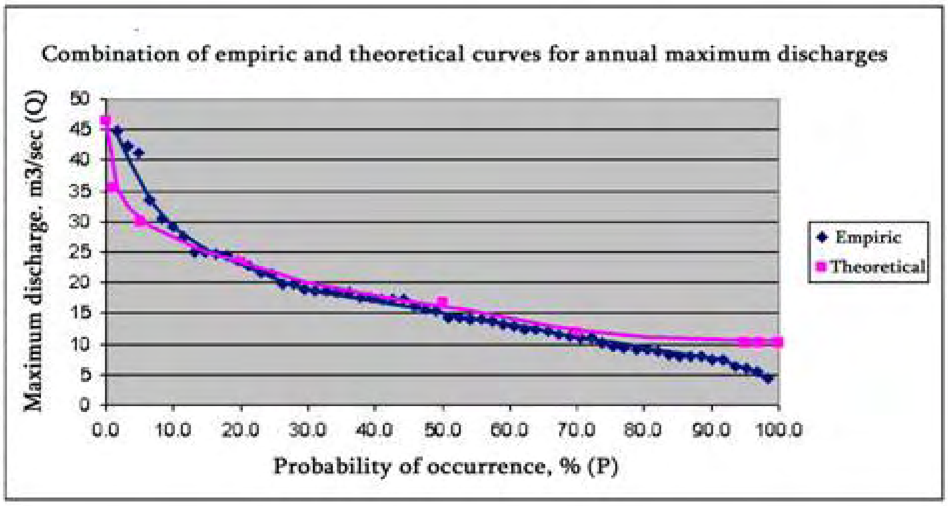
P	0.01	1	5	20	50	70	95	97	99.9
Φ	3.72	2.33	1.64	0.84	0.00	-0.62	-0.82	-0.83	-0.83
$Φ*C_v$	1.76	1.10	0.78	0.40	0.00	-0.29	-0.39	-0.39	-0.39
$K_h=1+Φ*C_v$	2.76	2.10	1.78	1.40	1.00	0.71	0.61	0.61	0.61
$Q_h=K_h*Q_0$	46.35	35.30	29.82	23.47	16.80	11.87	10.28	10.23	10.18

As a result the maximum calculated flows (Q_c) for different probabilities of occurrences are obtained.

8. Using date from the first and fifth rows of the table the theoretical curve of probability of occurrence is constructed:



9. It is necessary to combine the empiric and theoretical curves of probabilities of occurrences:



Thus, the maximum flows calculated for different probabilities of occurrences are presented below:

Table 5. Different probabilities of occurrences for maximum flows in Meghriget

P	0.01	1	5	20	50	70	95	97	99.9
$Q_h=K_h*Q_0$	46.35	35.30	29.82	23.47	16.80	11.87	10.28	10.23	10.18

b. Below the calculation of maximum discharge for 1% probability of occurrence for Malev River is provided:

1. Definition of isolines:

Table 6. Areas bounded by 1% probability of occurrence annual maximum flow module isolines for Malev River

Module izolines, l/sec. km^2	**Area, km^2**
<150	12.77
150-300	8.04
300-450	8.84
450-600	13.31
600-750	7.45
Total area	**50.42**

2. Calculation of maximum flow module:

Calculation of maximum flow module for 1% probability of occurrence:

$M_{1\%}$= [((M_1+M_2)/2)*F_1+((M_2+M_3)/2)*F_2+…+((M_n+M_{n+1})/2)*F_n…] /F=
= [((0+150)/2)*12.77+((150+300)/2)*8.04+((300+450)/2)*8.84+((450+600)/2)*13.31+
+((600+750/2)*7.45)]/50.42 = 359.03 l/sec. km^2.

Similarly, the calculation is done for other probabilities of occurrences. The values for 2% and 5% probabilities of occurrences are also calculated:

$M_{2\%}$= 221.80 l/sec. km^2, $M_{5\%}$= 134.16 l/sec. km^2.

3. Transfer from maximum flow module to maximum discharge:

Q=M*F/1000=359.03*50.42/1000=18.10,

where Q is the maximum discharge and F is the river basin area.

Thus, the maximum discharge of 1% probability of occurrence for Malev River composes 18.10 m^3/sec.

Making similar calculations, maximum annual discharges for 1%, 2% and 5% probabilities of occurrences for all small rivers adjacent to Meghriget are obtained. The results are presented in tables provided in section 4.3.

4.2 Examples of Input Data (Tables)

a. For Gauged Basins

Table 7. Multi-year series of maximum discharges

m	Year	Maximum discharge, m^3/sec
1	1945	8.7
2	1946	25
3	1947	9.1
4	1948	8.03
5	1949	7.55
6	1950	8.02
7	1951	9.06
8	1952	17.5
9	1953	18,3
10	1954	17.3
11	1955	41.2
12	1956	87.5
13	1957	21.5
14	1958	17.7
15	1959	18.4
16	1960	21.7
17	1961	10.2
18	1962	5.45
19	1963	33.4
20	1964	19.8
21	1965	19.7
22	1966	13.7
23	1967	18.7
24	1968	14.1
25	1969	42.3
26	1970	15.4
27	1971	6.2
28	1972	44.7
29	1973	19
30	1974	13.9
31	1975	12.5
32	1976	29
33	1977	16.3
34	1978	27.4
35	1979	11.4
36	1980	10.9
37	1981	14.2
38	1982	13
39	1983	30.5
40	1984	14.3
41	1985	22.8
42	1986	15.7
43	1987	11.4

m	Year	Maximum discharge, m^3/sec
44	1988	24.5
45	1989	6.03
46	1990	17.4
47	1991	10.9
48	1992	13.3
49	1993	24.6
50	1994	23.5
51	1995	9.5
52	1996	18.8
53	1997	12.3
54	1998	8.33
55	1999	7.95
56	2000	7.3
57	2001	4.5
58	2002	12.2
59	2003	24.99
60	2004	17.2
61	2005	9.3
n=61		

b. For Ungauged Basins

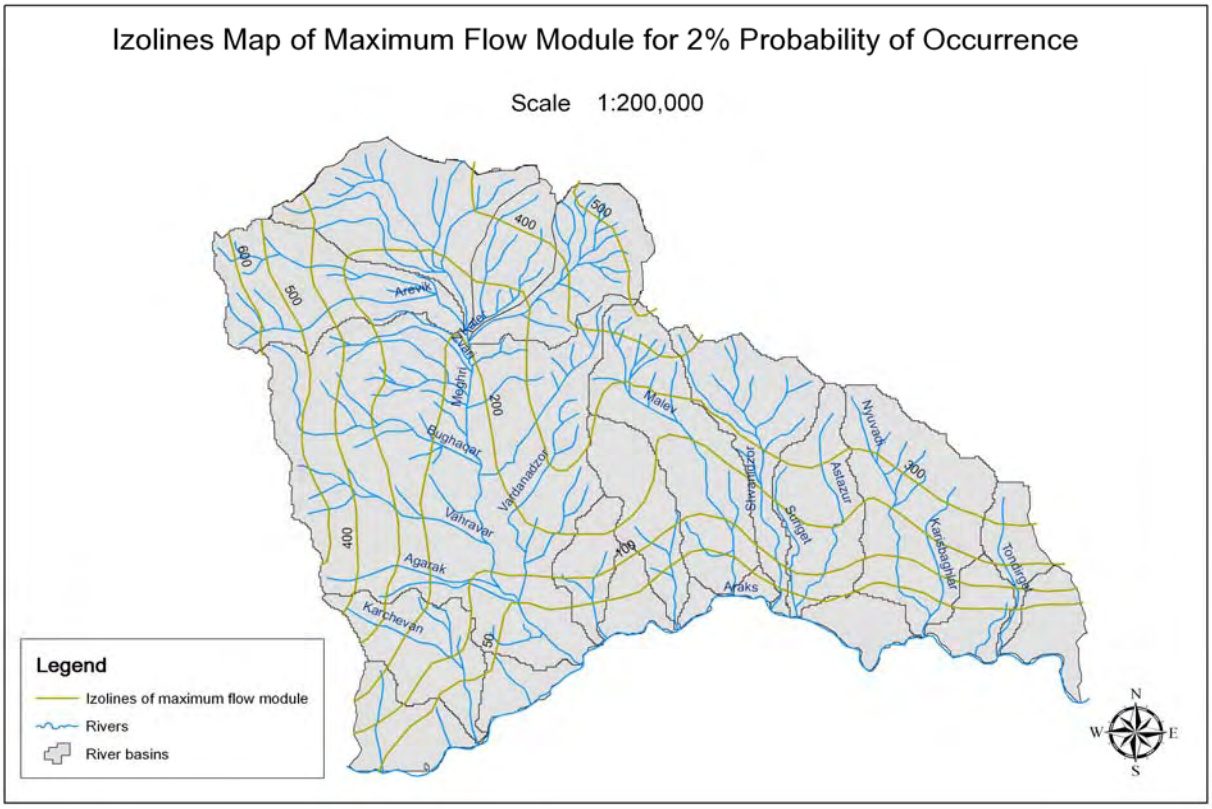


Table 8. Areas bounded by 1% probability of occurrence maximum flow module isolines of Malev River

Module izolines, l/sec. km^2	Area, km^2
<150	12.77
150-300	8.04
300-450	8.84
450-600	13.31
600-750	7.45
Total area	**50.42**

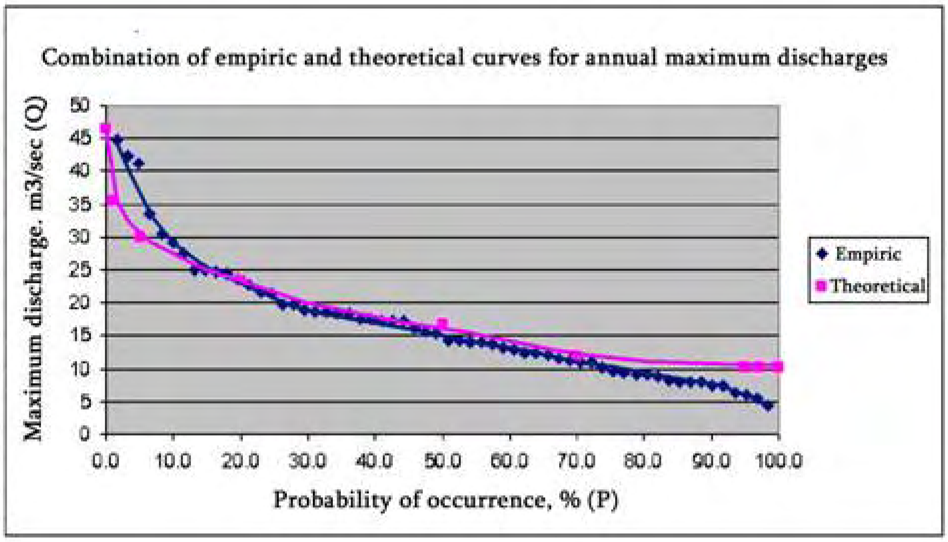
4.3 Examples of Output Data (Tables)

a. For Gauged Basins

Table 9. Calculation of theoretical probability of occurrence

P	0.01	1	5	20	50	70	95	97	99.9
Φ	3.72	2.33	1.64	0.84	0.00	-0.62	-0.82	-0.83	-0.83
Φ*C_v	1.76	1.10	0.78	0.40	0.00	-0.29	-0.39	-0.39	-0.39
K_h=1+Φ*C_v	2.76	2.10	1.78	1.40	1.00	0.71	0.61	0.61	0.61
Q_h=K_h*Q_0	46.35	35.30	29.82	23.47	16.80	11.87	10.28	10.23	10.18

As a result the maximum flows (Q_c) of different probabilities of occurrences are calculated.



b. For Ungauged Basins

Table 10. Maximum annual discharge of 1% probability of occurrence

River Basin	Area, km^2	Maximum discharge module, l/sec. km^2	Maximum discahrge, m^3/sec.
Nyuvadi	53.46	292.10	15.62
Tondirget	12.17	268.09	3.26
Suriget	31.28		
Astazurget	35.33	442.57	15.64
Malev	50.42	359.03	18.10
Karavget	22.99	290.68	6.68
Meghriget (middle and lower streams)	190.65	448.02	85.41
Meghriget-Kaler	31.95	642.14	20.52
Meghriget-Tashtun	14.64	572.95	8.39
Meghriget-Ayriget	44.22	680.97	30.11
Karchevan	27.86	281.28	7.84

Table 11. Maximum annual discharge of 2% probability of occurrence

River Basin	Area, km^2	Maximum discharge module, l/sec. km^2	Maximum discahrge, m^3/sec.
Nyuvadi	53.46	231.07	12.35
Tondirget	12.17	235.03	2.86
Suriget	31.28	211.85	6.63
Astazurget	35.33	300.38	10.61
Malev	50.42	221.80	11.18
Karavget	22.99	169.32	3.89
Meghriget (middle and lower streams)	190.65	273.78	52.20
Meghriget-Kaler	31.95	401.65	12.83
Meghriget-Tashtun	14.64	345.02	5.05
Meghriget-Ayriget	44.22	421.65	18.65
Karchevan	27.86	167.78	4.67

Table 12. Maximum annual discharge of 5% probability of occurrence

River Basin	Area, km^2	Maximum discharge module, l/sec. km^2	Maximum discahrge, m^3/sec.
Nyuvadi	53.46	80.98	4.33
Tondirget	12.17	47.71	0.58
Suriget	31.28	75.09	2.35
Astazurget	35.33	167.21	5.91
Malev	50.42	134.16	6.76
Karavget	22.99	91.17	2.10
Meghriget (middle and lower streams)	190.65	146.96	28.02
Meghriget-Kaler	31.95	297.53	9.51
Meghriget-Tashtun	14.64	236.11	3.46
Meghriget-Ayriget	44.22	304.66	13.47
Karchevan	27.86	76.65	2.14

4.4 Map of Application of the Method

b. See maps in section 4.2 of this guideline.

5. Bibliography for the Method

Luchsheva A., “Practical Hydrology ”, Leningrad 1976.
Luchsheva A., “Practical Hydrometry”, Leningrad 1983.

SYNTHESIS OF MEGHRIGET RIVER BASIN CHARACTERIZATION

1. Introduction to River Basin Management Planning in Armenia

River basin management planning supports long-term sustainable use of Armenia's water resources. Water use is an essential part of our social and economic well-being, but we also cause impacts to water by modifying land and other natural resources in the river basin. Development of agriculture, transportation, industry, urbanization, flood control and many other activities affect water resources and the aquatic environment. To reflect this diverse nature of our relationship to water, we need to adopt an approach which integrates the impacts of all those activities into a plan for protection and sustainable use of all waters within a river basin.

Integrated water resource management provides an approach to protection and use of water which takes into account the entire hydrologic cycle, including the relationship of surface water to groundwater, and the ecology of the water environment. The European Union Water Directive Framework (EU WFD) is an approach to integrated river basin management planning which is now being applied throughout Europe.

The EU WFD integrates diverse water resource concerns and also requires that other environmental priorities, economic considerations, and social issues be taken into account in setting environmental objectives for sustainable water use. This is important, because environmental protection must be achieved in a way that assures cost-effective essential services are provided to citizens and national development needs are supported by sustainable water resource use. Many aspects of the EU WFD can serve as a guide to effective river basin planning for Armenia. But the approach for Armenia must also take into account the reality of local conditions and the specific needs of the Armenian Water Resources Management Agency (WRMA).

Basin Characterization is the first step in the process of developing a river basin management plan. In the approach used here in Armenia, basin characterization is a description of the river basin, its human and natural resources, and a first attempt to identify the general broad water resource issues which confront that basin. The following stages of the river basin planning process will focus on delineating and classifying specific water bodies (management units) in each basin, setting environmental objectives for water quantity and quality, analyzing the pressures and impacts which affect those water bodies, developing measures to reduce the negative impacts of human activity and meet the objectives, and evaluating the social, economic, and environmental viability of distinct sets of measures.

This integrated river basin planning approach meets the requirements of Armenia's National Water Code (2002), particularly Article 11 of the Water Code; the Law on Fundamental Provisions of the National Water Policy (2005); and the activities implicit in the formation of the Basin Management Organizations within the WRMA by Prime Minister Decision N: 5-N (2003), Government Decision N1749-N (2004), and Order 237-A of the Minister of Nature Protection (2004).

1.1 Purpose of Basin Characterization

The purpose of basin characterization is to inventory the status of the human and natural resources, and particularly to review the existing information on water resources, to reveal the broad general issues affecting water in the basin. A well-prepared characterization report will assure that future stages of river basin planning are appropriately focused, realistic, and relevant to the stakeholders in the basin.

1.2 Scope of Planning Effort

Basin characterization in Armenia should focus on each major river system separately. For example in the Southern Basin, the Vorotan, Voghji and Meghriget areas need separate basin management planning efforts. Each basin plan will further divide each of those basins by distinct river, lake and groundwater water bodies, and each water body will fall within a classification type. Distinct types of rivers, lakes and aquifers will have, where necessary, distinct environmental objectives, due to differences in geology, water chemistry, and ecology. In the end, each distinct water body in the river system will have its own set of environmental objectives, based on its type classification, and particular measures defined to attain those objectives, based on actual pressures affecting it.

1.3 Planning Principles and Methodology

The river basin management planning effort is the responsibility of the Water Resources Management Agency, to be carried out in large part by the Basin Management Organizations. But the WRMA cannot carry out integrated river basin planning alone. Integration of water resource planning must include all aspects of the hydrologic cycle and integrate the water use priorities of all economic and social interests. Therefore, the basin planning effort must involve local and national governments, communities, civic groups, and private economic interests, as key stakeholders.

Partnership between the WRMA and other entities concerned with water resources is fundamental to the success of the river basin management plans. Agencies such as Armenia State Hydro Meteorological Service, Environmental Impact Monitoring Center, Hydrogeological Monitoring Center, Public Services Regulatory Commission, State Committee on Water Systems, State Environmental Inspectorate, and agencies involved in agricultural development, irrigation, and industry and commerce must be involved.

Public participation also must integrate the concerns of citizens, civic groups, and private economic interests in the key decisions being taken as part of the river basin planning.

River basin planning is a multi-year cyclic process which proceeds stepwise to conclude in the implementation of a set of recommended measures (policy actions and investments). However, each completed river basin plan must be revisited periodically to evaluate its implementation progress, to adapt it to new situations, and to improve its priorities. The EU WFD establishes a six-year planning cycle, for renewing river basin plans.

2. Meghriget River: Inventory of Bio-Physical and Geographic Characteristics (Guideline 1.1)

The Meghriget River basin is considered to be all of the watersheds which drain out of Syunik Marz directly into the Araks River within the boundaries of Armenia (see Annex: Map 1, 2). This includes the Meghriget River and all its tributaries, as well as the Karchevan, Shemeglukh, Karavget, Malev, Astazurget, Shvanidzor, Shavzir, Nuvadi, Kaisbajur and Tondirget drainages. The total area is 664 km^2, of which 336 km^2 is the Meghriget River watershed itself, and the remainder is the parallel smaller watersheds. The area has the following general characteristics.

2.1 Climate: precipitation, evapotranspiration, temperature

The Meghriget basin has a climate that varies dramatically according to altitude, with low-elevation areas being semi-arid, with mild winters and hot summers, while highest elevation areas are cool, sub-humid montane climates with long cold winters. Long-term averages of annual precipitation are summarized for four sites in Table 1 below:

Table 2.1: AVERAGE MONTHLY PRECIPITATION IN MEGHRIGET RIVER BASIN (mm):

Station name/dates:	Elev (m)	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Sep	Oct	Nov	Dec	Total (mm)
Meghri, 1949-2006	627	14	17	31	42	52	29	11	8	12	24	24	14	275
Lichq, 1956-99	1769	61	69	105	112	110	64	21	16	24	60	79	47	768
Kaler 1934-1962 (-1943/44)	2000	38	43	66	90	81	52	21	21	32	42	50	29	565
Shvanidzor, 1932-1965	640	24	27	41	50	58	32	13	7	14	26	30	18	380
Nuvadi 1949-1962	600	21	22	34	47	57	33	15	10	12	25	29	16	321

Source: ArmStateHydroMet

Obviously, annual precipitation increases dramatically with altitude in this region. GeoCom (2008) has used existing data from the basin, and nearby high-elevation zones to estimate the average monthly and annual precipitation by altitude zones:

Table 2.2: ESTIMATED AVERAGE MONTHLY PRECIPITATION BY ALTITUDE (mm)

Elevation range in Meghriget basin	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Sep	Oct	Nov	Dec	Total (mm)
0-1000 m	17	17	29	43	52	31	14	9	11	23	26	14	286
1000-2000m	29	38	54	64	45	33	32	20	11	41	36	36	439
2000-3000m	62	74	95	109	82	62	78	46	23	68	62	62	823
3000-3800m	89	103	116	150	117	104	90	47	42	65	82	82	1087

Source: GeoCom (2008)

These extrapolated data correspond fairly well to the suggested values from B. Mnatzakanyan (2005 "Water Balance of Armenia"), quoted in GeoCom (2008) which suggest average annual precipitation values as follows for Meghriget basin: 500m: 260 mm; 1500m: 630mm; 2500m: 920mm; and 3500m: 1000mm. Potential evapotranspiration is driven by temperature, humidity, soil conditions, and wind. It reflects evaporation from open water bodies or evaporation pressure on plants and soil. Potential evapotranspiration is a key variable in estimating the water needs of irrigated crops and in computing regional water balance. It can be calculated from temperature data, while some methods also use wind, humidity and sunshine data to improve the estimate, if these data are available.

Table 2.3: AVERAGE MONTHLY POTENTIAL EVAPOTRANSPIRATION (Est.)

Station name/ dates:	Elev. (m)	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Sep	Oct	Nov	Dec	Total (mm)
Meghri	**627**	25	31	61	117	152	174	203	192	115	75	35	21	**1201**
1000-2000m	---	18	24	47	95	127	148	175	170	100	64	29	16	**1014**
2000-3000m	---	12	17	33	73	102	118	143	139	79	52	22	14	**801**
3000-4000m	---	6	9	19	51	77	94	116	114	62	40	14	7	**613**

Source: Calculated by Hargreaves formula, FAO, 1998

Average annual evapotranspiration estimated by other authors, for example, the National Atlas of Armenia (Lemsel, V., et.al., 2007) gives the potential evapotranspiration (PET) for Meghriget basin as 600-1200 mm/year, depending on altitude, with higher PET at lowest altitudes. The International Water Management Institute water and climate database (www.iwmi.org) gives an estimate based on Penman calculations for Meghri (low-elevation) annual potential evapotranspiration as 1255 mm.

Average monthly temperatures for climate stations in the Meghriget basin are also highly related to elevation. Table 4 shows the actual long-term average monthly temperatures at Meghri, and the estimated average monthly temperatures at distinct altitudes in the basin, based on an increment of 5-6 degrees C for each 1000 m of altitude (GeoCom, 2008).

Table 2.4: AVERAGE MONTHLY TEMPERATURE (degrees C)

Elevation range, Meghriget basin (m)	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Au	Sep	Oct	Nov	Dec
Meghri (627 m)	1.7	3.6	8.1	14.1	18.7	22.9	26.2	25.8	21.4	15.3	9.2	4.1
0-1000 m	1.6	3.5	8.0	14.1	18.8	23.1	26.3	25.8	21.4	15.3	9.2	4.0
1000-2000m	-3.4	-1.5	2.0	8.1	12.8	17.1	20.3	20.8	16.4	10.3	4.2	-1.0
2000-3000m	-8.4	-6.5	-4.0	2.1	6.8	11.1	14.3	14.8	10.4	5.3	-0.8	--6.0
3000-3800m	-13.4	-11.5	-10.0	-3.9	0.8	5.1	8.3	8.8	4.4	-0.07	-6.8	-11.0

Source: GeoCom (2008a) and ArmStateHydroMet (2008)

2.2 Topography

The Meghriget basin has very steep topography, with elevations varying from slightly over 400 m.a.s.l. to over 3500 m.a.s.l. within relatively short distances. Only the Meghri basin has a significant drainage area above 3000m elevation, the other drainages have maximum elevations which are significantly lower. Since altitude is an important determinant of precipitation, this is a major factor in explaining why Meghriget River has abundant perennial flow, and the other basins have very small or non-existent summer flows. The major drainages of the basin have topographic and geomorphic characteristics displayed in Table 2.5 as follows:

Table 2.5: TOPOGRAPHIC CHARACTERISTICS OF DRAINAGE BASINS IN MEGHRIGET

Name of Drainage	*Size (km^2)*	*Maximum altitude (m)*	*Minimum altitude (m)*	*Average altitude of basin (m)*	*Total length of drainage (km)*	*Slope of drainage (m/m)*
Meghriget River	***336***	***3760***	***513***	***2070***	***35***	***0.092***
Karchevan	***19***	***2647***	***535***	***1415***	***11***	***0.192***
Shemeglukh	***13***	***2089***	***506***		***7***	***0.226***
Karavget	***23***	***2416***	***488***	***1203***	***12***	***0.161***
Malev	***51***	***2982***	***474***	***1576***	***17***	***0.148***
Astazurget	***35***	***2150***	***451***	***1556***	***16***	***0.106***
Shavriz-Suriget	***31***	***2345***	***442***	***1123***	***13***	***0.146***
Nuvadi-Karisbajur	***52***	***2366***	***412***	***1263***	***14***	***0.140***
Tondirget	***12***	***2232***	***416***		***9***	***0.201***
Other areas:	***92***					
TOTAL:	***664***					

Source: Armenia State Water Cadastre, 2007

2.3 Geology

2.3.1 Geology and Geomorphology

The geomorphology of the Meghriget basin is distinctive in Armenia, as the area of the Meghriget River basin contains the most extensive outcrops of Palaeogene (Tertiary) granitic and other intrusive rocks in the country. The Meghriget River drainage is almost entirely composed of these intrusives, and the area is highly dissected by steep drainages and narrow valleys, with abundant outcrops of these weathered intrusive rocks. Faulting is primarily NW-SE trending (see Annex: Map 11). In the easternmost part of the Meghriget basin, in the upper end of the Astazurget and Nuvadi-Karisbajur drainages, and separated by a major fault zone from Meghri, there are very distinctive and diverse Jurassic era sedimentary and volcanic formations, including carbonates (limestones, marl, dolomites, calcareous sandstones, tufa, and conglomerates) and a small area in the extreme eastern boundary, of Jurassic volcanic rocks, including porphyrites, diabases, and their pyroclasts (similar to much of the Shikahogh area).

2.3.2 Rock Types and Mineral Resources

The Palaeogene intrusive rocks of the Meghriget River drainage and adjoining areas are well-known for their economic mineralization with porphyry deposits of gold, copper, and molybdenum (JICA, 2003). One of the largest mines in Armenia, the Agarak copper-molybdenum mine, is located near the Araks valley in the lower Karchevan drainage in the extreme southwest. This facility includes an open-pit mine; mill/processing plant and large-scale tailings ponds. This mine has been exploiting copper and molybdenum in Agarak since 1963. There are other small mines and plans for mines in the Meghri drainage, including an underground gold mine (Lichvaz gold) which has recently been reactivated near the Meghriget River.

2.4 Hydrography and Hydrology

2.4.1 Surface Water Resources

Perennial surface water is abundant in the drainage above 2000m elevation, most importantly in the upper Meghriget River and its major tributaries, such as the Kaler, Gozgoz, Tashtun, Ayriget drainages and the upper end of the Vardanadzor, Bughakar, and Vagravar drainages. The flow from these uplands sustains diminished but perennial flows during late summer, fall and winter in the lower Meghriget River to its confluence with the Araks.

The other drainages which discharge directly to the Araks are mostly ephemeral, with spring flows in response to snowmelt, and no flow during long periods of summer, fall, and winter. This situation is typical of the Karchevan, Shemeglukh, Karavget, Malev, Astazurget, Suriget-Shavrahavzir, Nuvad-Karisbajur, Tondirget. Drainages with higher elevation headwaters (Karchevan, Malev, Astazurget) have more and longer sustained flows than the lower elevation systems.

Two small natural lakes exist in the uplands of the Meghriget River at approximately 3200 meters elevation. One, called Tsakqar, has a surface area of approximately 5 hectares, and a depth of 8 meters, and the other Kapuyt, has a surface area of 3 hectares, and a depth of 6 meters. No significant artificial reservoirs have been constructed in the region.

2.4.2 Watershed Morphologic Characteristics

The drainages of the Meghriget basin are extremely steep, with overall watershed slopes of 0.08 to 0.24 m/m (see Table 5). The Meghriget River is third-order dendrite drainage, with many lateral tributaries, but the remaining drainages are primarily first- or second-order streams which are linear in form. Channels are deeply incised, usually in intrusive bedrock, with large cobbles and boulders forming the channel bottom materials. At the mouth of each drainage, near where it discharges to the Araks, there is an alluvial fan of coarse gravelly material, and then the narrow floodplain of the Araks River.

2.4.3 Average Monthly Discharge of Major Drainages

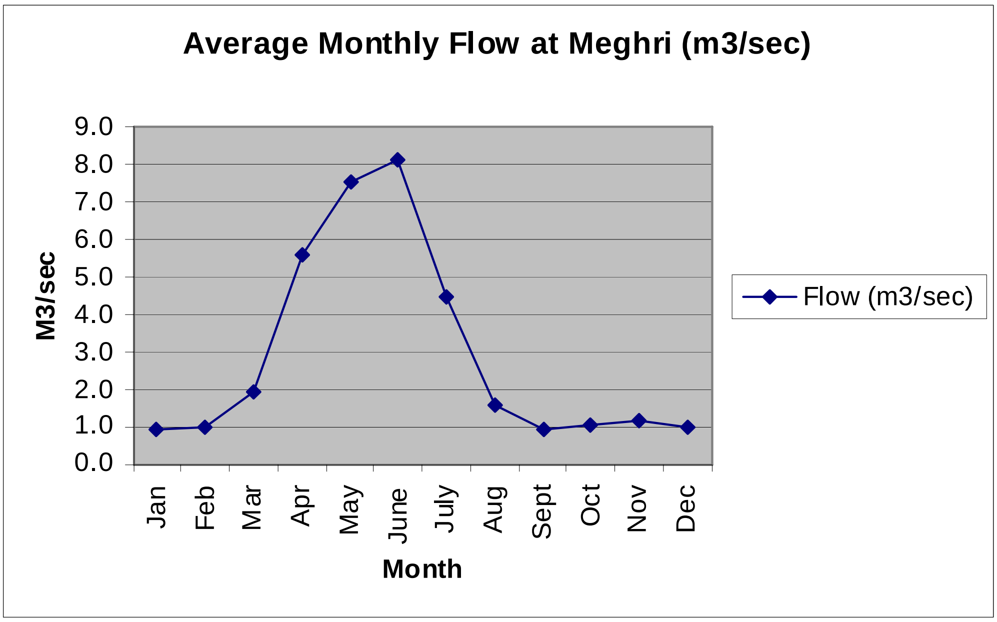
The daily discharge has been measured long-term by Armenia State Hydro Met at two hydrologic posts on the Meghriget River, and for shorter periods of time on the Astazurget and Karchevan drainages. The average monthly discharge statistics are as follows:

Table 2.6: AVERAGE MONTHLY DISCHARGE FOR MAJOR DRAINAGES (m^3/sec)

Station name/ Dates (basin area)	Elev(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	August	Sept	Oct	Nov	Dec	Annual
Meghriget, 1949-2006, (274 km^2)	692	0.91	0.99	1.92	5.61	7.52	8.13	4.48	1.56	0.92	1.03	1.14	1.01	2.94
Meghriget-Lichq, upper Meghri, 1956-1999 (21 km^2)	1738	0.11	0.11	0.15	0.49	1.36	2.44	1.64	0.57	0.24	0.18	0.16	0.13	0.63
Astazurget, 1967-1978, (32 km^2)	646	0.05	0.07	0.10	0.16	0.17	0.09	0.05	0.02	0.05	0.09	0.06	0.07	0.082
Karchevan, 1970-1974, (19 km^2)	536	0.00	0.00	0.09	0.19	0.08	0.04	06	0.00	0.00	0.00	0.00	0.00	0.038

Source: GeoCom, 2008

Figure 2.1: AVERAGE MONTHLY FLOW AT MEGHRI HYDRO POST ON MEGHRIGET RIVER, 1949-2006



Role of Snowpack in Surface Water Runoff

Winter snowpack is the primary source of water supplying stream flow in the Meghriget basin. In the Meghriget River, it can be seen in Table 2.6 and Figure 2.1 that nearly 70% of the annual flow occurs during the snowmelt months of April, May, June, and July. It is noteworthy that the baseflow of Meghriget River is quite steady through fall and winter at approximately 1 m^3/s. It is likely this baseflow is also derived in large part from snowmelt which has infiltrated into soils, channel, and stream banks draining back into the stream, since increased rainfall in Oct/Nov does not make much impact on stream flow.

Peak Flows in Major Drainages

Long-term hydrological records from ArmStateHydomet include peak flows which correspond to flood events for Meghriget River at two locations, and two smaller drainages:

Table 2.7: PEAK FLOWS (HISTORICAL) FOR MEGHRIGET DRAINAGES

Sub-basin:	Period of record	Basin Size (km^2)	Maximum instantaneous flows (m^3/sec)	Date
Meghriget	1945-2005	274	87.5	April 12, 1956
Meghriget	1945-2005	274	44.7	August 18, 1972
Meghriget	1945-2005	274	42.3	May 2, 1969
Lichq, upper Meghri	1946-2001	21	7.3	June 1958
Astazurget	1967-1978	32	20.2	May 1967
Karchevan	1970-1974	19	0.7	May 1973

Source: ArmStateHydomet

Table 2.8: LONG-TERM HISTORICAL MINIMUM FLOWS

Sub-basin:	Period of record	Basin Size (km^2)	Minimum instantaneous flows (m^3/sec)	Date
Meghriget	1945-2005	274	0.10	19 Sept 1999
Lichq (upper Meghri)	1946-2001	21	0.01	19 Jan. 1999
Astazurget	1967-1978	32	0.0	frequent
Karchevan	1970-1974	19	0.0	frequent

Source: ArmStateHydomet

2.4.4 Groundwater Resources

Aquifers and Discharge

The Meghriget basin is primarily steep incised channels in intrusive granitic outcrops, a geologic setting with very limited aquifers and even more limited aquifer storage. Very small shallow aquifers exist in the alluvium of narrow valleys in many drainages of the region. These small aquifers are important as sources of drinking water to communities such as Shvanidzor and Nuvadi, which exploit shallow alluvial groundwater by use of ancient horizontal wells (infiltration galleries), known locally as “qyahriz.”

The Araks River floodplain has a productive alluvial aquifer in certain areas. The floodplain aquifer near Agarak is exploited by several domestic and industrial wells with a yield of between 1 and 60 liters/second, with one industrial well which reportedly yields 377 liters/second. It is not known whether the cones of depression of these wells intersect the Araks River itself, or whether the river recharges these wells indirectly.

Springs

Several permanent springs exist in the uplands, particularly at Tashtun near 2200 meters elevation, where at least five springs discharge from 3 to 65 liters/second, and at Kaler, where four springs discharge between 1 and 21 liters/second at 2700 meters elevation. Both sites are between 2000 and 2700 meters elevation, and the discharge from these springs eventually feeds tributaries of the Meghriget River.

2.4.5 Water Quality (General characteristics)

Surface water quality in the Meghriget basin is expected to be generally good, due to the low human and livestock population densities, and the very limited industrial development of the area. There are several particular locations where impacts on surface water quality are expected to be significant, including the Meghri town area, and the Agarak town and mining district. A selection from the limited amount of surface water quality data available is summarized in Table 2.9 for selected parameters.

Table 2.9: SELECTED WATER QUALITY PARAMETERS MEASURED AT VARIOUS BASIN LOCATIONS

Location:	Date:	pH	TSS mg/L	TKN mg/L	NO3 mg/L	NH4 mg/L	Cu mg/L	Mo mg/L	Hg mg/L
Lichq, Upper Meghriget River	Nov 11, 2007	7.37	4.0	0.065	0.5	BD	0.0013*	BD	BD
Meghriget,above Meghri town	Nov 12, 2007	7.97	5.4	0.070	0.5	BD	0.015*	0.04	0.0038*
Karchevan River below Agarak	Nov 12, 2007	7.69	12064*	1.23	10.0	BD	0.0067*	0.40	0.0008
Meghriget, below town	June 26, 2005	8.1	102.7	NA	8.33	1.65*	0.0012*	0.0042	NA

BD= below detection limit for laboratory analysis method. NA = no analysis
*=above at least one Armenia water quality standard (either drinking water, recreation, or fisheries).
Source: American University of Armenia, 2007; State Water Cadastre, 2007

Although these are isolated observations, several interpretations are noteworthy regarding data in Table 2.9. First, nutrient contamination is present below Agarak and below Meghri town as indicated by nitrate measurements. The ammonia measurement below Meghri exceeds national standards for drinking water and fisheries protection, and may indicate a toxic level of ammonia for fish. Sewage and/or garbage are likely sources of nutrients in town areas due to lack of functioning wastewater treatment and solid waste systems.

The total suspended solids (TSS) measurement below Agarak is extraordinarily high, and this is confirmed by visual observations (and photos) at the site. These solids, as well as the molybdenum (Mo) concentration, may indicate some kind of contamination with mine process waste at this site. Copper (Cu) is elevated at the above Meghri site, as is mercury (Hg), and both of these concentrations exceed the fisheries standard for Armenia. Since the site upstream (at Lichq) had an order of magnitude lower copper concentration, and non-detection on mercury, it is suggested that a heavy metals contamination source, possibly from mining wastes, exists between these sampling points. Mercury accumulates in fish, and can be a danger to those who eat fish from contaminated waters.

Water quality in groundwater is unknown.

2.5 Soil Resources

Due to the exceedingly steep topography, and frequent rock outcrops, most soils in the Meghriget basin are shallow and rocky. Intensive agriculture is only practiced at Tashtun-Lichq, on brown steppe soils, on terraced hillsides and small plots along the Meghriget River, in alluvial soils in the Agarak valley, and in small plots in narrow valleys and alluvial fans near Aldara, Shvanidzor, and Nuvadi. Some uncultivated mountain meadows have deep brown steppe soils above 2000m, and above 3000m in alpine pastures there are some peaty soils with high organic matter content.

2.6 Biodiversity

2.6.1 Natural Vegetation and Ecosystem types

The Meghriget area includes four major natural vegetation types, which are segregated by altitude and aspect: 1) semi-desert shrubs below 1000m: 2) juniper woodlands at intermediate altitudes; 3) deciduous forest (*Quercus/Carpinus/Acer/Ulmus*) and sub-alpine meadows above 2000m; and 4) alpine meadows and talus/scree/snowfields above about 3000m. Deciduous woodlands in this area are among the most extensive in Armenia—Meghri Forestry (State Forest Enterprise) controls about 26,000 hectares of forested lands in the basin.

2.6.2 Terrestrial Plant and Animal Diversity

Terrestrial plant and animal diversity is relatively high in this area, and many animal species rare in Armenia are found here, due to the low human population, and relatively intact habitats found in the area. The hot dry hills near the Araks River are a desert shrub habitat type not found elsewhere in Armenia, and harbor plants, insects, reptiles, birds and some small mammals (bats) rarely found elsewhere in Armenia.

Large mammal species uncommon in other areas of Armenia are particularly well-represented in the area's remote upland juniper and deciduous woodlands, and include wild boar (*Sus scrofa),* roe deer *(Capreolus capreolus),* bezoar goat *(Capra aegagrus),* brown bear *(Ursus* arctos), Indian porcupine (*Hystix indica*), wolf (*Canis lupus*), and Persian leopard (*Panthera pardus saxicolor*), while high sub-alpine and alpine areas of the Zangezur range include remnant populations of rare Armenian mouflon (*Ovis orientalis gmelini*), an ancestor of the domestic sheep. This is also one of the few areas of Armenia where otters (*Lutra lutra*) are still present, which is a positive indicator of the health of at least some aquatic ecosystems (WWF, 2008).

Species diversity for plants, mammals, and birds in the Meghri area has been compiled by World Wide Fund for Nature in Armenia and includes the following statistics:

Table 2.10: BIODIVERSITY OF MEGHRIGET BASIN AREA OF SOUTHERN ARMENIA

Category:	Est. Total species in Armenia	Est. Species in Meghri-Arvik	Number of Endemic species in Meghri-Arvik for Armenia	Number of Rare and/or Endangered Species in Meghri-Arvik in the Red Data Book of Armenia/IUCN
Plants	3500	1503	19	24 rare 0 endangered
Mammals	78	38	0	12 rare 4 endangered
Birds	302	168	0	27 rare 5 endangered
Reptiles/amphib	53/7	39	1	10 rare 3 endangered
Insects	17000	4000	14	9 endangered

Source: WWF-Armenia, 2008

2.6.3 Aquatic Biodiversity

The streams in the Meghriget Basin are part of the greater Araks River watershed, and as such are potential habitat for a variety of native fishes of the Caspian Sea basin. Although no data from aquatic biologists is available, residents of the area report that brown trout (*Salmo trutta*) are found in the cold-water high elevation portions of the Meghriget River watershed, while barbel (*Barbus lacerta* or *Barbus sp*.), khramulya (*Capoeta capoeta*), catfish (*Siluris glanis*) and carp (*Cyprinus carpio*) are found in the lower Meghri watershed in or near Araks River, a warm-water environment.

Armenia has at least 39 species of native and introduced fishes; therefore, a number of other species may be present in the Meghriget River watershed (B.K. Gabrielyan, 2001, "Annotated Checklist of Fishes of Armenia," www.worldfishcenter.org/naga/Naga24-3&4/pdf/fishbyte_1.pdf). The status of the native fish populations, changes in numbers or species composition due to human impact, ecology and migratory needs, etc. are basically unknown for this region of Armenia. An understanding of these issues is vital to appropriate environmental planning for future water resource development, like the proposed Lichq irrigation reservoir (MCA, 2008).

Basic inventory data on other aquatic life, including native crustaceans, mollusks, aquatic insects and other aquatic invertebrates are also lacking. This makes it very difficult to assess the status of the aquatic environment in this area.

2.7 Actual Land Use on Community Lands in Meghriget Basin

The following table explains the land use patterns within the community-controlled lands (private lands) in each of the major communities of Meghriget. Other lands in the area are controlled by Meghri State Forestry (26,000 ha). These State Forestry lands include hardwood forests and dry juniper forests and surrounding pastures. The total of state forestry lands and community controlled lands is approximately 64,000 ha, or the nearly total area of the Meghriget basin as defined in this report. The discrepancy with the overall total of land (66,000 ha) is from unknown source.

Table 2.11: LAND USE IN MEGHRIGET COMMUNITIES (HA)

Community	crops	orchard	hay	pasture	forest	bush	urban	water	other	Total
t. Meghri	75.11	77.53	1.77	-	19.67	881.59	222.91	17.84	1701.71	**2998.13**
t. Agarak	21.52	97	-	-	-	-	234.1	6.57	12.21	**371.4**
Tashtun	78.01	5.2	52.3	495.09	183.57	99.8	29.4	12.02	737.38	**1692.77**
Lichq	164.11	0	7.2	1003.6	625.42	232.84	59.98	31.17	813.39	**2937.71**
Kuris	38.68	5.5	-	31.17	460.4	-	20.14	0.19	607.28	**1163.36**
Shvanidzor	101.91	23.53	0.89	512.83	520.4	976.88	64.57	27.62	1812.14	**4040.77**
Gudemnis	35.51	12.7	-	24.09	196.43	-	17.43	0.82	414.36	**701.34**
Nyuvadi	23.05	61	-	842.78	2989.2	2923	31.77	90.67	4484.57	**11446.04**
Lehvaz	47.85	39	-	314.77	-	0.33	50.43	11.64	532.7	**996.72**
Alvanq	101.97	39.82	31.07	821.1	1455.3	1138.2	50.24	91.53	2416.4	**6145.63**
Vardanidzor	108.56	19.1	12.21	445.48	210.46	236.84	37.38	7.34	1166.83	**2244.2**
Vahravar	26.04	13.4	-	169.13	53.09	-	16.45	0.13	495.98	**774.22**
Karchevan	59.88	8.15	-	74.64	359.76	34.32	39.1	46.36	2293.06	**2915.27**
TOTALS:	882.2	401.93	105.44	4734.68	7073.7	6523.8	873.9	343.9	17488.01	**38427.56**

Source: Syunik Marz land use, territorial management and agriculture departments, 2007

As can be seen, the total extent of cultivated cropland is very small in this region, with pastures, forest, bush, and other less-productive lands making up the vast majority of the community lands. A large proportion of the cropland, orchard, and hayfields are under irrigation, but the total irrigated area is only around 1000 hectares. Much of this irrigated area, especially near Alvanq, Shvanidzor and Nuvadi, is irrigated by high-lift pumping of surface water up from the Araks River (personal observation, 2007).

2.8 Land Ownership Patterns

The current land ownership pattern reflects the privatization program instituted by Armenia in the 1990s, whereby most State lands in the basin were assigned to communities, and within the communities, a small area of productive land was titled to individual families. Within the communities there also remain some State lands, and a very small area of protected lands. But at least 96% of the “community” lands are owned by the community or the State. The total area of Meghriget River basin, approximately 660 km^2, is made up of 402 km^2 of these four categories of land within communities, and the remaining approximately 260 km^2 is made up of Meghri State Forestry lands.

Meghri State Forestry lands are under the administration of Armenia State Forestry Enterprise, which manages them for firewood production, a very small amount of timber production, and other subsistence uses (mushroom and medicinal plant collection).

Table 2.12: LAND OWNERSHIP WITHIN COMMUNITIES OF MEGHRIGET BASIN

Community:	Private:	Community:	State:	Protected:	Totals:
Meghri town	262.94	1928.39	1010.04	4.44	**3206**
Agarak town	53.61	257.78	14.88	3.52	**330**
Shvanidzor	125.32	2405.46	1580.89	46.03	**4158**
Tashtun	96.02	1325.41	302.56	7.33	**1731**
Kuris	39.51	939.4	467.23	5.51	**1452**
Gudemnis	43.36	462.02	198.45	1.73	**706**
Nuvadi	0	4590.15	7182.77	12.9	**11786**
Lehvaz	91.31	901.28	15.18	0.16	**1008**
Alvanq	66	3415.33	2816.52	91.13	**6389**
Vardanidzor	97.68	1715.53	460.28	0.48	**2274**
Vahravar	45.82	682.28	72.93	15.94	**817**
Karchevan	70.13	2700	513.9	29.34	**3313**
Lichq	164.78	1897.98	930.15	32.02	**3025**
Totals:	1156.48	23221.01	15565.78	250.53	**40194**

Source: Syunik Marz Territorial Administration, 2007

2.9 Protected Areas

The Meghriget Basin is adjacent to the Shikahogh National Reserve to the northeast. Shikahogh was established in 1958, and is an important biodiversity reserve, containing one of the only large un-cut hardwood forests in Armenia. Shikahogh is managed by the Ministry for Nature Protection. A project is underway to design another protected area in the wooded highlands of Meghriget area, adjacent to Shikahogh, but to the south and west, called Arvik National Reserve, to conserve wildlife (WWF, 2008).

3. Socio-Economic Characterization (Guideline 1.2)

The Meghriget River basin is a predominantly rural area in the southernmost part of Armenia. For the purposes of this report "Meghriget basin" includes not only the Meghriget River, but the adjacent watersheds draining directly to the Araks River in southern Syunik Marz—the Karchevan, Shemeglukh, Karavget, Malev, Astazurget, Shvanidzor, Shavzir, Nuvadi, Kaisbajur and Tondirget drainages—an area totaling 664 km^2.

Meghriget basin is in the remote southern part of Syunik Marz, on the frontier with Iran and the Araks River. It is bordered on the west by Nakhchivan, and to the east by Nagoro-Karabakh/Azerbaijan. The largest town and commercial center is Meghri, with slightly less than 5,000 people. It is located in a small valley near the Araks River, while Agarak is a slightly smaller mining town in another small valley nearby. Otherwise, all other inhabitants of the Meghriget River basin live in a series of rural villages within a steep mountainous landscape. Small-scale farming, livestock herding, and mining are the primary occupations.

3.1 Demographics

3.1.1 Population and Demographic Growth

The total population of the Meghriget River basin area is approximately 11,909 permanent residents. Approximately 9,600 are urban, and 2309 are rural residents. The urban residents live entirely in Meghri (pop. 4800) and Agarak (pop. 4800). The largest rural villages are Lehvaz with 539 persons, Alvanq with 365 persons, Shvanidzor with 274 persons, and Karchevan with 268 persons. All other rural villages each have less than 200 permanent residents.

Table 3.1 POPULATION OF THE MEGHRIGET RIVER BASIN BY SUB-BASIN

Community:	Sub-basin:	Urban Population:	Rural Population:	Total by sub-basin:	Population Density (persons/km^2)
Meghri	Middle/lower Meghriget	4800			
Vahravar	Middle/lower Meghriget		61		
Lehvaz	Middle/lower Meghriget		539		
Gudemnis	Middle/lower Meghriget		42		
Kuris	Middle/lower Meghriget		67		
Vardanadzor	Middle/lower Meghriget		161		
Tkhkut-Aygedzor	Middle/lower Meghriget		84		
	Middle/lower Meghriget			**5754**	**22 pers/km^2 (approx.)**
Tashtun	Upper Meghriget		140		
Lichq	Upper Meghriget		172		
	Upper Meghriget			**312**	**3 pers/km^2**
	Meghriget total				**17 pers/km^2**
Agarak	Karchevan	4800			
Karchevan	Karchevan		268		
	Karchevan			**5068**	**181 per/km^2**
Alvanq	Malev		365	365	7 pers/km^2

Shvanidzor	Astazurget		274	274	7 pers/km^2
Nuyvadi	Nuyvadi/Karisbajur/ Tondirget		136	136	2 pers/km^2
TOTAL:		**9600**	**2309**	**11,909**	**19 pers/km^2**

Source: BMO/Syunik Marz

3.1.2 Age Structure and Life Expectancy

The rural areas of Meghriget River basin have an aging population, with nearly 21% of the population older than 62 years, and young people (less than 15 years) only 18% of the population. Many school-age children relocate to towns for educational purposes. The age structure in the urban areas of the basin is not known, but is thought to have a larger percentage of school-age children than the rural areas.

Life-expectancy data are not available, but in general, life expectancy in Armenia is 71.7 years (UNDP-05, http://hdrstats.undp.org/countries/country_fact_sheets/cty_fs_ARM.html).

3.1.3 Immigration and Emigration and Population Growth

Small numbers of Armenians are moving in and out of the Meghriget River basin, with a net emigration. Anecdotal information indicates local migration is occurring from villages towards towns, especially Agarak, due to work opportunities in the mining industry. As Armenia has a slightly negative national growth rate, and low levels of female fertility, no population growth is expected in this area.

3.1.4 Population Density

Population density in the Meghriget River basin is low, with an average of only 19 persons/ km^2. Since the bulk of the population lives in two downstream towns, the upper watersheds are quite under populated, with population density ranging from 2 to 7 persons/km^2 in the rugged upland watersheds.

3.2 Water and Sanitation Facilities and Citizen Access

The urban areas of Meghriget River basin have good access to water supply and wastewater collection services. There is a large gravity water system (Zvar system) feeding Meghri and nearby villages along the route. In total, Meghri has approximately 1360 connections to public water supplies, and 1250 connections to wastewater collection. In Agarak there are 1100 connections to public water supplies and 1100 connections to wastewater collection in the urban area (gravity surface water from Boghaqar system and deep wells). The wastewater collection systems of Meghri and Agarak both feed into a wastewater treatment system on the lower Meghriget River which is no longer functional.

The rural areas are also generally served by public water systems, with nearly 100% of the total population with some access, due to 13 small surface water and ground water systems. However, much of the infrastructure is very old and in need have to be repaired or upgraded. Latrines are the primary sanitation system in rural villages. Rate of latrine ownership and use is unknown, but is high.

3.3 Economy

3.3.1 Description of Major Sectors of Economy

The Meghriget River watershed has three principal economic sectors: mining, agriculture, and commerce. Mining, principally molybdenum and copper, is a major employer, especially in Agarak. This area has been important in metals mining since at least the 1949. Several smaller mines and incipient mining ventures exist. Agriculture, principally fruit production and mixed livestock (cattle, sheep and goats), is the principal economic activity in the rural villages. Meghri is a commercial center, with some light industry (food processing), and trade, including cross-border trade with Iran.

3.3.2 Major Infrastructure

The Meghriget watershed is bisected by a major national highway, which is used for transport from Iran to all parts of Armenia, across a mountain pass to Kajaran. Another paved highway parallels the Araks River from Agarak to near Shvanidzor. From this point a new highway was built in 2006-2007 across the mountain ridge to Kapan, through Shikahogh National Park. All other roads in the area are dirt. There is also a major natural gas transmission line, newly constructed, which generally parallels the Meghriget River, but on the ridges to the west of the river. Electrification and water supplies are available in every town and village.

3.3.3 Production by Sector (Mining, refining, manufacturing, etc)

Mining: Mining production in the Meghriget River basin is reported as 30,000 tons/year of molybdenum and copper ore from Agarak, and 2,000 tons/year of various metal ores from Meghri area mines (BMO, 2008). The Agarak mine is an open pit facility. Ore is milled and concentrated to 25% copper and 50% molybdenum before shipping out of Armenia overland. Smelting is done outside Armenia.

The Agarak molybdenum and copper processing plant generates tailings from the milling process which are pumped as slurry and deposited in a large tailings dam complex northeast of Agarak. As of May, 2007, the tailings dams receive all the process water (approximately 320 l/sec) and evaporate and infiltrate it. Infiltrate enters drainage pipes below the tailings (running up-down slope under the tailings, which are in dry canyons). Staff indicates that 40-50% of the water evaporates, and 30-35% drains out to the Araks River through drain pipes. It is assumed that remaining water is stored in the tailings matrix.

The tailings dams for this complex are quite large. In 1999 US Geological Survey estimated that Agarak was processing 300,000 tons/year of ore, yielding 800 tons of copper and 28 tons of Mb annually. It is not known if present production has drastically declined from these figures, or if current data are accurate.

The small stream called Karchevan draining the Agarak valley receives, according to the BMO, “intermittent contamination” from the Copper-Mb processing site.

Investments in small-scale gold mining along the Meghriget River have not yet come into production. In 2007 a company known as Iberian Resources was developing a small former underground gold mine near Lichvaz along the Meghriget River.

Food processing: The food processing industry in Meghri produces approximately 250 tons/year of preserved food products, while smaller scale food processing in Agrarak produces approximately 60 tons/year. It is not known how liquid discharge from these plants is handled, although it is assumed that they have been issued Water Use Permits by WRMA.

3.3.4 Inventory of Small businesses with water resource impacts

Other small enterprises in the Meghri town area with potential for negative effects on water resources include two petrol stations, one car wash, two maintenance facilities for equipment/machinery, and three butchers. Agarak has three petrol stations, two maintenance facilities, one car wash, four butchers. In other areas around the basin, there are petrol stations in Lehvaz and Vardanidzor, a maintenance facility in Vardanidzor, and two butchers in Vardanidzor.

3.3.5 Agricultural Production by Sub-sector

Livestock production is an important element of livestock production in the Meghriget River basin. Farmers use both lowland and highland pastures for livestock at different times of year. The livestock census for the basin is as follows:

Table 3.2: LIVESTOCK CENSUS FOR MEGHRIGET AREA COMMUNITIES

Community	Number farms	Cattle	Sheep/Goats	Pigs	Poultry
Meghri town	1360	207	164	149	1949
Agarak town	1100	172	183	323	1251
Shvanidzor	100	154	5	120	266
Tashtun	42	129	8	19	92
Lichq	60	77	174	22	108
Kuris	45	24	0	2	49
Gudemnis	29	20	90	0	0
Nuvadi	42	178	320	31	127
Lehvaz	170	53	87	111	315
Alvanq	94	33	188	22	358
Vardanidzor	110	101	178	81	513
Vahravar	30	45	12	26	87
Karchevan	90	38	16	44	346
TOTAL	3272	1231	891	950	5461

Source: BMO/Syunik Marz, 2008

Livestock are primarily for meat production, with only very small-scale dairy/cheese production. Farmers in the Meghriget basin also keep bees for pollination and honey production, and over 1500 beehives are kept throughout the basin. Overall, the density of livestock in the basin is relatively low, and livestock are not expected to be a big risk to water quality in this basin.

3.3.6 Irrigated and Dryland Crop Acreage

Meghriget River basin is primarily a fruit orchard production area, especially in the low valleys near the Araks River where the growing season is particularly long and warm. Some of the most important fruit crops are grapes, pomegranates, figs, peaches, and apricots. Irrigation is required for fruit production. Water for irrigation comes from the Meghriget River, some smaller streams, some deep wells in the Agarak area, but the majority of the irrigation water comes from pumping lift systems drawing water from the Araks River.

Table 3.3: CROP PRODUCTION AREA IN MEGHRIGET RIVER BASIN

Community	Wheat (ha)	Potato (ha)	Vegetable (ha)	Other food crops (ha)	Orchards(Fruit) (ha)
Meghri town	1.0	5.0	6.7	28.5	77.5
Agarak town	0	6.3	3.6	57.6	97.0
Shvanidzor	0.2	0	1.0	2.2	23.5
Tashtun	6.4	2.4	0.9	53.9	5.2
Lichq	0.2	0	1.0	2.2	23.5
Kuris	0.5	0.6	1.5	17.0	5.5
Gudemnis	0.4	0.3	0.6	11.7	12.7
Nuvadi	0	1.2	0.9	0.1	61.0
Lehvaz	1.3	1.3	3.8	45.0	39.0
Alvanq	1.2	4.2	15.3	24.4	39.8
Vardanidzor	4.7	7.3	13.7	10.0	19.1
Vahravar	1.0	5.0	6.7	28.5	77.5
Karchevan	0	6.3	3.6	57.6	97.0
TOTAL:	**16.9**	**28.6**	**59.3**	**338.7**	**578.3**

Source: BMO/Syunik Marz, 2008

3.3.7 Agricultural Inputs/Hectare/Crop

Fertilizer and pesticide inputs per crop are not known for the Meghriget River basin. In general, however, the purchased agricultural inputs on crops in this remote area are few, and risks to water quality are believed to be low from this sector. But further investigation of practices is needed.

3.4 Cultural/Historical Aspects of River Basin

3.4.1 Historical Settlement and land use

The southern area of Syunik Marz, including the Meghriget River basin, has been inhabited by the Armenian people for many centuries. A fort above the town of Meghri dates from the 10th century. The Armenian churches in this area (e.g. Meghri) date from the 17th century. It appears that recent land use for cropped agriculture, and especially fruit cultivation, is reduced from recent historical times in the Meghriget River canyon, because many abandoned terraces can be observed. However, water use in the Araks River floodplain and nearby alluvial fans increased during the Soviet period due to the implementation of the Araks River pumping stations.

4. Water Use (Guideline 1.3)

The Meghriget River basin is considered to be all of the watersheds which drain out of Syunik Marz directly into the Araks River within the boundaries of Armenia (see Annex: Map 3). This includes the Meghriget River and all its tributaries, as well as the Karchevan, Malev, Astazurget, Shvanidzor, Shavzir, Nuvadi, Kaisbajur and Tondirget drainages. The water use characteristics of this area are described below.

4.1 Water Use by Sector

4.1.1 Public Drinking Water Supply

Public water supplies for the basin are generally available for all communities, however their age and condition varies. Table 4.1 below gives a summary of the public drinking water supply system status for the Meghriget River basin.

Table 4.1: STATUS OF PUBLIC WATER SUPPLY WATER USE BY SUB-BASIN

Community	Name of supply	Use in m^3/day	Population served (persons)	Type of source	Construction Date	Losses (m^3/day)
Meghri	Zvar, Metants gravity systems	6480 864	4800	Surface ground	1960-1954	4536 604
Vahravar	Marg gravity system	60	60	ground	2004	44
Lehvaz	“Zvar” gravity system	260	575	surface	2002	140
Gudemnis	“Zvar” gravity system	60	45	surface	1985	49
Kuris	“Hand aghbyur” gravity, river	17 43	81	ground surface	2006	41
Vardanidzor, Tghkut/Aigedzor	“Gyughi ”, Vardanidzor gravity	43 260	299	ground surface	2003	235
Tashtun	“Vanna aghbyur”, “Yot Aghbyur” gravity systems	43 43	124	ground	1983 1983	53
Lichq	Geghi River, “Dzori teghamas” gravity	60 43	159	surface ground	1980 1980	65
MEGHRIGET RIVER SUB-BASIN Totals from above		**8276**	**6,134**	Rivers, springs		
Alvanq	Infiltration gallery capture	173	395	Malev groundwater	2001	88
Shvanidzor	Infiltration gallery capture	173, 17,9	274	Astazurget groundwater	2001	134
Nuvadi	Infiltration gallery	86	151	Nuvadi groundwater	2001	42
Agarak	Boghaqar gravity, Agarak deep wells	6048 5184	4800	Surface, Araks alluvial ground	1965 1970	4233, 3628
Karchevan	Boghaqar gravity, Tsurt	173 86	379	Surface, ground	1973	179
OTHER SUB-BASINS Totals from above		**11,949**	**5,999**	Rivers, deep wells, infil. galleries		**8,304**

Source: Southern Basin Management Organization, 2007

Drinking water supply systems listed in Table 13 manifest several important characteristics: most are older gravity systems, many nearly 50 years old. Over 60% of the total water delivery capacity for the region is in two gravity systems, the Zvar gravity system feeding Meghri and nearby communities, and the Boghaqar gravity system feeding Agarak and nearby communities. Both of these are large, old water systems with long transmission lines, aged intake structures and high rates of losses. The next largest public water system is the deep wells in Agarak, which abstract water from the floodplain aquifer of the Araks River.

4.1.2 Irrigation Water Supply

Irrigation is a major water use in the Meghriget basin, particularly for croplands, orchards and, in a few areas, hayfields. A number of irrigation systems exist, primarily abstracting water from the Meghriget River and its tributaries. A number of other systems based on large, high-lift electric pumps abstract water directly from the bi-national Araks River.

Table 4.2: STATUS OF IRRIGATION WATER USE BY SUB-BASINS (SOUTHERN BMO, 2007)

Source	Intake system name	Intake Altitude (m)	Volume 2006 (1000 M3)	Intake capacity (m3/sec)	Irrigated Area (ha)	Location of irrigated area
Meghriget River	Meghri pumps#1,2,3,4	586	211	0.29	19	Meghri town
spring	Shahi/Mair		858	0.07	78	Meghri town
Meghri tributaries	Tashtun-Lichq canal	1697	75	0.40	20	Tashtun, Lichq
Meghriget River	Tghkut canal	1408	205	0.10	5	Vardanidzor, Tghkut
Meghriget River	Vardanidzor canal	1211	102	0.03	10	Vardanidzor
Boqhaqar trib of Meghri	Agarak waterway	2021	592	0.5	170	Agarak, Kuris Gudemnis
spring	Lehvaz		225	0.1	25	Lehvaz
spring	Kuris		90	0.1	10	Kuris
spring	Gudemnis		54	0.1	6	Gudemnis
spring	Vahravar		54	0.1	6	Vahravar
Meghri Sub-basin total	-------	------	**2466**	**-------**	**349**	**Meghri sub-basin**
Alluvial aquifer Araks	Agarak deep wells		220	0.045	15	Agarak town
Araks River	Agarak #1	638	1025	0.30	70	Agarak town
Araks River	Agarak #2	560	733	0.30	50	Agarak town
Araks River	Karchevan #1	538	382	0.22	26	Agarak town and Karchevan
Araks River	Alvanq #1	484	84	0.025	14	Alvanq
Araks River	Alvanq #2	476	419	0.12	68	Alvanq
Araks River	Shvanidzor#1	470	443	0.18	56	Shvanidzor
Araks River	Shvanidzor#2	483	39.5	0.025	5	Shvanidzor
Araks River	Nuvadi 1,2,3	450	371	0.16	58	Nuvadi
Araks River	Bughaduzi 1	390	223	0.15	22	Prison area
Araks sub-basin total	---------	------	**3939.5**	-------	**384**	**Araks sub-basin**

The Meghriget River pumping stations supplying irrigation water to the Meghri town area, and all the Araks River pumping stations are unified in the Meghri Water Users Association. This Association receives large financial subsidies from the Government of Armenia to pay for electric pumping costs. Many of the lifts are high (100-200 meters vertical); therefore, the costs per hectare irrigated are extremely high. Electric pumps are generally old, Soviet-era centrifugal pumps, with high maintenance needs. Pumping stations along the Araks River occasionally flood during high water, causing damage to the pumps.

All of the major irrigated areas could theoretically be irrigated by gravity irrigation systems, but the intakes and canals for that purpose do not exist. The Meghri Irrigation system component in the proposed Millennium Challenge Account portfolio would include a water storage reservoir on a

Meghriget River tributary near Lichq at an altitude of approximately 2000 meters, a gravity conveyance system, and irrigation improvements at the primary irrigation locations in Meghri as well as Alvanq, Shvanidzor, and Nuvadi (MCA, 2006). Apparently, feasibility studies for this proposal are underway.

4.1.3 Status of Hydropower Water Use

The Meghriget region has significant hydropower potential due to the steep topography and water resources. Run-of-the river hydropower has no consumptive use of water, but does divert water away from in-stream flow. One small run-of-the river (off-stream) hydropower facility has been functioning for some time with water diverted from the Meghriget River above Meghri town (Q-Hash LLC). Two other more substantial hydropower facilities are under construction and one large international hydropower plant is planned for the Araks River (border with Iran).

Table 4.3: HYDROPOWER PROJECT STATUS IN MEGHRIGET REGION

Name	Location	Generating Capacity (KWt)	Pressure (m)	Intake in 2006 (m^3)	Status
Q-Hash LLC	Above Meghri town	840	51	21,400,000	Functioning
Griar LLC	Tashtun	6520	209	0	Under construction
Empathy LLC	Vardanidzor	4500	176	0	Under construction
Meghri HPP-1	Araks River	78900	93	0	In planning

Source: Southern Basin Management Organization, 2007

4.1.4 Status of Industrial Water Use

Several significant size industries exist in the region, particularly the Agarak copper and molybdenum mine. The Agarak Copper-Molybdenum processing plant currently uses approximately 11,880,000 m3 of water per year. This water is withdrawn from deep wells (30-60 meters total depth) near the Araks River, is used for metal ore processing, and is discharged as tailings water in the three mine tailings ponds. Estimates from on-site managers are that approximately 40-50% of the tailings water evaporates, and 30-35% of the 320 liters/second standard process water flow rate eventually is discharged through the three tailings dam filtration pipes to the Araks River (apparently they surmise that the remaining 15-30% of the water is stored in the tailings or infiltrates below the tailings).

A second, much smaller industrial water user is Sipan-1 LLC, which withdraws 138,000m^3/ year of water from river for mining purposes near Meghri, and discharges approximately 107,600 m^3.

4.1.5 Recreation, Fisheries and In-stream Uses

There are no explicit reservations or registered uses of water for recreation, fisheries, or aquatic life in the Meghriget River basin. Since various species of native fish, and rare aquatic mammals such as otters, do exist in the basin, there is a need for a determination of their in-stream flow requirements (environmental flows).

An understanding of seasonal native fish migrations is necessary to understand the specific quantity of flow required at different times of year and different locations in the basin. It is likely, for example, that native trout (*Salmo trutta*) move seasonally in the upland portions of the basin, to take advantage of distinct habitats best suiting over-wintering, adult feeding, juvenile growth, and fall spawning. Hydropower, irrigation, and drinking water abstraction and diversion systems need to take these needs into account, especially in places like Tashtun and Lichq, where significant water development has occurred or is occurring.

4.2 Inventory of Water Withdrawal/Discharge Permits

Water use permits are now managed by the Water Resources Management Agency, with field checking and local coordination by the local Basin Management Organizations. In the Meghriget Basin, the primary water use permits are listed in the following Table 4.4:

Table 4.4: CURRENT WATER USE PERMITS IN MEGHRIGET BASIN

Sub-basin	Name of Water User	Use	Annual abstraction volume (1000 m^3/yr)	Percent return flow (discharge)
Meghriget	Armenia Water and Sewer, Meghri District	Drinking water	2,680.6	6.17%
Meghriget	Armenia Water and Sewer, Agarak District	Drinking water	4,099.7	9.44%
Meghriget &Araks	Meghri Water Users Association (pumps)	Irrigation	3,157.2	7.27%
Meghriget	Sipan-1 LLC	Industrial	138.2	0.32%
Meghriget	Meghri RCO OJSC	Industrial	10.9	0.025%
Meghriget	Q-Hash LLC	Hydropower	21,400.0	49.3%
Karchevan & Araks	Agarak Copper Molybdenum Plant CJSC	Industrial	11,880.0	27.38%
Karchevan	Agarak Livestock Sanitary office	Industrial	20.7	0.047%

Source: Southern Basin Management Organization, 2007

These permits reflect most of the major water users mentioned in the preceding sections. However, there are informal irrigation water users groups, and small-scale drinking water systems which do not have formal water use permits.

4.3 Estimates of non-permit water use

Irrigation uses which are not permitted can be grossly estimated from information presented in Table above as at least 1,397,000 m^3 of irrigation water abstracted from tributaries of the Meghriget River, and from springs in the Meghriget River watershed, by users which are not part of the Meghri Water Users Association.

4.4 Inventory of Wastewater Discharges

The major wastewater dischargers in the Meghriget basin include the large industrial water users (mines) and the Armenia Water and Sewer Company districts in Meghri and Agarak towns. The only water use permit which has explicit wastewater contaminant concentration limits is the Agarak mine permit, which permits wastewater discharge to the Araks River. That permit has the following maximum allowable concentrations of contaminants:

Table 4.5:PERMIT REQUIREMENTS FOR WASTEWATER-ALLOWABLE CONTAMINANT CONCENTRATIONS FOR AGARAK COPPER AND MOLYBDENUM MINE

Parameter	Maximum allowable
Wastewater flow	3,360,000 m^3/year
pH	6.5-8.5
Turbidity	No data
Suspended solids (mg/L)	38
Copper (mg/L)	0.056
Molybdenum (mg;L ions)	0.05
Iron (mg/L Fe ions)	0.193
Chlorides (mg/L)	53.2
Magnesium (mg/L)	1.2
Calcium (mg/L)	3.0
Petroleum products (mg/L)	0.05323

Source: Southern Basin Management Organization, 2007

It is not known if the Agarak discharge meets these criteria, and with what frequency. It is known that during November, 2007, reconnaissance sampling revealed that the Karchevan River does not meet the suspended solids criteria here, and in fact had an extremely high suspended solids discharge of over 12,000mg/L.

Given the significant discharge of untreated wastewater from the Meghri and Agarak towns to the lower Meghriget River, it is important to prioritize the preparation of a permit for this wastewater discharge, in order to support the process of developing a reasonable wastewater treatment option in the near future.

4.5 Hydraulic Infrastructure--Capacities, condition, losses

Hydraulic facilities and their capacities are inventoried in Tables 4.1, 4.2 and 4.3.

In general, the major hydraulic facilities in the region are as follows:

Hydropower Facilities: There is one hydropower facility on the Meghriget River, the Q-Hash LLC facility with a capacity of 840 KW. Two other facilities are in planning and/or construction, at Tashtun and Vardanidzor.

Irrigation Pumping: The major irrigation pumping infrastructure operated by the Meghri Water Users Association is mostly old, and in need of rehabilitation and upgrade.

Potable Water Systems: Potable water systems are detailed in Table 13. Many are 40-50 years old and in need of rehabilitation and upgrades. Losses are estimated to be high; often 50% or more of intake is losses.

Wastewater Treatment Systems: The only wastewater treatment system, at Meghri, which formerly received inflows from both town of Meghri and town of Agarak, is not functioning.

5. Basin Water Balance (Guideline 1.4)

5.1 Basin Hydrologic Water Balance (monthly and annual)

Water balance for the Meghriget basin is presented in two parts. Part one is the Meghriget River itself, which is an important perennial river of Armenia. That water balance is based on abundant flow data collected for over 50 years. The second part is estimated water balances of several of the minor sub-basins which drain directly into the Araks River. These sub-basins are generally ephemeral---they only flow during the spring runoff season, if at all. Although some limited historical flow data exist for two of these—Karchevan and Astarzurget---estimates are made as if for ungauged basins.

The water balance in Meghriget River is calculated for the 336 km^2 area above the gauging station where flow measurements were taken, based on the concept of:

PPT = Evaporation + Runoff + Deep Flow.

Precipitation was calculated based on local and other Armenian historical records fitted to 1000-meter altitude bands from 0 to 3500 meters above sea level, and distributed according to actual watershed area within each altitude band. Actual evaporation was calculated according to Valesyan's method for Armenia, also on the basis of 1000-meter altitude bands. Flow was taken from long-term gauging station records. Deep flow (aquifer recharge) was calculated from the annual balance and distributed across months.

Table 5.1: WATER BALANCE FOR MEGHRIGET RIVER (336KM2)

Month:	Precipitation		Evaporation		River Discharge		Deep Flow	
	(mm)	Mm^3	(mm)	Mm^3	(mm)	Mm^3	(mm)	Mm^3
January	41	13.64	10	3.33	7	2.39	2	0.73
February	45	15.31	13	4.39	8	2.58	2	0.73
March	66	22.07	15	5.13	15	5.01	2	0.73
April	81	27.12	27	9.02	44	14.83	2	0.73
May	86	28.96	39	13.16	59	19.93	2	0.73
June	61	20.55	46	15.53	64	21.69	2	0.73
July	39	13.10	41	13.77	36	12.12	2	0.73
August	29	9.72	41	13.79	13	4.48	2	0.73
September	26	8.69	34	11.45	8	2.59	2	0.73
October	56	18.96	26	8.77	8	2.70	2	0.73
November	49	16.37	16	5.31	9	2.96	2	0.73
December	45	15.26	10	3.36	8	2.63	2	0.73
ANNUAL:	**624**	**209.75**	**318**	**107.01**	**279**	**93.91**	**26**	**8.82**

Source: GeoCom, 2008a

It can be clearly seen that the Meghriget River is a classic mountain snowpack river, which discharges the majority of its annual flow during the spring snowmelt season. The river does not seem to respond to fall rainfall with an increase in flow, but maintains a steady baseflow through fall and winter, indicating little if any surface runoff during those seasons. All fall and winter flow (prior to March) appears due to sub-surface inflows. Deep flow is estimated as the recharge to the alluvial fan at the lower end of the watershed, which itself discharges into a larger alluvial aquifer along the Araks River.

Analysis of the altitudinal data indicates that probably 75% or more of the total annual runoff originates in the areas above 2000 meters elevation. The areas below 1000 meters have extremely low rainfall and essentially zero runoff.

These characteristics of the area are illustrated in the estimates for the smaller ungauged basins—lower elevation watersheds have little or no runoff except during spring snowmelt, and even there, only the watersheds with significant area above 2000 meters generate snowmelt. Residents of Nuvadi in a relatively large, but low-elevation watershed (maximum elevation 2100 meters) remark that their drainages flow with surface water very few days of the year. While Astazurget a very similar drainage, but with maximum elevations of 2600 meters has a small flow nearly year-round.

Table 5.2: WATER BALANCE FOR UNGAUGED BASIN: KARCHEVAN (19 km^2, max. elev. 2293m)

Month	Precipitation		Evaporation		River Discharge		Deep Flow	
	(mm)	Mm^3	(mm)	Mm^3	(mm)	Mm^3	(mm)	Mm^3
ANNUAL	412	7.82	343	6.52	69	1.31	0	0

Source: Calculations, see GeoCom model, 2008

In Karchevan, the limited actual data (Table 2.6) indicate that the stream flows only from March-July, with no flow for all of late summer, fall and winter. Most of the smaller sub-basins which drain directly to the Araks River in southern Syunik Marz have this type of water balance, characterized by very low or no flow at all for most of the year with a spring flush of snowmelt from higher elevations. If elevations above 2000 meters are not significant in the drainage, then essentially no surface flow is expected for most of the year.

5.2 Economic Water Balance (incorporating actual uses)

Incorporating water use into the water balance gives an "economic water balance" or actual water availability through the year. This calculation is based on actual data for potable water withdrawals and industrial water withdrawals, and estimates of irrigation withdrawals and return flows for the Meghriget River, as well as actual flow data for the lower river.

Table 5.3: ECONOMIC WATER BALANCE FOR THE MEGHRIGET RIVER

Month	Measured River Flow Mm^3	Total withdrawals (est) Mm^3	Return Flows (est) Mm^3	Net withdrawals as % of flow %	Measured Mean River Flow M^3/sec	Calculated Environ. Flow Req. M^3/sec
January	2.36	0.28	0.02	0.11	0.91	0.3
February	2.57	0.24	0.01	0.09	0.99	0.3
March	4.98	0.29	0.02	0.05	1.92	0.3
April	14.54	0.66	0.09	0.04	5.61	0.3
May	19.49	0.93	0.15	0.04	7.52	0.3
June	21.07	1.46	0.25	0.06	8.13	0.3
July	11.61	1.58	0.28	0.11	4.48	0.3
August	4.04	1.15	0.19	0.24	1.56	0.3
September	2.38	0.54	0.07	0.20	0.92	0.3
October	2.67	0.29	0.02	0.10	1.03	0.3
November	2.95	0.24	0.01	0.08	1.14	0.3
December	2.62	0.24	0.01	0.09	1.01	0.3
ANNUAL:	**91.28**	**7.9**	**1.12**	**0.07**	**2.9**	**0.3**

Source: GeoCom, 2008a

The economic water balance suggests that flow availability is adequate in all months of the year in the Meghriget River. Although flow is much more abundant in April-July, the calculations also show adequate flows in the low-flow months of August-Dec, and Jan-March for the withdrawals calculated. In August and September, the most critical months, the calculated withdrawals are between 20-25% of total available flow. However, this calculation is based on an estimate of irrigation withdrawals, not measured withdrawals.

It is possible, and perhaps likely, that actual irrigation withdrawals are much larger than the calculated, and that the amount of water available in late August and September for late season irrigation is much more critical. In fact, reports from the field indicate that there is a shortage of late-season irrigation water in some years, and minimum flows (Table 2.8) have been measured as low as 0.10 m^3/sec in September in Meghri.

Also, the environmental flows calculated by this method may not relate to specific requirements of fish or other aquatic species actually present in the Meghriget River. Low flow requirements of the existing aquatic species are not known.

5.3 Annual and Seasonal Water Shortages (Drought frequency)

Drought frequency should be calculated for the available record for Meghriget River. Probabilities of low flows (95%, 75%, 50%) during August and September should be calculated in order to predict frequency of drought stress situations.

6. Geologic Hazards Related to Water Resources (Guideline 1.7)

6.1 Historical Flooding Experiences

Southern Syunik Marz is not a flood hazard area. This is because streams are incised in narrow, rocky stream channels, or canyons, and human habitations and other infrastructure are not located adjacent to the streams in most cases. Meghriget River does pass through the town of Meghri, but it is incised, and has not recently caused any floods. Specifically for the period 2003-2006 there were no damaging floods recorded in Syunik Marz (GeoCom, 2008a).

Landslides are a hazard in southern Syunik Marz. Approximately 11 landslide hazard sites were identified in 1994 along the highway from Meghri to Kajaran within the Meghriget River basin. Mudflows are another related hazard and have been recorded from a number of sites in southern Syunik Marz. A number of damaging mudflows were recorded during Soviet times, in Meghri, Agarak, Lehvaz, Karchevan, Vardanidzor, and other locations. But protective measures taken since the 1970s have reduced the vulnerability of those areas.

6.2 Calculated Peak Flows and Flood Probabilities

In order to estimate potential flood peaks in the ungauged basins of southern Syunik Marz, GeoCom (2008a) used the maps of maximum flow (isolines) for various probabilities published in the Hydrologic Atlas of the Republic of Armenia (1990). The digitalization of these maps has permitted the use of GIS to interpolate from flow module isolines (estimates of liters/sec/km2), and generate flood estimates using computerized computations. The results of this work for southern Syunik Marz are as follows:

Table 6.1: ESTIMATED FLOOD PEAK FLOWS FOR SOUTHERN SYUNIK RIVER BASINS

Sub-basin:	Area (km^2)	1% probability flood (m^3/sec)	2% probability flood (m^3/sec)	5% probability flood (m^3/sec)
Nuvadi	53.5	15.6	12.3	4.3
Tondiget	12.2	3.3	2.9	0.6
Suriget	31.3	9.2	6.6	2.3
Astazurget	35.3	15.6	10.6	5.9
Malev	50.4	18.1	11.2	6.8
Karavget	23.0	6.7	3.9	2.1
Meghriget (lower)	190.6	85.4	52.2	28.0
Meghriget (Kaler)	31.9	20.4	12.8	9.5

Meghriget (Tashtun)	14.6	8.4	5.0	3.5
Meghriget (Ayriget)	44.2	30.11	18.6	13.5
Karchevan	19.0	5.3	3.2	1.4

Source: GeoCom, 2008a

The highest recorded flood on the Meghriget River (in a 61-year record) was 87.5 m^3/sec at the Meghri gauging station (274 km^2) in 1956. This is equal to a flow module of 0.32 $m^3/sec/km^2$. This is roughly equivalent to the 2% probability event in the table above.

6.3 Flood-prone Areas and Flood Protection Infrastructure

No floodplains have been calculated for the theoretical flood events in the preceding table. However, it is likely that in the large, rare events, some areas of Meghri town would be at flood risk, because the river flows through the center of town. A map which shows the general areas of flood risk for different return period events was produced by GeoCom 2008 A substantial area of low-lying ground near the Araks River is particularly vulnerable.

These risks should be analyzed in detail due to the high level of potential damages. Flood control structures are not visible in Meghri, due to the fact that the majority of the residents live in areas well-protected from flooding by the hillside locations.

6.4 Mudflow/Landslide Risk Areas

GeoCom (2008) has generated maps of landslide risk and mudflow risk areas determined by recent studies by JICA (see Map 9 of the Annex).

7. Water Management Institutions and Programs

7.1 Roles and Responsibilities of National and Local Institutions

The management of water resources in Armenia involves a variety of institutions, as depicted in Diagram 7.1 below. The WRMA and the BMO, working as the WRMA's local agency representative, are the legally designated leaders in river basin management planning. In particular, they are responsible for implementing a water permit system which designates the amount of water to be withdrawn by water users from rivers and aquifers, and the quality of waste water to be discharged into natural waters.

7.2 Institutional Jurisdictional Issues

The principal water resource inter-institutional jurisdictional issues which must be addressed in all of rural Armenia, including Syunik Marz-Meghriget basin, are the following (USAID South Caucasus Water Management Program, 2007):

- In general, the enforcement function of State Environmental Inspectorate and the water use permitting function of the BMO are closely related, or overlapping, yet sometimes coordination is weak. This results in lack of clarity between agencies and the water user about obligations, needs, and requirements for improving water management.
- Improving coordination on organizing water quality monitoring to complement the water permitting process. Monitoring violations, reporting and accessing actual data and enforcement on violations all require improved coordination between EIMC, WRMA, and SEI. In particular, spot monitoring of identified problems is not within the capacity of the BMOs or the SEI, therefore timely response to problems is difficult.
- Decentralized water quality laboratory (in Syunik Marz) would be very useful, especially if resulting data were freely available to all government institutions.
- Promoting the use of water permits in remote villages requires coordination between Marz officials, BMOs and SHAEI. Remote villages often cannot demonstrate a clean water supply and therefore they do not want to be permitted because SHAEI will close them down.
- Coordination of water quantity measurement between ASH, SEI and WRMA. The measurement of water flows is often not coordinated to meet the specific needs of WRMA

and SEI on permits. ArmStateHydromet needs to have clear requirements and funding in its plan in order to collect the required data. Usually the BMOs and other agencies do not have a funding source to allow them to request additional flow data collection (beyond ASH's basic routine).

- BMOs need to work more closely with Marz governments to share water use permit information, so that such information can be incorporated into Marz planning for infrastructure (e.g. irrigation and drinking water facilities).

It should be pointed out that coordination is not an aim in itself, rather the resolution of specific issues should be the focus for local agencies. The development of an effective basin management plan will require specific focus guidance on the goals, scope and methods of improved inter-agency cooperation.

7.3 Ongoing Water Projects

Hydro-electric facilities were planned for Tashtun and Vadanidzor, but the status of these facilities is presently unknown.

7.4 Proposed New Water Projects

The MCA proposal in the bi-lateral agreement with the U.S. government includes a major proposed irrigation project in Meghriget basin. It consists of a proposed irrigation water storage reservoir at Lichk, and a gravity canal system to provide this water to 13 communities. It is intended to replace 14 existing irrigation pumps on the Araks River, and expand irrigation from 496 ha to 1,200 ha.

Table 7.1: BASIC DATA FOR MEGHRI IRRIGATION SCHEME PROPOSED UNDER MCA

Component	**Beneficiaries**	**Location**	**Benefits**
Meghri gravity irrigation canals	2,300 persons	Meghri, Alvanq, Shvanidzor, Nuvadi, etc.	Increase irrigated lands from 496 to 1200 hectares for production of grapes and orchard crops. Save 4.5 MkWhrs of electricity for pumping costs
Lichk reservoir	2,300 persons	Lichk village in upper Meghriget River drainage	Provide storage for Meghri gravity system (see above)
Meghri tertiary canals		Meghri and surrounding villages	Improve efficiency of water management on 496 hectares

Source: MCA, 2005 EIA at http://www.mca.am/en/pdf/eia_eng.pdf

This project is in the very initial stages of planning, and specific data on the reservoir's location and proposed dimensions are not available. In July, 2008, the MCA will make a selection of projects that will be funded.

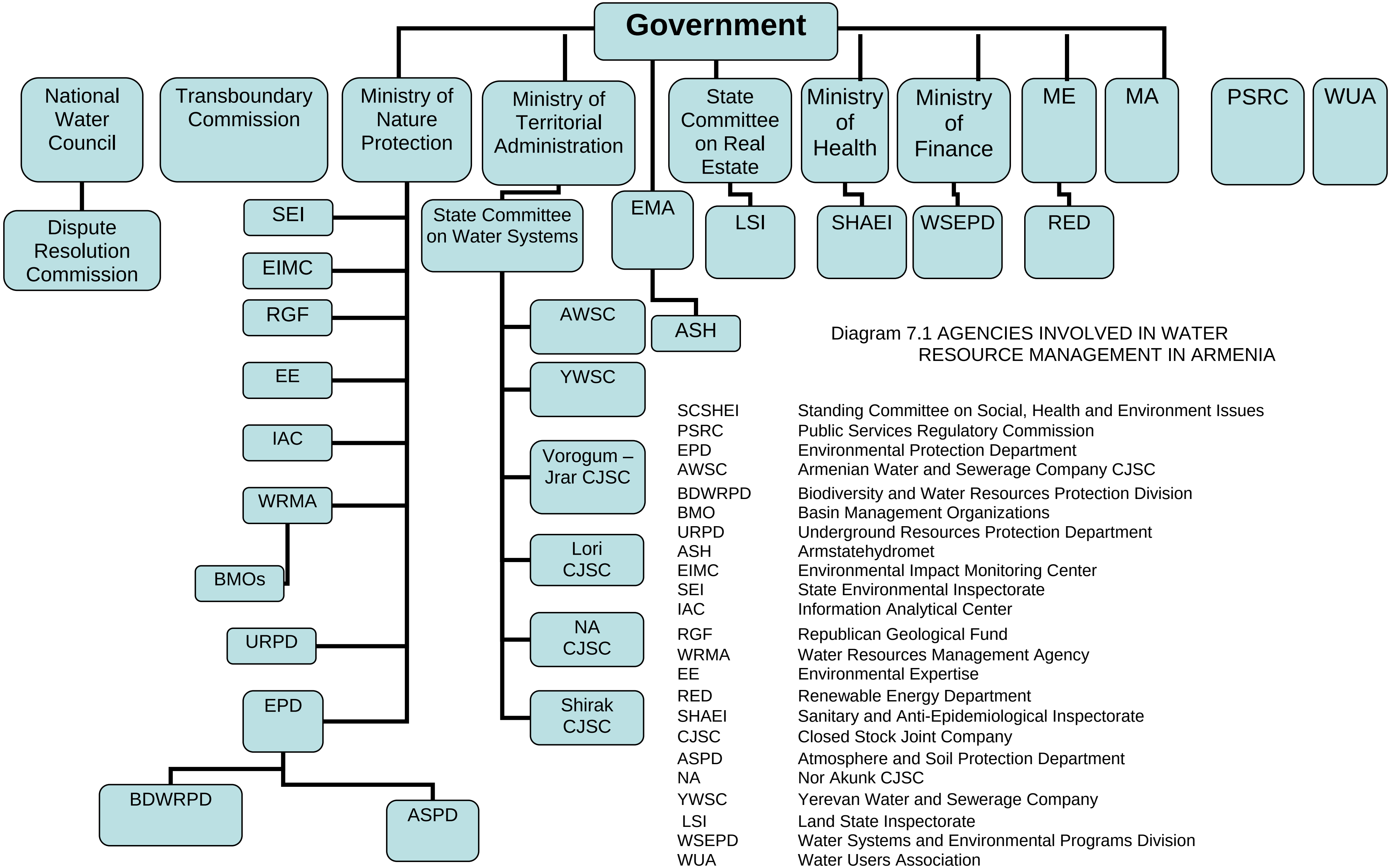


Diagram 7.1 AGENCIES INVOLVED IN WATER RESOURCE MANAGEMENT IN ARMENIA

SCSHEI	Standing Committee on Social, Health and Environment Issues
PSRC	Public Services Regulatory Commission
EPD	Environmental Protection Department
AWSC	Armenian Water and Sewerage Company CJSC
BDWRPD	Biodiversity and Water Resources Protection Division
BMO	Basin Management Organizations
URPD	Underground Resources Protection Department
ASH	Armstatehydromet
EIMC	Environmental Impact Monitoring Center
SEI	State Environmental Inspectorate
IAC	Information Analytical Center
RGF	Republican Geological Fund
WRMA	Water Resources Management Agency
EE	Environmental Expertise
RED	Renewable Energy Department
SHAEI	Sanitary and Anti-Epidemiological Inspectorate
CJSC	Closed Stock Joint Company
ASPD	Atmosphere and Soil Protection Department
NA	Nor Akunk CJSC
YWSC	Yerevan Water and Sewerage Company
LSI	Land State Inspectorate
WSEPD	Water Systems and Environmental Programs Division
WUA	Water Users Association
EMA	Emergency Management Admibistration
ME	Ministry of Energy and Natural Resources
MA	Ministry of Agriculture

8. Definition of Basin Vision and Issues (Guideline 5.2)

8.1 Stakeholder Vision for the River Basin

Stakeholders in the Meghriget River basin have not developed a formal vision for future water resources management in their area. Typically a basin "vision" is a general picture of desired future environmental, economic, and aesthetic conditions in the communities within a river basin. Based on discussions with key local stakeholders, elements of a vision for Meghriget area may include:

- Developing irrigation water storage projects to better use abundant seasonal runoff.
- Improving or replacing old irrigation pumping schemes on Araks River.
- Maintaining high water quality in the upper basin, while developing employment opportunities with environmentally-sound mining or other investments.
- Improving overall environmental sanitation in urban and rural areas.

8.2 Identification of Key Issues in Water Resources

In a Stakeholder Forum in Kapan, in May, 2007, led by the Southern Basin Management Organization and PA Government Services, the residents and authorities of Syunik Marz identified the following key issues in their area, including Meghriget basin.

1) <u>Seasonal water shortages for irrigation and drinking water</u>

These late summer water shortages are particularly severe in Meghriget basin, because of an almost complete dependence on surface waters, and very few groundwater resources available. In 2005 the mean September flows in the Meghriget River ranged as low as 0.2 m^3/sec in the river.

2) <u>Lack of water treatment plants and other infrastructure for drinking water</u>.

Small rural communities are usually not served by water supply companies, and are "on their own" in terms of providing adequate drinking water supplies. The drinking water supply infrastructure that does exist is often obsolete and in serious need of upgrade and repairs. Some areas suffer from sediment in their drinking water. Other communities have severely limited access to water resources adequate for public water supplies (e.g. Shvanidzor and Nuvadi use a very limited groundwater resource).

3) <u>Pollution of water by industry and agriculture.</u>

Wastewaters from industry, including mining and food processing are not adequately treated, resulting in pollution of receiving waters (rivers). Agriculture may also be the source of some pollution, particularly from livestock or from pesticide use.

Although waters in this area are generally in good condition, two examples of documented pollution were found during the characterization process, affecting two rivers: Meghriget River itself, and the Karchevan River. First, in lower Karchevan River there are extremely high levels of turbidity/suspended solids, and high levels of nitrate and metals downstream of Agarak (this includes copper levels and suspended solids levels in excess of national water quality standards—the turbidity was clearly visible on field trips to the area and confirmed by sampling (AUA, 2007)). Second, in Meghriget River there occur levels of ammonia in excess of national fisheries standards below Meghri town (State Water Cadastre, 2007), and mercury levels in the Meghriget River upstream of the town in excess of national standards (AUA, 2007). Ammonia is toxic to fish at the levels detected below Meghri, and mercury is a dangerous toxin which bio-accumulates in fish, and can seriously affect human health when fish from an affected river are consumed.

4) <u>Lack of water quality data—no general public knowledge of water quality</u>

The general public and the local agency personnel do not have access to good water quality information. Information is generally managed by a few technical agencies and is not easily available to others. Also this information is difficult to interpret, and no agency has yet taken responsibility for interpreting this information for public use.

5) Aquatic animals and plants have vanished because of pollution. When water quality data are scarce, informal observations of aquatic life, including fish and other organisms, is an important means of interpreting the health of rivers and lakes. Local residents know the environmental history of their area, and are often aware of species that have disappeared, especially fish that were formerly used for food—this information is critical to interpreting the actual status of rivers and lakes. Local aquatic life may have been damaged by a variety of problems, including water pollution, excessive extraction of water for human uses, changes in water temperature, changes to the form or stability of channels, loss of streamside forests or other riparian habitat changes, loss of ability to migrate up and down streams (due to dams) and many others. Better information on this situation in the Meghriget area is urgently needed.

6) Low level of ecological education in the population. In general, the people of the area, including many local officials, do not understand some of the potential consequences of their actions on the aquatic environment. For example, the existence of toxic metals residues from mining is generally known, but the ways in which they can enter the river systems and affect fish and human health (for example, mercury) is not well-known. Means of preventing damage to aquatic ecosystems are also not well-known. More environmental education for adults and children could be an important part of improving water management in the basin.

7) Poor location of domestic/industrial solid wastes. Solid wastes, including domestic garbage, industrial wastes, mine tailings, and derelict machinery, among other examples, are potential sources of pollution for surface and ground waters. The solid waste and water resource issues must be addressed in a coordinated way in a river basin management plan.

A summary of existing risks to specific water resources in the basin is found in Table 8.1:

Table 8.1 SUMMARY OF SIGNIFICANT WATER RESOURCES AT RISK IN MEGHRIGET BASIN AREA

Resource and Use at Risk	Specific Risks	Causes (if known)	Level of Risk
Middle and Lower Meghriget River fisheries and recreation uses	Ammonia (NH4); Mercury (Hg) Nutrients (N, P)	Raw sewage Possible mining runoff, or acid drainage but unknown.	Medium (NH_4 and nutrients); High (Mercury)
Lower Meghriget River irrigation and fisheries uses	Dewatering of stream; extreme low flows	Competition for irrigation water. Irrigation efficiency problem?	Medium (economic impacts in irrigation)
Lower Karchevan River, fisheries, recreation, agricultural use	Total Suspended Solids/ Turbidity; Copper	Unknown mining related source	High

Source: developed for this report.

8.3 Opportunities for Improved Water Management

The activities of the Southern Basin Management Organization can lead to a successful river basin planning process. A successful planning process in the Meghriget area of Syunik Marz must address the following opportunities in a concrete way:

- Improve coordination among agencies which deal with water resources.
- Assist to the effective management of basin natural resources in the Syunik Marz.
- Specifically support investment programs for improved irrigation infrastructure in the Meghriget basin, for example, the Lichk reservoir proposal now under evaluation by MCA.
- Address toxic waste (heavy metals, including mercury if confirmed) issues with improved monitoring programs, and clean up of major sources.
- Stimulate the improvement of environmental practices in the mining sector, specifically the management of wastewater and solid wastes with residual heavy metals.
- Catalyze investment in rehabilitated drinking water systems for rural communities.
- Develop better sources of environmental information in Syunik Marz, and help citizens to learn more about the health of their rivers and other waters.
- Protect and restore native fisheries for local use and to enhance tourism.

9. References

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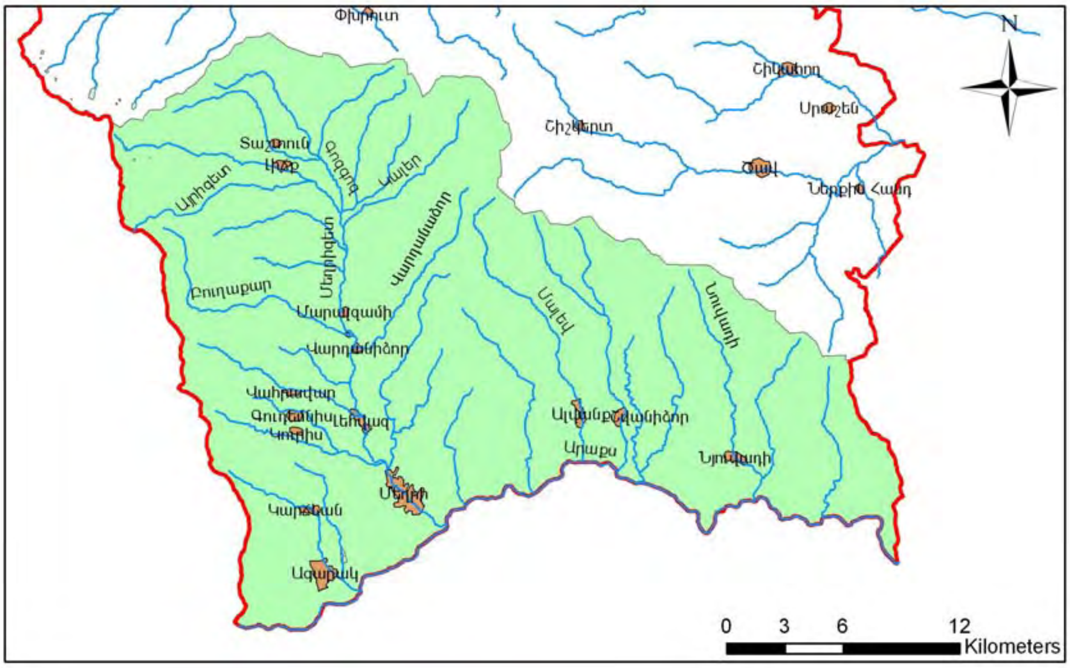
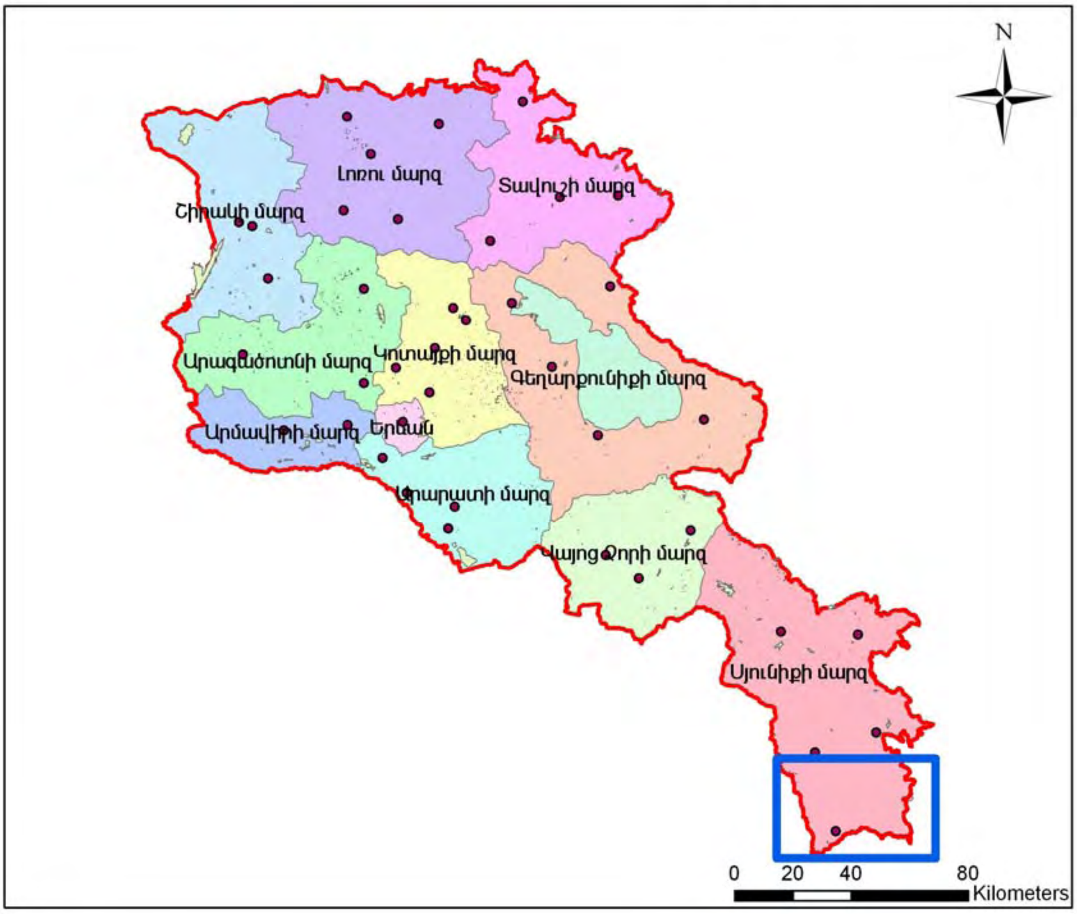
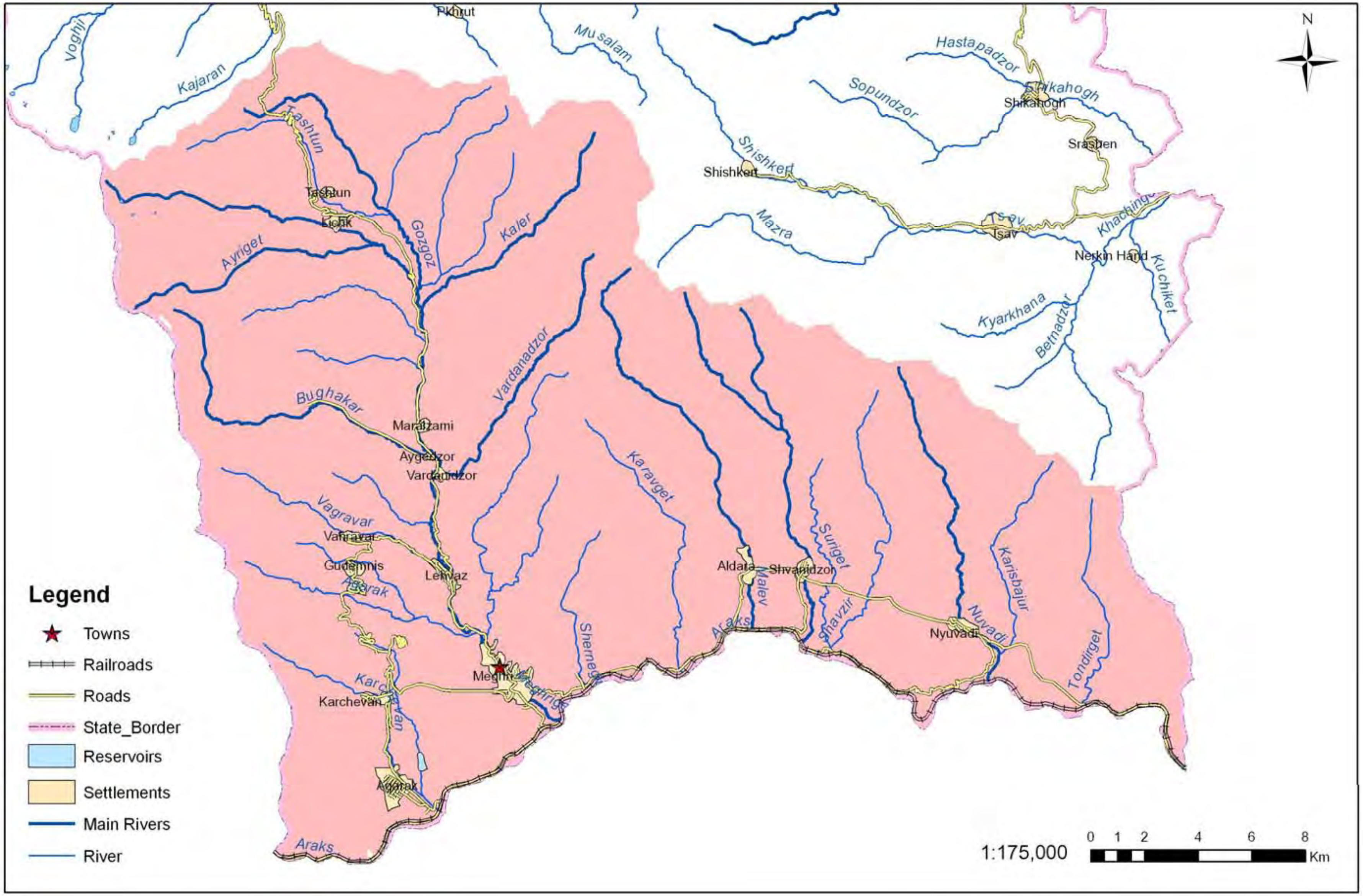
10. Annex: MAPS

Map 1. Location of Meghriget River Basin

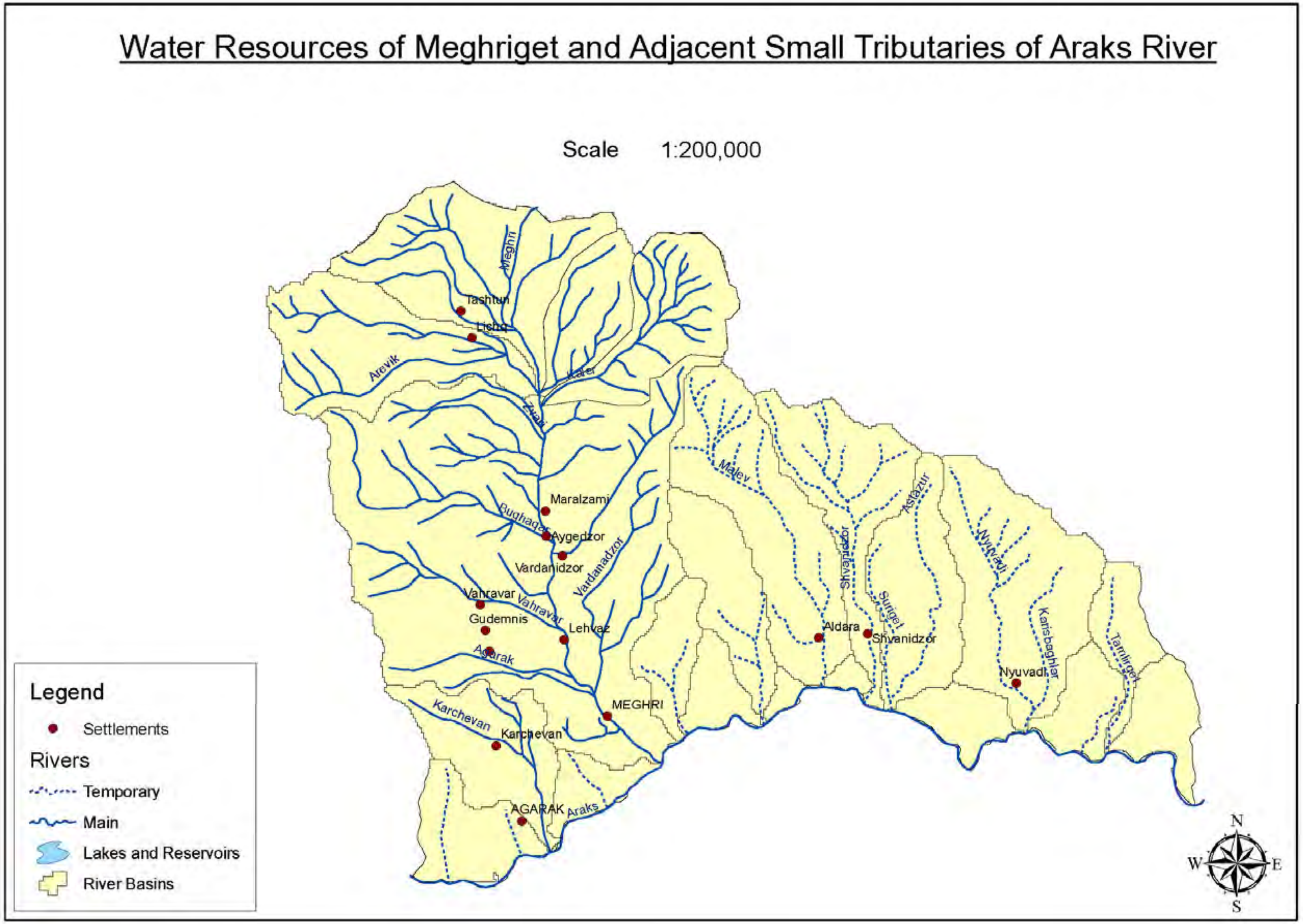




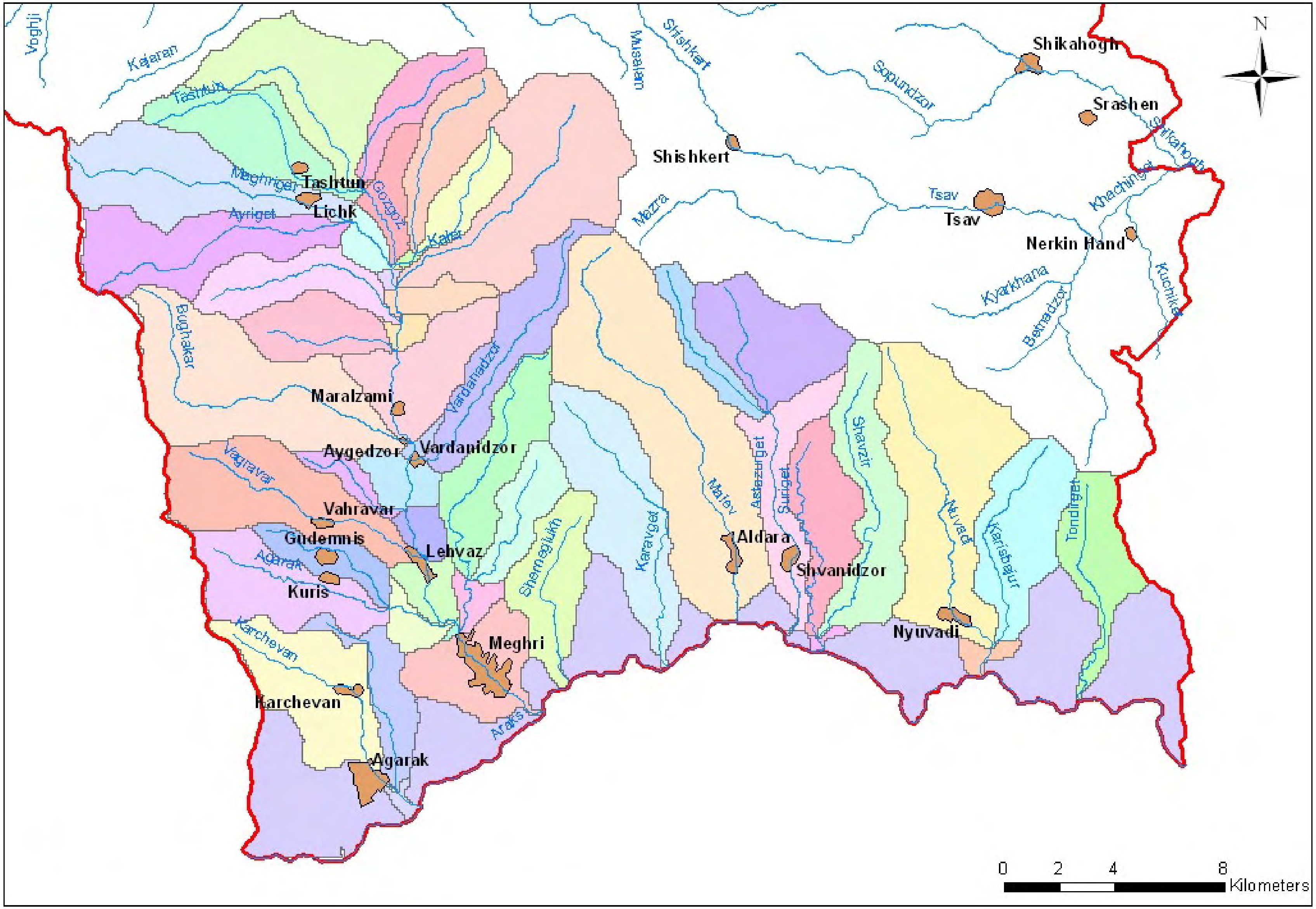
Map 2. General Map of Meghriget Basin



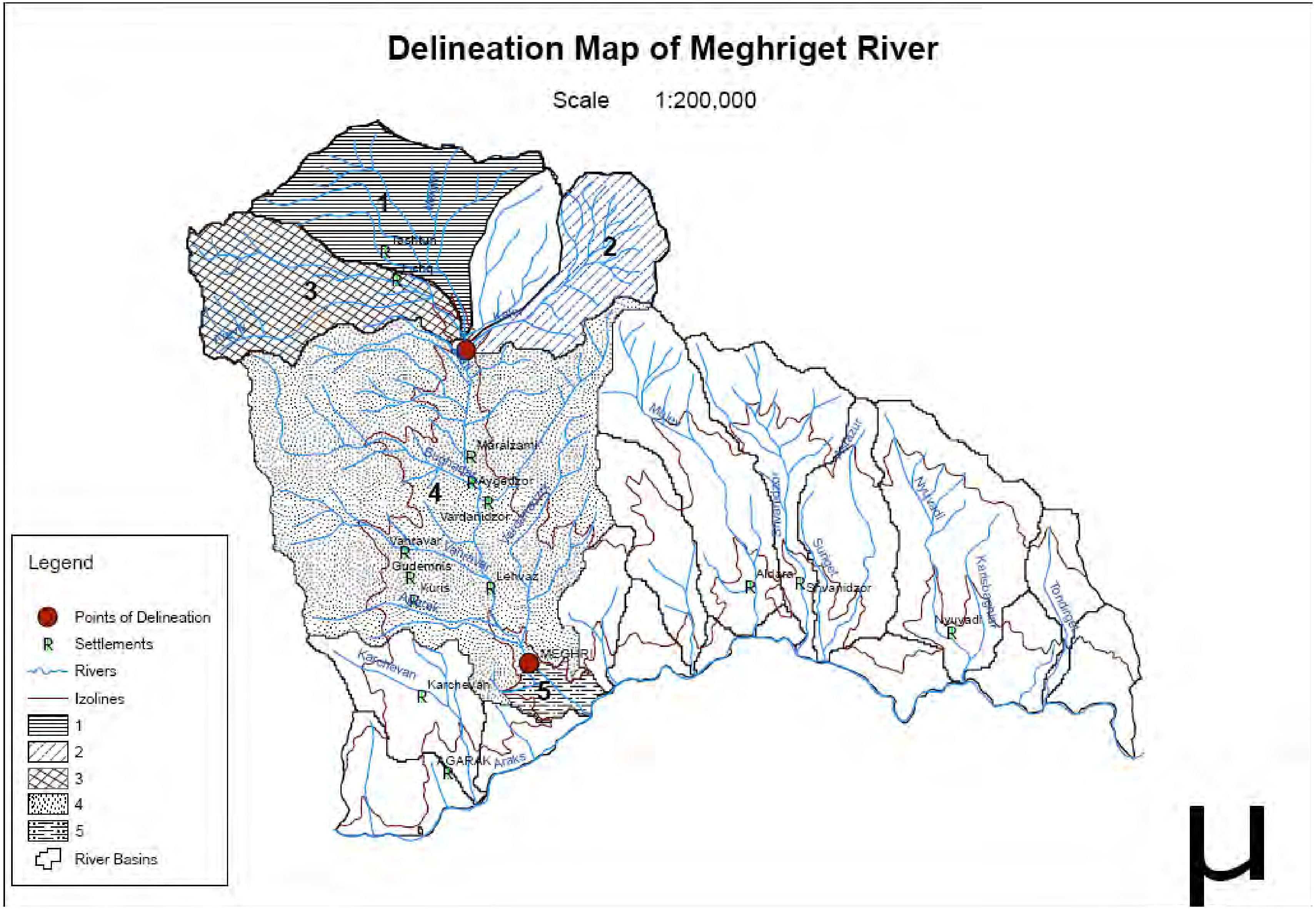
Map 3. Water Resources of Meghriget River Basin and Adjacent Basins



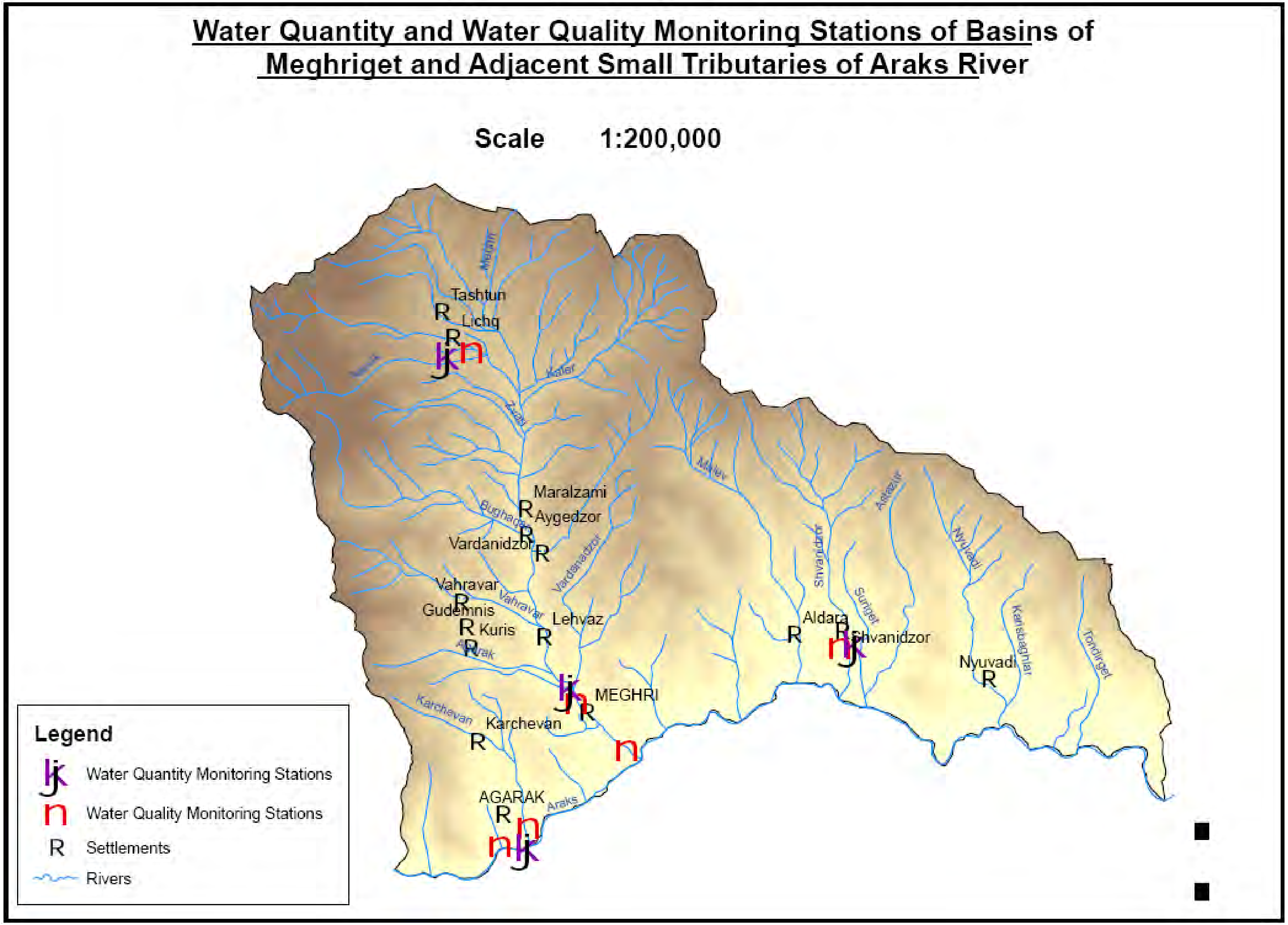
Map 4. Catchments Areas in Meghruiget Basin



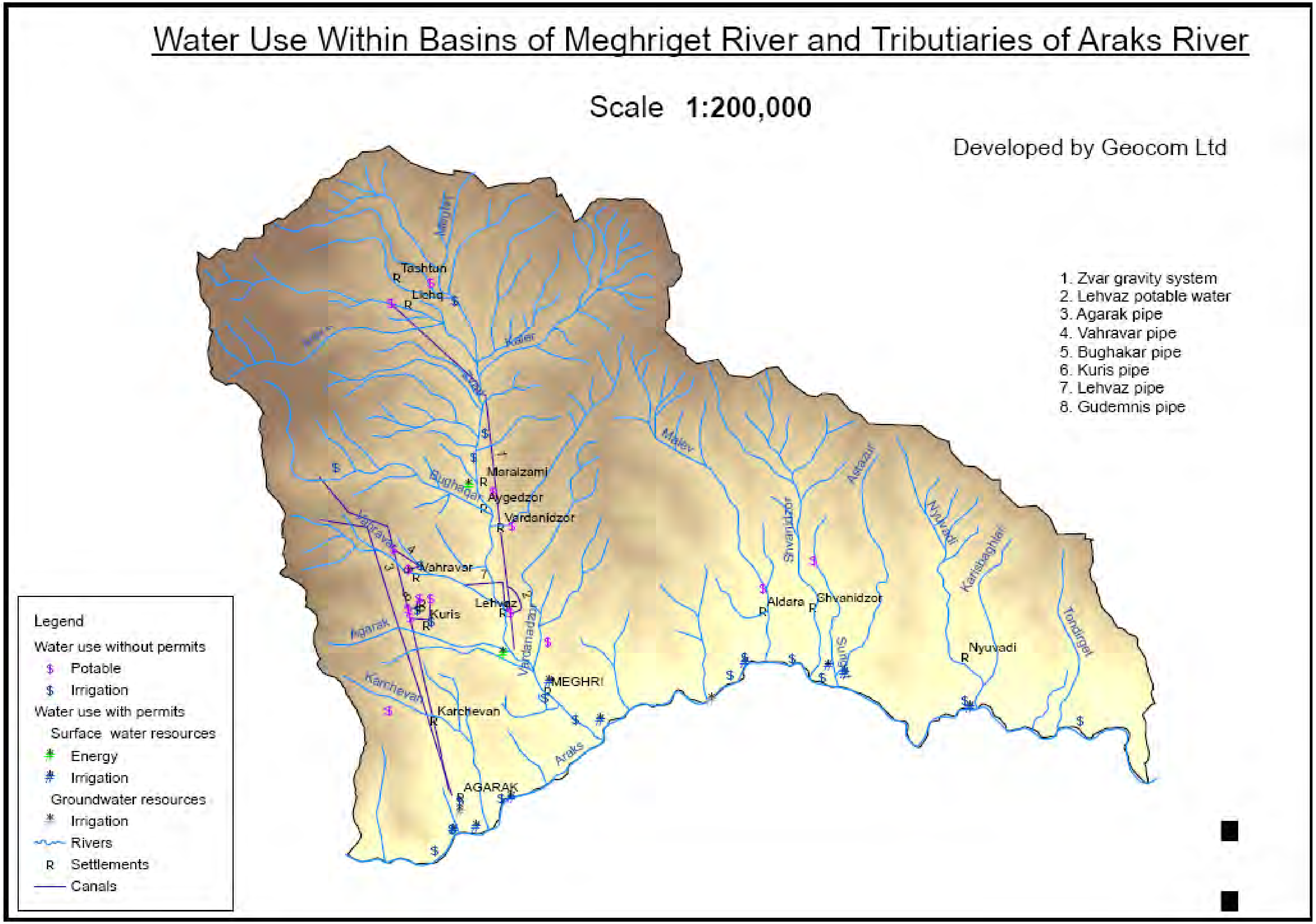
Map 5. Delineation Map of Meghriget Basin



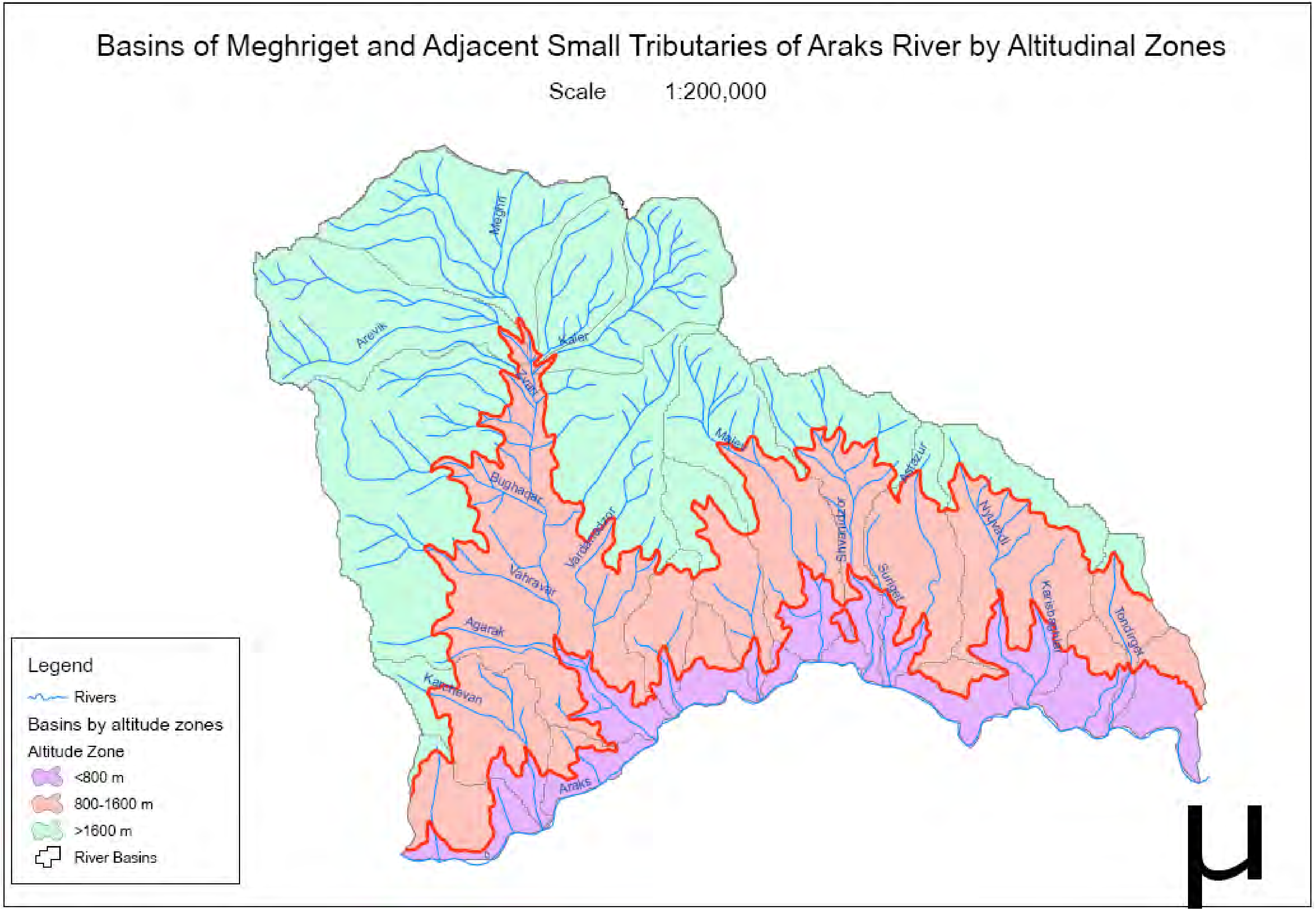
Map 6. Hydrological and Water Quality Observation Points in Meghriget River Basin and Adjacent Basins



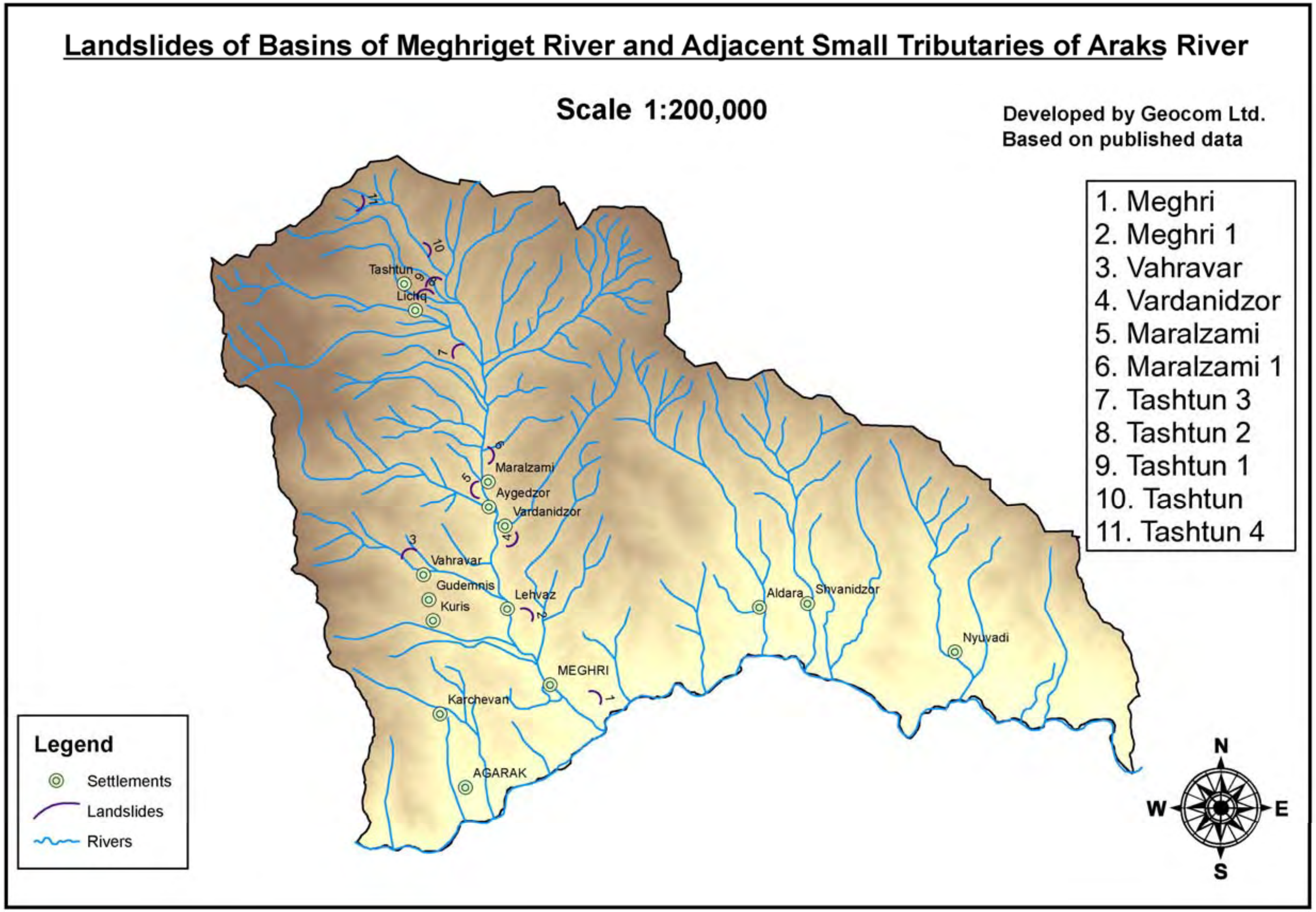
Map 7. Water Use in Meghriget River Basin and Adjacent Small Basins According to Water User Permits



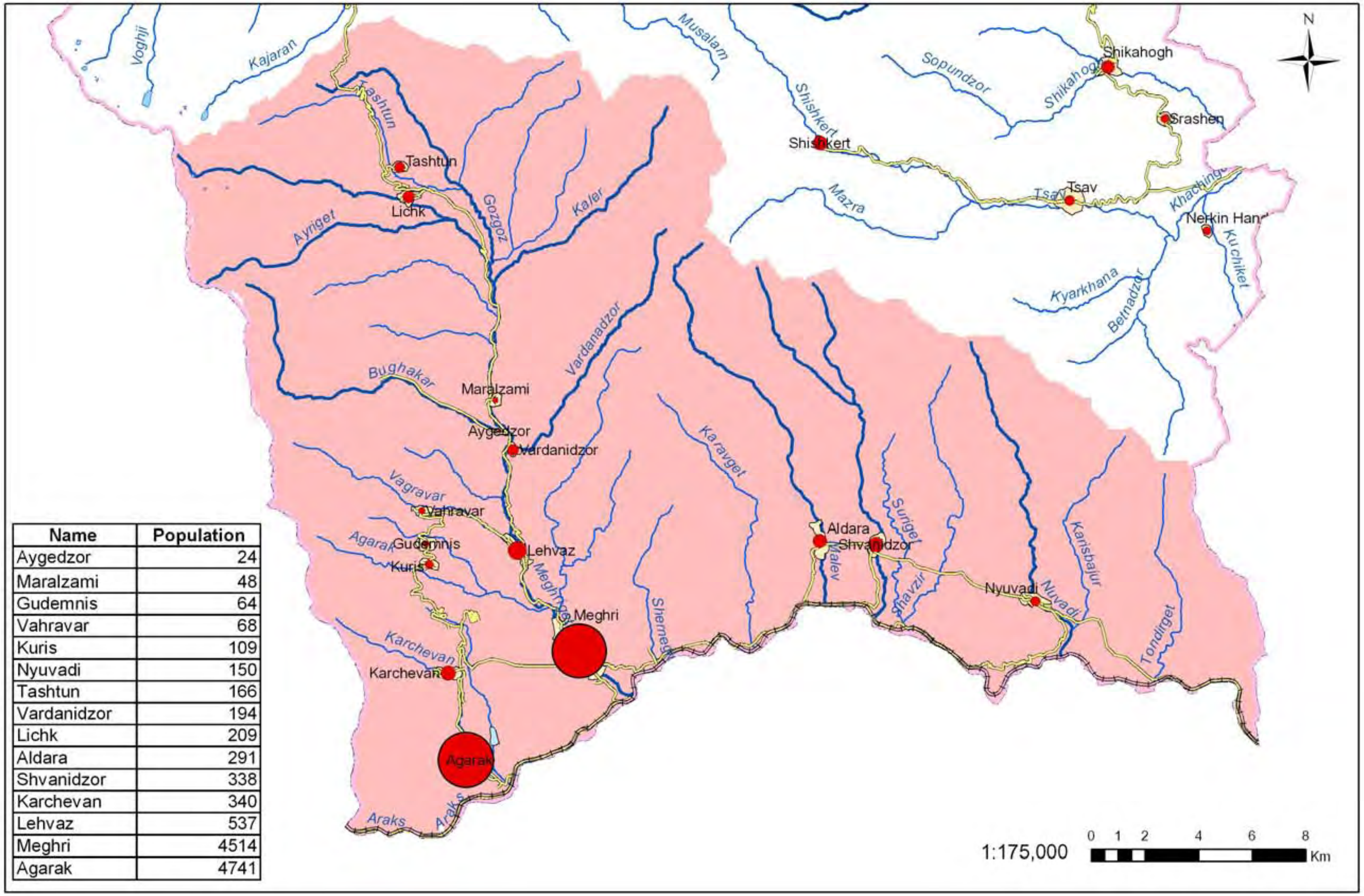
Map 8. Meghriget and Adjacent River Basins According to Altitudes Zones



Map 9. Landslides Map of Meghriget and Adjacent River Basins

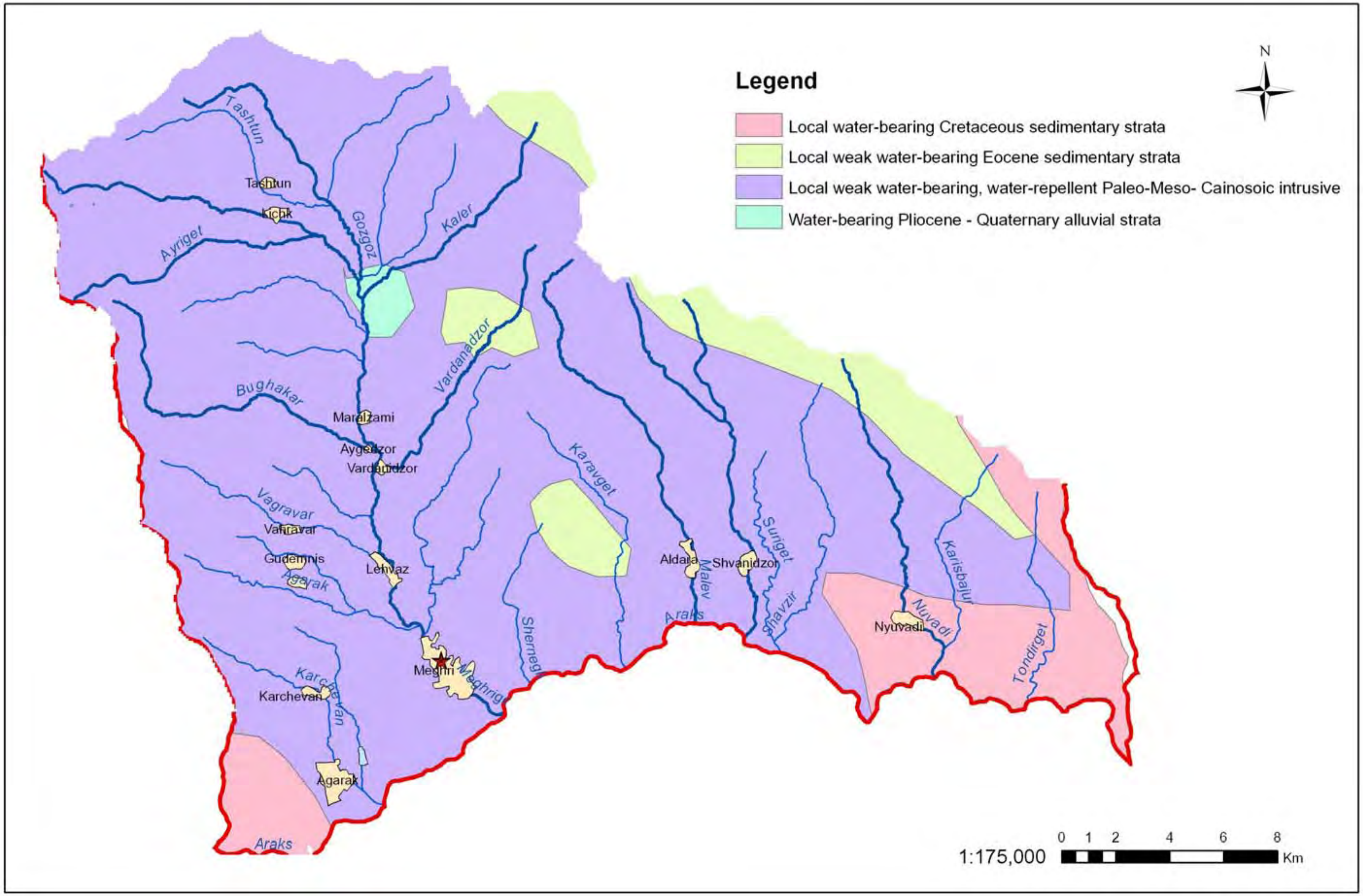


Map 10. Population Distribution at Meghriget and Adjacent River Basins

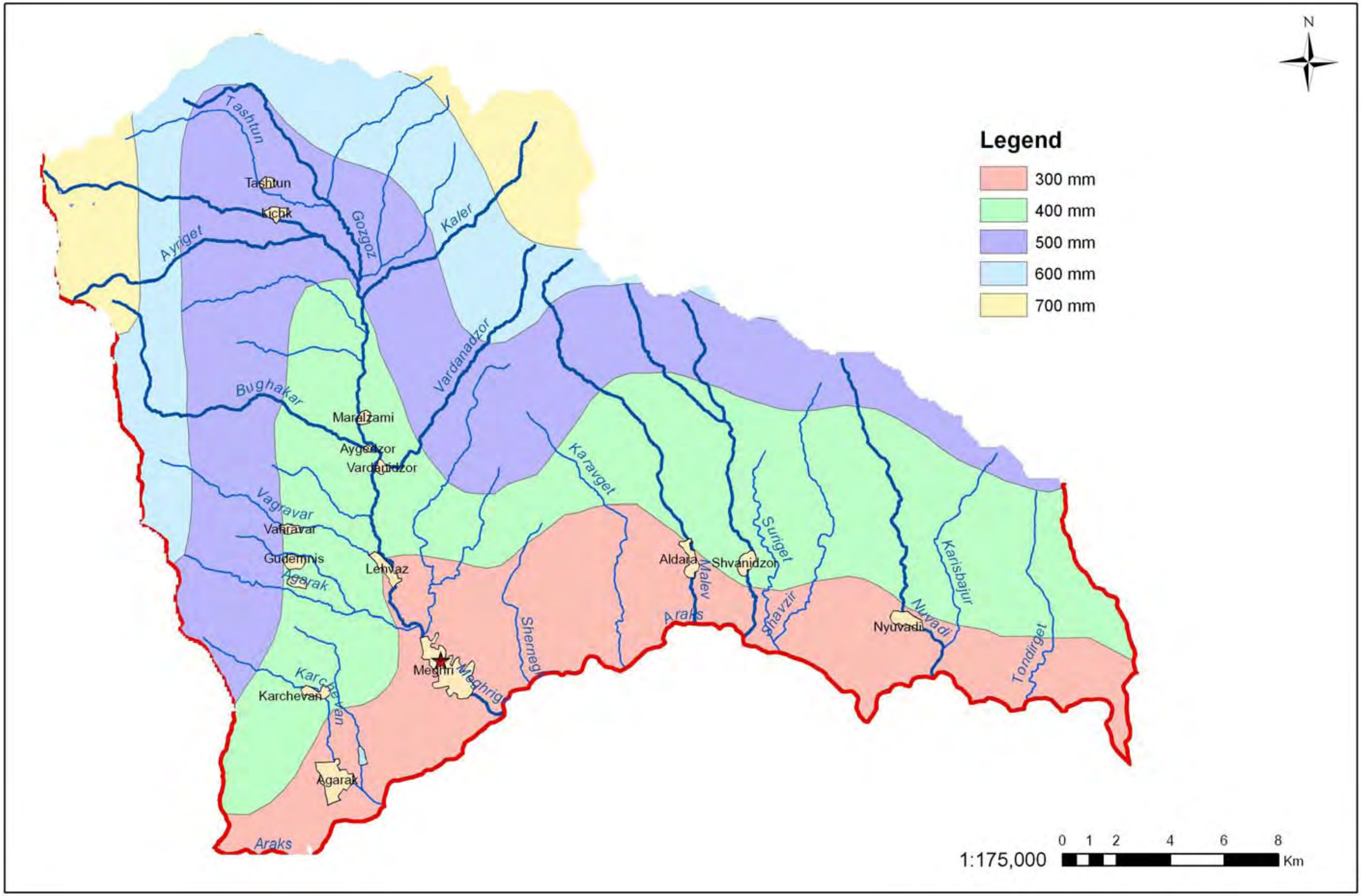


Name	Population
Aygedzor	24
Maralzami	48
Gudemnis	64
Vahravar	68
Kuris	109
Nyuvadi	150
Tashtun	166
Vardanidzor	194
Lichk	209
Aldara	291
Shvanidzor	338
Karchevan	340
Lehvaz	537
Meghri	4514
Agarak	4741

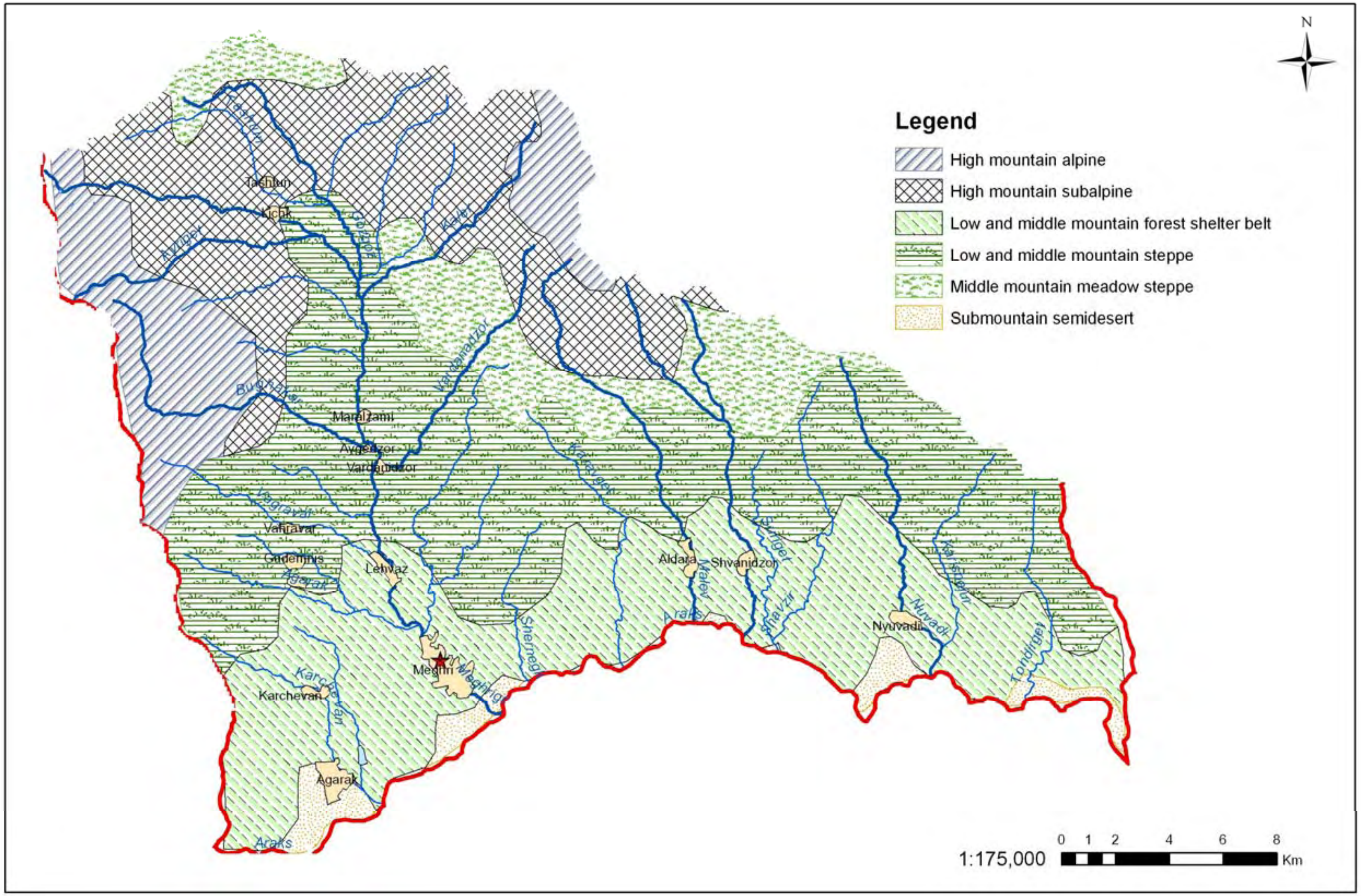
Map 11. Geologic Map of Meghriget and Adjacent River Basins



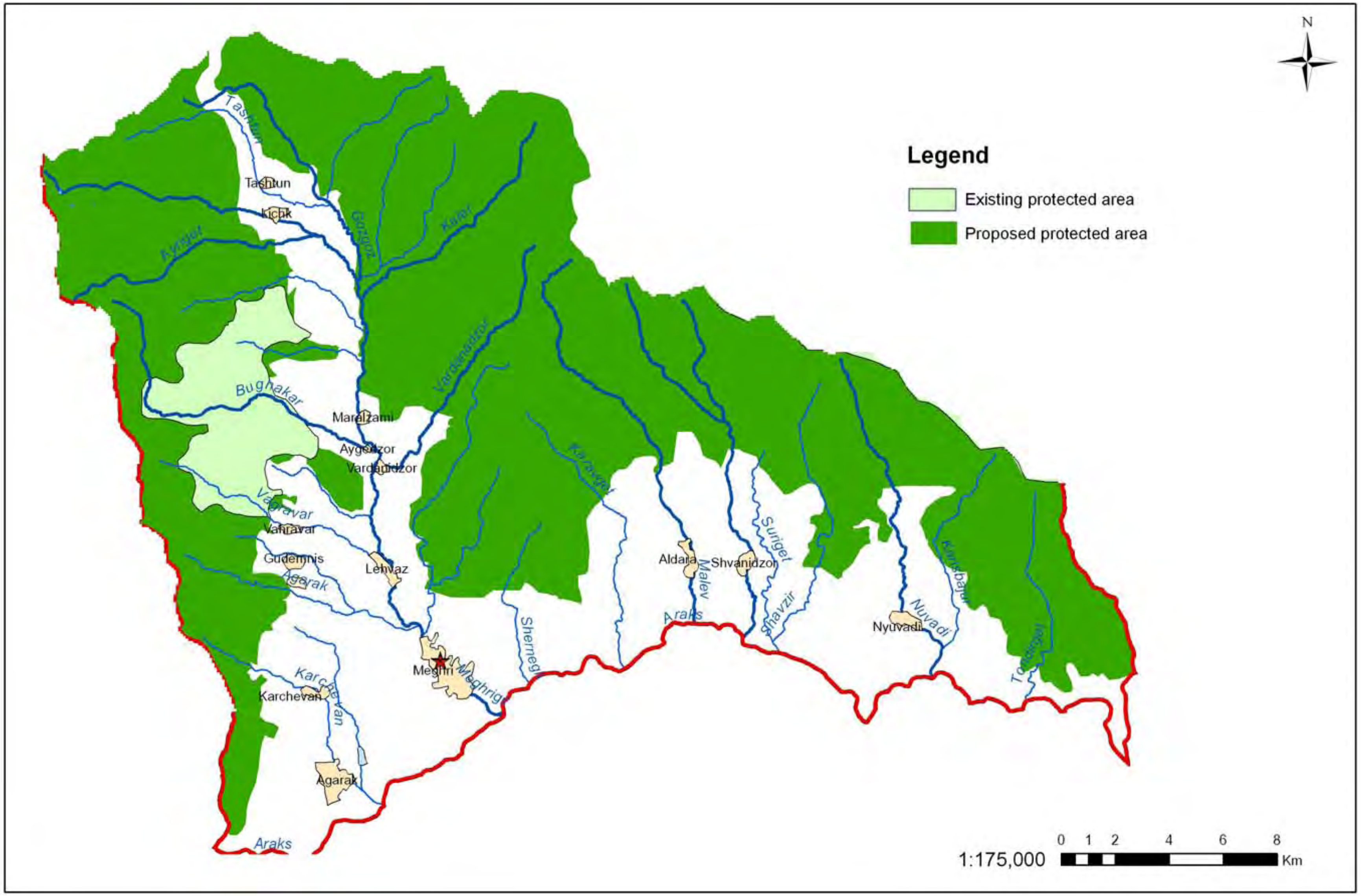
Map 12. Annual Precipitation Map for Meghriget and Adjacent River Basins



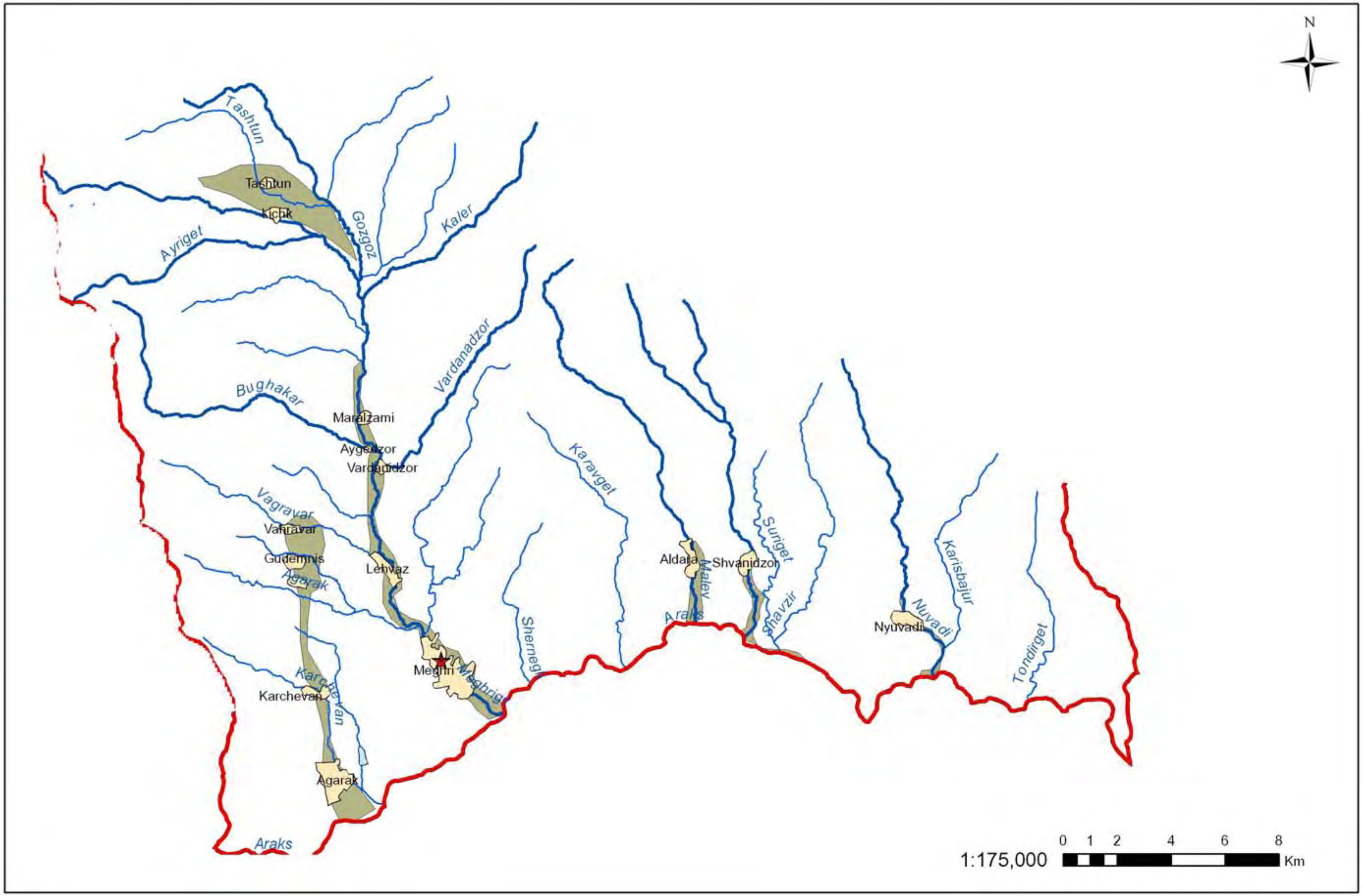
Map 13. Landscape Zones of Meghriget and Adjacent River Basins



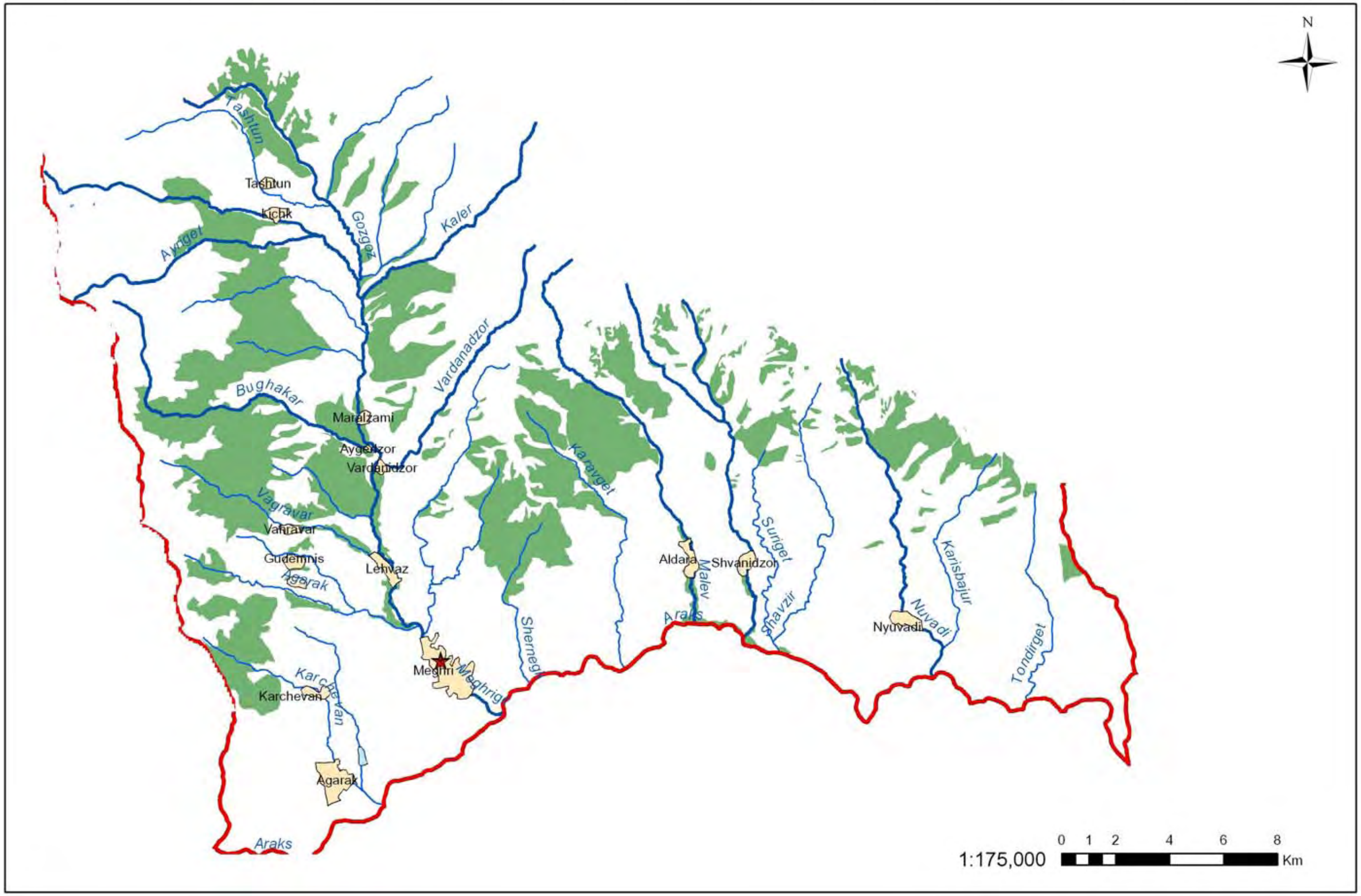
Map 14. Protected Areas at Meghriget and Adjacent River Basins



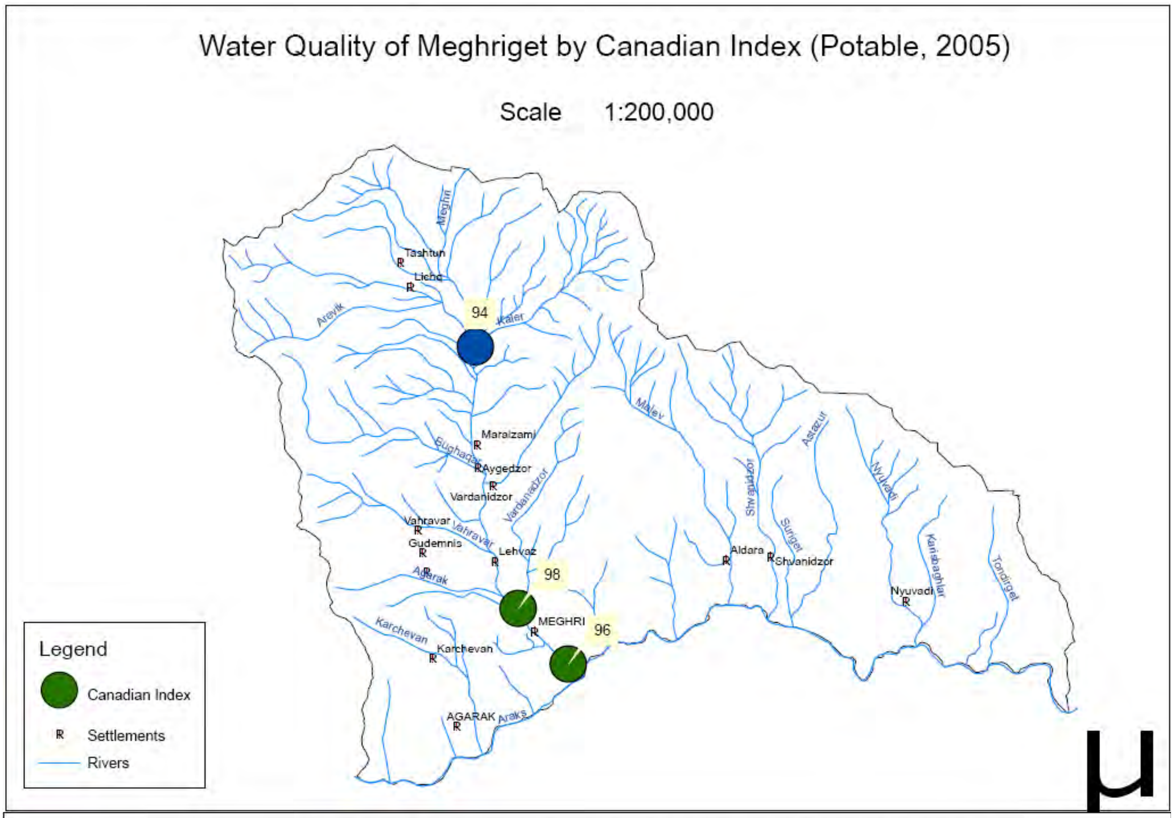
Map 15. Irrigated Areas at Meghriget and Adjacent River Basins

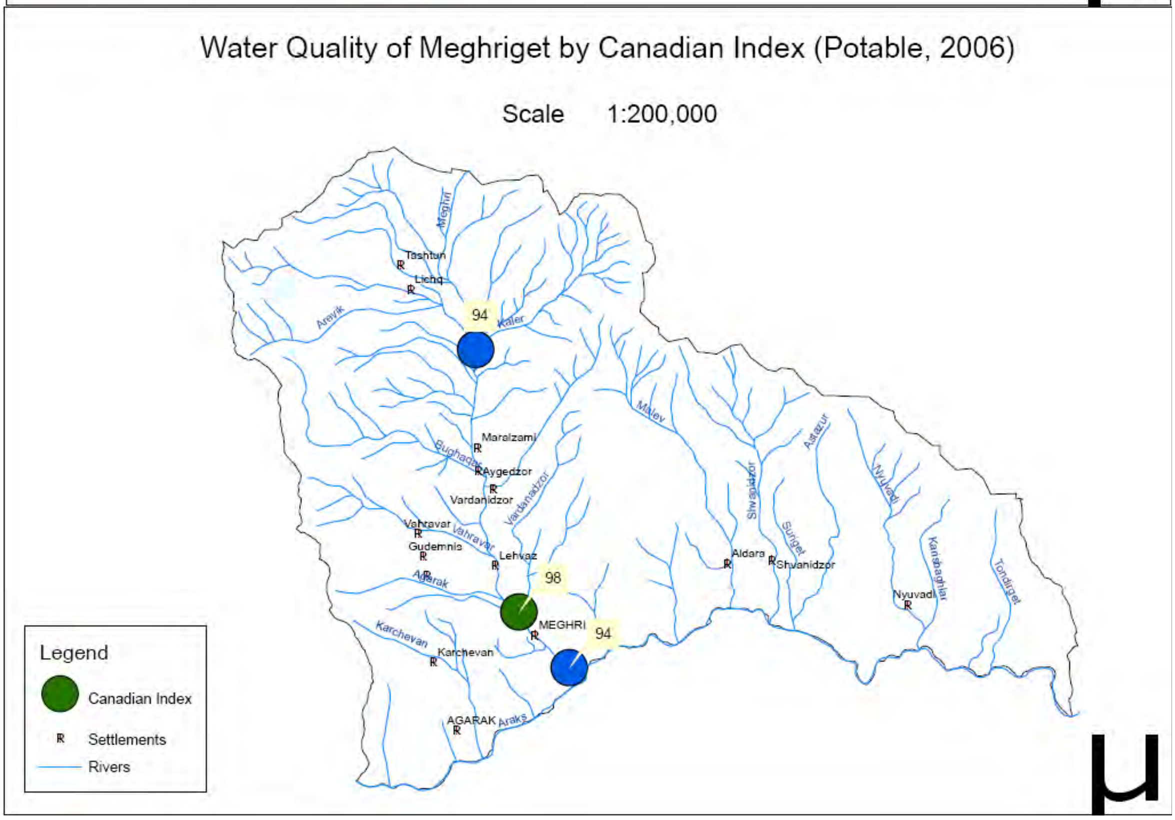


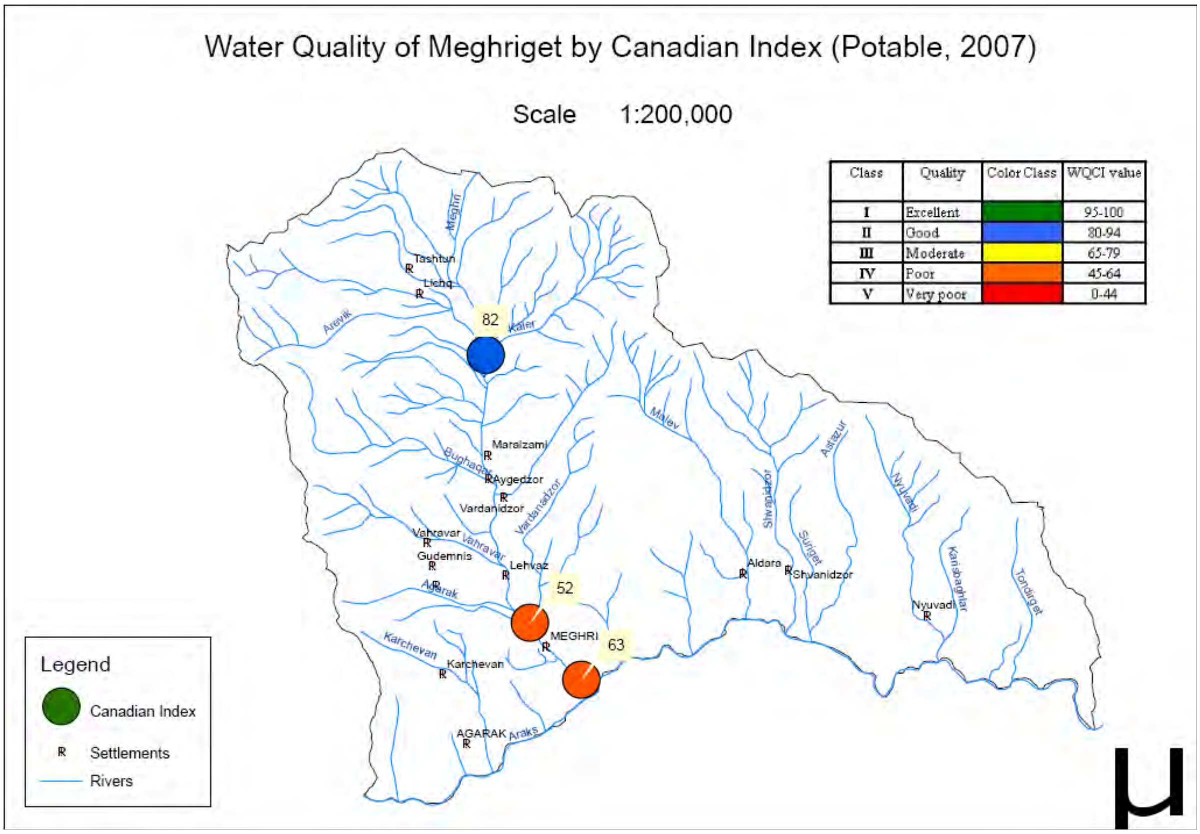
Map 16. Forest Cover of Meghriget and Adjacent River Basins



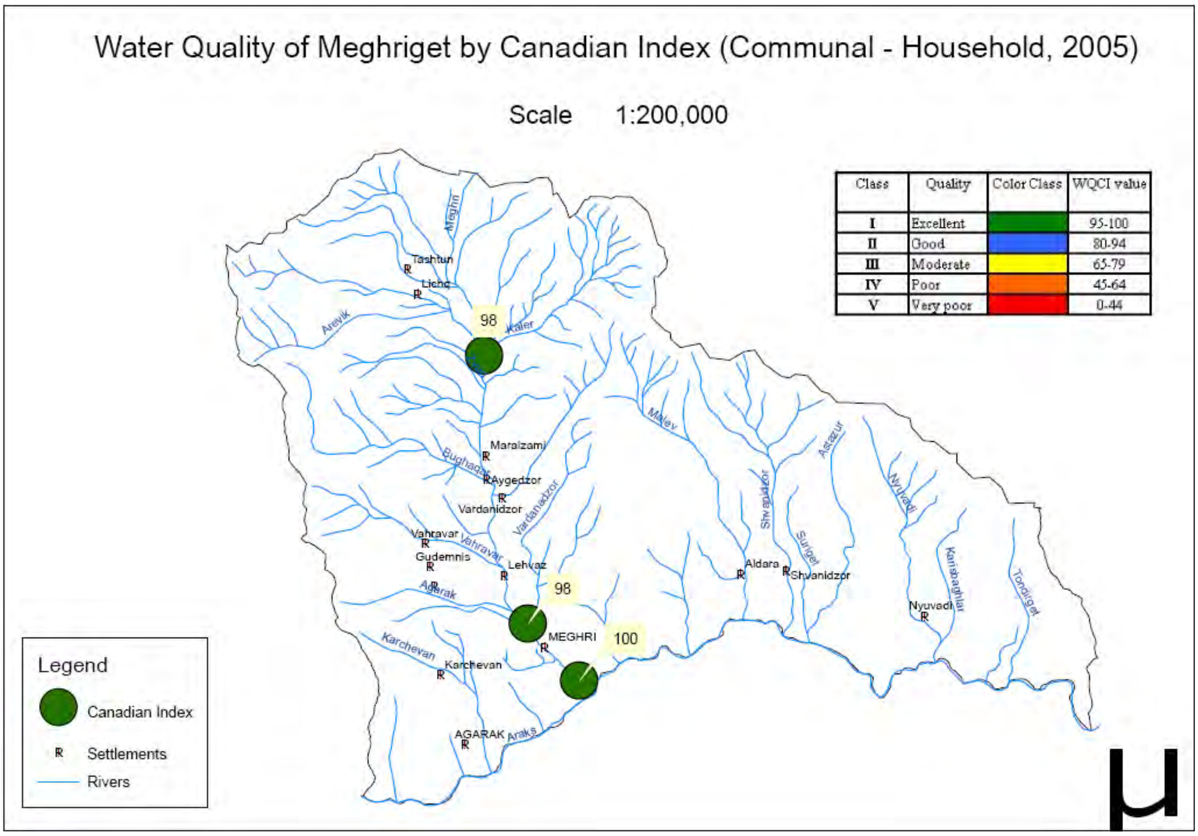
Map 17. Water Quality of Meghriget by Canadian Index (Potable)





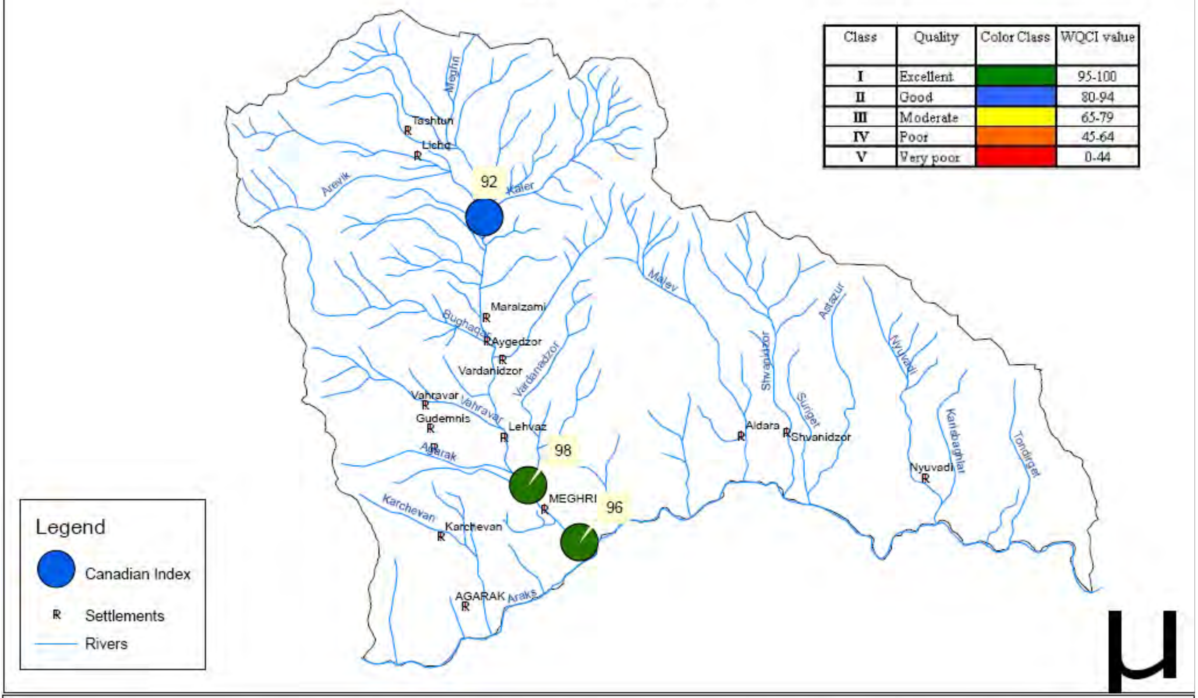


Map 18. Water Quality of Meghriget by Canadian Index (Communal-Household)



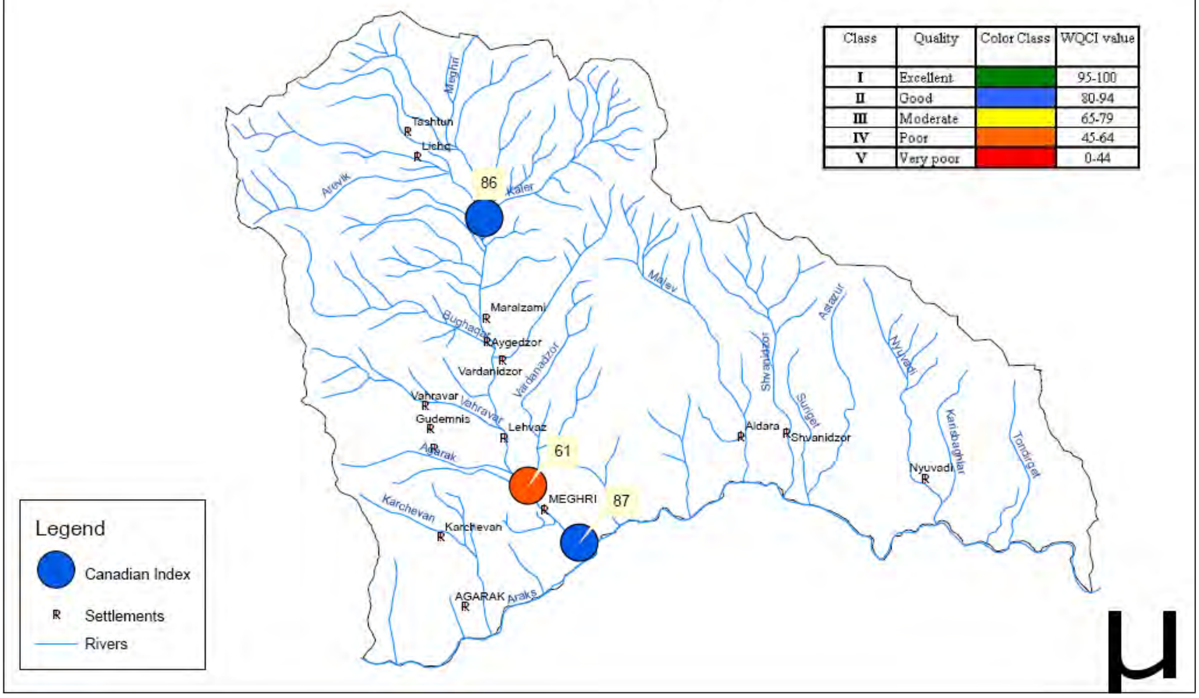
Water Quality of Meghriget by Canadian Index (Communal - Household, 2006)

Scale 1:200,000

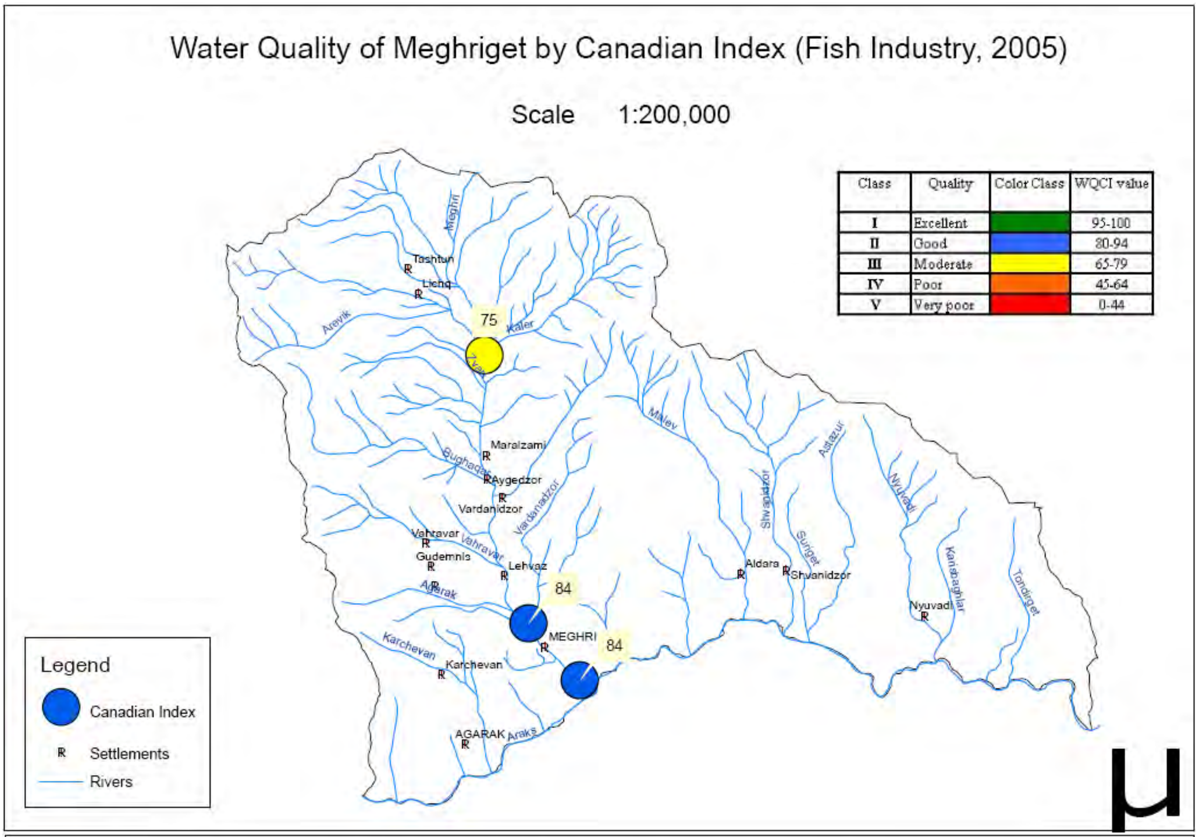


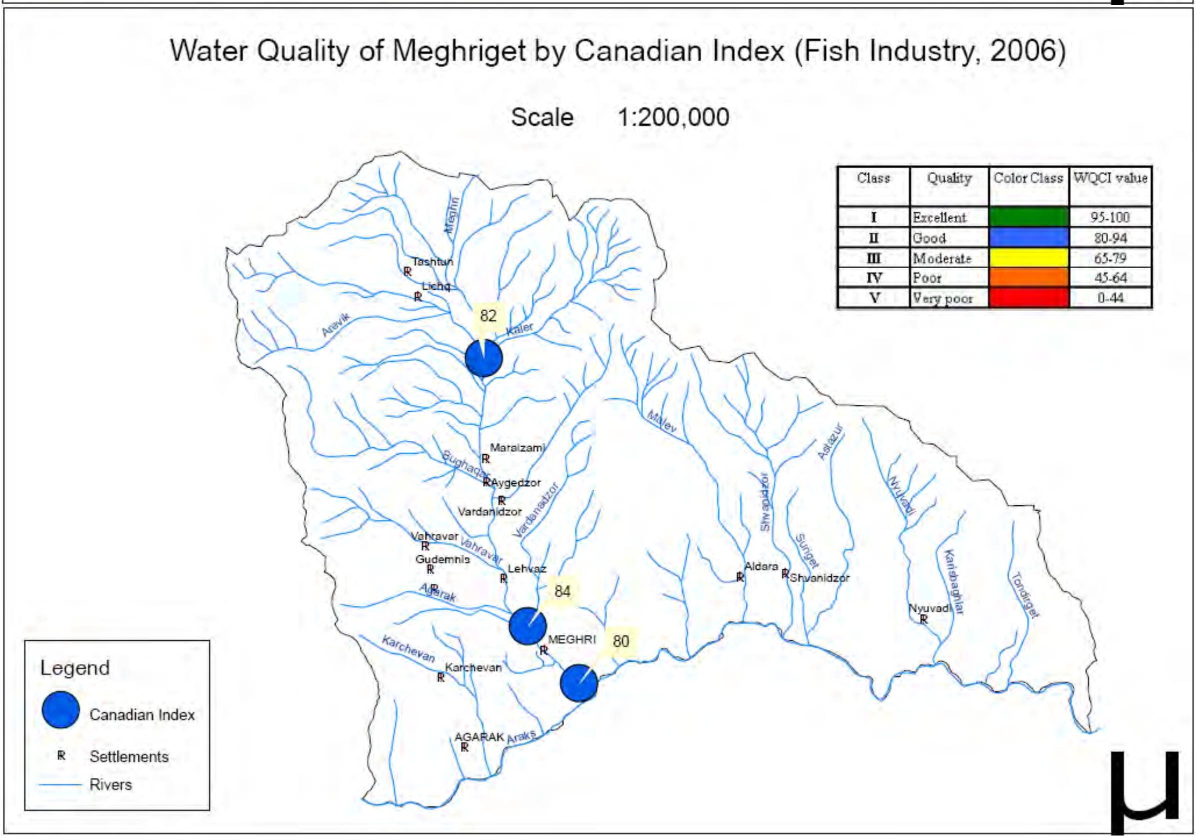
Water Quality of Meghriget by Canadian Index (Communal - Household, 2007)

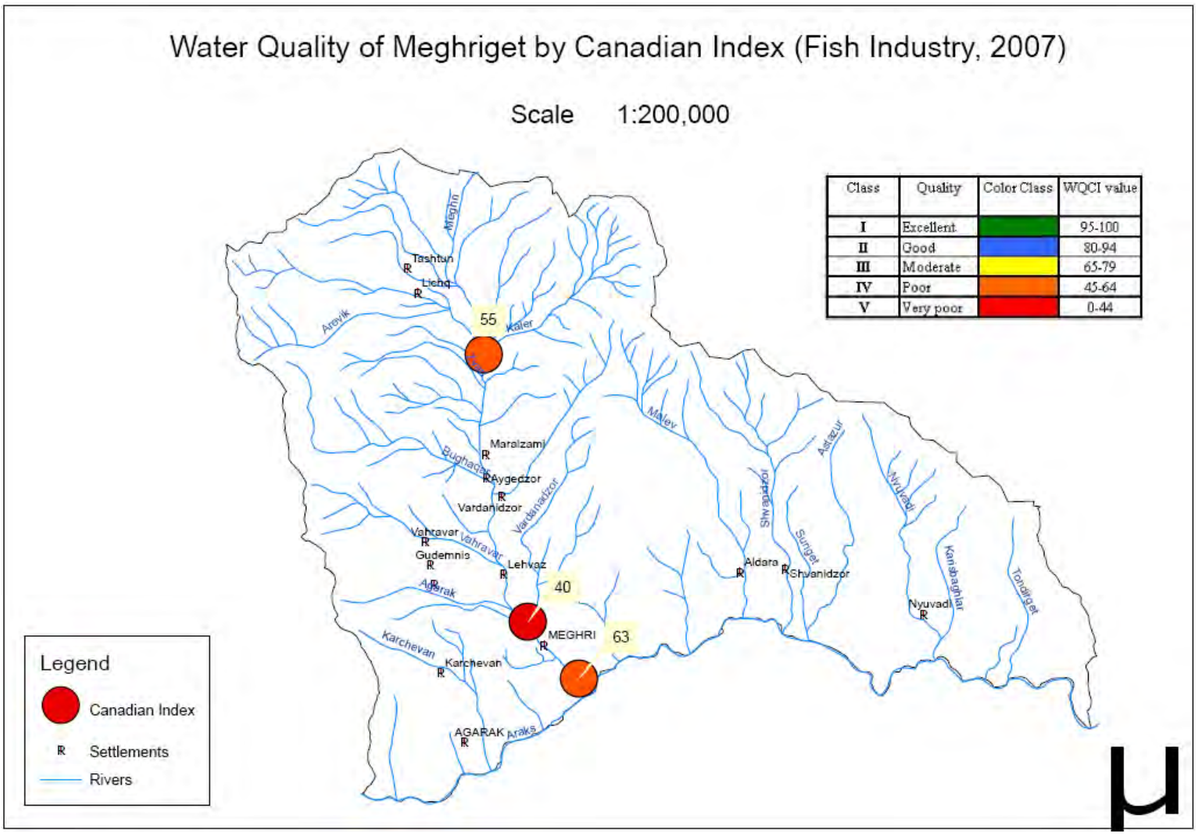
Scale 1:200,000



Map 19. Water Quality of Meghriget by Canadian Index (Fish Industry)






Water Quality of Meghriget by Canadian Index (Fish Industry, 2007)
Scale 1:200,000
Class
Quality
Color Class
WQCI value
I
Excellent
95-100
II
Good
80-94
III
Moderate
65-79
IV
Poor
45-64
V
Very poor
0-44
Legend
Canadian Index
Settlements
Rivers
55
40
63
Tashtun
Lichq
Arevik
Meghri
Maralzami
Aygedzor
Vardanidzor
Vahravar
Gudemnis
Lehvaz
MEGHRI
Karchevan
AGARAK
Araks
Malev
Astazur
Nyuvadi
Aldara
Shvanidzor
Nyuvadi
Tondriget

STEP 2. CLASSIFICATION OF WATER RESOURCES

Introduction to Step 2: Classification

Classification is the second step in the river basin planning process. The primary purpose of classification is to assign each surface water body (stream, lake, canal, or reservoir) and ground water body (aquifer) to a category or type which has its own set of distinct, and ecologically appropriate environmental objectives. Categories are usually defined by ecological characteristics which determine what type of chemical water quality and aquatic life is found there under natural conditions—altitude, geology, etc. River basin planning is simpler if the number of water body categories is few, therefore classification systems should be as simple as possible. Large water bodies are delineated, or separated, according to objective criteria so that each part (e.g. tributary) of a larger system falls within the appropriate category.

Classification systems encompass natural water bodies, and man-made water bodies. The European Water Framework directive recognizes that certain types of man-made waters, known as highly-modified water bodies (canals, some reservoirs) cannot be expected to reach the same high environmental objectives as natural waters. Armenia's approach reflects the European approach in this and several other aspects. However, Armenia's Water Code also requires that water bodies be "classified" or described, according to a large set of criteria. This descriptive classification is complementary and parallel to the system described here.

GUIDELINE 2.1: DELINEATION OF SURFACE WATER RESOURCES INTO SEPARATE WATER BODIES

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to briefly present the method of delineation of surface water resources into discrete sections, as well as the role and importance of delineation in river basin planning. The guideline also presents the practical implementation of delineation together with example of application of the method.

1.2 Role of this Activity in River Basin Planning

Delineation of water resources into discrete sections ("water bodies") is one of the required steps in river basin planning. Delineation is the process of selecting the management units which the Armenian Water Resources Management Agency (WRMA) will focus on in its planning. Delineation allows the WRMA to promote and measure its progress in the protection and improvement of water resources quantity and quality through water use permits. Delineated sections are used as planning units and later on as management units, since each "water body" requires specific management objectives.

2. Technical Approach

2.1 Methodology: Approach and Justification

Water resources cannot have the same natural and anthropogenic conditions (thus the same quantity and quality indicators) throughout their entire length (rivers), volume (lakes) or area (groundwater). That is why the application of the same standards for planning and management on the entire water resources will not be efficient. It is necessary to delineate water resources into discrete sections, or "water bodies" so that each section, within its length, volume or area has similarnatural and anthropogenic conditions, and as a result can be represented by a single set of water quantity and quality indicators.

The first item in delineation of "water bodies" is selection of delineation criteria.

EU proposes the following groups of characterization indicators: physical and biological, socio-economic, actual water use in the basin, water balance, environmental factors affecting the water and water use patterns. Below the main factors are listed, the existence of which causes quantitative and qualitative changes in water resources. That is why they might serve as criteria for delineation.

1. Absolute altitude of the territory above the sea level, which defines changes in water ecology (warm and cold waters),
2. River basin relief (field, plain, mountainous, valley),
3. The main confluences (junctions) of rivers,
4. Large settlements, industrial enterprises, or intensive agricultural zones,
5. Hydromorphological criteria, which include the extent of modification of natural river bed or lake bed.

Thus, the above-mentioned list includes criteria, based on which water resources are delineated into separate water bodies, as autonomous objects for management planning.

2.2 Input Data Requirement

For delineation it is necessary to have a map of corresponding scale, if possible not less than the scale 1:200 000. The map should include the following information:

- Absolute altitude above the sea level,
- Relief types or spatial image of the relief,
- River network,
- Settlements,
- Large industrial enterprises and agricultural objects,
- Water systems, including reservoirs, canals, hydropower plants, other hydro-technical structures, which have impact on morphological properties of the water resources.

As additional data, it is desirable to use water use and land use data.

2.3 Where to Acquire Input Data

It is desirable to use the digital maps and databases of the Geographic Information System (GIS) of the State Water Cadastre.

2.4 Explanation of Analysis Procedures

Delineation is composed of the following sequential steps:

1. Obtain topographic maps (electronic format or hard copy), which will include the relief of the territory, rive network, settlements, major industrial and agricultural activities, water economic systems (hydromorphological factors).
2. Analysis of the relief, separating high mountainous, average hilly relief and valley relief. Afterwards, absolute altitude levels are studied and sections below 800 m and above 800 m are separated (according to EU criteria). Selected parts of the river basin are divided into separate sections. Delineated river sections are correspondingly marked on the map.
3. The structure of the river network is analyzed, including selection of the main river and its main tributaries, based on contributing area. Afterwards, the confluence points of tributaries are selected. The separate sections of river bounded by the selected points are marked appropriately.
4. The location of large urban areas and industries in the river basin is analyzed, including their assessment on the quantity and quality of water resources. If the impact of those areas is considered significant, then the water resources are delineated into separate sections above and below the points of impact.

5. Hydromorphological factors are analyzed, after which major river bed (channel) modifications are marked on the delineation map and their impact is correspondingly assessed. If the modification has significant impact, then it is necessary to delineate the water resource (river) into two different sections—the modified and unmodified channel.
6. Combination of delineated sections is in place as a result of the above mentioned steps. It is necessary to generalize the sections and describe final delineation into separate sections in a way that takes into consideration all the above-mentioned factors, and at the same time obtaining a minimum quantity of delineated sections.
7. Mark on the map the final delineations into different sections (water bodies) and number the sections starting from the upstream part of the river down to downstream part.

The criterion for success in delineation is that water resource is delineated into different sections within which the range of natural and anthropogenic factors are homogeneous and uniform, and thus each delineated section can serve as an optimal planning unit.

Although the criteria factors for delineation of water resources into different sections are clear, there is no single solution to the challenge of delineation of rivers or lakes. This process, based on the above-mentioned criteria and aimed at efficient management of water resources, can have several different, but satisfactory solutions. For each case it is necessary to observe and analyze different solutions, in order to select the most appropriate one from a management perspective.

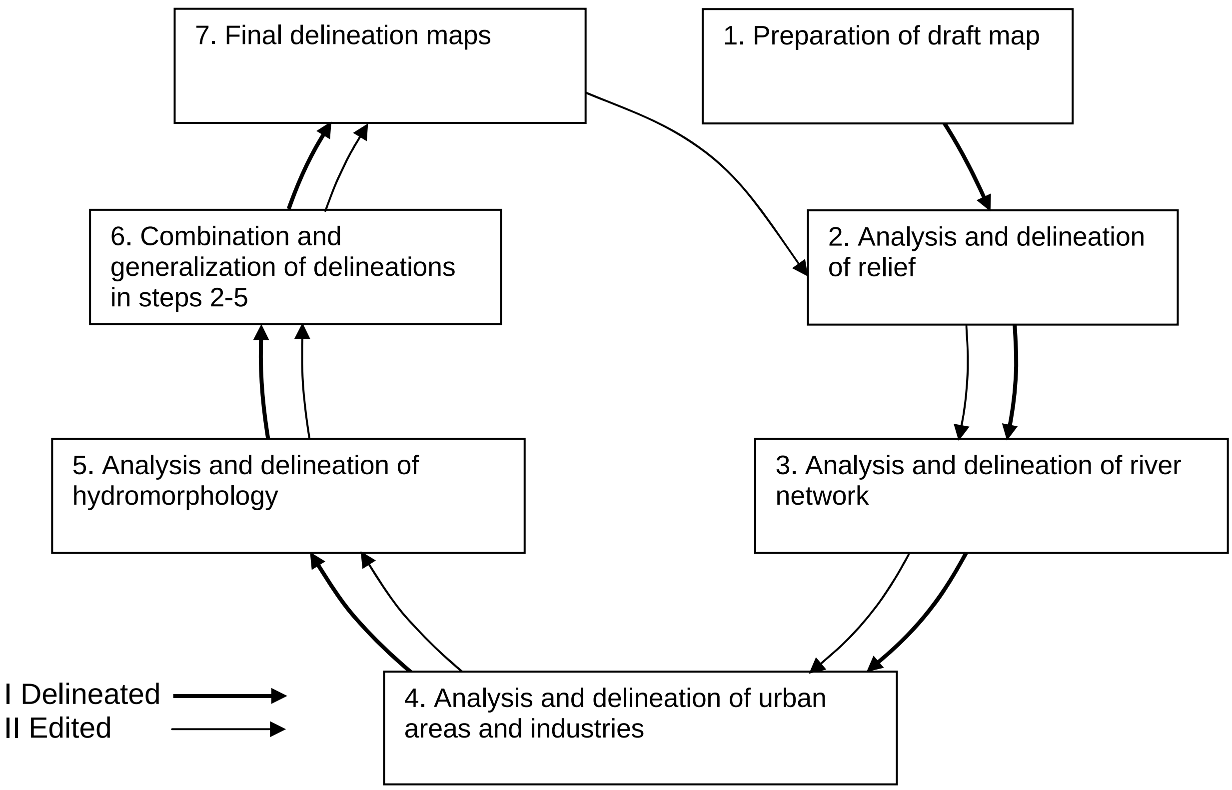
2.5 Type and Format of Output Data

The result of delineation is represented by map using any graphic format software.

2.6 Computer Progam or Other Analysis Aid for Delineation

There is no specialized computer program or other analysis aid for delineation. However, delineation can be done using the GIS interface of the State Water Cadastre, using its base maps, databases, as well as mapping and printing possibilities.

3. Diagram of Approach for Delineation



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

The physical-geographical characteristics for Meghriget, such as diversity of relief forms and existence of tributaries with significant flows, as well as impact of industries and Meghri city, provide the basis for delineating Meghriget into the following discrete sections:

Section 1 - Upper flow of Meghriget River through Tashtun tributary up to the confluence of tributaries Ayriget (Arevik) and Kaler with Meghriget River. This section of Meghriget River has highly incised topography, high peaks, deep canyons and forest-covered hills with steep slopes. The minimum absolute altitude of the delineated section is 1600 m. The territory is sparsely populated.

Section 2 - Tributary Kaler, which confluences with Meghriget at the absolute altitude of 1600 m. The topography of the tributary's basin is lower compared to the previous basin, and the topography is milder. The territory is sparsely populated.

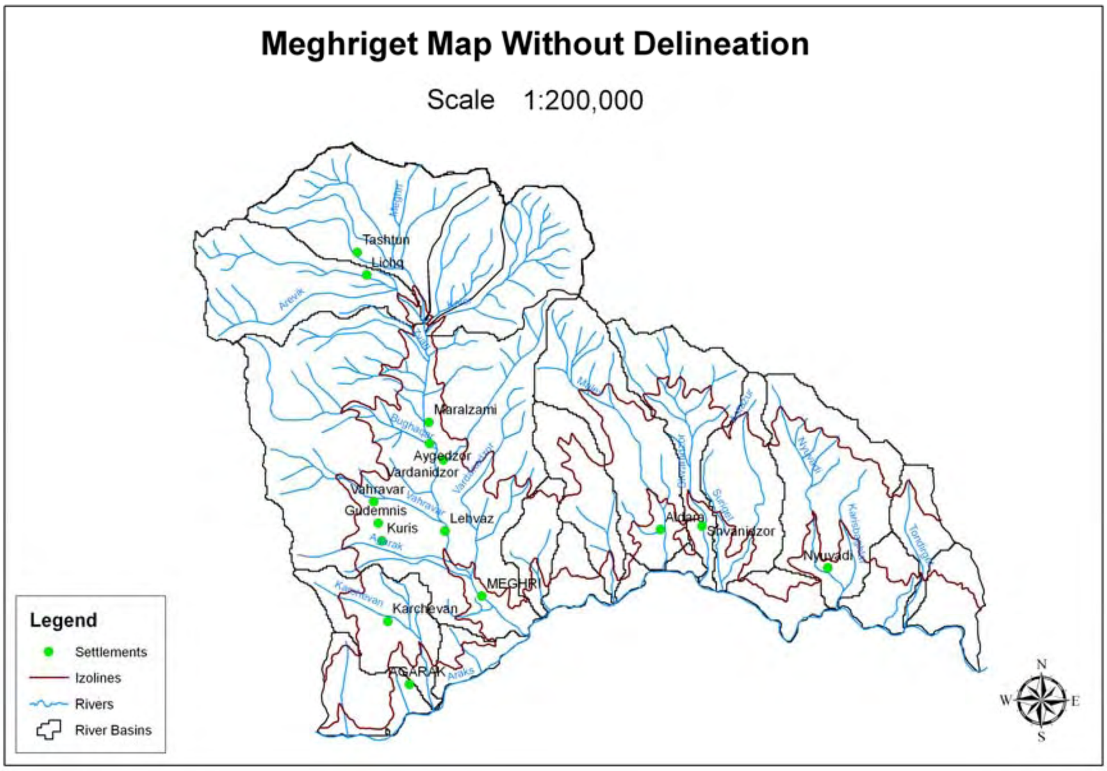
Section 3 - Tributary Arevik (Ayriget), which also forms a confluence with Meghriget near the mouth of river Kaler. The topography of tributary's basin is also lower compared to the previous one, and the types of topography are milder. The territory is sparsely populated.

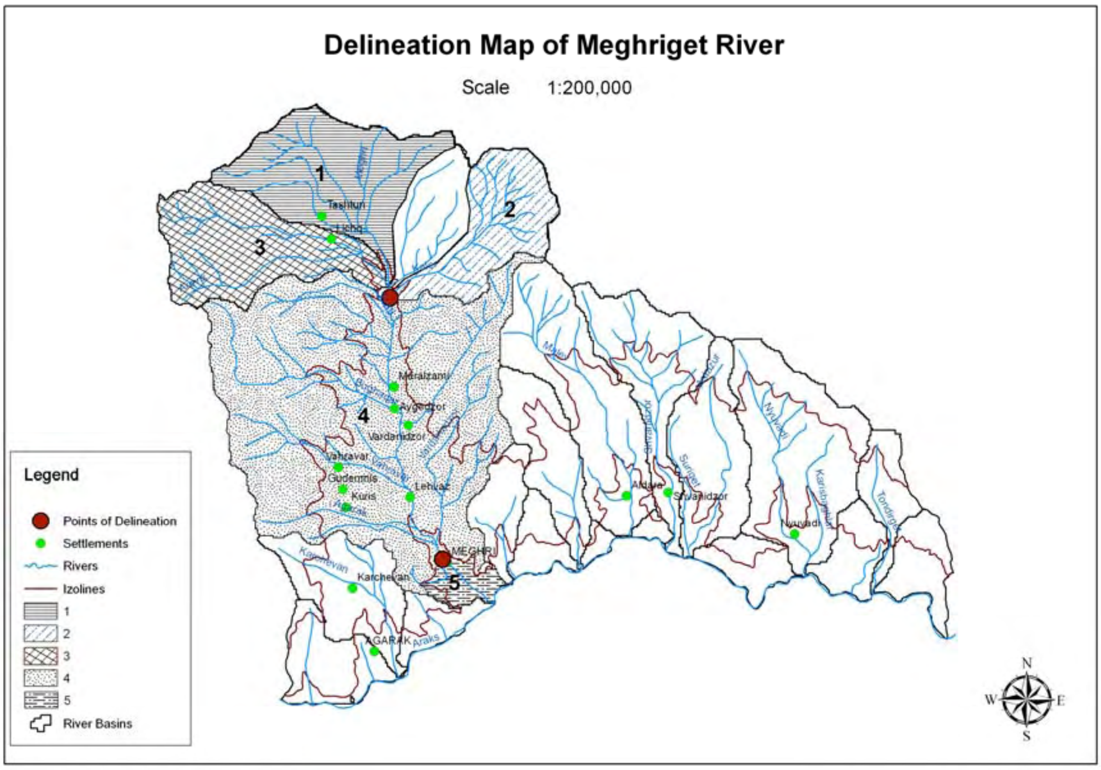
Section 4 - Middle section and part of the lower section of Meghriget River, up to Meghri city. This section is characterized by relatively low, less steep but still incised topography. The altitude boundaries of the section vary between 800-1600 m. The main criterion for delineation is Meghri city, the impact of which on water quality is defined by continuous monitoring.

Section 5 - The last section is the lower part of Meghriget River, from Meghri city up to the river mouth at Araks River. The altitude of the section does not exceed 800 m above the sea level. This delineated section has a valley topography.

The small tributaries of Araks River have altitudes mostly below 2000 m above the sea level. These tributaries are minor and water scarce. The basin includes mountains of average height, and types of topography are relatively mild. There are no major settlements or other pollution sources. Due to the stability of the mentioned characteristics there is no need to delineate the small tributaries of Araks into discrete sections and each of them can be observed as one section or water body.

4.2 Map of Application of the Method





5. Bibliography for Method

Water Resources Management Agency of the Ministry of Nature Protection of Armenia, “Supplement and Reconstruction of GIS Databases, Development of Database and Management Programs”, Yerevan, 2007.

Technical Report – Delineation into Discrete Sections and Classification of Water Resources, Yerevan, 2008.

EU 2000.Directive 2000/60/EC of the European Parliament and if the Council establishing a framework for the Community action in the field of water policy.

EU 2000. Guidance Document No.9 Implementing the Geographic Information System Elements of the Water Framework Directive.

GUIDELINE 2.2: SURFACE WATER RESOURCES CLASSIFICATION

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to present the classification approach for delineated water resources. The objective of classification is to group water resources, and particularly separate water bodies, according to ecological types which require different management approaches. Classification will help the decision makers to define the requirements and priorities, including environmental objectives, of water resources use and maintenance according to aquatic ecosystem characteristics.

1.2 Role of this Activity in River Basin Planning

Classification of delineated water resources is one of the important steps in river basin planning. Classification, together with other operations of river basin planning, comprises the following logical chain of activities:

- Delineation of water resources into separate sections,
- Classification of delineated sections,
- Definition of quality status for each delineated section,
- Definition of realistic environmental objectives for water quality protection and improvement in each delineated section,
- Development of measures for improvement, including such policy for provision of water use permits, that will promote implementation of tasks directed towards protection and improvement of water quality and quantity.

2. Technical Approach

2.1 Methodology: Approach and Justification

The European Union Water Framework Directive approaches for classification of delineated water sections are provided in Appendix 2 of the Directive. According to that Appendix, the criteria for classification are proposed, that generalize the characteristics into the following groups:

- Physical-geographical characteristics,
- Ecological types,
- Conditions characteristic to each type
    - o Hydro-morphological,
    - o Physical-chemical,
    - o Biological,
- Anthropogenic impact, which is a result of socio-economic conditions,
- Assessment of changes.

The classification is performed based on the characteristics, which are distinct for rivers, lakes and artificial reservoirs.

2.2 Input Data Requirement

For classification it is necessary to input several data on rivers and lakes. Particularly, one criterion for classification of rivers relates to the absolute altitude of the water resource location (this is related to water temperature). The following distinct groups are identified: high > 800m, average 200-800m, and low < 200m.

The next value, according to which rivers are classified, refers to the size of the river basin. According to the EUWF Directive, the river basins are divided into the following classes according to their scale: small 10-100 km^2, average 100-1000 km^2, large 1000-10000 km^2, very large 10.000 km^2 river basins.

A geology characteristic takes into consideration the type of rocks which make up the majority of the river basin. The characteristic is contingent upon the origin and composition of the rocks. The Directive proposes the following characteristics for geology: calcareous, siliceous and organic geology. This is because calcareous geology (karst) has peculiar physical characteristics, including high permeability, and chemical characteristics. Organic (humus or peat) geology also has particular physical and chemical characteristics which affect river and lake ecosystems.

Regarding lakes, their absolute altitudes are divided to the same intervals as for rivers, according to the Directive.

The average depth is one of the characteristics for sorting lake ecosystems. It is divided into the following intervals: up to 3m, 3-15m, >15m.

According to the Directive, characterization of lakes according to surface area is performed using the following intervals: 0.5-1km^2, 1-10km^2, 10-100km^2, 100km^2 and more.

The geological factor takes into consideration the origin of mountainous rocks of the watershed of lakes and explains their composition. As already mentioned, in case of the characterization of geological structure of the river basin the EU WFD proposes three geological characteristics, of which only calcareous and siliceous types of rocks are to be found in the territory of Armenia.

2.3 Where to Acquire Input Data

Hydrological data on rivers and lakes can be obtained from the following publication: “Chilingaryan L., Mnatzakanyan B., Aghababyan K., Toqmajyan G., Hydrology of Armenia’s Rivers and Lakes, 2002”, as well as from “ArmStateHydromet” SNCO of the Ministry of Emergency of the Republic of Armenia.

Geology data can be obtained from the Institute of Geology of the National Academy of Sciences of Armenia.

2.4 Explanation of Analysis Procedures

In the EU WFD, each category of water resources (river, lake and other) can be described using one of two systems – A + B need to be defined here. Being a method for characterization of basins and surface water resources, both systems allow delineation of water resources into discrete bodies based on the values of characteristics, as well as the following classification of water resources and their discrete bodies.

Rivers: River and lakes of Armenia are described in the system “A” of continental ecological regions. According to the system “A” it is suggested to apply the absolute altitude of rivers while characterizing as follows: high > 800m, average 200-800m, low < 200m.

In Armenia there are no rivers below 200 m. Thus according to the EU WED absolute altitude scale, the Armenian rivers will be characterized only as being average and high altitude.

The next value, according to which rivers are classified, refers to the size of the river basin. According to the Directive, the river basins are divided according to these classes: small 10-100 km^2, average 100-1000 km^2, large 1000-10000 km^2, very large 10.000 km^2 river basins. It is suggested that this characteristic of river basins can be used to distinguish Local, National and International rivers (per definitions of the National Water Program), such that rivers with basins of less than 100 km^2 are coded as “Local,” rivers of 100-1000 km^2 are coded as “National,” and rivers of greater than 1000 km^2 (or river which form international borders) are classified as “International.”

In this case the number of classes for the territory of Armenia is reduced, since there are no river basins with an area of more than 10000 km^2. Thus, in this case the rivers or their different sections are divided into three classes.

A geology characteristic takes into consideration the type of rocks which make up the majority of the river basin. The characteristic is contingent upon the origin and composition of the rocks. The EU WFD proposes the following characteristics for geology: calcareous, siliceous and organic geology.

The geology of the Republic of Armenia is represented only by two types of rocks: calcareous and siliceous. The geology factor explains several properties of the river basin. For example, siliceous rocks are weakly dissolvable, and except cracked rocks, they have low water-bearing properties, whereas calcareous rocks are usually porous and easily dissolvable.

Lakes: Regarging lakes, their absolute altitudes are divided to the same intervals as for rivers, according to the EU WFD.

Table 1 - Criteria for delineation and classification of lakes

Absolute Altitude	Lake Type According to Location
> 800 m	high
200 – 800 m	low
< 200 m	average

The 63 Armenian lakes and ponds, according to the absolute altitude of their location, are distributed in the following way:

Table 2 - Distribution of Armenian lakes according to absolute altitude

Absolute Altitude	Quantity
> 3000m	23
2000-3000m	21
1000-2000m	16
Up to 1000m	3

Thus, all the lakes in Armenia are classified as high according to EU WFD characterization.

The average depth is a characteristic for classifying lake ecosystems. It is divided into the following interval: up to 3m, 3-15m, >15m. It is obvious that these average depths will correspond to ecosystems with different property types. Moreover, various segments of the same water resource (lake) might have significantly different depths, based on which the separate segments of the lake will be delineated (for example large and small Sevan).

According to the Directive, characterization and delineation of lakes according to surface area is done using the following intervals: 0,5-1 km^2, 1-10 km^2, 10-100 km^2, 100 km^2 and more. According to that characteristic the number of Armenia's lakes is distributed in the following way:

Table 3 - Armenian lakes according to surface area

Interval	0,5 – 1km^2	1–10 km^2	10-100km^2	100km^2 and more	Total
Number of lakes	5	47	11	1	63

The geology characteristic takes into consideration the origin of mountainous rocks comprising the watershed of the lake, and correspondingly their composition, which is the same as for the rivers.

Heavily-modified and Artificial Water Bodies: A very important distinction in the EU Water Framework Directive is made between natural water bodies (lakes and rivers) and heavily-modified water bodies (reservoirs, canals, constructed channels). The key difference is that natural water bodies must meet a higher standard of ecological status than heavily-modified and artificial water bodies. This means that reservoirs and urbanized, channelized rivers are given a different consideration due to the difficulty of their meeting more stringent environmental objectives.

This option gives some leeway to governments struggling with the difficulties of promoting economic development options which may have negative effects on natural waters. Armenia must clearly define heavily-modified water bodies and assure that delineation efforts define these areas as distinct water bodies so that appropriate environmental management objectives can be defined there, in line with their real potential. Examples of heavily-modified and artificial water bodies include:

*reservoirs
*drainage canals and irrigation works
*straightened, channelized, and reinforced urban river channels
*artificial ponds constructed for agricultural or other economic purposes

Some characteristics which help distinguish heavily-modified water bodies from natural water bodies: they are physically altered in a major way, and they have suffered substantial and permanent changes to their form and function.

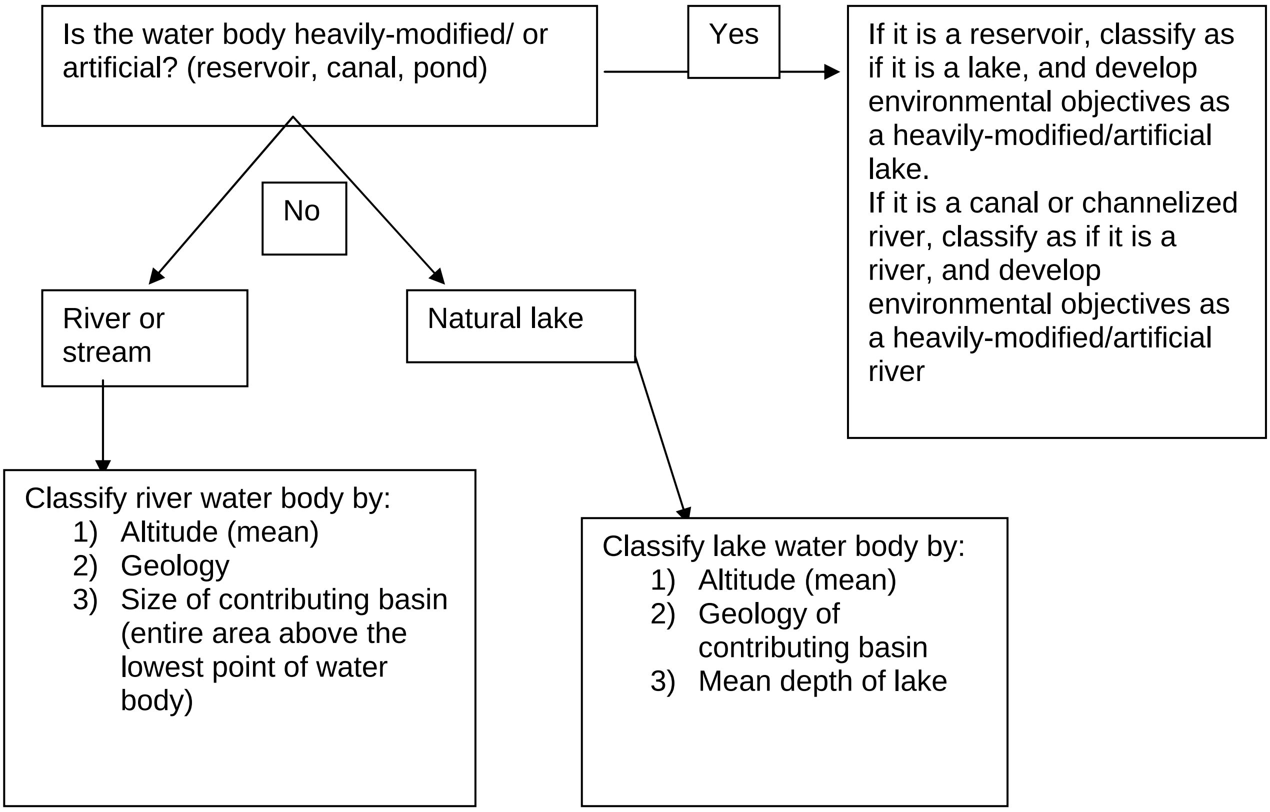
2.5 Type and Format of Output Data

As a result of classification the following output table is established for rivers:

Table 4 – Sample output table

	Varying size of river basin		
	Small River Basin	**Average River Basin**	**Large River Basin**
Varying geology, altitude<800m	10-100 km^2 Local importance Altitude< 800m Geology - siliceous	100 -1000km^2 National importance Altitude<800m Geology - siliceous	1000-10000km^2 International Importance Altitude<800m Geology - siliceous
	10-100km^2 Local importance Altitude<800մ Geology - calcareous	100 -1000km^2 National importance Altitude<800m Geology - calcareous	1000-10000km^2 International importance Altitude<800m Geology - calcareous
Varying geology, stable altitude>800m	10-100km^2 Local importance Altitude>800m Geology - siliceous	100 -1000km^2 National importance Altitude>800m Geology - siliceous	1000-10000km^2 International importance Altitude>800m Geology - siliceous
	10-100km^2 Local importance Altitude>800m Geology - calcareous	100 -1000km^2 National importance Altitude>800m Geology - calcareous	1000-10000km^2 International importance Altitude>800m Geology - calcareous

3. Diagram of Approach for Classification:



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

As a result of delineation of Meghriget River basin the following five sections are obtained:

1. *Meghriget 1* - Upper flow of Meghriget River through Tashtun tributary up to the confluence of tributaries Ayriget (Arevik) and Kaler with Meghriget River. This section of Meghriget River has highly incised topography, high peaks, deep canyons and forest-covered hills with great incline. The minimum absolute altitude of the delineated section is 1600 m. The territory is sparsely populated.
2. *Meghriget 2* - Tributary Kaler, which confluences with Meghriget at the absolute altitude of 1600 m. The topography of the tributary's basin is lower compared to the previous basin, and the topography is milder. The territory is sparsely populated.
3. *Meghriget 3* - Tributary Arevik (Ayriget), which also confluences with Meghriget near the river mouth of Kaler. The topography of the tributary's basin is also lower compared to the previous one, and the types of topography are milder. The territory is sparsely populated.
4. *Meghriget 4* - Middle section and part of the lower section of Meghriget River, up to Meghri city. This section is characterized by relatively low, not incised topography. The altitude boundaries of the section vary between 800-1600 m. The main criterion for delineation is Meghri city, the impact of which on water quality is defined by continuous monitoring.
5. *Meghriget 5* - The last section is the lower part of Meghriget River, from Meghri city up to the river mouth. The altitude of the section does not exceed 800 m above sea level. This delineated section has valley topography.

The delineated section of the lower part of Meghriget River (Meghriget 5) is classified in the group below 800 m of absolute altitude, and the remaining four sections (Meghriget 1, Meghriget 2, Meghriget 3, Meghriget 4) are classified in the group above 800 m altitude.

All the small tributaries to Araks are classified into one group, since they have not been delineated into discrete bodies. Such classification of tributaries results in certain inaccuracy due to the fact that the major part of the tributaries is located below 800 m. This inaccuracy, in our opinion, does not have practical importance, since the areas of the lower watersheds comprise only 10-15% of the entire area of the basin. In cases of practical importance to increase the accuracy of classification we can delineate the sections below and above 800 m beforehand, after which classification can be done.

4.2 Input Data Examples (Tables)

For input data it is necessary to provide the altitude of delineated section, the total are of the delineated sections' basins, as well as geology. The above-mentioned information is obtained through application of a GIS software package on digital map layers of Meghriget River basin. For the other territories of Armenia such maps are available with the State Water Cadastre Information System located in the Water Resources Management Agency of the Ministry of Nature Protection.

4.3 Output Data Examples (Tables)

As a result of classification of delineated sections of Meghriget and Araks tributaries the following table summarizes the information:

Table 5 – Classification of Meghriget River basin

Altitude, m	Geology	Basin Area		
		Up to 100 km^2 Local	100-1000 km^2, Republican	>1000 km^2, International
<800 m	Siliceous	Meghriget – 5 (Lower)		
	Calcareous			
>800 m	Siliceous	Meghriget – 1 (Tashtun) Meghriget - 2, (Kaler) Meghriget - 3, (Arevik) Meghriget - 4, (Middle) Nyuvadi Tondirget Suriget Astazurget Malev Karavget Karchevan		
	Calcareous	None		

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GUIDELINE 2.3: CLASSIFICATION OF GROUNDWATER RESOURSES

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to present methods for delineation and classification of underground water bodies. The proposed method is in line with the overall strategy of implementation of EU the Water Framework Directive and Armenia's water code.

1.2 Role of this Activity in River Basin Planning

Delineation and classification of water bodies is an intermediate step between characterization of waters, and evaluation of status. The proposed delineation and classification contributes to river basin planning through definition of the location, quality and quantity of underground water resources (aquifers) in each basin, monitoring and forecast of water supply and demand, as well as protection of water bodies from contamination and of managing their water use.

According to the above mentioned EU document "The groundwater body must be a coherent sub-unit of the river basin to which the environmental objectives apply. Hence the main objective of delineating these groundwater bodies is to allow their quantitative and chemical status to be evaluated, and compared to environmental objectives". The environmental objectives that will be developed (in a later guideline) are to prevent the pollution of ground water bodies and to maintain a balance between recharge and water abstraction (pumping).

2. Technical Approach

2.1 Methodology: Approach and Justification

Armenia's underground waters are delineated and mapped as 43 distinct, significant underground water bodies. They are located in different hydrogeological conditions, and thus vary from each other in numerous properties. Among these different properties are the economic importance of the ground water body, hydraulic regime of the aquifer, linkage to surface water resources, chemical composition of waters, and temperature. Many minor underground water bodies, not existing on the map, also exist in Armenia. These should be described and classified as well as possible, preferably with the help of a geologist familiar with local conditions.

Following the EU experience, hereby, it is suggested to classify the separate water bearing bodies, according to geologic and hydraulic features, and overall vulnerability to pollution.

As classification criteria, the main hydro-geological conditions are selected, that form the main properties of underground water bearing bodies: these are geological conditions, structure, lithological composition, location depth of water bodies, and the nature of pressure of water bodies, which play an important role in forming resources for underground waters. Based on the above-mentioned factors, the classification of underground waters in Armenia is presented below.

Table 1 –Classification of underground waters in Armenia

Geological conditions of rocks	Water bearing property of rocks	Location depth of water bodies from the Earth's surface, m	Nature of water pressure	Vunlerability of water bodies to pollution
Alluvial, colluvial, fluvial	Low water bearing	< 10	Non-pressure	Highly vulnerable
	Water bearing			
		10-100	Non-pressure Non-pressure	Slightly vulnerable
		>100	Pressure	Not vulnerable
Volcanic	Local water bearing	10-100	Non-pressure	Slightly vulnerable
	Local water bearing	>100	Pressure Non-pressure	Not vulnerable
Other rocks	Local water bearing Low water bearing	< 10	Non-pressure	Highly vulnerable
	Water bearing	10-100	Non-pressure	Slightly vulnerable

2.2 Input Data Requirement

The following information is required:

- Natural-climatic conditions and parameters, including precipitation quantity, evaporation, depth of snow cover and other,
- Geological and structural composition,
- Lithological composition of mountainous rocks,
- Hydro-geological conditions,
- Level of porosity and cracks,
- Location boundaries, depth and capacity of water bodies,
- Underground water sources, including natural springs, boreholes, qyahrizes[1], wells,
- Quantitative (pumping records) and water quality data for ground water.

From drawings, it is necessary to have the following:

- Large-scale geological and hydro-geological maps and cuts, including location of water bodies, if available,
- Special maps, including hydro-isolines, underground waters, water capture structures.

2.3 Where to Acquire Input Data

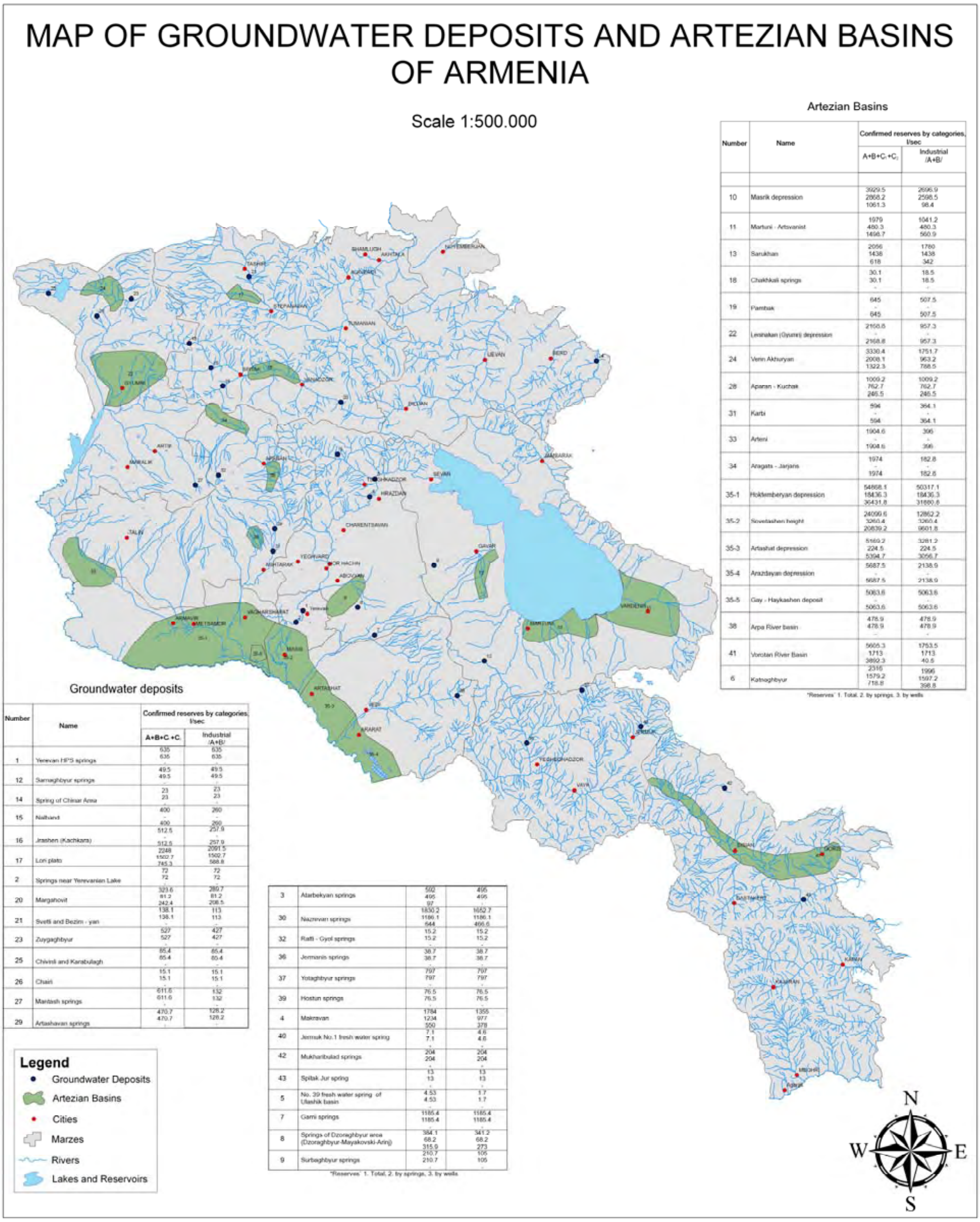
Delineation map of underground waters can be obtained from GIS system of the State Water Cadastre of the Republic of Armenia.

Data for classification of underground waters can be found in the Republican Geological Fund of Armenia. Some data (on chemical composition of waters) is available in the Institute of Geology of the National Academy of Sciences of Armenia, as well as in Republican and local branches of Sanitary and Anti-Epidemiological Inspectorates of the Ministry of Health. Some data characterizing quantitative and qualitative properties of underground waters can be found in “ArmWaterSupply” and “Yerevan Djur” Closed Joint Stock Companies (water suppliers).

[1] Kyahriz - horizontal irrigation tunnels linking underground wells. The wells collect and then transfer the underground water to the surface using gravity.

Since the 1990s, some data has been collected by limited liability companies, involved in water supply design works.

The guaranteed deposits of the main 34 underground water exploitation sites located in 12 underground and surface river basins comprise approximately 102.27 m^3/sec, which is being used for drinking, irrigation and other economic purposes. Information on the mentioned deposits is available from the report "UNDP/GEF "Main Deposits, Useful Storage and Current Conditions of Groundwater in the Republic of Armenia", "Reducing Transboundary Degradation in Kura-Aras River Basin" 2006".



Artezian Basins

Number	Name	Confirmed reserves by categories, l/sec	
		$A+B+C_1+C_2$	Industrial /A+B/
10	Masrik depression	3929.5 2868.2 1061.3	2696.9 2598.5 98.4
11	Martuni - Artsvanist	1979 480.3 1498.7	1041.2 480.3 560.9
13	Sarukhan	2056 1438 618	1780 1438 342
18	Chakhkali springs	30.1 30.1 -	18.5 18.5 -
19	Pambak	645 - 645	507.5 - 507.5
22	Leninakan (Gyumri) depression	2168.8 - 2168.8	957.3 - 957.3
24	Verin Akhuryan	3330.4 2008.1 1322.3	1751.7 963.2 788.5
28	Aparan - Kuchak	1009.2 762.7 246.5	1009.2 762.7 246.5
31	Karbi	594 - 594	364.1 - 364.1
33	Arteni	1904.6 - 1904.6	396 - 396
34	Aragats - Jarjaris	1974 - 1974	182.8 - 182.8
35-1	Hoktemberyan depression	54868.1 18436.3 36431.8	50317.1 18436.3 31880.8
35-2	Sovetashen height	24099.6 3260.4 20839.2	12862.2 3260.4 9601.8
35-3	Artashat depression	5169.2 224.5 5394.7	3281.2 224.5 3056.7
35-4	Arazdayan depression	5687.5 - 5687.5	2138.9 - 2138.9
35-5	Gay - Haykashen deposit	5063.6 - 5063.6	5063.6 - 5063.6
38	Arpa River basin	478.9 478.9 -	478.9 478.9 -
41	Vorotan River Basin	5605.3 1713 3892.3	1753.5 1713 40.5
6	Katnaghbyur	2316 1579.2 718.8	1996 1597.2 398.8

"Reserves" 1. Total, 2. by springs, 3. by wells

Groundwater deposits

Number	Name	Confirmed reserves by categories, l/sec	
		$A+B+C_1+C_2$	Industrial /A+B/
1	Yerevan HPS springs	635 635 -	635 635 -
12	Sarnaghbyur springs	49.5 49.5 -	49.5 49.5 -
14	Spring of Chinar Area	23 23 -	23 23 -
15	Nalband	400 - 400	260 - 260
16	Jrashen (Kachkara)	512.5 - 512.5	257.9 - 257.9
17	Lori plato	2248 1502.7 745.3	2091.5 1502.7 588.8
2	Springs near Yerevanian Lake	72 72 -	72 72 -
20	Margahovit	323.6 81.2 242.4	289.7 81.2 208.5
21	Svetli and Bezim - yan	138.1 138.1 -	113 113 -
23	Zuygaghbyur	527 527 -	427 427 -
25	Chivinli and Karabulagh	85.4 85.4 -	85.4 85.4 -
26	Chairi	15.1 15.1 -	15.1 15.1 -
27	Mantash springs	611.6 611.6 -	132 132 -
29	Artashavan springs	470.7 470.7 -	128.2 128.2 -
3	Atarbekyan springs	592 495 97	495 495 -
30	Naznivan springs	1830.2 1186.1 644	1652.7 1186.1 466.6
32	Rafli - Gyol springs	15.2 15.2 -	15.2 15.2 -
36	Jermanis springs	38.7 38.7 -	38.7 38.7 -
37	Yotaghbyur springs	797 797 -	797 797 -
39	Hostun springs	76.5 76.5 -	76.5 76.5 -
4	Makravan	1784 1234 550	1355 977 378
40	Jermuk No.1 fresh water spring	7.1 7.1 -	4.6 4.6 -
42	Mukharibulad springs	204 204 -	204 204 -
43	Spitak Jur spring	13 13 -	13 13 -
5	No. 39 fresh water spring of Ulashik basin	4.53 4.53 -	1.7 1.7 -
7	Garni springs	1185.4 1185.4 -	1185.4 1185.4 -
8	Springs of Dzoraghbyur area (Dzoraghbyur-Mayakovski-Arinj)	384.1 68.2 315.9	341.2 68.2 273
9	Surbaghbyur springs	210.7 210.7 -	105 105 -

"Reserves" 1. Total, 2. by springs, 3. by wells

If the above-mentioned materials are not available, then the result of classification will be limited.

2.4 Explanation of Analysis Procedures in Classification of Groundwater Resources

Based on collected information, the classification of underground waters is done in the following sequence:

- Water bodies are grouped according to the origin of rocks distributed in the vicinity: a) alluvial, colluvial, fluvial; b) volcanic; c) other including intrusive, metamorphic, and sedimentary.
- Water bodies are grouped according to lithological composition of the level of water bearing
- Water bodies are grouped according to depth to underground water from the earth's surface: a) up to 10 m, b) 10-100 m, c) more than 100 m.
- Based on hydrogeological structures the hydraulic status of groundwater is determined – pressure or non-pressure groundwater,
- Based on the map of hydro-isolines the linkage of groundwater with surface water is assessed,
- According to depth location of groundwater and lithological composition of water bodies the level of vulnerability of water bodies is assessed: a) highly vulnerable – porous lithology with depth to water less than 10 m, b) slightly vulnerable – lithology of moderate porosity and depth to water 10-100 m, c) not vulnerable – lithology of low porosity, or pressure water protected by low porosity overlying layer, and more than 100 m. depth to water

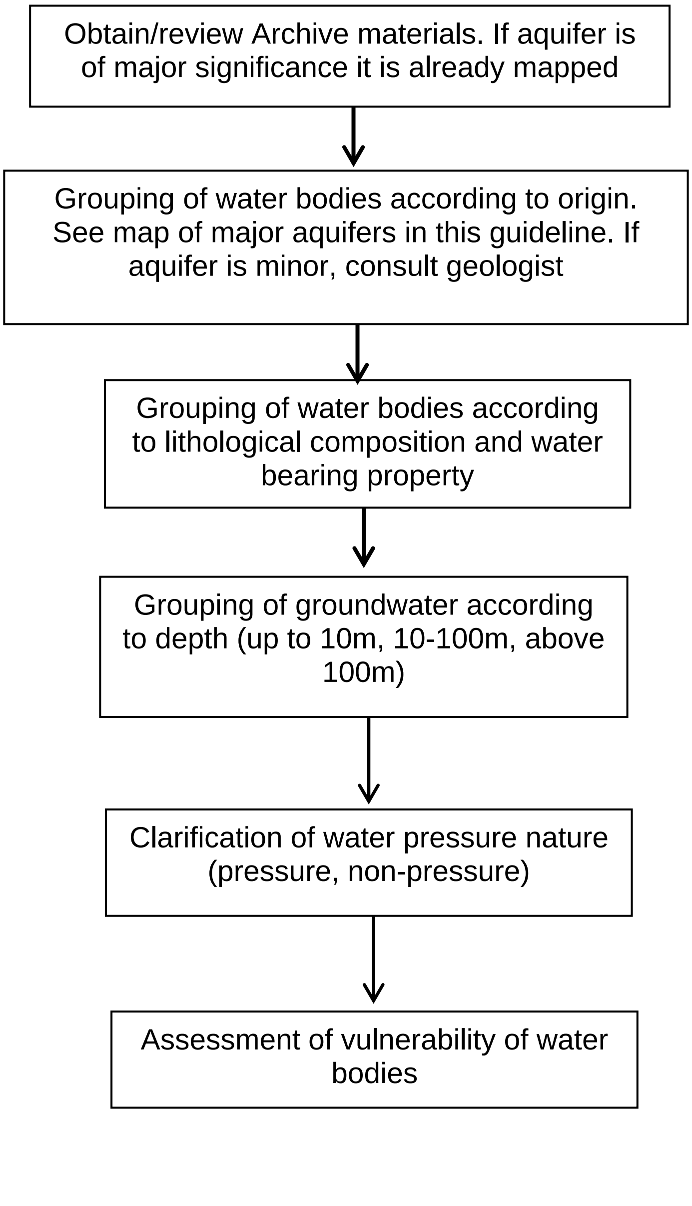
As a result of implementation of the above-mentioned sequential steps the classification of groundwater will be obtained.

2.5 Type and Format of Output Data

Output data is represented in the form of specialized text, text appendix, maps and other graphic annexes. The classification properties of water bearing bodies and qualitative and quantitative indicators (hydrodynamic parameters, chemical composition, and description of water sources) of groundwater will be represented in the specialized text. The indicators will be presented in the form of a table. Upon availability the results of routine observations of groundwater, as well as geological maps, location of water bodies and special maps (hydroisolines and others, if available) will be presented.

3. Diagram of Approach

The sequential steps for application of the proposed classification approach are presented in the flowchart below. The flow chart represents the process of works and summarizes its contents. Collection of archive materials and their processing includes drawings, which summarize the distribution of aquifers, their type, spatial and boundary conditions, as well as qualitative and quantitative properties of its water. The text part summarizes the geological structure and hydrogeological conditions, as well as the type, classification and other properties of groundwater. The text materials should be located and compared with drawing materials. In case of a discrepancy there would be need for additional field work, whereas in the event of data agreement the work can be considered as completed.



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

In the geological structures of Meghriget and adjacent sections the following rocks are part of geological structures: Paleozoic metamorphic rocks, mezzo kayos intrusive rocks, volcanic rocks, as well as upper layer alluvial-prolluvial origins of the above-mentioned fundamental rocks (Fig. 1).

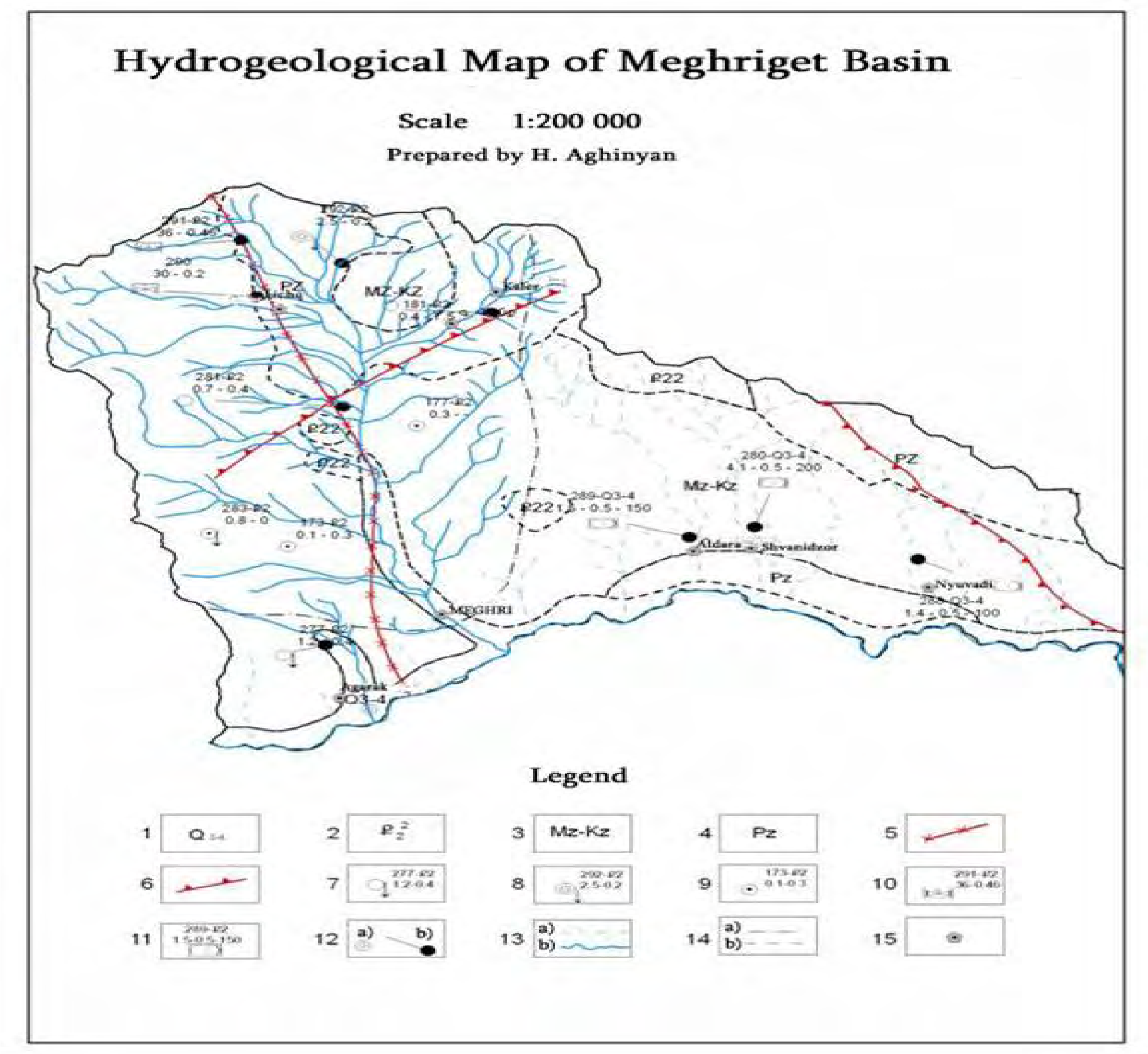


Fig. 1

Legend used in figure 1:

1. Aquifer of upper layer alluvial-colluvial origins: river-stone, pebble, sand, clay-sand, 2. Complex of local low water-bearing-water resistant volcanic-sediment rocks of eocene period, 3. Complex of local low water-bearing-water resistant intrusive rocks of age of reptiles-mammals, 4. Complex of water-resistant palaeozoic-metamorphic rocks, 5. Watered fault zones, 6. Fault zones in the form of groundwater outflows, 7. Down-flowing springs: from above - the number of spring and water-bearing structure index, from left – discharge (l/sec.), from right – mineralization (g/l), 8. Group of springs: from above – the number of index of water bearing structure, from left – discharge (l/sec.), from right – mineralization (g/l), 9. Borehole: from above – the number of index of water bearing structure, from left – discharge (l/sec.), from right – restored level (m), 10. Captured springs: from above - the number of spring and water-bearing structure index, from left – discharge (l/sec.), from right – mineralization (g/l), 11. Qyuhrizes: from above – the number and index of water bearing structure, from below – discharge (l/sec.) and length (m), 12. a) vertical capture structures, b) location of springs, 13. Rivers: a) temporary flows, b) main flows, 14. a) boundary of lower section of Meghriget River basin, b) boundary of hydro-geological structure, 15. Settlements.

The above-mentioned geological types together with natural-climatic conditions form the below mentioned water bodies, which are not hydraulically connected (fig. 2).

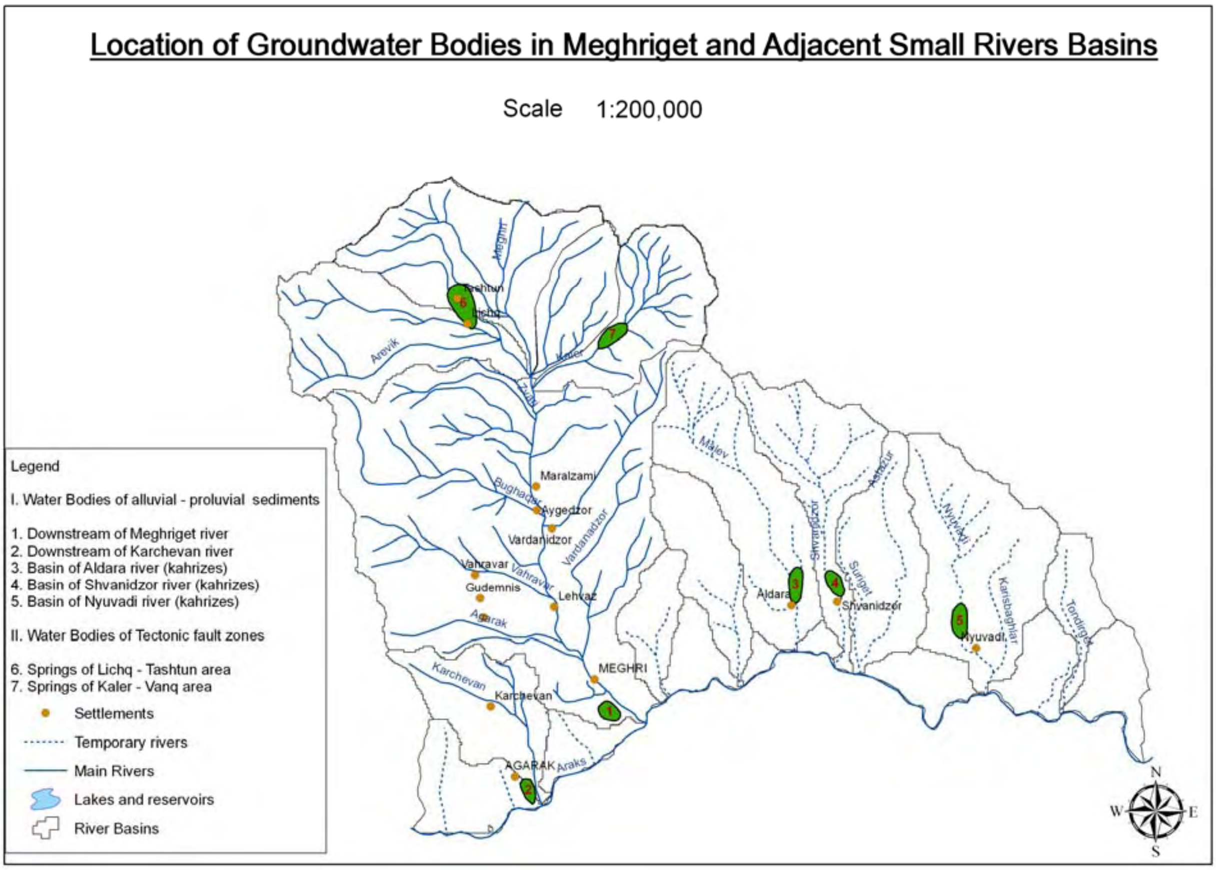


Fig. 2

The following water bodies are related to alluvial-colluvial origins: lower section of Meghriget River (№1), lower section of Karchevan River (№2), Alvanq (Aldara) (№3), Shvanidzor (№4) and Nrnadzor (Nyuvadi) (№5).

The following water bodies are related to fault zones: Tashtun-Lichq (№6) and Kaler-Vanq (№7). Waters collected in those bodies (№6,7) are discharged into the surface in the form of springs. Springs of the section Tashtun-Lichq are entirely used. In the section Kaler-Vanq there are unused springs with 1 l/sec and higher discharge.

4.2 Examples of Input Data (Tables)

Tabel 2 – Water body of lower section of Meghriget River (fig. 2, water body №1)

Descriptions	Results
1. Natural-climatic conditions	Contingent upon hypsometric altitude the quantity of annual precipitation varies in the range of 250-700 mm, and evaporation 300-450 mm. It is characterized by highly cut relief, and an average annual air temperature above 10° C
2. Geological and structural composition	Of practical importance to upper layer alluvial-colluvial sediments and watered tectonic fault zones
3. Lithological composition, pores and cracks of mountainous rocks	River-stone, pebble, clay-sand, for which the active porosity varies between 10-20%
4. Hydrogeological conditions	The main source of feeding of groundwater is the river flow. The water body is formed due to infiltration of river's waters
5. Location boundaries, depth and capacity of water bodies	Actual data is absent. It is assumed that the water body is located within the depth of 8-29 m, and the capacity is approximately 21 m
6. Groundwater sources	Underground water abstractions (deep wells, qyuhrizes) and springs are rare only a few wells exist in Agarak, and qyuhrizes in Aldara, Shavanidzor, Nyuvadi
7. Quantitative and qualitative indicators of waters	Are absent - no data

4.3 Examples of Output Data (Tables)

Table 3 – Output data table on the example of Meghriget River basin

Rock types	Water bearing property	Location depth of water bodies from the earth's surface, m	Water pressure type	Vunlerability of water bodies	Water bodies of Meghriget River basin (according to fig. 2)
Alluvial, prolluvial, fluvial	Low water bearing	<10	Non-pressure	Highly vulnerable	№1, 2, 3, 4, 5
	water bearing	10-100	Non-pressure	Slightly vulnerable	Absent
			Pressure	Not vulnerable	Absent
		>100	Pressure	Not vulnerable	Absent
Volcanic	Local water bearing	10-100	Non-pressure	Slightly vunlerable	Absent
		>100	Pressure, Non-pressure	Not vulnerable	Absent
Other rocks	Local low water - bearing	10-100	Non-pressure Low pressure	Slightly vulnerable	Absent
	Water-bearing (fault zones)	10-100	Non-pressure	Slightly vulnerable	№6, 7

Table 4 – Hydrogeological conditions of water resources, and qualitative and quantitative properties of underground waters

Spring number according to report / Hypsometric altitude, m	Location	Hydrogeological Conditions	Discharge, l/sec.	Water temp. ^0C / pH	Quality Properties: Cl, mg/l	SO$_4$, mg/l	Total mineralization, g/l	Total hardness / of which carbonated mg equiv/l
1 840	1.95 km north-west of Meghri city	Related to monzonite cracks (tectonic fault zone)	1.6	13 5.5	17.5	64	0.4	13.8 10.6
22 1100	4.85 km south-west of Alvanq village	Related to gabbro-diorites	0.06	12 6.8	24.8	37	0.6	14.9 14.9
37 885	1.75 km north-west of Alvanq village	Related to nepheline syenites, discharge is observed from rock debris	0.1	15 6.7	14.6	41.5	0.4	12.2 11.7
50 650	Qyuhriz in the southern part of Shvanidzor village	Related to alluvial-colluvial origins	2.0	14 6.4	21.9	90	0.5	15.4 14.5
53 850	1.9 km north-west of Shvanidzor village	Related to degraded syenites, discharge is observed from rock debris	0.1	14 7.3	21.9	11.6	0.5	13.05 12.32
102 450	Qyuhriz 2.1 km south-east of Nrnadzor village	Related to debris rocks, alluvial-colluvial rocks	5.0	13 7.2	18.4	25	0.4	14.17 13.49
124-130 2330-2660	Group of springs 3.2-4.0 km west of Lichq village	Related to granitoid cracks (tectonic fault zones)	40.0	5 6.4	6.39	6	0.1-0.2	1.29 1.29
240 2700	2.8 km north of Kaler village	Related to granitoid cracks (tectonic fault zones)	6.0	9.5 7.2	7.0	4.0	0.10	3.08 3.08

Table 5 – Output data table using the example of Meghriget

Name of groundwater basins	Perspective sections of water supply	Aquifers	Name of springs and their current condition	Necessary output materials
First order basin of groundwater in Meghriget	Springs adjacent to Lichq-Tashtun settlements	Watered fault zones	Springs that are currently captures and used	Large-scale (preferable 1:25000) hydrogeological map of location of springs, inventory of springs, research of intakes, current condition of with supply in settlements and future perspectives. Monitoring data (discharge, temperature and chemical composition) of springs' waters.
	Springs adjacent to Vanq-Kaler settlements	Watered fault zones	Springs, that are not used to some extent	Inventory of springs, descriptions, possibilities of use, large-scale hydrogeological map of location, monitoring data of springs' waters.
	Section of watersheds in Agarak	Alluvial-colluvial sediments	Deep wells, which are exploited	Quantity of used deep wells, their technical condition, overall discharge, technical sections of hydrogeological wells, location map, qualitative properties of river waters and groundwater and their connection.
	Basin of Meghriget lower flows	Alluvial-colluvial sediments	Deep wells are absent	It is necessary to have at least 3 deep wells.

5. Bibliography for the Method

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STEP 3. SETTING ENVIRONMENTAL OBJECTIVES AND REVIEWING WATER STATUS

Introduction to Step 3: Setting Environmental Objectives

Setting environmental objectives is the third step in the river basin planning process. Environmental objectives are the desired future conditions of water quality and water quantity expected for each distinct water body. These objectives (also called "targets") are set in order to measure the progress of improvement in water resources during a river basin planning period, usually a number of years. Environmental objectives are quantitative and can be measured by monitoring. They often reflect water quality "standards" but are more specific than standards, and can vary from one class, or category, of water to another.

Modern river basin plans, such as those required by the European Union Water Framework Directive, require water bodies to meet biological, chemical/physical and hydrologic objectives, which in combination, reflect a desired "good water status." In this document the focus is primarily on chemical/physical and hydrologic objectives, because Armenia has limited data available on biological conditions. In the future, with more research on Armenia's aquatic biology, biological objectives can and should be incorporated into this system.

GUIDELINE 3.1: EVALUATION OF STATUS OF SURFACE WATER RESOURCES ACCORDING TO QUALITY

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to describe in detail the application of the method for evaluation of surface water resources of Armenia according to physical-chemical quality. The proposed method provides an opportunity to present large-volume measurements of various water quality indicators by index values. These index values mathematically combine all the water quality measurements and provide for a simple description of water quality.

Taking into consideration the analysis of various methods for classification of surface water resources, including their advantages and disadvantages, as well as existing monitoring information in Armenia, it is suggested to use the Water Quality Canadian Index for classification of surface water quality in Armenia. This will provide for obtaining description of water status (excellent, good, moderate, poor, very poor):

1.2 Role of this Activity in River Basin Planning

Evaluation of the status of water resources requires a three-part approach. Physical-chemical water quality, flows, and biological status all play a part in determining water quality status. In Armenia physical-chemical quality evaluation is important because that is the type of data that is most widely available. Calculation and evaluation of minimum ecological flows is discussed in Guideline 3.2. Evaluation of biological status is important, but a standard method, based on sufficient field data, has not yet been developed for Armenia. Therefore, this guideline will focus on physical-chemical water quality parameters.

Description of a status of surface quality of delineated section has significant importance in river basin planning and is considered as one of the most important steps in river basin planning. In particular, classification of water according to quality enables the decision-making authority in charge of river basin management to define qualitative objectives for classified water resources, to determine the maximum allowable level of wastewater discharge, and to develop measures toward improvement of polluted water quality and/or towards maintenance of high quality of water.

2. Technical Approach

2.1 Methodology: Description and Justification

Water Quality Canadian Index (WQCI) makes it possible to present the water quality indicators of large-scale measurements through the index value. This mathematically combines all the measurements of water quality and provides for a clear and understandable description of water quality for water users.

The index is based on combination of 3 main components:

$$F_1 = \left(\frac{\text{number of indicators no satisfying MAC}}{\text{total number of indicators}} \right) x\,100$$

where F_1 is the percentage of exceeding water quality criteria.

$$F_2 = \left(\frac{\text{number of analysis not satisfying MAC}}{\text{Total number of samples}} \right) x\,100$$

F_2 is the percentage of results, in which one or more criteria exceed the corresponding Maximum Allowable Concentrations (MAC).

F_3 is the overall normed value of all indicators not satisfying the MAC. It is defined through the following formula:

$$F_3 = \frac{\sum_{i=1}^{n} \left(\frac{C_i}{\text{MAC}_i} - 1 \right) / N}{0.01 \left[\sum_{i=1}^{n} \left(\frac{C_i}{\text{MAC}_i} - 1 \right) / N \right] + 0.01}$$

where N is the total number of analysis, C_i is the value of i-th concentration not satisfying to MAC.

The Water Quality Canadian Index is determined through the following formula:

$$\text{WQCI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

The values of the index lie within the range of 1-100, and the water quality is divided into five categories. The values of index and water quality classification according to WQCI are presented in the table below.

Table 1 - Classification of Water Quality According to WQCI values

Class	Quality	Color Class	WQCI value	Description of water condition
I	Excellent		95-100	Water quality is well protected, there is no danger of water quality deterioration, overall condition is close to original condition
II	Good		80-94	Water quality is well maintained, there is only minor deterioration, the overall condition slightly differs from the original condition
III	Satisfactory		65-79	Water quality is mainly protected, but sometimes there are dangers to water quality, overall condition sometimes differs from the desired condition
IV	Poor		45-64	Water quality is often deteriorated conditions differ from the original condition from time to time
V	Very poor		0-44	Water quality is almost always in danger, conditions are usually significantly different from the natural condition

2.2 Input Data Requirement

As input data it is necessary to take a list of monitoring indicators (for example, a selection made from the entire list of monitoring indicators), as well as the values of their respective MACs.

The values of MACs are presented in the table below.

Table 2 – Water quality indicators and corresponding MACs for Armenia according to water use purpose

Pollution Indicator	MAC, fisheries	MAC, household-communal	MAC, drinking, WHO
Dissolved oxygen, mg/dm^3	>6	>4	-
BOD_5, mg/dm^3	3	6	-
NO_2^-, mg/dm^3	0.024	0.024	0.91
NO_3^{--}, mgN/dm^3	9	9	11.3
NH_4^{+-}, mgN/dm^3	0.39	2.6	1.5
SO_4^{2-}, mg/dm^3	100	500	250
Cl^-, mg/dm^3	300	350	250
Na, mg/dm^3	120	-	200
Mg, mg/dm^3	40	-	-
Al, mg/dm^3	0.04	0.5	0.2
Fe, mg/dm^3	0.5	0.5	0.3
Cu, mg/dm^3	0.001	0.01	1
Zn, mg/dm^3	0.01	1	3
Ni, mg/dm^3	0.01	0.1	0.02
Mn, mg/dm^3	0.01	-	0.1
V, mg/dm^3	0.001	-	-

Pollution Indicator	MAC, fisheries	MAC, household-communal	MAC, drinking, WHO
Cr, mg/dm^3	0.001	0.5	0.05
Pb, mg/dm^3	0.01	0.03	0.01
K, mg/dm^3	50	-	-
Ca, mg/dm^3	180	-	-
Co, mg/dm^3	0.01	1	-
As, mg/dm^3	0.05	0.05	0.01
Suspended particles, mg/dm^3	30	-	-
Se, mg/dm^3	0.001	-	0.01
Hydrogen index	6.5-8.5	6.5-8.5	6.5-8.5
Mineralization, mg/dm^3	1000	1000	-
Cd, mg/dm^3	0.005	0.01	0.003
P, mg/dm^3	0.6*	-	-
Si, mg/dm^3	10	-	-
Mo, mg/dm^3	0.5	0.5	0.07
B, mg/dm^3	0.018	0.5	0.3

While selecting the list of monitoring indicators it is necessary to take into account the existence of data for each indicator. Parallel to existence of data, norms for the given parameters should also be present. For each indicator the results of at least 4 analysis are required, although 12 analyses are preferable.

2.3 Where to Acquire Input Data

After selecting the studie's water resource (for example delineated section of the river) and assessment period, it is necessary to take monitoring data on the selected section from the "Environmental Impact Monitoring Center" SNCO of the Ministry of Nature Protection.

2.4 Explanation of Analysis Procedure

The sequence of steps for calculation of WQCI is presented below:

a) Studied water resource is selected, for example a river or its delineated section.

b) The observation point or points and assessed time-period are selected.

c) A list of indicators for calculation of WQCI is compiled (for example, from the complete list of monitoring indicators a selection is made). For example, 5, 8, 12, 202 or any other number of indicators can be selected. The existence of data for each indicator should be assessed. During selection of the list one should also take into account the existence of data and existence of norms for the given parameter. For each indicator the results of at least 4 analyses are necessary.

d) The corresponding data are obtained from the Environmental Impact Monitoring Center.

e) For all the indicators on the assessment list we will take corresponding values of the MACs according to water use type, for example, drinking or fisheries. For the parameters for which drinking and household-communal norms are absent, the fisheries norms will be applied.

f) A comparison of the quantitative characteristics of the selected indicators and MACs is completed.

g) Next, the formulas for calculating F_1, F_2, F_3 and WQCI are applied (the explanation is provided below or obtained from the Canadian website: http://www.ccme.ca/ourwork/water.html?category_id=102http://www.ccme.ca/ourwork/water.html?category_id=102) and corresponding calculations are made.

2.5 Type and Format of Output Data

After obtaining input data and applying on data the above-mentioned method for calculation of WQCI it is necessary to obtain the corresponding values of calculation parameters as output data.

Table 3 – Format of output data

Calculation Parameters	**Value**
Total number of indicators	
Number of indicators not satisfying MACs	
Total number of analysis	
Number of analysis not satisfying MACs	
Total number of analysis	
F_1	
F_2	
F_3	
Value of Water Quality Canadian Index	

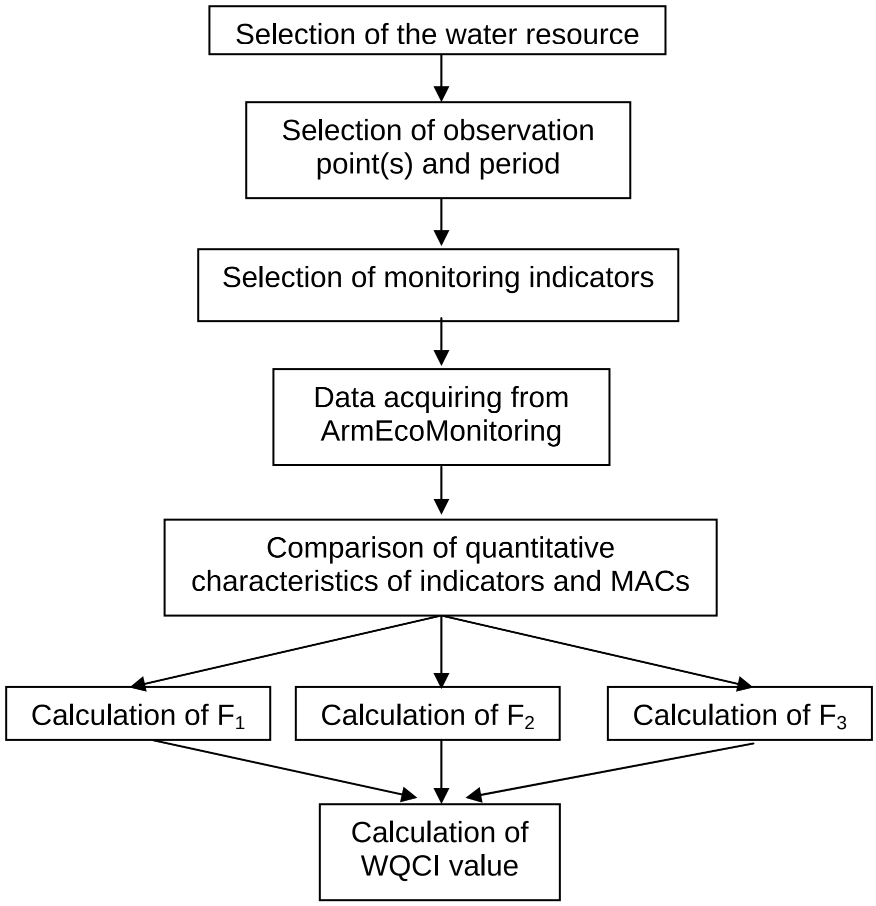
Having the corresponding value of Water Quality Canadian Index we will classify according to classes of WQCI (see table 4 below). Afterwards, the decision-making authority in the water sector can correspondingly define water quality management objectives with short-, medium- or long-term perspectives.

Table 4 – Water quality classification according to WQCI

Class	Quality	Color Class	WQCI value
I	Excellent		95-100
II	Good		80-94
III	Moderate		65-79
IV	Poor		45-64
V	Very poor		0-44

3. Diagram of Approach

Schematically, the sequence of steps for calculating WQCI is presented below:



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

In applying the formulas for F_1, F_2, F_3 and WQCI and making corresponding calculations, as for example for water quality sampling data from observation point #89 in Meghriget River against MACs for fisheries (see table 5), the following steps are taken:

Calculation of F_1: Assuming the assessment is done for 31 indicators (see table 5), the value of each of the 31 selected indicators is compared with the corresponding values of MAC (see table 2). If the value of any indicator at least once exceeds the value of MAC, then it is calculated as 1 point (even if the indicator of any concentration exceeds the value of MAC more than once, in that case it is also calculated as only 1 point). Afterwards, the calculated points for all indicators are summed up. Specifically for observation point #89 in Meghriget the number of indicators not satisfying the MAC is 6 (they are included in table 6). Next, the obtained result is divided by the total number of indicators (in case of Meghriget it is 31). Thus, the resulting value equals to 6/31 or 0.19355. Finally, in order to obtain F_1 we multiply the obtained value with 100 and arrive at 19.355.

Calculation of F_2: Date from all 31 indicators of all samples are compared with the values of corresponding MACs. The result of each analysis, which exceeded the value of MAC, is calculated as 1 point. The sum of the calculated points shows the number of analysis not satisfying the MAC, which in our case is 22. Then, the number of analysis not satisfying the standard is divided by the total number of analysis, which in this case is 211. The result is 22/211 or 0.10427. In order to get F_2 multiply the obtained value with 100 and arrive at 10.427.

Calculation of F_3: The value of each of the selected 31 indicators is compared with the corresponding value of the maximum allowable concentration. If the value of the indicator exceeds the value of the MAC, then the value of concentration of the given parameter is divided by the value of the corresponding MAC. The obtained values from each parameter then are summed up and in the case of Meghriget is 64.63. From those results subtract the total number of analyses not satisfying the values of MACs, in this case 22, and then divide by the total number of analyses. This result is an intermediate parameter of 0.202. Then that intermediate parameter (denote as “nse”) is divided by (0.01*nse+0.01). The obtained result represents the value of F_3, or 16.806 in this case.

The resulted values of parameters F_1, F_2, F_3 are plugged in the formula for calculating the Water Quality Canadian Index.

In a similar way this Program calculated the values of Water Quality Canadian Index for the period of 2005, 2006 and 2007 in three observation points in Meghriget: above the mixture point with Gotzgotz River (No. 89-0), above the city Meghri (No. 89) and at the Meghri river mouth (No. 90).

For calculating the index 31 indicators of monitoring, were used as well as their corresponding MACs for fisheries, communal-household and drinking water (World Health Organization), which are currently effective in Armenia (see table 2). In total, data from analysis of 48 samples taken from the river during the period 2005-2007 have been used.

4.2 Examples of Input Data (Tables)

As input data we will take monitoring date from 2005-2007 from sampling points #89-0, #89 and #90 in the Meghriget River Basin. The table below provides monitoring information from observation point #89 taken in 2006.

Table 5 – Data from sample taken from #89 water quality sampling point in Meghriget in 2006

Concentrations of indicators of chemical composition of water, mg/dm^3	**Date**						
	16III	**18V**	**19VI**	**20VII**	**25VIII**	**17X**	**20XI**
Dissolved oxygen	8.3	9.79	10.04	8.43	8.6	9.47	8.28
Hydrogen index	7.82	7.93	8.06	8.13	8.14	8.84	7.85
BOD_5	1.9	2.4	0.76	0.87	2.96	2.00	2.77
Suspended particles	3.0	7.0	21.0	2.6	4.1	5.7	1.2
Total dissolved salts	271.24	133.72	144.02	130.62	185.71	221.06	321.83
P	0.0273	0.02377	0.06024	0.05804	0.07399	0.015999	0.007756
NO_3^-	1.06	0.21	0.17	0.12	0.11	0.03	0.02
NH_4^+	0.09	0.01	0.00	0.00	0.00	0.00	0.00
NO_2^-	0.005	0.000	0.000	0.010	0.000	0.002	0.000
SO_4^{2-}	33.34	15.2	9.2	15.9	31.3	24.6	22.6
Cl^-	14.0	5.5	6.9	8.3	22.1	12.4	14.6
Na	10.110	5.275	0.673	1.561	3.190	16.004	19.140
Mg	8.200	4.819	0.576	1.127	2.311	10.280	11.757
Al	0.0882		0.1286	0.0261	0.0073	0.0501	0.0949
Fe	0.0486	0.21092	0.0117	0.0036	0.0021	0.0654	0.1536
Cu	0.004114	0.00620	0.00308	0.00185	0.00133	0.001876	0.001212
Zn	0.0139	0.00000	0.0065	0.0052	0.0055	0.0013	0.0013
Ni	0	0.00019	0.0011	0.0013	0.001	0	
Mn	0.00594	0.01636	0.01174	0.00329	0.00113	0.002959	0.011263
V	0	0.00083	0.00034	0.00025	0.00029	0.000983	0.000561
Cr	0.0002	0.00202	0.0005	0.0007	0.0009	0.0004	0.0003
Pb	0.00027	0.00070	0.00274	0.00047	0.00025	0.00028	
K	2.23	1.45	0.28	0.51	0.83	2.75	2.67

Concentrations of indicators of chemical composition of water, mg/dm^3	Date						
	16III	18V	19VI	20VII	25VIII	17X	20XI
Ca	39.98	21.18	3.59	8.15	12.59	41.94	49.57
Co	0.0001	0.00025	0.0002	7E-05	7E-05	9E-05	0.0002
As	0.001427	0.00165	0.000819	0.000689	0.001126	0.002374	0.000708
Se	0.0004	0.00024	0.0002	0.0003		0.0004	0.0003
Cd	2.23E-05	0.00002	0.00003	0.00003	0.00004	5.6E-06	2.08E-05
Si	8.17	5.4	5.81	5.59	6.88	8.0	2.8
Mo	0.00647	0.00512	0.00388	0.00584	0.00505	0.00928	0.00684
B	0.10790	0.03802	0.00867	0.01834	0.03865	0.14734	0.16406

4.3 Examples of Output Data (Tables)

The following calculation parameters were obtained for observation point #89 in Meghriget in 2006.

Table 6 – The values of calculation parameters from observation point #89 from 2006

Calculation Parameters	Value
Total number of indicators	31
Number of indicators not satisfying MACs	6
Total number of analyses	211
Number of analyses not satisfying MACs	22
Total number of analyses	211
F_1	19.35
F_2	10.43
F_3	16.81
Water Quality Canadian Index	84.02

As output data water quality of Meghriget for the period 2005-2007 was obtained and classified according to uses for communal-household, drinking and fisheries purposes. In addition to classification according to water quality, this also shows the dynamics of water quality change in Meghriget River for the period 2005-2008.

Table 7 – Classification of Meghriget River water quality according to WQCI (calculated by 9 indicators) for the period 2005-2008

Observation point	Communal-household water use		Drinking water use		FIsheries water use	
	WQCI value	Quality	WQCI value	Quality	WQCI value	Quality
Meghriget, above the junction with Gotzgotz River (89-0)	87	Good	87	Good	67	Marginally clean
Meghriget, above Meghri (89)	90	Good	89	Good	69	Marginally clean
Meghriget, Meghri River mouth (90)	92	Good	87	Good	69	Marginally clean

Table 8 – Classification of Meghriget River water quality according to WQCI (calculated by 31 indicators) for the period of 2005-2008

Observation point	Communal-household water use		Drinking water use		FIsheries water use	
	WQCI value	Quality	WQCI value	Quality	WQCI value	Quality
Meghriget, above the junction with Gotzgotz River (89-0)	85	Good	78	Marginally clean	70	Marginally clean
Meghriget, above Meghri (89)	81	Good	75	Marginally clean	68	Marginally clean
Meghriget, Meghri River mouth (90)	85	Good	78	Marginally clean	71	Marginally clean

5. Bibliography for the Method

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Mercier V., Fox D., Khan H., Taylor D., Raymond B., Bond W., Caux P., Application and testing of the water quality index in Atlantic Canada report summary, Canadian Council of Ministers of the environment, 2004

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GUIDELINE 3.2: SETTING ECOLOGICAL FLOW

1. Introduction

1.1 Purpose of this Guideline

The purpose of this guideline is to describe the application of the method for setting of ecological flows for surface waters in Armenia. Ecological flow is the minimum level of river flows, required to maintain the proper functions of river network ecosystem.

Assessment of ecological flow requires taking into consideration several factors, and is a complex issue. That is why as a first step it is necessary to consider the "ecological flow" to be the minimum quantity of water for which the river system has functioned under natural conditions. Moreover, the value of ecological flow cannot be considered constant throughout the year. Ecological flow should be defined for each month separately, to take into account that natural flows vary throughout the year, and aquatic species often require this seasonal variation in flow to implement their life cycle.

For ecological flow it is suggested to define 75% of the average flow of 10 consecutive days with minimum flow in winter period (normally the lowest flow of the year in Armenia). This is necessary given the fact that in winter season the impact of economic activities on flowing regimes is very low, and the flow in the rivers is not influenced by snowmelt. Later, the ecological flow will be adjusted for each month of the year.

1.2 Role of Setting Ecological Flow in River Basin Planning

Assessment of the value of ecological flow is contingent upon consideration of sanitary, recreational and fish-protection requirements, as well as conditions for biological equilibrium of rivers and self-cleaning capacities. In order to define the ecological flow objectively it is necessary to conduct complex hydrological, hydrodynamic, hydro-biological and hydro-chemical research. For assessment methods it is appropriate to consider the river's hydrological regime, geographic location, form and extent of its economic use.

For management of the river basin's water resources planning the assessment of ecological flow is of great importance, since it allows determination of the volume of water, that should not be permitted for abstraction or consumptive use. The calculated minimum flow should serve the needs of native aquatic life and thereby provide for maintenance of biodiversity in the given river basin.

2. Technical Approach

2.1 Methodology: Background and Justification

In order to determine the values of ecological flow for gauged river basins it is advised to take as basis the average value of the 10-day minimum daily water flow in winter low-flow period. The reason for such an approach is that in winter period the impact of economic activities on the river flow is very little, and it can be claimed that the flow in winter time is very close to the value of the natural flow. Next is to define the value of the ecological flow, which is considered as 75% of the above-mentioned average flow value. Finally, for gauged river basins (river sections) the value of ecological flow for each month of the year for average water availability year is to be defined (annual distribution of the flow according to months, in % of total annual flow).

For ungauged river basins use the map of modules of the Water Atlas of Armenia, which represents map of the flow modules for the 10-day minimum daily water flow in winter period. The average module of the minimum flow (in l/sec. km^2) for each separated ecological section of the river is defined, after which the flow module value (in l/sec. km^2) into discharge value is transferred and the discharge in m^3/sec calculated. And, finally, the value of ecological flow for a given territory as 75% of the calculated discharge is defined. Taking into consideration the inter-annual distribution of the annual flow, the monthly ecological flow for all months will be obtained.

2.2 Input Data Requirements

Input data requirements for calculating ecological flow in delineated sections of rivers should be clear. Both for gauged and ungauged river basins in order to calculate the value of ecological flow for delineated sections of the rivers it is necessary to have the average value of the 10-day minimum daily water flow in winter low-flow period.

2.3 Where to Acquire Input Data

For gauged rivers basins (or sections of the rivers) the monthly values of ecological flow can be defined for average water-availability years using table 45 (monthly distribution of the flow, as % of the annual flow) of “Multi-year Data on the Regime and Resources of Surface Land Waters, Volume XIII, Armenian SSR, Leningrad, 1987”.

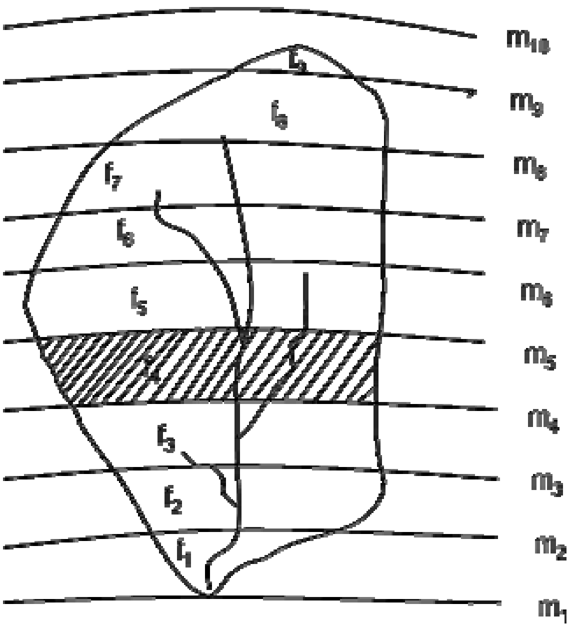
For ungauged river basins it is necessary to use the “Atlas of Natural Conditions and Natural Resources of the Republic of Armenia, Hydrology, Yerevan, 1990.” Particularly, page 44 of the Atlas provides a map of the flow modules of the 10-day minimum daily water flow during winter low-flow period. Copies of these maps are available from “Geocom” Ltd and can be placed on State Water Cadastre website.

2.4 Explanation of Analysis Procedure

For river basins having hydrological observation points, as a first step it is necessary to use the results of classification of surface water resources. During delineation, large river basins are divided into separate sections taking into consideration hydrological regimes, geographic zoning, where the basins are located, as well as other factors, such as the level and extent of economic use of the basins, qualitative composition of the water and others. The second step is to take as the basis for setting the value of ecological flow the average of the 10-day minimum daily water flow in the winter low-flow period. The third step is defined as the value of ecological flow as 75% of the value obtained in the second step. Next, for gauged river basins (river sections) the value of ecological flow for each month of the year for average water availability year is defined (annual distribution of the flow according to months, in % of total annual flow).

For ungauged river basins the map of modules presented in page 44 of the Hydrological Atlas is used. It presents a map of the flow modules for the 10-day minimum daily water flow in the winter period. Average module of the minimum flow (in l/sec. km^2) for each separated ecological section of the river is defined using the following method:

a) First is to take from the map the image corresponding to the area of the relevant watershed, as well as isolines of the flow module (see picture below),



b) The average value of the flow module for that area is determined using the following formulae,

$M_{ave} = (f_1*m_1 + f_2*m_2 + ... + f_n*m_n)/F$, (1)

where, M_{ave} is the average module of the given area in l/sec. km^2, m is the average value of modules (in l/sec. km^2) corresponding to two neighboring isolines, f is the area (in km^2) between the two neighboring isolines, which is calculated using area-meters or planimeter, and F is the sum of the areas in km^2. For determining the areas planimeter can be used. There is also a computer method for calculating the area, which as available at the Cadastre Division of WRMA.

Next, from the average values of the flow module (l/sec. km^2) switch to the value of discharge (in m^3/sec.) using the following formula:

$Q_{ave} = 1000 * M_{ave} / F$: (2)

And, finally, define the value of annual ecological flow for a given territory (Q_{ec}) using the following formula:

$Q_{ec} = 0.75 * Q_{ave}$. (3)

Given the value of ecological flow for a one-month period, it is necessary to distribute this flow through a 12-months period. For that purpose it is necessary to select an analogous river to the studied river. The annual distribution of the flow of the analogous river according to months (as % of annual flow) will be used for the calculated river and the same ratio will be used for calculated of river flow distribution according to months.

2.5 Type and Format of Output Data

As a result of application of the proposed method for setting ecological flow the monthly distribution of the flow and calculated ecological flow are obtained. The tabular format of the output results is presented below.

Table 1 – Monthly distribution of the flow in delineated sections

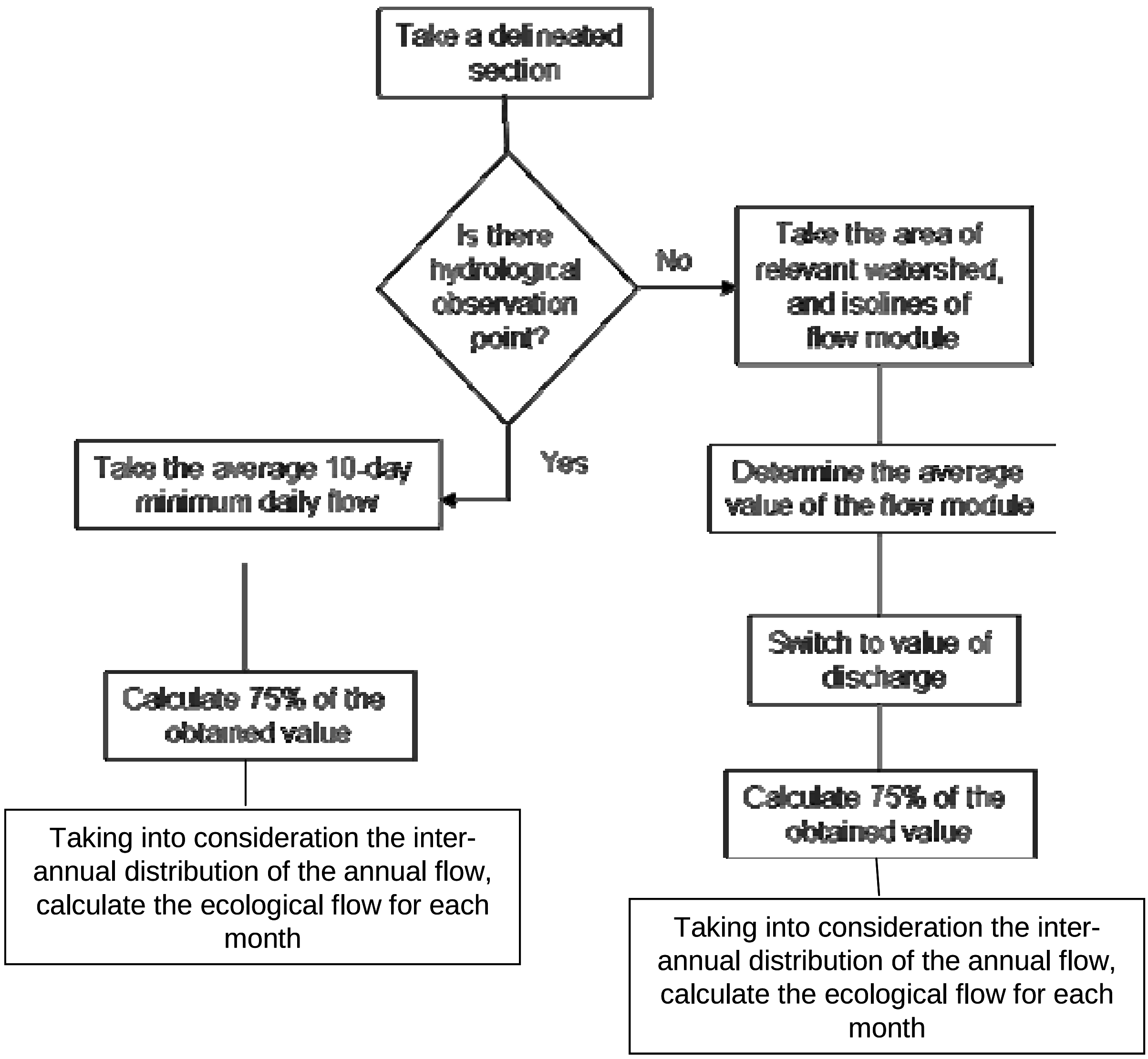
Monthly flow, %											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Delineated section % of annual											
1.9	1.6	2.0	6.3	18.2	29.0	20.8	8.8	4.2	2.8	2.2	2.2

Table 2 – Calculated ecological flow in delineated section of the river

Monthly ecological flow, m^3/sec.											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Delineated section											
0.11	0.090	0.11	0.35	1.02	1.63	1.17	0.50	0.24	0.16	0.12	0.12

3. Diagram of Approach

The sequence of steps for application of ecological flow calculation method is presented in the flowchart below.



4. Application of Method on Meghriget

4.1 Explanation of Application to Meghriget

Assume that as a result of surface water classification Meghriget River is defined as two sections: Meghriget-Meghri and Meghriget-Lichq.

Then, from table 84 of "Multi-year Data on the Regime and Resources of Surface Land Waters, Volume XIII, Armenian SSR, Leningrad, 1987" take the average value of the 10-day minimum daily water flow in winter low-flow period. According to table such discharge in Meghriget-Lichq observation point is 0.12 m^3/sec., and in Meghriget-Meghri the observation point is 0.80 m^3/sec. For the ecological flow take 75% of those discharges. Thus, the ecological flow in Meghriget-Lichq will be 0.12*0.75 = 0.090 m^3/sec., and in Meghriget-Meghri it will be 0.80*0.75 = 0.60 m^3/sec.

Next, from table 45 of "Multi-year Data on the Regime and Resources of Surface Land Waters, Volume XIII, Armenian SSR, Leningrad, 1987" we will the monthly distribution of the flow (according to months, as % of the annual flow) for Meghriget-Lichq and Meghriget-Meghri observation points. As a result the calculated ecological flow in Meghriget-Meghri and Meghriget-Lichq sections is defined.

The calculated ecological flow should be compared to actual flow data to determine if the flow is meeting estimated ecological requirements in all months of the year. Actual flow data are available from Armenia State Hydromet. In the case of Meghri, the use of 2005 flow data shows that the ecological flow is not met in July-October 2005, with a particular short-fall in September 2005 (actual mean monthly flow of 0.24 m^3/sec is less than 30% of calculated 0.85 m^3/sec ecological flow).

4.2 Examples of Input Data

In order to determine the value of ecological flow it is necessary to have the average value of the 10-day minimum daily water flow in winter low-flow period in the sections Meghriget-Meghri and Meghriget-Meghri as input data. According to table 84 of "Multi-year Data on the Regime and Resources of Surface Land Waters, Volume XIII, Armenian SSR, Leningrad, 1987" discharge for Meghriget-Lichq hydrological observation point will be 0.12 m^3/sec., and for Meghriget-Meghri hydrological observation point it will be 0.80 m^3/sec. Take 75% of those discharges as the value of ecological flow. Thus, for Meghriget-Lichq the ecological flow will be 0.12 * 0.75 = 0.090 m^3/sec., and for Meghriget-Meghri will be 0.80 * 0.75 = 0.60 m^3/sec.

4.3 Examples of Output Data (Tables)

As a result of application of the method obtain the monthly distribution of the flow and calculated ecological flow in delineated sections.

Table 3 – Monthly distribution of the flow in hydrological observation points Meghriget-Meghri and Meghriget-Lichq

Monthly Flow, %											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Meghriget-Lichq											
1.9	1.6	2.0	6.3	18.2	29.0	20.8	8.8	4.2	2.8	2.2	2.2
Meghriget-Meghri											
2.8	2.5	5.0	12.5	24.2	20.2	14.0	6.2	3.6	3.1	2.8	3.1

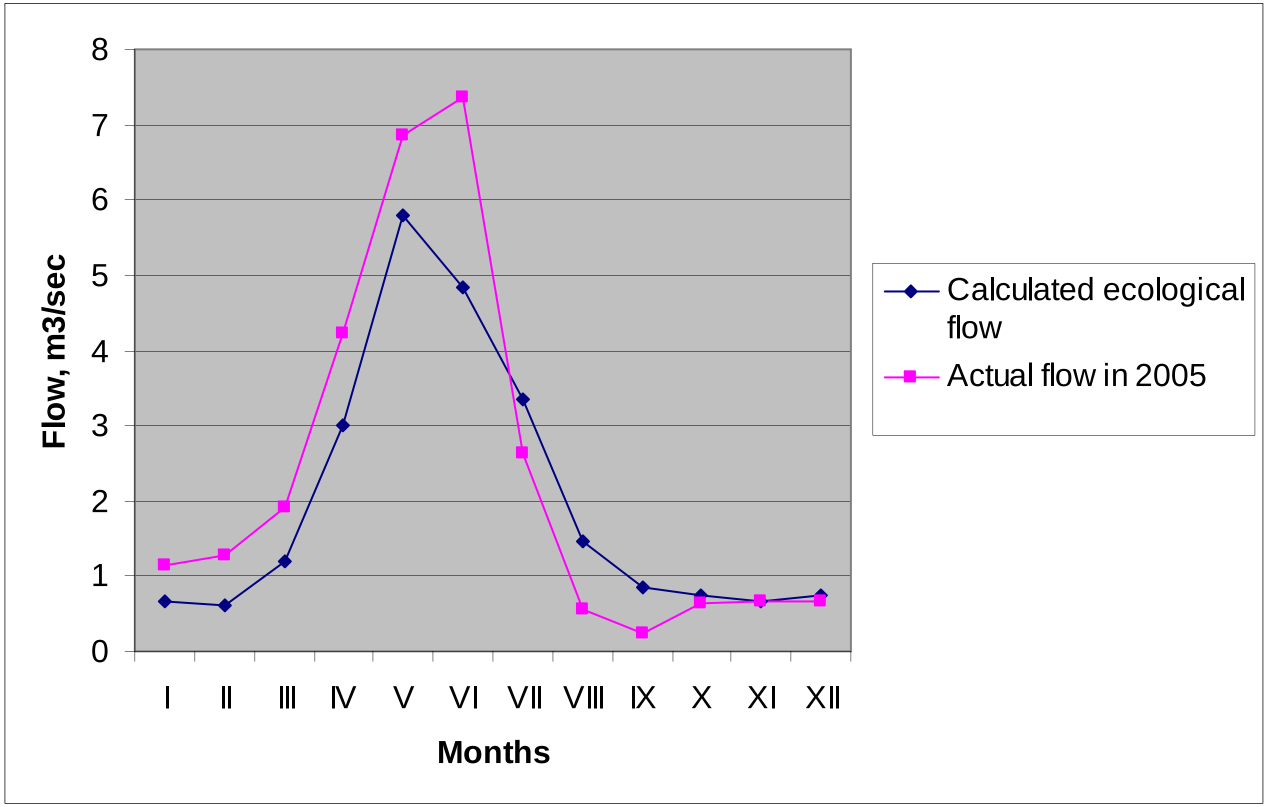
Using the table above and taking into consideration that the minimum flow in Armenian rivers is mostly observed in February, assume that the ecological flow in February is: for Meghriget-Lichq - 0.090 m^3/sec, or 1.6% of the flow, and for Meghriget-Meghri - 0.60 m^3/sec, or 2.5% of the flow. Thus, for the remaining 11 months the values of the ecological flow will be as presented in the table below:

Table 4 – Calculated ecological flow in sections Meghriget-Meghri and Meghriget-Lichq

Monthly Ecological Flow, m^3/sec.											
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Meghriget-Lichq											
0.11	0.090	0.11	0.35	1.02	1.63	1.17	0.50	0.24	0.16	0.12	0.12
Meghriget-Meghri											
0.67	0.60	1.20	3.01	5.80	4.85	3.36	1.45	0.86	0.74	0.67	0.74

Table 5 – Value of the calculated ecological flow and actual flow in 2005 in Meghriget-Meghri section.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Calculated ecological flow	0,67	0,6	1,2	3,01	5,8	4,85	3,36	1,45	0,86	0,74	0,67	0,74
Actual flow in 2005	1,15	1,27	1,92	4,22	6,85	7,37	2,63	0,55	0,24	0,64	0,67	0,66



5. Bibliography for the Method

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GUIDELINE 3.3: SETTING ENVIRONMENTAL OBJECTIVES FOR WATER BODIES

1. Introduction

1.1 Purpose of this Guideline

This Guideline explains how to set environmental objectives for water bodies, especially those which do not meet good or excellent ecological status due to physical-chemical, flow-related, or biological issues. This guidance should assist river basin planners in setting justifiable, quantitative environmental objectives for the future status of waters in their basin. These environmental objectives are also known as “targets” or “goals” in various water quality management systems in other countries.

1.2 Role of this Activity in River Basin Planning

The setting of environmental objectives is a key step in river basin planning, coming after evaluation of water body status, and just before the pressure/impact analysis of problems.

1. Characterization of River Basin.
2. Delineation, classification and evaluation of status of water bodies in basin.
3. **Setting environmental objectives** for the river basin, by water bodies.
4. Analysis of anthropogenic pressures and environmental impacts on water bodies.
5. Development of a program of measures to address the specific impacts which affect the water resources of the basin.

Setting environmental objectives focuses on how to measure future progress in improving water resources, in terms of water quality, flow management, and biological resources. Environmental objectives should be set for each water body in the basin, with particular focus on the water bodies which did not achieve “good status” in their evaluation. It is important that setting of environmental objectives be done ***with participation of stakeholders***, so that all involved parties understand how much water must be improved, why and how.

2. Technical Approach

2.1 Methodology, Background and Justification

The Guideline is based on the conceptual model of the European Union Water Framework Directive, in which water bodies are qualified as “high,” “good,” “moderate,” “poor,” and “bad.” The Water Framework Directive Guidance Document No. 13, “Overall Approach to the Classification of Ecological Status and Ecological Potential,” (EU, 2005) provides important conceptual background on establishing water body ecological status. The three components of status are water quality, water flow (quantity) and aquatic biology. The water quality status evaluation approach outlined in the Guideline 3.1 is also used here. It is based on the WQCI.

Flow maintenance criteria are based on the ecological minimum flow calculation method recommended in Guideline 3.2. The biological criteria have not been developed yet for Armenia, but it is understood that native fish species can be an excellent indicator for biological integrity of a river/stream or lake ecosystem.

2.2 Data Requirements

The data requirements for setting environmental objectives in Armenia are distinct from those in European Union countries. This is because Armenia does not have the aquatic biology databases necessary to use a “reference reach” system for setting objectives. In Europe the “good” and “high” status of water are defined by the biological conditions in pristine rivers and lakes with little or no human interference or impact. A level slightly below these conditions becomes the “high status” or “good status” objective.

Since Armenia does not have this biological data for rivers and lakes, the best option is to use existing water quality standards (they are distinct for drinking water, recreation and fisheries uses) for physical-chemical status, use minimum ecological flows and observations of channel condition for hydrologic and hydro-morphic issues, and use presence/absence data for native fish as an initial substitute for more sophisticated biological data. If a water body meets all standards, has no ecological flow issues, and has no known biological issues, then it can be assigned "good status."

2.3 Sources of Data

The water quality standards for Armenia are available at the National Institute of Standards (http://www.sarm.am/?go=order&PHPSESSID=6c178f66b295ce38638c1de9b03682f5&LanguageID=1). Note that there are separate standards for drinking water, recreation, and fisheries. Ecological minimum flow is calculated according to Guideline 3.2. Biological data may be available from the Institute of Hydrobiology of the National Academy of Sciences, Yerevan. Actual water quality data are available from the Environmental Impact Monitoring Center (EIMC) or State Water Cadastre at WRMA.

2.4 Explanation of Procedure

Setting environmental objectives needs to be done based on good scientific data, and a rigorous method. Local stakeholder input should be sought out, but it should be clear that basic standards outlined in this guideline will apply unless some unanticipated issue arises.

Basic Assumptions in Setting Objectives: Armenia needs to protect its waters for all uses. In keeping with EU guidance, maintaining the native aquatic ecosystem is the primary idea of the EU Water Directive Framework. The following assumptions are essential for constructing a rigorous environmental objectives methodology:

1) All waters have multiple uses; protecting the most sensitive use generally will protect all other uses. Therefore, in Armenia, the fisheries water quality standards (MACs) should be the basis for maintaining native aquatic ecosystems, with the idea that "if natural fisheries are protected, overall environment and humans will be protected."
2) Armenia needs to promote economic development, and recognizes that it is unlikely to maintain extremely high water quality and all elements of native aquatic ecosystems in urban and industrial settings. Highly modified water bodies and wastewater-dominated systems should be evaluated using Armenia recreation MACs, which are substantially less stringent than fisheries standards, based on the idea "all waters should at least be safe for human contact."
3) Aquatic ecosystems respond dramatically to temperature variations—warm-water systems are distinct, with different species, than cold-water systems. Warmer surface waters tend to host aquatic life which is adapted to more severe stress in terms of dissolved oxygen, turbidity, suspended solids, and other common pollutants. Although there is little study of this phenomenon in Armenia, it is assumed that Armenian aquatic ecology is broadly similar to that of much of Europe (e.g., several common fish genera exist throughout Europe and Armenia).
4) Therefore, it is proposed to use the EU classification system and assume water bodies above 800 meters will be evaluated as cold-water systems using Armenia fisheries MACs. Water bodies below 800 meters will be evaluated as warm-water systems using Armenia fisheries MACs.
5) The environmental objectives can be expressed as a combination of physical-chemical, hydrologic, and biological objectives. The environmental objectives will be higher for certain types of water bodies, especially those that represent high-quality or potentially high-quality waters in upper watersheds. For example, high-elevation cold-water streams and lakes will have higher basic objectives, because native aquatic life is often adapted to these conditions.

Given these assumptions, the basic objectives for all natural waters will be:

- Meet WQCI value of "good status" (>80) for nine basic hydrobiological and sanitary variables (9 variables=dissolved oxygen, BOD5, COD, total dissolved solids, total suspended solids, nitrate, ammonia, total phosphorus, pH) compared to fisheries standards. This is roughly equivalent to saying "80% of water quality measurements will meet fisheries standards for these parameters."

- Meet WQCI value of "good status" (>80) for all 30 variables proposed by EIMC.
- Meet Armenia fisheries guidelines for temperature (cold-water systems must not exceed 20º C in summer, warm-water systems should not exceed 28º C in summer, etc.)
- No serious violation (mean higher than fisheries MAC or highest measurement >200% of fisheries MAC) of heavy metal or toxics—see list of priority toxic substances from EU.
- Natural streams and rivers in drinking water supply areas, protected areas and other areas above 800 meters with little industrial development should aim for minimum WQCI value of 90.
- Natural streams and rivers should meet "good status" on ecological flows—their minimum flows should be above the calculated minimum ecological flows in each month of the year.
- Presence of biological indicators (native fish) is initially confirmed by consultation with local residents. Benthic invertebrate surveys, if they are done, should indicate "healthy" status.
- Heavily modified and wastewater-dominated water bodies should aim for WQCI of moderate status (>70) for nine basic physical-chemical parameters, and >75 for all chemical values, using recreational MACs for Armenia. Mean values of toxic pollutants above MACs for recreation cannot be allowed—the objective should be for all means to be below recreational MAC.

These are basic suggestions for how to structure environmental objectives. It is probable, and appropriate, that environmental objectives for each water body will be distinct, as each BMO will learn to adjust environmental objectives to the reality of their area. Some stakeholders (polluters) will want to push objectives lower. For this reason WRMA should have clear Guidelines on how to set objectives and manage stakeholder input.

2.5 Type and Format of Output Data

An environmental objective for a specific water body will look like this:

- WATER BODY NAME:
- ACTUAL STATUS (2008): Moderate
- WATER BODY TYPE: Natural stream, cold-water
- WQCI value (9 basic parameters) >80 (Actual value, 2008 =68)
- WQCI value (30 EIMC parameters)>80
- Temperature (Armenia warm-water): Temperature should not be elevated more than 5º C. over background, with Maximum summer 28º C., and Maximum winter 8º C.
- No priority toxic substances above fisheries MACs.
- Flow: Meets ecological minimum flows every month (4 out of 5 years).
- Biological indicators: At least three native fish species present.

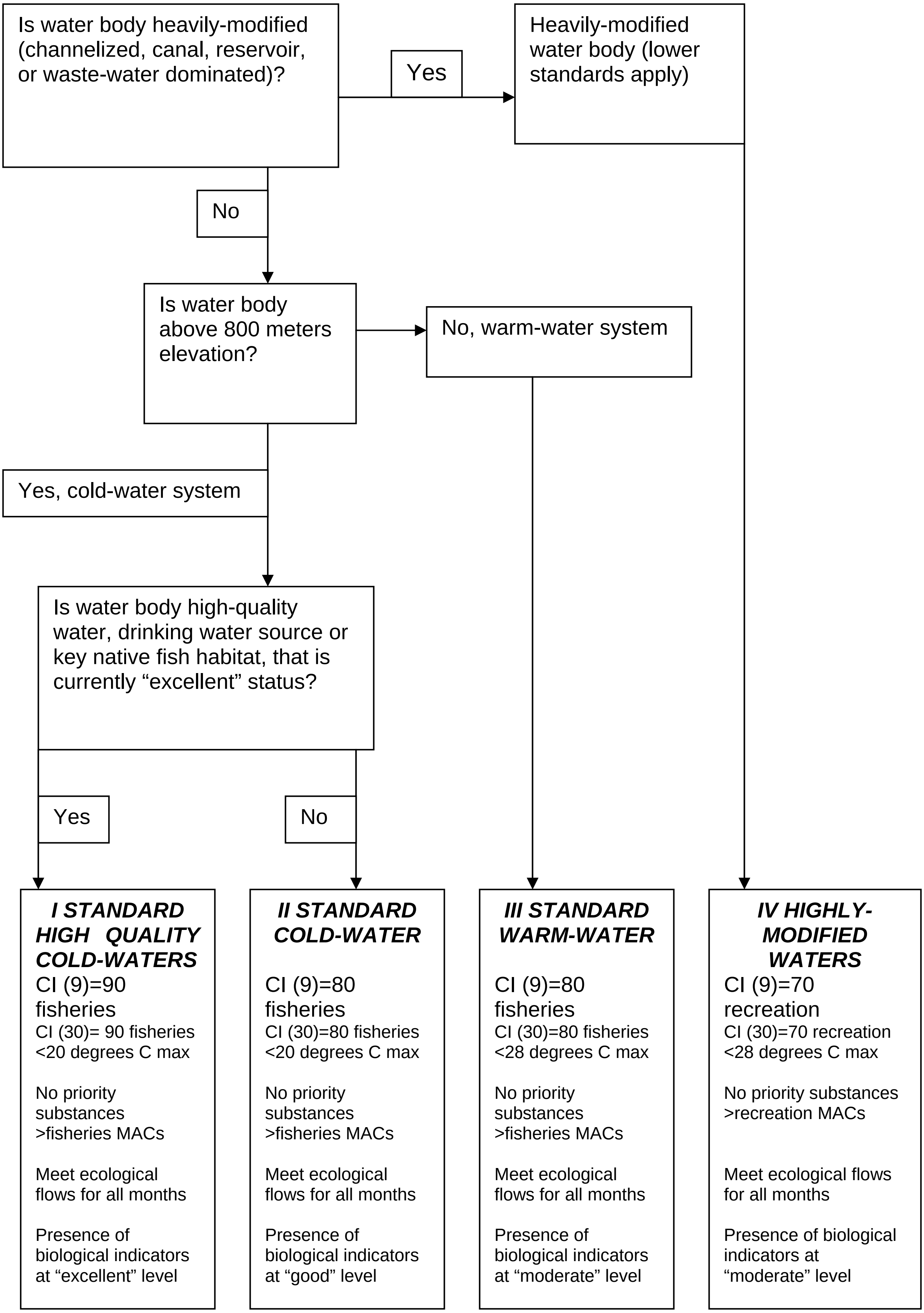
2.6 Computer programs and other Analysis Aids

To meet the new environmental objectives where "good status" is not obtained, WRMA and BMOs will have to suggest specific measures to be taken by each significant water user in the affected basin. Many times this will involve adjusting a Water Use Permit. Proposing appropriate measures are described in next Step 4 Guidelines.

Specific recommendations on how to calculate and assign pollution loads to different discharges requires computer modeling which is beyond the scope of this guideline. If many water use permit stakeholders are involved in a pollution issue, and pollution loads need to be assigned to each, then a separate detailed study is required. Modeling studies can be one of the measures recommended by BMOs in order to better establish permit limits in complex sub-basins.

3. Diagram of Approach

FLOW CHART: APPLICATION OF ENVIRONMENTAL OBJECTIVES



Application of Environmental Objectives to the Classified Water Resources

4.1 Explanation of Application

From the above flow chart it is obvious that finally from our abstract consideration of possible environmental objectives there are 4 standards. Standards are usually not obligatory requirement for following on. However, the standards are desirable to achieve. Therefore consider the above defined standards as Environmental Objectives for classified water bodies. According to the Guideline 2.2 it is known that there are 12 distinct classes of water bodies (see Table 4 in Guideline 4). In the Table 1 it is shown the way of application of 4 types of environmental objectives to the 12 classes of water bodies.

I OBJECTIVES	***II OBJECTIVES***	***III OBJECTIVES***	***IV OBJECTIVES***
Cl (9)=90 fisheries Cl (30)= 90 fisheries <20 degrees C max No priority substances >fisheries MACs Meet ecological flows for all months Presence of biological indicators at "excellent" level	***Cl (9)=80 fisheries*** Cl (30)=80 fisheries <20 degrees C max No priority substances >fisheries MACs Meet ecological flows for all months Presence of biological indicators at "good" level	***Cl (9)=80 fisheries*** Cl (30)=80 fisheries <28 degrees C max No priority substances >fisheries MACs Meet ecological flows for all months Presence of biological indicators at "moderate" level	***Cl (9)=70 recreation*** Cl (30)=70 recreation <28 degrees C max No priority substances >recreation MACs Meet ecological flows for all months Presence of biological indicators at "moderate" level

Table 1. Application of environmental objectives to the classes of water bodies

	Varying size of river basin		
	Small River Basin	**Average River Basin**	**Large River Basin**
Varying geology, altitude<800m	**1.** 10-100 km^2 Local importance Altitude< 800m Geology – siliceous ***III or IV***	**2.** 100 -1000km^2 National importance Altitude<800m Geology – siliceous ***III or IV***	**3.** 1000-10000km^2 International Importance Altitude<800m Geology – siliceous ***III or IV***
	4. 10-100km^2 Local importance Altitude<800m Geology – calcareous ***III or IV*** (with distinct biological indicators)	**5.** 100 -1000km^2 National importance Altitude<800m Geology – calcareous ***III or IV*** (with distinct biological indicators)	**6.** 1000-10000km^2 International importance Altitude<800m Geology - calcareous ***III or IV*** (with distinct biological indicators)
Varying geology, stable altitude>800m	**7.** 10-100km^2 Local importance Altitude>800m Geology – siliceous ***I or II***	**8.** 100 -1000km^2 National importance Altitude>800m Geology – siliceous ***I or II***	**9.** 1000-10000km^2 International importance Altitude>800m Geology – siliceous ***I or II***
	10. 10-100km^2 Local importance Altitude>800m Geology – calcareous ***I or II*** (with distinct biological indicators)	**11.** 100 -1000km^2 National importance Altitude>800m Geology – calcareous ***I or II*** (with distinct biological indicators)	**12.** 1000-10000km^2 International importance Altitude>800m Geology – calcareous ***I or II*** (with distinct biological indicators)

4.2 Input Data Examples

The input data are classified water bodies with their characteristics and evaluation values for classified bodies.

4.3 Output Data Examples (Tables)

As a result of application of environmental objectives to classified and evaluated sections of Meghriget the following tables are obtained:

Table 2 – Environmental objectives for Meghriget River

Delineated parts of the Meghriget River	Classes	Current Status	Environmental Objectives
Meghriget, above the junction with Gotzgotz River (89-0)	**(7)** 10-100km^2 Local importance Altitude>800m Geology – siliceous	**Satisfactory** CI (9)=67 fisheries CI (31)=70 fisheries	**Good (II)** **CI (9)=80 fisheries** **CI (30)=80 fisheries** **<20 degrees C max** **No priority substances >fisheries MACs** **Meet ecological flows for all months** **Presence of biological indicators at "good" level**
Meghriget, above Meghri (89)	**(7)** 10-100km^2 Local importance Altitude>800m Geology – siliceous	**Satisfactory** CI (9)=69 fisheries CI (31)=68 fisheries	**Good (II)** **CI (9)=80 fisheries** **CI (30)=80 fisheries** **<20 degrees C max** **No priority substances >fisheries MACs** **Meet ecological flows for all months** **Presence of biological indicators at "good" level**
Meghriget, Meghri River mouth (90)	**(1)** 10-100 km^2 Local importance Altitude< 800m Geology – siliceous	**Satisfactory** CI (9)=69 fisheries CI (31)=71 fisheries	**Good (IV)** **CI (9)=70 recreation** **CI (30)=70 recreation** **<28 degrees C max** **No priority substances >recreation MACs** **Meet ecological flows for all months** **Presence of biological indicators at "moderate" level**

As observed in Table 2, from the two available objectives the milder one was chosen. After successful application of all the river basin management measures and achievement of the lower objective, during the next step regulators could set stricter objectives. However, the main principle of the EU Water Framework Directive – achievement of "Good" status for all water bodies in the future five years will be kept.

STEP 4. IDENTIFICATION OF PRESSURES AND MEASURES

Introduction to Step 4: Identification of Pressures, Impacts and Measures

Identification of pressures, impacts and measures is the fourth step of the river basin planning process. Pressures and impacts analysis is the analysis of the causes of water resource problems-- the reasons that water bodies are not achieving their environmental objectives. From this analysis, if properly done, it is usually clear, at a conceptual level, what types of solutions, or measures are needed to resolve the water resource problems. Arriving at realistic, feasible solutions sometimes is more challenging, and may require modeling or other mathematically complex analyses. Within this document, the analysis is conceptual—mathematical water resource modeling is beyond the scope of this guideline. In other cases, there is insufficient data to understand the water resource problems. In this case, a river basin plan must include further studies to define the source of problems better. Ultimately, the program of measures is a list of proposed activities, which may include policy development, educational programs, further studies or infrastructure investments, among other solutions.

GUIDELINE 4.1: PRESSURES AND IMPACTS ON SURFACE WATER

1. Introduction

1.1 Purpose of this Guideline

This Guideline explains how to identify and describe surface water resource problems in a logical way. It assists the river basin manager in analyzing how distinct land use and development pressures affect surface water resources, and in deciding how to design solutions for surface water resource problems.

1.2 Role of this Activity in River Basin Planning

The analysis of pressures and impacts on surface waters is a key step in the river basin planning process, which starts with diagnosis of river basin issues, and concludes with the development of a prioritized program of measures to address specific components of those issues. It can be visualized as an analysis of the "components of each water resource problem." It fits into the river basin planning process in the following ways:

- Characterization of River Basin: a description of natural and human resources, with identification of general water resource issues
- Delineation, classification and evaluation of status of all water bodies in basin
- Setting environmental objectives for each water body in the entire basin management area
- Analysis of anthropogenic pressures and environmental impacts on each water body
- Development of a program of measures to address the specific impacts that are included in the overall water resource issues in the basin

2. Technical Approach

2.1 Methodology: Background and Justification for Method

The Guideline is based on a conceptual model used by the EU Water Framework Directive called: "Driver-Pressure-State-Impact-Response (DPSIR)." This approach is outlined in the EU WFD Guidance No. 3: "Analysis of Pressures and Impacts," EU, published in 2003: http://circa.europa.eu/Public/irc/env/wfd/library/framework_directive/guidance_documents

The DPSIR is a means of logically structuring the relationship between human development pressures and the impacts on the water environment. It provides an initial scope of pressures related to human activities, and requires the basin planner to clarify how each type of pressure is affecting water resources in their area. It is important to understand that the analysis includes human activities that affect water quality, water quantity (abstraction for use), morphological changes to surface waters (dams, diversions, flood control), and biological aspects of surface water (fishing, introduction of invasive species).

2.2 Data Requirements

The pressure and impacts analysis requires a broad understanding of all human activities in the river basin, an ability to quantify those pressures, and access to monitoring data, which allows the basin planner to evaluate whether the likely impacts are actually causing environmental impacts in the basin. Specific types of data required include:

- Land use data in a format which permits analysis by water body (usually GIS layers), especially agriculture, forestry, pasture (livestock), industrial and urban areas
- Inventory of water use by sector and by specific industries in the basin
- Inventory of specific industries and their capacities and practices, including chemical substances likely to appear in their wastewater discharge
- Inventory and mapping of crop and livestock production, and understanding of cultural practices (e.g., fertilizers and pesticides used)
- Urban areas, building and road densities, populations, wastewater and stormwater system characteristics
- Inventory of water use permits and wastewater discharge quantities and quality, and composition and concentrations of pollutants in discharges
- Status of river channels, reservoirs, other hydraulic infrastructure and its capacities
- Biological data on fisheries production, status and distribution of native and non-native fish, plants, other aquatic organisms within the river basin
- Monitoring data on water resources including flow data, physical-chemical data, and biological surveys of aquatic life

2.3 Sources of Data

Much of the data required for pressures and impacts analysis should be collected as part of the river basin characterization, the first step of the river basin planning process. The pressures and impacts analysis requires that this data be organized and quantified in a structured way, to indicate what types and approximate dimensions of surface water impacts are expected. The main sources of this data should include:

- GIS data from State Water Cadastre (Armenia WRMA)
- Land use data from Marz Territorial Administration
- Agricultural data from Ministry of Agriculture and Marz agricultural department
- Industrial data from State Registry of Organizations, Armenia National Statistical Service
- Demographic data from National Statistical Service
- Water systems management data from State Committee on Water Systems, Ministry of Energy, and Public Services Regulatory Commission
- Water use permits from WRMA and Basin Management Organization files
- Water systems use permits from PSRC
- Water quality data from the Environmental Impact Monitoring Centre (EIMC) and Inspectorate of Hygiene and Epidemiology, Ministry of Health
- Flow and temperature data for rivers from Armenia State Hydromet
- Water balance and minimum ecological flow data (see Guidelines)
- Aquatic biology data from the Bio-resources Management Agency under Ministry of Nature Protection

2.4 Explanation of Analysis Procedure

The DPSIR pressures and impacts analysis is based on the following definitions:

1. Driver - Anthropogenic activities that affect water resources (e.g. population growth, agriculture, transportation, industry)

2. Pressure - Direct effects of drivers (e.g. discharge of pollutants, abstraction of water)

3. State - Physical, chemical or biological condition measured in water resource (e.g. level of contamination, change in temperature, level of bacteria)

4. Impact - Effect on aquatic ecosystem (e.g. reduction in fish, eutrophication -algae bloom, etc.)

5. Response - Proposed actions (measures) to reduce impacts by altering drivers or pressures

In actual practice, the focus of the analysis is on the pressures and the impacts—hence the name of the method. But very often the actual ecological impacts are obscure or undetermined. The “state” is more easily measured—for example water quality data—and the resulting impacts are inferred as risks caused by the state of the water resource. This linkage of state and risk of impact is the justification for most water quality standards, minimum flow standards, or biological standards (diversity indicators, etc.). The ecological impacts are assumed to occur, or be at risk of occurring, because of established relationships published in the literature of aquatic ecology.

The general process for pressures and impacts analysis is diagrammed in the flow chart in Section 3 of this guideline. Population increases, change in land use intensity, or economic activities are the overall greatest driving forces which affect water resources. If population, land use intensity, or raw materials processing (e.g. industry, mining) are increasing in a river basin, the potential for water resource impacts is also increasing. Driving forces are related to water resource impacts as follows:

IMPACTS: DIFFUSE POLLUTION

1. Land Use Intensification: Diffuse (non-point) pollution increases as the proportion of land use in the sub-basin shifts from natural forest>commercial timber>grazing land>cropland>urban residential>industrial/commercial. Each change in land use tends to increase concentration of sediment, nutrients, and other contaminants in diffuse runoff. ANALYSIS: Prepare land use chart by sub-basin.
2. Urbanization (non-point source): Increasing density of residential land use in an urban area increases quantity of excess storm water runoff and concentration of contaminants. Commercial and industrial areas usually have even higher impervious surface ratios, which increase potential for diffuse pollution. ANALYSIS: If urban land use is >5% of a sub-basin, map location and density of use (residences per hectare).
3. Agriculture (non-point source): Increased intensity of agriculture from grazing>crops>confined livestock (pigs, poultry, dairy, feedlots) increases risk of nutrient and organic matter pollution to water bodies, and potential for pesticide contamination. ANALYSIS: Map agricultural land uses, with focus on intensively farmed, high fertilizer and pesticide input crops or confined livestock facilities.
4. Air pollution: Industries, heavy traffics on the streets and international or national highways with trucks load cause air pollution which is non-point pollution for nearby located water resources. This pollution is washed out to the rivers, lakes and underground sources with the precipitations. ANALYSIS: Consider air polluting industries in the river basin on the subject whether their emissions violate the MACs in the given area, according to the EIMC monitoring data.

IMPACTS: POINT-SOURCE POLLUTION

5. Industry (point source): Wastewater discharges from mining, chemical, processing and other types of industry are a key risk for water quality (temperature, chemical contamination, nutrients). ANALYSIS: Use water permits, business inventories and known un-permitted

discharges from large manufacturing/ processing industries and small businesses (petrol stations, automobile maintenance, repair and painting, car washes, dry cleaning, tanning, food processing, etc.) to map their locations relative to sub-basins.

6. Municipal wastewater and other sanitation disposal technologies: Wastewater from sewered towns and waste streams from septic systems and pit latrines can be major sources of fecal coliform bacteria and other pathogens, BOD, nutrients, toxic ammonia and other pollutants to surface waters. Percentage of population using sewers, latrines or other sanitary disposal is important to know. ANALYSIS: Quantify population on sewers and other sanitation systems and map key discharge locations.

IMPACTS: ABSTRACTION AND OTHER FLOW ALTERATIONS

7. Water diversion and consumptive use by irrigated agriculture, municipal, hydropower and industrial ventures can alter or diminish flows. ANALYSIS: Compile total water use by season or consult economic water balance of basin and sub-basins.

IMPACTS: HYDRO-MORPHOLOGICAL CHANGES

8. Flow regulation by dams and reservoirs, canals, and various hydraulic control structures are substantive morphological and functional changes in rivers and lakes that alter the aquatic habitat and ability to support native species. ANALYSIS: Map location of altered rivers, lakes, and reservoirs.
9. Flood control channels, hardened bank protection (riprap), and dykes for protection of urban or transportation infrastructure alter the river-floodplain interaction, and cause many ecological changes. ANALYSIS: Map the altered channels.

IMPACTS: BIOLOGICAL CHANGES

10. Commercial fishing, introduction of non-native invasive plants, fish, mollusks and other aquatic animals often causes major impacts on native species (decline or extinction) and ecology of rivers and lakes (change in species). ANALYSIS: Compile information on non-native species and their relative abundance of native species.

IMPACT: RIVER AND STREAM EUTROPHICATION

11. River and stream eutrophication is caused by the over stimulation of plant growth due to the discharge or runoff of excess nutrients to the water bodies. This is especially true in agriculturalized and urbanized river basins. Eutrophication can have the following deleterious effects on rivers or streams:
    - Profuse growth of plants decreases water clarity and may form unattractive scum
    - Certain species of algae cause taste and odor problems for drinking water
    - Certain species of algae are toxic to animals
    - Composition of species of plants and animals are altered over long-term
    - Nutrients indirectly affect river and stream chemistry (i.e. uptake and release of carbon dioxide by plants will change the pH balance)

    ANALYSIS: Consider the monitoring data from EIMC on the levels of Nitrogen, Phosphorus, Ammonium and pH of water.

IMPACT: WETLAND ECOSYSTEMS

12. “Wetlands” is a generic collective term used to describe a great diversity of ecosystems worldwide whose formation and existence is dominated by water. Wetland ecosystems represent the transition between terrestrial and aquatic systems and have water near the surface of the ground for much of the year. Native plants and animals living in wetlands are uniquely adapted to live under conditions of intermittent flooding, saturated soil conditions, lack of oxygen (anoxia), and harsh (toxic) conditions of unstable chemical species (i.e. H_2S rather than SO_4). The primary functions and value of wetlands includes providing habitats for fishing, hunting, waterfowl, timber harvesting, aquifer recharge, wastewater assimilation, water quality filtering, flood control, water and nutrient storage, chemical transformations of Nitrogen, Phosphorous, Sulfur, and Carbon with storage of vast amounts of Carbon as peat due to low decomposition rates.

ANALYSIS: Map locations and vastness of wetlands and record the species of plants, wildlife, and fish, which should be protected from development pressures.

General Analysis Procedure: Review water quality and flow monitoring data, consult with biologists, hydrologists and other experts with local knowledge, and make field trips to view water resource conditions and interview local water users. This will allow the basin planners to determine the most obvious state and impact changes in each part of the basin. These observations should then be compared to the driving forces and pressures to see if there is a clear correspondence between types of pressures and types of impacts. If expected impacts are not seen, then pressures are not significant or monitoring is insufficient to note actual changes in state or impact of the water resources. If impacts are noted but pressures creating these impacts are complex or unclear, then further work is required to quantify and prioritize likely pressures. Examples of how to relate noted changes in state and impacts to possible pressures are shown in the table below:

STATE/IMPACT	PATHWAY OR PROCESS	POSSIBLE PRESSURES
Elevated nutrients (N,P)/ eutrophication of lakes and rivers, excess algae/weeds in rivers	Diffuse runoff Point-source discharges	Fertilizer and manure from croplands; agricultural drainage; urban stormwater runoff. Municipal wastewater; industrial wastewater
Elevated BOD/low dissolved oxygen content	Diffuse runoff Leaching Point-source discharges	Manure from feedlots, dairies. Garbage or solid waste. Industrial (e..g. food or meat processing) wastewater. Municipal wastewater.
Sedimentation/destroys benthic fauna, changes habitat for spawning	Erosion, diffuse runoff	Roads (unpaved or borrow ditch) Agricultural croplands Landslides Construction sites/mines
Increased acidity/soluble metals toxicity to aquatic life	Direct runoff from mines Leaching from mine tailings	Underground or pit mines Mills; mine tailings l
Elevated heavy metals/toxicity to aquatic life	Diffuse runoff Drainage, point-source	Urban stormwater from roads. Mills; mine tailings.
Pesticide or other organic chemical/toxicity to aquatic life and humans	Runoff Leaching	Agricultural crop production Agricultural storage areas, chemical storage or manufacturing Organic solvent use (cleaning or degreasing etc.)
Depleted or drained wetlands / toxicity to plants, aquatic life and loss of buffer zone value to humans	Urban development	Filling in of wetlands, removal of buffer zones between humans and water bodies

STATE/IMPACT	PATHWAY OR PROCESS	POSSIBLE PRESSURES
Increased temperature/lowers dissolved oxygen, inhibits completion of aquatic life cycles	Reduced shade-more solar radiation Discharge of warm water Change in channel/lake form or depth	Cutting forest by stream Cultivating to streambank Power plant or agricultural or industrial return flows Sedimentation or widening of channel, loss of flow
Flow reduction/alters habitat/reduces dilution of contaminants/increases temperature	Diversion or pumping of water	Irrigation or other large-scale use
Block migration of fish/reduction or loss of species	Building dams or diversions without fish passage Small culverts for roads	Hydro-electric,. flood control or irrigation reservoirs Road construction
Increased velocity of flow/eroding channels and banks	Straightening/channelizing stream Riprap or concrete channel	Urbanization or agricultural use of streamside land.

In summary:

1) Identify the drivers/pressures on water bodies in each sub-basin from basin characterization work.
2) Use field trips, interviews and monitoring data to determine changes in state of water resources, and impacts if known or suspected.
3) Estimate susceptibility of water body to each impact qualitatively. Susceptibility is related to flow (potential for dilution), proximity of pollution sources to channels, and any soil or geologic factors (erosion rates). Use high/medium/low.
4) Rank the pressures in terms of relative importance to each water body.
5) If possible quantify changes in state/impact: concentrations of toxins, kilometers of channel altered, percentage of decline in abundance of fish, percentage flow abstracted.
6) If the situation is complex, consider a further study or model to estimate the relative contribution (e.g. load of contaminants) of different pressures to the total impact. Modeling is beyond the scope of this guideline.

2.5 Type and Format of Output Data

The output of the pressures and impacts analysis will be a matrix of information, with each water body within the basin given its own section of the matrix.

WATER BODY: BASIN:

Pressures:	Pathways:	Susceptibility (high, medium, low):	State (supporting data):	Impacts:

2.6 Computer Programs or Other Analysis Aids

It is extremely helpful to have access to good maps, and particularly to good GIS layers to look at the potential pressures. Types of maps are mentioned in the input data section.

Susceptibility to problems is related to hydrologic and geologic factors which make a river or stream resilient to pressures, and the degree of protection afforded by existing policies to alteration of the rivers' natural form, quality and flow.

High susceptibility means that those pressures should be rated as high priority. Medium susceptibility means those pressures are rated lower, and so on. Generally small streams which are located near large urban or industrial areas, and sometimes near intensive agriculture, are most susceptible. Large rivers have greater capacity for dilution, maintaining habitat diversity even when losing substantial water to abstractions, etc. Large rivers are most susceptible to major hydro-morphic changes such as dams. Lakes, even large lakes, are usually not as resilient to pressures as rivers, because their water is not being replaced rapidly.

3. Diagram of Approach (Flowchart for Pressures and Impacts Analysis)

Describe the driving forces most prevalent in the river basin, and in its various water bodies. Identify and quantify, if possible, the particular pressures which exist and are associated with those driving forces. Note particularly any pressures generating priority toxic substances (see EU reference in bibliography).

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Qualify the susceptibility of the water body, depending on its type and size, and dimensions of pressure (a small stream with large pollution loads is very susceptible, while a large river with small pollution loads is less susceptible to pressures). Urban areas close to water body make it highly susceptible, but if urban areas in sub-basin are distant from the actual water body, it is less susceptible. Wetlands act as buffer zones between urbanization and water bodies.

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Rank the pressures on each water body, in light of its susceptibility, and the quantification of pressures.

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Assess the changes in state/impacts on water resources (using field visits, interviews, monitoring data), and outline potential ecological impacts. Check for priority toxic substances. Quantify the impacts as possible with data.

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Compare actual changes in state and impacts to what is expected. Look for new drivers and pressures if necessary. Change priorities of pressures if data includes new information. Outline needs for developing further monitoring data or doing specific studies required to quantify risks to aquatic life or human health.

4. Example of Method (applied to Meghriget River Basin)

The application of the pressures and impacts analysis to the Meghriget River Basin in Southern Armenia is based primarily on information included in the River Basin Characterization Synthesis Report for Meghriget, complemented by field visits, interviews with stakeholders and with the Southern Basin Management Organization (BMO). Delineation of water bodies was done by GEOCOM, a consulting firm. Driving forces are primarily large and small-scale mining, and irrigation.

WATER BODY: Meghriget River, Meghri to mouth BASIN: Meghriget

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Abstraction of irrigation water upstream and in Meghri	Diversion dams	Seasonally High (Aug-Sept)	Flows reduced in late summer—no quantitative data	May affect fish habitat, water temperature
Municipal wastewater	Direct discharge (point-source) from sewer (no treatment plant)	Medium	Nutrients: High nitrate and sometimes high ammonia concentrations; ammonia above standard ; Population 4800 persons on town sewer	Ammonia can be toxic to aquatic life; potential negative effects on dissolved oxygen in summer/fall
Solid waste & stormwater in Meghri town	Leaching and direct runoff from roadsides	Medium	Suspended Sediments elevated, nutrients, BOD, slightly elevated (TSS >100 in June, 2005 when levels upstream of town not elevated)	High suspended solids; likely nutrients and BOD elevated; negative effects on benthic life
Metals mines, natural sources upstream	Unknown; leaching	Medium	Cu, Mo, Zn at very low levels from upstream areas	May have minor impact on aquatic life
Small-scale industry (food processing, vehicle maintenance) in Meghri	Direct discharge (not confirmed)	Medium	Nutrients: High nitrate levels, BOD likely elevated, but data doesn't reflect a problem; and O2 not high	Likely nutrients and BOD: none confirmed
Channel constriction	Highway and roads in town along river	Low—not a broad valley	Observations without data	Increase velocity and erosiveness of flow

WATER BODY: Meghriget River, Middle Reach (this is from confluence of Kaler, Ayriget and Tashtun to upstream end of Meghri town) BASIN: Meghriget

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Mining wastewater (Lichvaz area or other)	Direct discharge of tailings, leaching from adits or old mine wastes	High	Levels of mercury and Cu elevated above upstream background (note Cu in Meghri 10x higher than in Lichq)	Not known, may affect aquatic life; human risk unknown
Abstraction of irrigation water	Diversion dams	Seasonally High (Aug-Sept)	Flows reduced in late summer—as low as 0.2 m3/sec	May affect fish habitat, water temperature

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Agriculture-crops and livestock	Runoff	Medium	Nutrient (NO3) levels high	Minimal---O2 high due to re-aeration of fast-flowing stream
Village domestic wastewater	Direct discharge, runoff, leaching	Low	Nutrient (NO3) levels high	Minimal---population low
Road, pipeline infrastructure & construction & maintenance	Runoff and erosion	Low	Increased turbidity from suspended sediment in stream likely.	Minimal

WATER BODY: Tashtun/Lichq Tributaries to Meghriget BASIN: Meghriget

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Agriculture-crops and livestock	Runoff	Low	Nutrient (NO3) levels high	Minimal---O2 high due to reaeration of fast-flowing stream
Village domestic wastewater	Direct discharge, runoff, leaching	Low	Nutrient (NO3) levels high	Minimal---population low
Abstraction of irrigation water	Small diversion dams	Low	None	Minimal

WATER BODIES: Kaler/ Ayriget Tributaries to Meghriget BASIN: Meghriget

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Agriculture-crops and livestock	Runoff	Low	None	Minimal---O_2 high due to reaeration of fast-flowing stream
Abstraction of irrigation water	Small diversion dams	Low	None	Minimal

WATER BODIES: Karavget-Sherneglukh/Malev/Astazurget/Shavriz-Suriget/Nuvadi/Tondirget BASIN: Meghriget (tribs to Araks)

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Agriculture-crops and livestock	Runoff	Low	None	Minimal – O_2 high due to reaeration of fast-flowing stream
Abstraction of irrigation water	(Pumped Water from Araks)	Low-surface water ephemeral	None	Minimal

WATER BODY: Karchevan BASIN: Meghriget (Agarak area-drains to Araks)

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Mining waste	Direct discharge of mill waste, erosion of tailings in floodplain	High	Extremely high suspended solids, turbidity. Levels of Mo and Cu elevated above upstream background	Likely damage to aquatic life; human risk unknown
Agriculture-crops and livestock	Runoff	Medium	Nutrient (NO_3) levels high	Not known

Pressures:	**Pathways:**	**Suscept-ibility:**	**State (supporting data):**	**Impacts:**
Stormwater and solid waste from Agarak town	Direct discharge, runoff, leaching	Medium	Nutrient (NO_3) levels high; BOD likely an issue	Not known
Abstraction of irrigation water	Diversion	Seasonal: Medium	No data. Stream dries up in winter	Not known

5. Bibliography

EU WDF, 2008, "Priority Toxic Substances," see website: http://ec.europa.eu/environment/water/water-framework/priority_substances.htm

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Water Resources Handbook, Larry W. Mays, Author, Published by McGraw Hill, 1996.

GUIDELINE 4.2: PRESSURES AND IMPACTS ON GROUNDWATER RESOURCES

1. Introduction

1.1 Purpose of this Guideline

This Guideline explains how to identify and describe ground water resource problems in a logical way. It assists the river basin manager in analyzing how distinct land use and development pressures affect ground water aquifers, including water quality and water withdrawal (abstraction) issues, and in deciding how to design solutions for these ground water resource problems.

1.2 Role of this Activity in River Basin Planning

The analysis of pressures and impacts on ground water is similar to the surface water pressures and impacts analysis. Ground water analysis is a key step in the river basin planning process. Ground waters in Armenia are a key source of drinking water, and are used for irrigation and industry in some cases. Ground waters are inter-related with surface waters due to the ground water-surface water connection. The analysis of pressures and impacts is a diagnosis of the potential sources of problems with ground water. It prepares the planner for the development of a prioritized program of measures to address specific components of those problems or issues. The pressures and impacts analysis can be visualized as an analysis of the "components of each ground water resource problem". It fits into the river basin planning process in the following way:

- Characterization of River Basin: a description of natural and human resources, with identification of general water resource issues
- Delineation, classification and evaluation of status of all water bodies in basin
- Setting environmental objectives for each water body in the entire basin management area (surface water and ground water)
- Analysis of anthropogenic pressures and environmental impacts on each water body including surface water, **and ground water bodies**
- Development of a program of measures (projects and policies) to address the specific negative impacts on water resources in the basin

2. Technical Approach

2.1 Methodology: Background and Justification for Method

The Guideline is based on a conceptual model used by the European Union Water Framework Directive (EU WFD) called: "Driver-Pressure-State-Impact-Response (DPSIR)." This approach is outlined in the EU WFD Guidance No. 3: "Analysis of Pressures and Impacts," EU, published in 2003 (see:
http://circa.europa.eu/Public/irc/env/wfd/library/framework_directive/guidance_documents

The DPSIR is a means of logically structuring the relationship between human development pressures and the impacts on the water environment. It provides an initial scope of pressures related to human activities, and requires the basin planner to clarify how each type of pressure is affecting water resources in their area. It is important to understand that the analysis includes human activities which affect both groundwater quality, and water quantity (abstraction for use). The basic EU WFD concept is that objectives for ground water bodies should seek 1) good chemical status (non-polluted); and 2) a balance of withdrawal (abstraction) and recharge. Therefore the pressures/impacts analysis seeks to identify negative impacts and suggest ways to alleviate them, in order to achieve these objectives.

2.2 Data Requirements

The pressure and impacts analysis requires a broad understanding of all human activities in the river basin which can affect ground water, an ability to quantify those pressures, and access to monitoring data which allows the basin planner to evaluate whether the likely impacts are actually causing impacts in the ground waters of the basin. Specific types of data required include:

- Land use data in a format which permits analysis by water body (usually GIS layers), especially agriculture, forestry, pasture, industrial and urban areas
- Inventory of water use by sector and by specific industries in the basin
- Inventory of specific industries and their capacities and practices, including chemical substances likely to appear in their wastewater discharge
- Inventory and mapping of crop and livestock production, and understanding of cultural practices (e.g., fertilizers and pesticides used)
- Urban areas, building and road densities, populations, wastewater and stormwater system characteristics
- Inventory of water use permits and wastewater discharge quantities and quality, and composition and concentrations of pollutants in discharges
- Status of river channels, reservoirs, other hydraulic infrastructure and its capacities and relationship to groundwaters.
- Relationship of groundwater to wetlands or other surface waters.
- Monitoring data on water resources including physical-chemical data, and water withdrawal (pumping) data.

2.3 Sources of Data

Much of the data required for pressures and impacts analysis should be collected as part of the river basin characterization, the first step of the river basin planning process. The pressures and impacts analysis requires that this data be organized and quantified in a structured way, to indicate what types and approximate dimensions of surface water impacts are expected. The main sources of these data should include:

- GIS data from State Water Cadastre (Armenia WRMA)
- Land use data from Marz Territorial Administration
- Agricultural data from Ministry of Agriculture and Marz agricultural department
- Industrial data from State Registry of Organizations, Armenia National Statistical Service
- Demographic data from National Statistical Service
- Water systems management data from State Committee on Water Systems, Ministry of Energy, and Public Services Regulatory Commission
- Water use permits from WRMA and Basin Management Organization files
- Water systems use permits from PSRC
- Water quality data from the Environmental Impact Monitoring Centre (EIMC) and Inspectorate of Hygiene and Epidemiology, Ministry of Health
- Flow and temperature data for rivers from Armenia State Hydromet
- Hydrogeologic data from Armenia Republican Geological Fund

2.4 Explanation of Analysis Procedure

The DPSIR pressures and impacts analysis is based on the following definitions:

1. ***Driver*** - Anthropogenic activities which affect water resources (e.g. population growth, agriculture, transportation, industry)

2. ***Pressure*** - Direct effects of drivers (e.g. discharge of pollutants, abstraction of water)

3. ***State*** – Physical or chemical condition measured in water resource (e.g. level of contamination, change in water level, loss of spring flow or winter river flow)

4. ***Impact*** – Effect on water users and ground water dependent ecosystem (spring, wetland, if any)

5. ***Response*** - Proposed actions (measures) to reduce impacts by altering drivers or pressures

In actual practice, the focus of the analysis is on the pressures and the impacts – hence the name of the method. But often the actual human or ecological impacts are obscure or undetermined. The "state" is more easily measured – for example water quality data—and the resulting impacts are inferred as risks caused by the state of the water resource. This linkage of state and risk of impact is the justification for most water quality standards, minimum flow standards, or biological standards (diversity indicators, etc.). The human or ecological impacts are assumed to occur, or be at risk of occurring, because of established relationships published in the literature of epidemiology or aquatic ecology.

Vulnerability of the groundwater bodies (aquifers) is also an important factor in pressure/impact analysis. Geology, depth to water and soils are important factors in determining vulnerability of ground waters to pollution. Shallower groundwater, lack of a protecting layer, porous soils (sand or gravel or boulders), or limestone geology all can increase the vulnerability to the penetration of pollutants from the land surface.

The general process for pressures and impacts analysis is diagrammed in the flow chart in Section 3 of these guidelines. Population increases, change in land use intensity, or economic activities are the overall greatest driving forces which affect ground water resources. If population, land use intensity, or raw materials processing (e.g. industry, mining) are increasing in a river basin, the potential for groundwater resource impacts is also increasing. Driving forces are related to groundwater resource impacts as follows:

IMPACTS: DIFFUSE POLLUTION

1. Land Use Intensification: Diffuse (non-point) pollution increases as the proportion of land use in the sub-basin shifts from natural forest>commercial timber>grazing land>cropland>urban residential>industrial/commercial. Each change in land use tends to increase concentration of sediment, nutrients, and other contaminants in diffuse runoff. It is expected that these contaminants will cause an proportional increase in nitrates, and possibly other contaminants in ground water as land use intensifies ANALYSIS: Prepare land use chart by sub-basin.
2. Urbanization (non-point source): Increasing density of residential land use in an urban area increases quantity of excess stormwater runoff and concentration of contaminants. Commercial and industrial areas usually have even higher impervious surface ratios, which increases potential for diffuse pollution. If stormwater injection wells or leaky stormwater pipes exist, groundwater may be affected. ANALYSIS: If urban land use is >5% of a sub-basin, map location and density of use (residences per hectare).
3. Agriculture (non-point source): Increased intensity of agriculture from grazing>crops>confined livestock (pigs, poultry, dairy, feedlots) increases risk of nutrient pollution to groundwater bodies, and potential for pesticide contamination. ANALYSIS: Map agricultural land uses, with focus on intensively farmed, high fertilizer and pesticide input crops or confined livestock facilities.

IMPACTS: POINT-SOURCE POLLUTION

4. Industry (point source): Wastewater discharges from industry are a key risk for groundwater quality (chemical contamination, including volatile organic compounds and nutrients). ANALYSIS: Use water permits, business inventories and known un-permitted discharges from large manufacturing/ processing industries and small businesses (petrol stations, automobile maintenance, repair and painting, car washes, dry cleaning, tanning, food processing, etc.) to map their locations relative to sub-basins. For example, dry cleaning uses solvent (tetrachloroethylene or perchloroethylene) which is a potent carcinogenic contaminant of groundwater, especially drinking water supplies.
5. Municipal wastewater and other sanitation disposal technologies: Wastewater from sewered towns and waste streams from septic systems and pit latrines can be major sources of fecal coliform bacteria and other pathogens, BOD, nutrients, toxic ammonia and other pollutants to ground water, especially in poorly functioning systems. The percentage of population using sewers, latrines or other sanitary disposal is important to know.

ANALYSIS: Quantify population on sewers and other sanitation systems and map key discharge locations.

6. Mining: Metals mining is a high-risk activity for water quality due to complex multiple sources of discharge: mine drainage, mill processing sites, and tailings are all potential sources of sediment, toxic heavy metals, and acidity among other contaminants. Metals mining operations can contaminate surface water and ground water, especially in areas where surface water and ground water interact. ANALYSIS: Map location and dimensions of historical and current mining operations.

IMPACTS: ABSTRACTION OF GROUND WATER

7. Abstraction of groundwater is a key issue because recharge of groundwater bodies is often slow or difficult to quantify. Water diversion and consumptive use by irrigated agriculture, municipal and industrial ventures can alter or diminish groundwater aquifers. ANALYSIS: Compile data on well yields, and total seasonal pumping from groundwater aquifers, also data on historical water levels in wells. Ground water water balance of aquifers within the basin and sub-basins are very valuable if they exist, or have been created by the river basin planning team.

IMPACT: WETLAND ECOSYSTEMS

8. “Wetlands” is a generic collective term used to describe a great diversity of ecosystems worldwide whose formation and existence is dominated by water. Wetlands are often sustained by groundwater inflows. Other wetlands can be key areas of groundwater recharge. Alteration of groundwater balance under a wetland can cause that wetland (or even a river) to dry up. The primary functions and value of wetlands includes providing habitats for fishing, hunting, waterfowl, timber harvesting, aquifer recharge, wastewater assimilation, water quality filtering, flood control, water and nutrient storage, chemical transformations of Nitrogen, Phosphorous, Sulfur, and Carbon with storage of vast amounts of Carbon as peat due to low decomposition rates.
   ANALYSIS: Map locations of wetlands and make special note of those wetlands which appear to be sustained by groundwater inflows, including the size and type of aquifer providing that inflow.

General Analysis Procedure: Review groundwater quality and hydrogeologic monitoring data, consult hydrologists and other experts with local knowledge, and make field trips to view water resource conditions and interview local water users. This will allow the basin planners to determine the most obvious state and impact changes to groundwater in each part of the basin. These observations should then be compared to the driving forces and pressures to see if there is a clear correspondence between types of pressures and types of impacts. If expected impacts are not seen, then pressures are not significant or monitoring is insufficient to note actual changes in state or impact of the water resources. If impacts are noted but pressures creating these impacts are complex or unclear, then further work is required to quantify and prioritize likely pressures. Examples of how to relate noted changes in state and impacts to possible pressures are shown in the table below:

STATE/IMPACT:	PATHWAY OR PROCESS:	POSSIBLE PRESSURES:
Elevated nutrients (especially nitrates NO_3) in aquifers; Risk to drinking water sources; also an indicator of other possible contaminants	Diffuse runoff infiltrating to aquifers in recharge zones, ponds or porous soils overlying shallow aquifers Point-source discharges infiltrating to groundwater through porous soils overlying shallow aquifers or ponds connected to groundwater; also recharge wells	Fertilizer and manure from croplands; agricultural drainage; urban storm water runoff. Municipal wastewater; industrial wastewater

STATE/IMPACT:	PATHWAY OR PROCESS:	POSSIBLE PRESSURES:
Increased acidity/soluble metals risk to drinking water	Direct runoff from mines to ponds or streams recharging groundwater; tailing ponds infiltrating to ground water Leaching from mine tailings into porous soils above shallow aquifers, or through surface waters to groundwater	Underground or pit mines; Tailings ponds Mills; mine tailings
Elevated heavy metals, risk to human drinking water	Diffuse runoff infiltrating in ponds or recharge zones Drainage, point-source	Urban stormwater from roads. Mills; mine tailings.
Pesticide or other organic chemical/toxicity to humans' drinking water	Irrigated crop runoff Leaching	Agricultural crop production runoff. Agricultural drainage systems, irrigation return flow storage ponds. Agricultural storage areas, chemical storage or manufacturing sites, Organic solvent use (cleaning or degreasing etc.)
Depleted or drained wetlands / loss of wetland species and function and loss of buffer zone value to humans	Pumping or agricultural drainage system construction Urban development	Agricultural drainage schemes; filling in of wetlands
Lowering water table, aquifer depletion, land subsidence	Over-pumping of aquifer relative to recharge potential	Excessive irrigation pumping

In summary:

1) Identify the drivers/pressures on groundwater bodies in each sub-basin from basin characterization work.
2) Use field trips, interviews and monitoring data to determine changes in state of groundwater resources, and impacts if known or suspected.
3) Estimate susceptibility (vulnerability) of ground water body to each impact qualitatively. Susceptibility is related to type of aquifer (shallow non-pressure aquifers and limestone aquifers are two highly susceptible types), interaction with surface waters, type of recharge zones, soils overlying aquifers (more porous, coarse soils like sands/gravels are more vulnerable to penetration), and depth to water (deeper aquifers are usually safer). Use high/medium/low identifying levels.
4) Rank the pressures in terms of relative importance to each water body.
5) If possible quantify changes in state/impact: concentrations of pollutants, historical change in aquifer levels measured in wells.
6) If the situation is complex, consider a further study or model to estimate the relative contribution (e.g. load of contaminants) of different pressures to the total impact. Modeling may be necessary, but is beyond the scope of this Guideline.

2.5 Type and Format of Output Data

The output of the pressures and impacts analysis will be a matrix of information, with each water body within the basin given its own section of the matrix.

GROUND WATER BODY: **BASIN:**

Pressures:	Pathways:	Susceptibility (high, medium, low):	State (supporting data):	Impacts:

2.6 Computer Programs or Other Analysis Aids

It is extremely helpful to have access to reliable maps, and particularly to good GIS layers to assess the potential pressures. Types of maps are mentioned in the input data section.

Susceptibility to problems is related to hydrologic and geologic factors which make a ground water body vulnerable or resilient to pressures, and the degree of protection afforded by existing policies.

High susceptibility means that those pressures should be rated as high priority. Medium susceptibility means those pressures are rated lower, and so on.

See the classification of aquifer types (groundwater delineation/classification guideline) for general susceptibility to pollution. In general deeper aquifers are more resistant to pollution pressures than shallower aquifers. Pressure aquifers are better protected than non-pressure aquifers (unless you are in the recharge zone). Fine soils (clays) overlaying aquifers are better filters for contaminants than coarse sandy or gravelly soils with rapid infiltration.

3. Diagram of Approach (Flowchart for Pressures and Impacts Analysis)

Describe the driving forces most prevalent in the river basin, and particularly those which geographically coincide with the various groundwater bodies. Identify and quantify, if possible, the particular pressures which exist and are associated with those driving forces. Note particularly any pressures generating priority toxic substances (see EU reference in bibliography).

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Locate the key areas of use (pumping) of the groundwater body. Specify which pressures occur within different zones of influence of the wells, for example within 100 meters, and within 500 meters of the wells. Estimate the dimensions of these pressures.

For pumping (over-exploitation pressure), locate the areas where aquifer depletion (drop in historical levels) are most severe, and areas where pumping is expanding.

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Rank the pressures on each groundwater body, in light of its susceptibility, and the quantification of pressures.

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Assess the changes in state/impacts on groundwater resources (using field visits, interviews, monitoring data), and outline potential impacts. Check for priority toxic substances in monitoring data, and in local industrial use. Quantify the impacts as possible with data.

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Compare actual changes in state and impacts to what is expected. Look for new drivers and pressures if necessary. Change priorities of pressures if data includes new information. Outline needs for developing further monitoring data or doing specific studies required to quantify risks to human health.

4. Example of Method (applied to Meghriget River Basin)

The application of the pressures and impacts analysis for groundwater to the Meghriget River Basin in Southern Armenia is based primarily on information included in the River Basin Characterization Synthesis Report for Meghriget, complemented by field visits, interviews with stakeholders and with the Southern Basin Management Organization (BMO). Delineation of groundwater bodies was done by Geocom, a consulting firm. Driving forces are primarily large and small-scale mining, and irrigation.

From the Table 3 in the Guideline 2.3 – Classification of groundwater resources, it is clear that the most vulnerable groundwater sources in the Meghriget river basin are the aquifers of alluvial-colluvial origins: lower section of Meghriget River (№1), lower section of Karchevan River (№2), Alvanq (Aldara) kyahrizes (№3), Shvanidzor kyahrizes (№4) and Nrnadzor (Nyuvadi) kyahrizes (№5). For those underground water bodies the main pressures and impacts could be identified as following:

WATER BODY: №№1, 2, 3, 4 and 5 **BASIN: Meghriget**

Pressures:	Pathways:	Suscept-ibility:	State (supporting data):	Impacts:
Mining waste	Direct discharge of mill waste, erosion of tailings in floodplain	High	Extremely high suspended solids, turbidity. Levels of Mo and Cu elevated above upstream background	Likely damage to aquatic life; human risk unknown
Metals mines, natural sources upstream	Unknown; leaching	Medium	Cu, Mo, Zn at very low levels from upstream areas	May have minor impact on aquatic life
Solid waste & storm water in Meghri town	Leaching and direct runoff from roadsides	Medium	Suspended sediments elevated, nutrients, BOD, slightly elevated (TSS >100 in June, 2005 when levels upstream of town not elevated)	High suspended solids; likely nutrients and BOD elevated; negative effects on benthic life
Agriculture-crops and livestock	Runoff	Medium	Nutrient (NO_3) levels high	Not known
Storm water and solid waste from Agarak town	Direct discharge, runoff, leaching	Medium	Nutrient (NO_3) levels high; BOD likely an issue	Not known
Abstraction of irrigation water	Diversion	Seasonal: Medium	No data. Stream dries up in winter	Not known

5. Bibliography:

EU WDF, 2008, “Priority Toxic Substances,” see website: http://ec.europa.eu/environment/water/water-framework/priority_substances.htm

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GUIDELINE 4.3: IDENTIFY DATA GAPS AND DESIGN MONITORING PROGRAM

1. Introduction

1.1 Purpose of this Guideline

This guideline should assist the Basin Management Organizations in identifying the instances where they need more information on water quality and water quantity to improve river basin planning. The identification of data gaps focuses on what types of water resource problems have been identified, and evaluation of whether there is sufficient data to understand their causes, and to design solutions to those problems. Monitoring design focuses on defining what type of additional water resource information is necessary to collect in the field to proceed with rational river basin planning.

1.2 Role of this activity in River Basin Planning

This activity is part of the problem diagnosis (pressures/impacts) phase of river basin planning. It should be done immediately following the pressure and impacts analysis, and before the program of measures. The pressures/impacts analysis will be helpful in identification of data gaps, because it will help the basin planner see what types of pressures exist, and decide whether there has been sufficient monitoring to detect and define the impacts of those pressures. Designing a supplemental monitoring plan is necessary in most river basin management exercises, because sufficient data to understand thoroughly the basin water resources problems are almost always lacking. In fact, further monitoring studies on the source and causes of water resource problems will probably be included in almost every “program of measures.”

2. Technical Approach

2.1 Methodology: Background and Justification

In general the methodology of the river basin planning guidelines is based on the EU WFD (see EU WFD, 2004, “Policy Summary to Guidance Document No. 7: Monitoring under the Water Framework Directive.”). The Directive requires characterization of river basins, including status of all surface waters and groundwater bodies, based on monitoring. The Directive also recommends further monitoring for purposes such as:

- Assessment of long-term changes, both natural and those due to human (anthropogenic) activity;
- Estimating flows and pollutant loads to surface water;
- Ascertaining causes for water bodies not meeting environmental objectives;
- Assessing quantitative status (balance of recharge/discharge) of groundwater bodies;
- Assessment of changes in groundwater status due to pollutants;
- Detection of new or unknown pollutants in groundwater.

In general these purposes are accomplished by three types of monitoring[2]:
1) surveillance monitoring, in which conditions over a large area (many water bodies) are quickly assessed; 2) operational monitoring, in which established monitoring networks are systematically sampled to reveal changes in status and trends (general-purpose or reference monitoring); and 3) investigative monitoring, in which particular problems identified are studied in-depth.

2.2 Data Requirements

Assessment of data gaps and design of monitoring programs requires several types of data:

1) Water quality and flow data from existing government (EIMC, ArmState Hydromet) surface water monitoring networks.
2) Water quality and abstraction data from existing groundwater monitoring programs.

[2] In terms of groundwater chemical status, surveillance and operational monitoring are required.

3) Water quality data on discharges from private industries (self-monitoring) and businesses being monitored by State Environmental Inspectorate (compliance assurance inspection).
4) Special studies or investigations by academic or private researchers (e.g. biomonitoring or specific-purpose monitoring).
5) Special reports on water resource accidents or complaints received at level of municipal or Marz government offices.
6) Data on diversions and pumping from irrigation associations and industries.

The other type of data which must be assessed is the results of the pressures and impacts analysis (Guideline #4.1 and 4.2). This data should indicate what types of risks to water resources exist in the basin, particularly risks associated with water quality deterioration.

2.3 Where to acquire input data:

The major sources of water quality and flow data in Armenia are:

- Environmental Impact Monitoring Center/Water Resources Management Agency
- State Environmental Inspectorate
- Republican Geological Fund[3]
- Armenia State Hydrometeorological Service

2.4 Explanation of Analysis Procedure

The analysis of data gaps in the river basin planning process is as follows:

1) Characterization of river basin: this includes basic information on flows and water quality, a water balance, and geologic hazards, with a summary of potential basin water resource issues. Issues point to the need for information to describe those issues in detail.
2) Delineation and Classification of Water Bodies (surface and groundwater).
3) Evaluation of the Status of Water Bodies (surface and groundwater): Evaluation requires reviewing all available data for designated water bodies, to determine which a) have documented water quality problems; b) have documented flow or water balance problems; c) have major hydro-morphological or biological alterations. If data exists, then these surface water and groundwater bodies are evaluated as to their ecological status. If sufficient water quality and flow information to evaluate does not exist, then doing broader surveillance monitoring to fill in data gaps for various water bodies is recommended.
4) Pressure and Impact Analysis: Determination of particular human activities causing possible negative impacts on quality and quantity of waters. If activities with high probability of negative impact are noted, but data are not sufficient to describe the actual impact, then further surveillance monitoring will be done to describe the actual impacts. If partial data indicate that high-risk impacts are possible, such as severe risks to human health from toxic contaminants, then an in-depth risk assessment study may be warranted, including detailed social, environmental and epidemiological studies (investigative monitoring).
5) Program of Measures Assessed and Prioritzed: In the last stage of river basin planning, the need for more long-range monitoring of trends and status will be evaluated (reviewed). The existing operational monitoring program and network will need to be evaluated, and selection of new sites and new parameters added to improve the long-term program.

In summary, the assessment of data gaps should reveal:

- Need for new surveillance monitoring to establish status of unmonitored water bodies, and explore possible impacts which have not been confirmed.
- Need for investigative monitoring of serious risks, to clarify what are the sources (causes) of risk, what are the processes which transmit that risk to the population or the environment, what are the levels of exposure to the risk in the population, and what are

[3] At present, under the coordination of the RA Ministry of Energy and Natural Resources

the dimensions of possible impacts to health of human population (public health) or the environment.
- Need for expanding the long-term operational monitoring to provide information about changes in status of water bodies.

The design of each further monitoring element must follow a logical sequence:
- Determination of specific objectives for monitoring.
- Determination of which water bodies will be sampled.
- Determination of relevant parameters, sampling frequency, and analysis methods (design Sampling and Analysis Plan).
- Development of budget and manpower estimates to realize sampling.
- Coordination of logistics and execution of monitoring, including data management.

Often it may prove necessary to use an external specialist to design a statistically sound sampling and analysis plan, especially for operational and investigative monitoring. The EU Water Framework Directive is clear that monitoring of environmental objectives must include both physical-chemical and hydro-morphological indicators, as well as biological indicators of ecological status. In Armenia's case the biological monitoring mechanisms remain to be designed, therefore the physical-chemical and hydro-morphological elements are the only quantitative indicators to date.

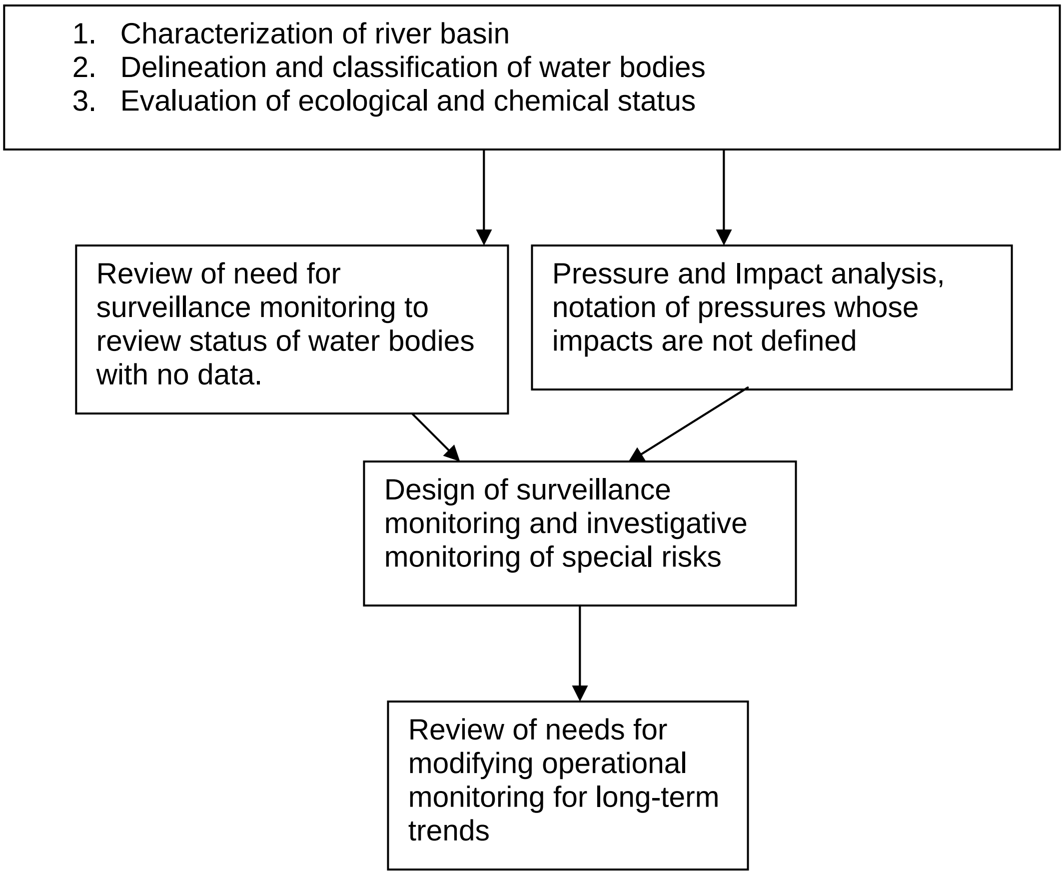
INDICATORS ASSOCIATED WITH VARIOUS TYPES OF PRESSURES

Pressures (Activity):	**Indicators:**
Municipal wastewater	BOD5, Ammonia, nutrients (N and P), coliforms
Stormwater runoff	Turbidity, nutrients, metals
Industrial wastewater	Temperature, COD, BOD5, TDS, metals, turbidity, solvents (organics)
Irrigation return flows	Salts (TDS), sediment, some metals (e.g. selenium)
Agricultural runoff/erosion	Sediments (TSS), nutrients (N and P), organic pesticides
Livestock	Nutrients (N and P), ammonia, sediments, turbidity
Mining wastewaters	Acidity (pH), heavy metals, color, turbidity or TSS
Construction/ transportation	Sediments (TSS), oils and grease, salts (TDS), metals, solvents

2.5 Type and format of Output data:

Monitoring programs should be defined by type (surveillance, operational, and investigative), and each recommended program should be outlined to include, as previously mentioned, the following elements:
- Specific objectives for monitoring
- Water bodies to be sampled
- Relevant indicative parameters, sampling frequency, and analysis methods
- Budget and manpower estimates to realize sampling
- Coordination of logistics and execution of monitoring, including data management

3. Diagram of Approach



4. Example of Application of Method to Meghriget River Basin

4.1 General Analysis

The Meghriget River basin has been characterized, with the major drivers of potential impacts on surface waters being localized mining and ore processing and small-scale agriculture. The river has been separated into five major water bodies. Evaluation of status of those water bodies shows that occasional exceedances of nutrients and BOD occur in all sampled water bodies both upstream and downstream in the basin, and exceedances of some metals, including copper, aluminium, zinc and other metals occur frequently. These exceedances cause the WQCI for these sites to vary from moderate to good. Meanwhile, in water supply, irrigation water shortages in Meghri (region) are frequent in August-September due to high demand and low flows.

A close examination of the water quality data is required, and when requested, EIMC did provide detailed data on three monitoring sites on the Meghriget River. One site upstream (EIMC 89-0) is affected primarily by agricultural land uses and livestock runoff, with large areas in forest. A lower elevation site above Meghri town (EIMC 89) is influenced by agriculture, small villages, and some small-scale mining. The lowest site (EIMC 90) is downstream of Meghri town and is influenced by urban runoff, small-scale industries, raw municipal sewage, and other pressures typical of the areas farther upstream.

The water quality monitoring data show that spikes of nutrients (including nitrate and ammonia) are seen in spring-time during higher flows, and these spikes are seen in all three sampling sites, including the upstream area where only agricultural pressures are present—therefore, the source is believed to be agriculture, probably manure management. Significantly, during late summer and winter low flows, when diminished dilution water would highlight the presence of sewage, there is very little indication of significant BOD and nutrient pollution in the area downstream of Meghri town. The exceedances of metals pollution are also seen in the upstream area, indicating that background levels of some metals (e.g. copper) are above the fisheries standards. However, exceedances of metals standards are more common in the middle and lower basin, indicating that other sources of metals other than natural minerals in the water are impacting the middle and lower Meghriget River.

A single surveillance sampling run in November 2007 also detected mercury (Hg – a high priority pollutant) above the Armenia fisheries standard in the middle river, but, perhaps significantly, there was no mercury detected the same day in the upper river. This may indicate that the mercury is not a background metal, but has a distinct source.

4.2 Operational Monitoring

After review, the existing EIMC operational sampling on the Meghriget River is sufficient and useful, and should be maintained. This includes three (3) sampling points and at least quarterly sampling for over 30 parameters. However, mercury (Hg) should be added to the operational sampling program (mercury is not a parameter in current operational sampling due to the lack of specific analytical equipment at EIMC). If presence of mercury is confirmed, then an investigative sampling program should be designed and initiated to determine its source, and, if it is present, determine whether it is bio-accumulating in fish (determining content of Hg and other heavy metals accumulated in fish tissues/organs once a year).

Monitoring daily stream flows (ArmState HydroMet) in the Meghriget River should also be continued, as this data is key to working out the water shortage issues in the lower Meghriget basin.

In the Karchevan River, near Agarak, there is no current EIMC operational monitoring program (sampling point). However, this area has some severe water quality issues—especially high turbidity/color and suspended solids, and some associated nutrients and metals. The following operational monitoring program is recommended:

- **Objectives:** Determine the severity, frequency, and source of water quality standards violations in the Karchevan river.
- **Location:** Karchevan river **upsteam of Agarak** (above all minerals mining and processing areas), and **downstream of Agarak** near the main highway bridge.
- **Relevant Indicator parameters**: Total suspended solids, total dissolved solids, pH, and full suite of nutrients and metals used by national EIMC monitoring program (but add mercury--Hg). Flow should also be monitored here to understand pollutant loads.
- **Budget and manpower:** these sampling two sites can be added to EIMC's quarterly monitoring program. The additional estimated cost for one year of quarterly monitoring: ~$1500 (including additional mercury sampling/analysis, see above). This potentially a major source of pollution to the international Araks River, and may be able to leverage resources from projects related to Araks River management.
- **Coordination of logistics and execution of monitoring,** including data management: EIMC is the recommended institution to do this additional monitoring, given that they already have personnel traveling to the Meghri area (only a few kilometers away) on a quarterly basis. Data from this operational monitoring and all annual reports of EIMC for Southern Basin, need to be provided to the BMO (by WRMA – primary recipient of complete monitoring reports).

Groundwater monitoring (local network and special sampling point) in the Agarak area should be considered for inclusion in the operational monitoring program of Hydrogeological Monitoring Center/EIMC, due to some large capacity pumping wells in the immediate vicinity of Agarak, as well as potential pollution sources of the aquifers from copper-molubdenum mining/ore-processing.

GUIDELINE 4.4: IDENTIFICATION OF A PROGRAM OF MEASURES

1. Introduction

1.1 Purpose of this Guideline

This Guideline explains how to develop a program of measures for improving surface water and groundwater status in a river basin. The measures are proposed policies, educational programs, and infrastructure investments which address specific water resource problems in specific water bodies. The Guideline assists the river basin manager in deciding what mix of activities will best address the known causes of issues such as pollution, depletion of waters, and loss of healthy aquatic ecosystems in specific water bodies, and prevention of similar negative impacts on other water bodies.

1.2 Role of this Activity in River Basin Planning

The identification of measures is the culmination of the diagnostic phase of river basin planning; it is the development of the proposed priority actions for the river basin. The identification of measures follows, and is based directly on the pressures and impacts analysis, which should have clarified the most important sources and root causes of various water resource problems. It is critical that this pressures and impacts work be well done; otherwise the program of measures may be badly oriented. It is also important to realize that for some water bodies, and some impacts, a clear set of recommended remedial measures cannot be developed with the existing data. Frequently, more study is required to clarify complex problems, and these studies become part of the program of measures.

2. Technical Approach

2.1 Methodology

This Guideline is based on the conceptual model of the EU WFD, including the “Driver-Pressure-State-Impact-Response (DPSIR)” model. The program of measures is the set of “Responses” in the DPSIR approach. According to the WFD approach measures should include:

- measures to promote an efficient and sustainable water use;
- measures to safeguard water quality, particularly drinking water quality;
- controls over the abstraction of fresh water from surface waters and groundwater;
- controls on artificial recharge of ground waters;
- emission controls for point-source pollution;
- measures to prevent and control the input of diffuse source pollutants to all waters;
- measures to ensure that hydro-morphological conditions are consistent with achievement of good water status in surface waters;
- prohibition of direct pollutant discharges into groundwater;
- measures to eliminate the pollution of surface waters with priority toxic substances;
- measures to prevent the loss of pollutants due to accidents such as floods

The elaboration of the program of measures is a participatory process. In order to develop feasible measures, the key local stakeholders must be involved. Measures need to have broad support, and political backing, to succeed. The river basin planner needs to assure that local authorities understand the pressures and impacts analysis, and articulate clearly what measures should be undertaken.

2.2 Data Requirements

The program of measures is built on all the prior analysis done in the river basin plan. To successfully develop a rational, feasible program of measures, the river basin planning process requires:

- Full characterization of the river basin, and inventory of its water bodies
- An evaluation of the ecological status of all surface waters, and the chemical status and water balance of all aquifer groundwater bodies.

- A clear definition of environmental objectives for each water body.
- A complete pressures and impacts analysis for surface waters and groundwater.

These are all products of prior phases of river basin planning. The elaboration of measures also requires information about what water resource projects or programs are ongoing or planned in the basin, so that the program of measures is integrated into ongoing programs.

2.3 Sources of data

One main source of input information to the process of elaboration of program of measures is the previously mentioned sections of the river basin plan. The other main source of input to the program of measures is the detailed information on existing and proposed development and environmental programs that may affect water resources, brought to the table by the participants in the planning process. These participants should include:

- Local government officials: Marz staff dedicated to planning, economic development, and resource management
- Representative village leaders involved in water resource management
- Water user association leaders
- Private industry representatives involved in the water sector
- NGO representatives concerned about water, environment, and health
- Ministry of Nature Protection staff from WRMA, EIMC, SEI, and other agencies
- Ministry of Health staff

These stakeholders also will bring other new types of information to the discussion of possible measures, such as opportunities and constraints for all types of measures, including legal constraints and opportunities, financial constraints and opportunities, and social constraints and opportunities.

2.4 Explanation of Procedure

The elaboration of a program of measures needs to be both a rigorous, structured process and a creative process. The river basin planners need to make sure that there are structured responses (proposed measures) for every major impact in every water body in the basin.

Commonly, certain impacts are common throughout a river basin, affecting multiple water bodies, and the proper response to that issue, are general measures that cover the entire river basin. For example, certain sources of pollution, such as livestock, may be generally problematic throughout the basin, and require certain basic measures to prevent water resource degradation.

The process of developing a proposed program of measures for each water body in the basin is as follows:

1) Review pressures and impact analysis for completeness
2) Make list of key stakeholders, plan and organize meeting
3) Present the pressures and impact analysis to stakeholders
4) Modify the pressures and impact analysis as necessary with stakeholder input
5) Have sub-groups of stakeholders examine pressures for specific geographic groups of water bodies
6) Use brain-storming techniques to generate options for mitigating or preventing the impact of pressures for each water body
7) Review the impacts and proposed responses in the sub-groups, and consolidate and improve the brainstormed results
8) Consolidate the work from various sub-groups, and combine measures which can be applied at a general or Marz-wide level
9) Evaluate the feasibility and relative priority of proposed measures, and develop a set of alternative measures, some of which may complement each other

At this early stage, it is important to include all reasonable proposed measures. Evaluation of the feasibility and merit and relationship of various proposed measures will take place in next steps. The purpose of the initial exercise is to generate a range of ideas from the stakeholders.

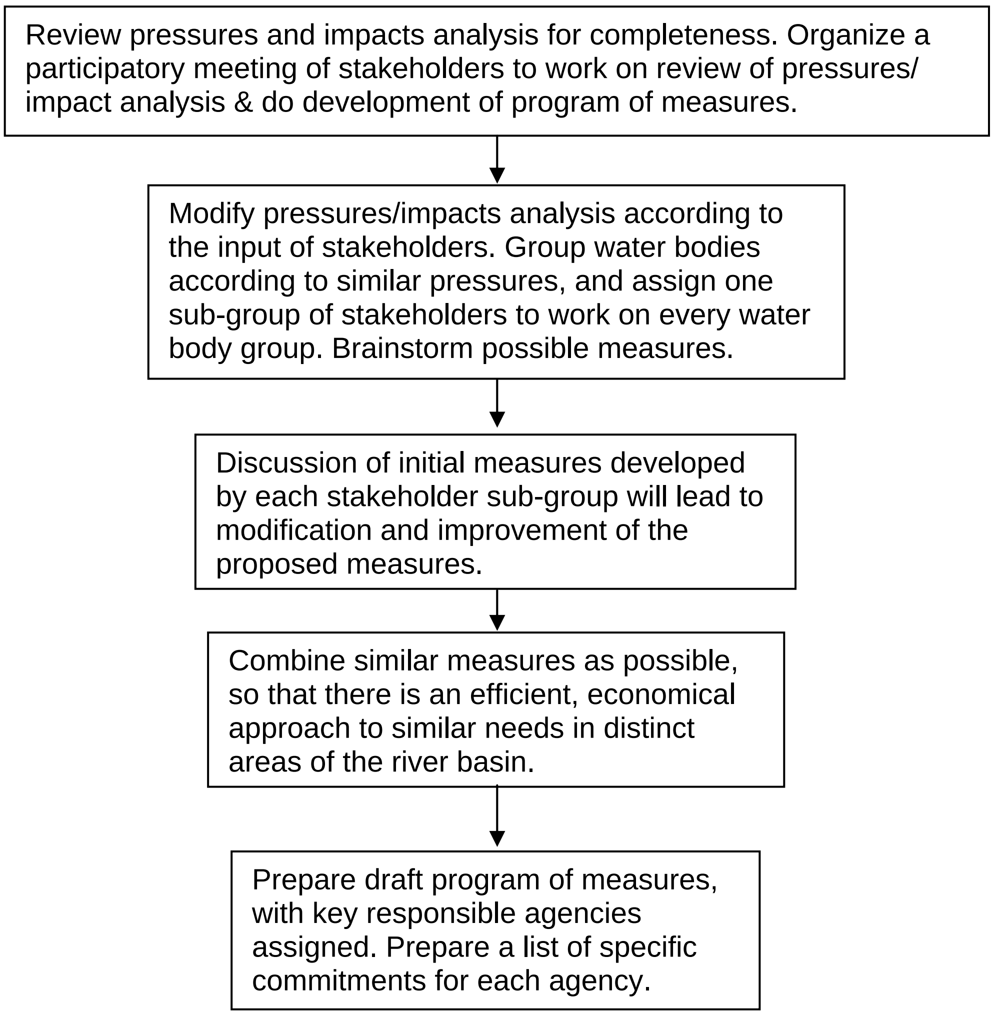
2.5 Type and Format of Output data

The initial development of measures can, at first, be tabulated using tables such as the following:

Water Body: EXAMPLE **Basin: Meghriget River**

Pressure:	**Impact:**	**Proposed Measures:**	**Responsible Authority:**
Food processing industry wastewater discharged into river	Reducing dissolved oxygen in water, causing odors	1) Reduce BOD discharged from plant using WU permit restrictions. ***2) Perform clean production audit on plant to identify ways to limit generation of waste material*** 3) Coordinate with other factories to develop a wastewater management plan.	1) BMO 2) Industry as a condition of WU permit 3) Industry

3. Diagram of Approach (Flowchart for Elaboration of Measures)



4. Example of Method (Applied to Meghriget River Basin)

The measures should be developed using a participatory process as outlined in the procedure section above. The following are examples of possible measures. Although not generated by the requisite participatory process, they provide useful examples.

Water Body: Lower Meghriget (below Meghri) Basin: Meghriget River

Pressure:	Impact:	Proposed Measures:	Responsible Authority:
Abstraction of irrigation water	Reducing flow below ecological minimum, affecting fish habitat and increasing water temperature	1) Adjust water use permits for Aug-Sept. period using ecological flow guidance. ***2) Improve water conveyance structures and reduce withdrawals in Aug-Sept.*** 3) Study irrigation storage options for upper river	1) BMO 2) Water user associations 3) Marz authorities
Municipal wastewater discharge	Ammonia toxicity to aquatic life, depressing O2 in late summer	1) Study options for simple treatment (sludge settling and simple oxidation pond) 2) Review options for re-use as irrigation water	1) Marz authorities 2) Marz authorities
Solid waste and stormwater in Meghri town	High suspended solids, nutrients, bacteria and BOD washed into river, may be health hazard and negative effects on benthic life	1) Develop solid waste management program for Meghri 2) Do annual clean-up/ education program 3) Study stormwater management options	1) Municipal authorities 2) Municipal authorities 3) Marz authorities
Small-scale industries (food-processing and vehicle maintenance)	Likely increase in nutrients/BOD; possible oil and grease	1) Review the WU Permits for nutrients/BOD 2) On-site inspection of vehicle maintenance facilities to assure safe disposal of lubricants (oil/grease)	1)BMO 2) BMO
Channel constriction in town	Possible flood hazard in Meghri town due to loss of channel capacity	1) Study flood peaks impact on channels in Meghri town (combine with stormwater study)	1) Marz authorities

Water Body: Middle Meghriget Basin: Meghriget River

Pressure:	Impact:	Proposed Measures:	Responsible Authority:
Mining wastewater	Mercury and Cu (both toxic to aquatic life) may affect aquatic life, possible risk to human health	1) Do quarterly monitoring of Hg and Cu above Meghri, various sites. 2) Review discharge permits for mining operations; inspect sites	1)EIMC 2) BMO

Pressure:	Impact:	Proposed Measures:	Responsible Authority:
Abstraction of irrigation water	Reducing flow below ecological minimum, affecting fish habitat and increasing water temperature	1) Adjust water use permits for Aug-Sept. period using ecological flow guidance. ***2) Improve water conveyance structures and reduce withdrawals in Aug-Sept.*** 3) Study irrigation storage options for upper river	1) BMO 2) Water user associations 3) Marz authorities
Agriculture-crops and livestock	Nutrient levels high	1) Review livestock and crop-management practices for runoff risks; note problem areas for educational efforts	1) Marz agriculture dept.

NOTE: Water bodies in the Meghriget Basin, other than Karchevan (see below), do not have specific measures designed for them, because the pressures and impacts are not so severe, and the susceptibility of the water bodies are estimated to be LOW.

Water Body: Karchevan **Basin: Meghriget River**

Pressure:	Impact:	Proposed Measures:	Responsible Authority:
Mining waste discharged	Mo, Cu and suspended solids elevated, likely damage to aquatic life, risk to human health unknown	1) Do quarterly monitoring of Hg Mo, and Cu below Agarak 2) Review discharge permits for mining operations; inspect sites, develop clean-up plan with company 3) Get clean production audit, and develop option for reducing wastes	1)EIMC 2) BMO 3) Agarak mining company
Mining waste deposited in floodplain areas	Mo, Cu and suspended solids elevated	1) Develop clean-up plan for wastes in floodplain of Karchevan	1) BMO with Agarak mining
Abstraction of irrigation water	Reducing flow below ecological minimum, affecting fish habitat and increasing water temperature	1) Adjust water use permits for Aug-Sept. period using ecological flow guidance. ***2) Improve water conveyance structures and reduce withdrawals in Aug-Sept.*** 3) Study irrigation storage options for upper river	1) BMO 2) Water user associations 3) Marz authorities
Agriculture-crops and livestock	Nutrient levels high	1) Review livestock and crop-management practices for runoff risks; note problem areas for educational efforts	1) Marz agriculture dept.
Solid waste and stormwater in Meghri town	High suspended solids, nutrients, bacteria and BOD washed into river, may be health hazard and negative effects on benthic life	1) Develop solid waste management program for Meghri 2) Do annual clean-up/ education program 3) Study stormwater management options	1) Municipal authorities 2) Municipal authorities 3) Marz authorities

STEP 5. REVIEW OF MEASURES

Introduction to Step 5: Review of Measures

Review of the program of measures is the fifth step in a river basin plan. The measures proposed in the preceding steps are potential activities which can help resolve water resource problems in the basin. This step involves evaluating those measures to determine which are most potentially most effective, most efficient, most environmentally sound, and in sum, highest priority. One of the key tools for evaluating the potential measures is economic analysis. Another important aspect of the review is participatory evaluation of measures. Stakeholders who understand the water resource problems in their own area, and the resources locally available for solving those problems, must be involved in selecting the most appropriate solutions. Broad participation in decision-making is a key to success at this stage of river basin planning.

GUIDELINE 5.1: ECONOMIC REVIEW OF MEASURES

1. Introduction

1.1 Purpose of this Guideline

This Guidance Document will help to make the economic analysis a reality and to:

- Know when to establish 'knowledge links' with other disciplines for the preparation of the economic analysis and the programme of measures;
- Understand which information will be needed for carrying out the analysis and to fill the gaps once they have been identified;
- Estimate costs on the basis of common definitions and in particular to identify methods for estimating environmental and resource costs.

1.2 Role of this Activity in River Basin Planning

The review of measures is a process of evaluating the program of measures, using economic criteria. With increasing scarcity of both water resources and financial resources allocated to the water sector, economic analysis and expertise is increasingly called for in supporting water management and policy decisions. Overall, a sound economic analysis can help in:

- Understanding the **economic issues and tradeoffs at stake** in a river basin – restoring water quality can impact on economic sectors that can have significant role and importance in the local, regional and national economy (be it in terms of overall economic output, trade or employment). Also, different economic sectors are often competing for the same (good quality) water resources;
- Assessing the **least-costly way** for the economy or for specific economic sectors to achieve **well-defined environmental objectives** for water resources. Clearly, this ensures best use of limited financial resources allocated to the water sector;
- Assessing the **economic impact of proposed programmes of measures** aimed at improving water status (i.e. who are the *losers*, who are the *gainers*). In some cases, this assessment may stress the need for developing specific accompanying measures that would (partially) compensate *losers*, and thus facilitate the implementation of proposed measures;
- Assessing regions or water bodies where **environmental objectives need to be made less stringent to account for economic and social impacts** in a search for overall sustainability; and
- Supporting the **development of economic and financial instruments** (e.g. water prices or supplementary measures such as pollution charges or environmental taxes), that may be effective in reaching environmental objectives.

Overall, the economic analysis is a **process of providing valuable information to aid decision-making** and should be an essential part of the overall approach for supporting decisions. The economic analysis is also a source of information of interest to stakeholders and the public in the context of information and consultation activities. For example, discussing significant water management issues in a river basin is likely to require information on who pollutes, who uses, which environmental impact occurs, but also on what it costs, who pays, who gains and who suffers from the current situation.

2. Technical Approach

2.1 Methodology: Background and Justification for Method

To support the development of river basin management plans, a three step economic analysis should be conducted. This 3-step approach aims at providing a coherent framework to the different functions of the economic analysis:

Step 1 - Characterising the river basin in terms of the economics of water uses, trends in water supply and demand and current levels of recovery of the costs of water services.
This step is directed towards assessment of economic significance of water use. The principal activities for this step include:

- Identify human pressures on water bodies;
- Localise water uses in the river basin district;
- Identify water uses and services by socio-economic sector (agriculture, industry, households and recreation);
- Assess the relative socio-economic importance of water uses;
- Identify areas designated for the protection of economically significant aquatic species.

Step 2 - Identifying water bodies or group of water bodies not achieving the environmental objectives of the River Basin (i.e. identifying gaps or risks of failure in achieving objectives).
The purpose of this step is to identify the gaps between the water status resulting from the baseline scenario and the defined environmental objectives (good water status). That process should assist in understanding of **significant water management issues** in the river basin and pave the way for the preparation of a programme of measures to address those issues.
Gap identification analysis consists of the following actions:

- Translate the forecast analysis of pressures and investments in the water sector into a forecast of impact;
- To assess the gap between the environmental objectives with respect to water status and the water status achieved with the baseline scenario and optimistic and pessimistic variations:

Gap:

- Identify water bodies where there is a gap;
- Define the main drivers of pressures (particularly, in terms of socio-economic groups) in order to facilitate the selection of appropriate measures in Step 3;
- Start identifying main options/measures likely to be investigated in subsequent steps as guide;
- Evaluate how socio-economic groups may be affected by main options/measures taken to reduce the gap.

No Gap:

- measures for complying with existing water legislation are sufficient to meet the Directive's objectives;
- In the preparatory documents, propose to confirm those objectives and the programme of measures required by existing water legislation;
- If considered necessary, estimate the costs of these basic measures and provide a first assessment of the impact of these measures on socio-economic sectors and cost-recovery

Step 3 - Supporting the development of the **programme of measures** to be integrated in river basin management plans **through cost-effectiveness analysis** and justifying from an economic point of view possible (time, objective) derogation.

This step is the key economic input into the preparation of the RBMP. It is important efforts are targeted to areas and issues required for aiding decision making. During this step there is a need to evaluate the costs and effectiveness of potential measures, construct a cost-effective program of measures, evaluate whether the costs are disproportionate and assess the financial implications of program of measures. However, this guideline doesl not provide the techniques on two latter issues, as it encompasses many complex decisional, institutional and socio-economic elements. Judgment needs to be made prior the analysis to decide whether to embark into the analysis or not. Thus, the scope of activities under this step includes:

- Identify potential measures to achieve the environmental objectives defined in the Guideline 3.3, including basic and supplementary measures;
- Estimate the costs of each measure;
- Estimate the effectiveness (environmental impact) of each measure;
- Assess and rank cost-effectiveness of measures;
- Select the most cost-effective programme of measures that can reach environmental objectives;
- Calculate range for the total discounted costs of this program;
- Undertake a sensitivity analysis to assess robustness of results.

2.2 Data Requirements

The First step will require a high level of coordination with other experts and stakeholders to build a common knowledge and representation of the River Basin. Some of the required information will be collected in the river basin characterization, but for this purpose more economic data must be collected. Key is to collect information that is relevant to water management issues in the river basin and to key economic sectors likely to be affected by the RBMP Implementation. Combining biophysical and economic information will require agreement on common spatial scale of analysis and reporting. A good understanding of regional planning issues will also be required for this step.

The Second Step economic analysis will use a high level of input from more technical analysis. However, sufficient economic elements should be provided to organise meaningful stakeholder consultation. Assessing the gap in water status is equivalent to the more rigorous assessing risk of non-compliance. Public consultation is clearly specified in this Step. It will be important to have preliminary assessments of cost and socio-economic impacts to provide a basis for consultation. Information for this Step will mostly come from other competencies at river basin level, such as from the experts in charge of determining pressures and impacts.

Given potential interaction between measures, it is important to assess by the Third Step the effectiveness of basic measures and integrate them into the cost-effectiveness analysis. Uncertainty on costs, effectiveness and time-lagged effects of measures needs to be considered in the cost-effectiveness analysis. It is worth mentioning that the economic analysis can only formulate recommendations: estimating the need for derogation will ultimately remain a political decision.

2.3 Explanation of Analysis Procedure

The primary objective of the economic analysis of water uses is (i) to assess **how important water is for the economy and socio-economic development of the river basin**, and (ii) to **pave the way for the assessment of significant water uses and analysis of disproportionate costs.**
(i) The **economic analysis of water uses** is used to construct the general economic profile of the river basin and of its key water uses and significant pressures in terms of:

- Economic analysis of water uses, e.g. collating information for significant water uses on gross income, turnover, number of beneficiaries, agricultural and industrial area or employment, etc as considered relevant;
- Stressing the importance of water for economic and regional development and the evidence of this importance provided in existing economic strategies and plans; and
- Areas designated for the protection of economically significant aquatic species, as input into the register of protected areas.

These general economic indicators will be computed at the **scale of the river basin or basin management area**. This analysis is mainly based on easily available statistics and information.

Specific approaches may be used to transform existing information (often available for administrative regions or water service areas) to the scale of the river basin or basin management area.

(ii) In parallel, the economic analysis of water uses needs **to pave the way for the assessment of the significant water uses** to be reported to the public by 2009 and related understanding of the likely tradeoffs and conflicts between socio-economic development, environment and water protection that can be fed into the public information and participation process regarding the development of river basin management plans.

The indicators computed are similar to the ones listed above, complemented with variables and indicators that are specific to the significant water uses identified for the river basin considered, e.g. cropping pattern for specific irrigated schemes that impose high pressures on water resources, turnover and main products of industrial sub-sectors that are highly polluting rivers, etc. However, the computation scale or desegregation level is the **area linked to a given significant pressure or to specific economic sectors/sub-sectors.**

Overall, the analysis should remain proportionate and not entail extensive collection of new data, i.e. dealing primarily with clear conflicts/water management issues based on information of relevance to significant water uses. The spatial scale or region at which the analysis should be undertaken will be defined by both the analysis of pressures and impacts developed for the characterisation of the river basin, and the outcome of the participation process and stakeholders input/request for specific further desegregation.

Feeding into the **identification of significant water management issues**, the analysis needs to complement the characterisation of the river basin today by an assessment of its future likely trends and baseline scenarios. This assessment is the basis for analysing the gap between likely water status and good water status (**risk of non-compliance**) and for undertaking the subsequent **cost-effectiveness analysis of measures**.

Being a joint activity between different expertise and disciplines, the specific role of the economic analysis in the development of baseline scenarios and the analysis of the dynamics of the river basin is the assessment of forecasts in **key (non-water related) policy and economic drivers** likely to influence pressures and thus water status.

Focus is likely to be on foreseen trends in (non-exhaustive list):

- General socio-economic indicators and variables (e.g. population growth);
- Key sector policies that influence the significant water uses identified in the river basin investigated (e.g. agricultural policy);
- Production or turnover of main economic sectors/significant water uses in the river basin;
- Land planning and its effects on the spatial allocation of pressures and economic sectors;
- Implementation of existing water sector regulation and directives; or
- Implementation of environmental policies likely to affect water.

Some of these forecasts will be developed jointly with technical experts (see for example the implementation of water sector directives and other environmental legislation). Complemented by analysis of changes in the hydrological cycle, e.g. for accounting for climate change, it will feed into an overall assessment of changes in key pressures, including water demand, and resulting impact on water status as key input into the identification of significant water management issues

It is important to stress that **some analyses can be organised at the territorial (Marz) or national scale** as all river basins of a given Marz or Armenia will face similar changes (this is for example the case for changes in Armenian policies such as the National Agricultural Policy). Other analyses such as changes in production and turnover of significant water uses and economic sectors will need to be developed **at the scale of the river basin or for parts of the river basin** according to the scale at which related pressures take place.

Along with results of the different components of the economic analysis, it will be important to **systematically report** on:

- Information, assumptions and approaches used for computing key indicators. It is important that this is made transparent (i) to ensure easy updating/upgrading of results as new information is made available and (ii) to facilitate comparisons between results obtained in different river basins or sub-basins (especially in transboundary river basins).

Practical steps and measures will be identified and proposed for **filling key information and knowledge gaps:**

- Identified during the first analysis aimed at characterising the river basin in economic terms- for ensuring key indicators (e.g. cost-recovery levels) can be further improved and refined;
- Likely to arise when developing integrated river basin management plans – for ensuring the cost-effectiveness analysis can be performed at a later stage. This indeed requires undertaking the feasibility study for the entire economic analysis process (which information to be collected, at which scale, which data collection or computation method, which periodicity, etc).

Although it is too early to specify the main focus of such activities, as they will be based on both general and local assessments of information and knowledge needs, likely candidates that will require further work combining economic and technical expertise include:

- The assessment of water-related environmental costs (benefits) and the development/strengthening of environmental costs databases;
- Methods for assessing the direct economic impact of range of measures for key economic sectors (e.g. industrial sub-sectors, agricultural sub-sectors);
- Methods for assessing the effectiveness of measures or combination of measures.

The costs of activities proposed for enhancing the information and knowledge base will be assessed and reported. Feedback to research programmes may also be developed to ensure research needs are tackled in a timely manner.

2.4 Type and Format of Output Data

The tables presented below are by no means exhaustive and final. They have been developed as examples to support experts in different river basins in developing their own templates. The tables do not mention the information on water uses, wastewater treatment, pollution emitted, changes in hydromorphology, changes in ecology, etc. that will come from the analysis of pressures and impacts as specified in Guideline 4.1. Clearly, similar tables can be draw for this biophysical information. Key is to ensure consistency and coherence (e.g. in selecting spatial scale of computation and reporting) between pressures and impacts and the economic analyses.

Table 1. Economic analysis of water uses

Key variable	Source of data	Date	Spatial scale, lowest disaggre-gation level	Quality of data (good, medium, poor)	Avail-ability of data	Cost	Comments
Drinking water supply 1. Population connected to public water supply system							
2. Population with self-supply							
3. Number of water supply companies							
Wastewater treatment 1. Population connected to sewerage system							

Key variable	Source of data	Date	Spatial scale, lowest disaggre-gation level	Quality of data (good, medium, poor)	Avail-ability of data	Cost	Comments
2. Population connected with wastewater treatment plant							
3. Number of wastewater treatment companies							
Economic characteristics of key water uses 1. Agriculture o Total cropped area o Cropping pattern o Livestock o Gross production o Income o Total farm population							
2. Industry o Turn over for key sub-sectors o Employment for key sub-sectors							
3. Hydropower o Installed power capacity o Electricity production							
4. Gravel extraction o Number of extracting companies o Total employment o Total turnover							
5. Fish farming o Number of fish farms o Total employment o Total turnover							
6. Water-related tourism o Total number of tourist-day o Daily expense per tourist day o Total employment in the tourism sector o Total turnover of the tourism sector							
7. Flood control o Total population protected o Total turn-over of protected economic activities							

Table 2. Assessing trends and baseline scenario

Key variable	Source of data	Date	Spatial scale, lowest disaggre-gation level	Quality of data (good, medium, poor)	Avail-abiliy of data	Cost	Comments
Trends in macro-economic policies 1. Existing studies and reports on trends in agricultural policy 2. Existing studies and reports on trends in industrial policy 3. Existing studies and reports on trends in energy policy 4. Existing studies and reports on trends in transport policy 5. Existing studies and reports on trends in other policies							
Trends in exogenous variables 1. Population growth 2. Changes in economic development (DGP change) 3. Changes in water pricing policies 4. Technological changes o Households water use o Agriculture and irrigation o Industry 5. Climate change 6. Other							
Planned policies and investments 1. Proposed investments in water supply and wastewater treatment 2. Proposed investment in pollution reduction programmes for agriculture 3. Proposed investments in flood protection 4. Proposed investments in wetland restoration 5. Proposed investments in improved technology 6. Proposed investment in water supply enhancement 7. Other programmes and measures							

Table 3. Basic economic information and indicators

Key variable	Source of data	Date	Spatial scale, lowest disaggre-gation level	Quality of data (good, medium, poor)	Avail-abiliy of data	Cost	Comments
1. Unemployment 2. Discount rate 3. Economic growth rate 4. Income per capita 5. Other							

Example of Summary of Economic Analysis

(I) Key messages with regards to the economics of water uses
1.
2.
3.
(II) Description of the river basin and economic importance of key water uses

Table II.1. Economic importance of key water uses for the river basin

Water use	Water consumption	Pollution	Total “production”	Turnover AMD	Employment	Number of beneficiaries
Use 1						
Use 2						
Use 3						
Use 4						

Note: figures can be given in absolute terms and in relative terms (relative to the river basin as a whole or to the economic sector for the country if seen as of national strategic importance)

(III) Map 1. Localisation of key water uses in the river basin

(IV) Assessing trends and identifying the baseline scenario

Table IV.1. Foreseen trends in key water uses in the river basin up to 2015

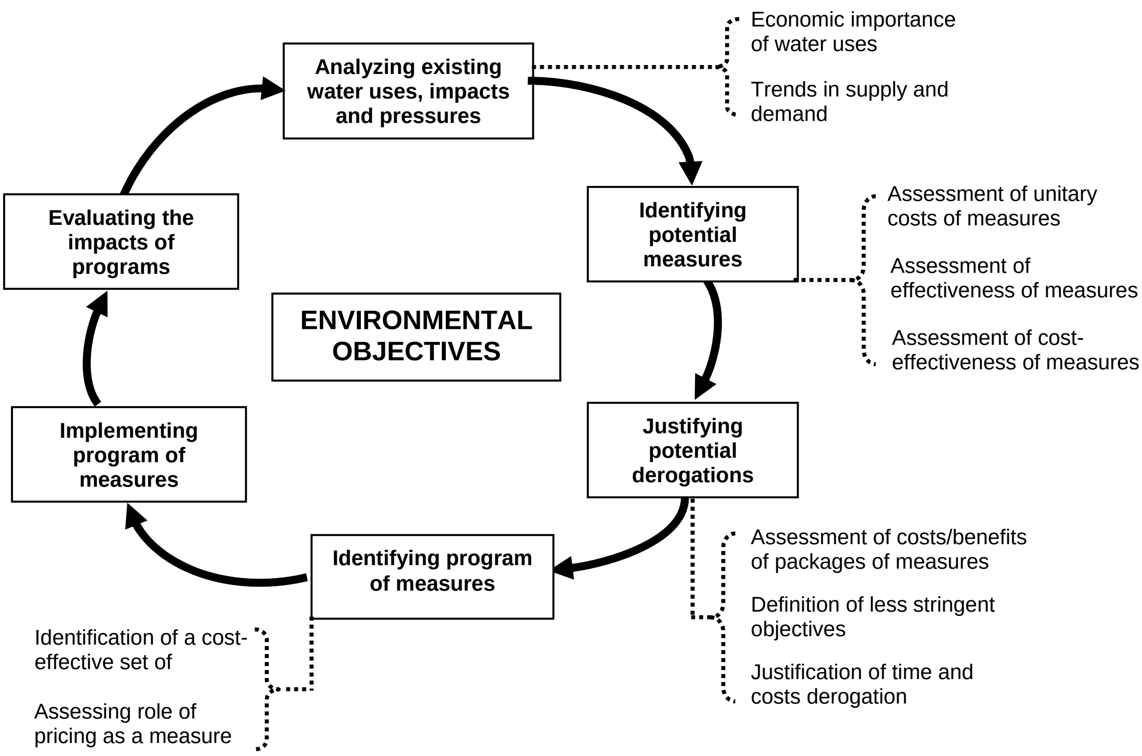
Water use	Change in beneficiaries	Change in production	Technological change	Overall change in pressure (qualitative)	Comments
Use 1					
Use 2					
Use 3					
Use 4					

Table IV.2. Foreseen investments and measures targeted to the water sector up to 2015

Main policy	Planned measures	Proposed costs AMD	Likely change in water status	Comments
Policy 1				
Policy 2				
Policy 3				

(V) Proposed activities for improving the information and knowledge base

3. Diagram of approach



4. Bibliography for Method

Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance Document No.1 - Economics and the Environment – The Implementation Challenge of the Water Framework Directive, Luxembourg: Office for Official Publications of the European Communities, 2003.

GUIDELINE 5.2: PUBLIC PARTICIPATION IN RIVER BASIN PLANNING

1. Introduction

1.1 Purpose of this Guideline

This guideline describes how to involve stakeholders in river basin planning. Modern river basin planning involves the stakeholders public in various parts of the process, especially in the identification of issues, in setting environmental objectives, and in selecting appropriate measures for resolving water problems. This guideline refers to using stakeholder input for improving the information and decision-making in river basin planning. Stakeholders are all people and institutions who have a strong interest in the future use of water resources, including local government, private industry, non-profit organizations (including environmental and social service organizations), citizen groups, irrigators, and the general public. In fact, all these stakeholders are known as “the public.” Stakeholder participation in planning is critical to successful and efficient management of water resources. One of the four Dublin Principles of Integrated Water Resources Management emphasizes public participation: “Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.”

For successful participation stakeholders need to be aware of institutional and legal aspects of water management in Armenia, water quality and quantity issues, as well as be in line with current reforms in the water sector. Successful public participation is not possible without high level of public awareness. There are different levels of participation: information, consultation and active involvement. The lowest level of participation is providing access to information and disseminating information actively. Sufficient information supply is a prerequisite for meaningful involvement of the public and moreover it is legally required.

The type of participation depends upon the spatial scale relevant to particular water management and investment decisions and upon the nature of the political economy in which such decisions take place. An integrated approach to water resources management entails identification of conflicts of interest between upstream and downstream stakeholders.

1.2 Role of Public Participation in River Basin Planning

River basin planning starts with a broad characterizationf of water use and status, looking at all aspects of water management. But in this process it is important to narrow the focus fairly quickly to the most important issues which exist in that particular basin. The planning work must concentrate on the environmental, socio-economic and institutional priorities of stakeholders. That is why the river basin characterization, as the first step in basin planning, must conclude with the participatory identification of water resource issues and opportunities.

The second stage of river basin planning where public participation is vital is in the setting of environmental objectives. Although this is a technical task, large-scale water users, such as industry and irrigators, have a large interest in understanding and influencing the objective-setting process. Their participation must be managed so that they provide useful input and not just arguments against reasonable objectives.

The third stage where public participation is vital is in the selection of a program of measures. One of the biggest errors that can be committed in river basin planning is to select measures based only on technical or government perspectives. Actual water users often can best select the most feasible and reasonable measures, based on their knowledge of what is practical.

GENERAL CONCEPTS IN PUBLIC PARTICIPATION:

The following can be considered as important rules in a public participation process in general and in river basin planning specifically.

- The public should have a say in decisions about actions that affect their lives
- Public participation includes the promise that the public’s contribution will influence the decision

- Incorporate the diverse interests and cultures of the community in the community development process; and disengage from support of any effort that is likely to adversely affect the disadvantaged members of a community
- Be open to using the full range of action strategies to work toward the long term sustainability and well being of the community
- Practitioners are the guardians of the process (operating within code of ethics)

Practitioners should use the three senses; feel, see and hear as illustrated in Figure 1 below:

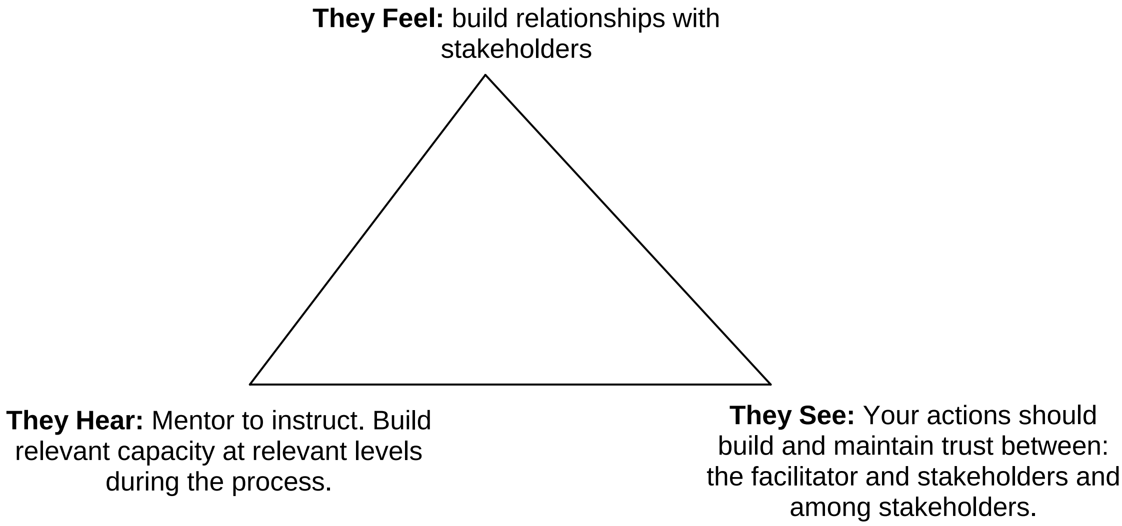


Figure 1: Core values in public participation

In a capacity building process in water resource management issues using public participation, leadership is very important. Figure 1 suggests that for a leader or facilitator in a capacity process to gain the trust of the people in public participation exercises, he should be able to:

- *Build relationships*: There are conflicts in many watersheds due to conflicting interests. This could be non-equal access to the water resource or inequality in allocation or even conflicts involving land ownership in the particular watershed. The facilitator should do his/her homework on the roots of such conflicts if there is any. He/She should go the extra mile to convince the relevant authorities about the need to rectify the situation in the basin. If the relevant authority manages to rectify the situation or assures the people that he is doing something about the problem, the community will be ready to listen to the facilitator and elect to participate in projects he/she intends to initiate. Building of such bridges should be a continuous process and so are capacity building and public participation.
- *Actions:* The facilitator should be fair and consistent in his/her dealings and should have the patience to listen to the people. He/She should be tolerant of all opposing views. The facilitator should be neutral and should act as the arbitrator in times conflicts – either during meetings or in the execution of projects. The body language of the facilitator and his/her actions will determine if the public participation process will be successful or build the needed capacity amongst the people. The leader should be open to using the full range of action strategies to work toward the long term sustainability and well being of the community.
- *Mentor to instruct:* This is another important aspect of building capacity in the form of public participation. In many instances, a majority of the stakeholders or the community know very little about the technical issues in watershed management. It is therefore advisable that the facilitator, the guardian of the process, to be knowledgeable in the public participation process and the problem at stake. He/She should explain technical issues or terms to the understanding of people of low educational backgrounds. This

point becomes relevant in the problem awareness, assessment, developing strategies, implementing the plan, monitoring and evaluation. He/She should work actively to enhance the leadership capacity of community members, leaders, and groups within the community. Most public forums need good facilitation to ensure high quality dialogue.

All the three points in Figure 1 are processes that complement each other and as such all are necessary if a facilitator is going to be successful in a public participation process. They are ongoing and none of them should be thrown away during this long process of public participation.

Modern river basin planning experience has shown that participation of the public in early stages of the planning process, including identification of issues, is particularly important. Water resource agencies and decision-makers have now recognized that participation of the public, including water users, non-governmental organizations, citizen's groups, private business and industry representatives, and other government agencies (e.g. agriculture, health, finance) at an early stage in planning, will help the planning process be successful. Although participation may slow down the planning process at the beginning stages, experience shows that it will speed up the implementation process, making overall work more effective.

A public participation process should be designed for the river basin plan, and it should incorporate these four basic principles (HarmoniCOP-EC, 2005):

OPENNESS	1. All relevant stakeholders should be able to participate in the decision-making process. 2. Participants should be relevant decision-makers from their organization. 3. The process should be transparent.
PROTECTION OF CORE VALUES	4. The process should respect the livelihood and identity of stakeholders. 5. Stakeholders should commit formally to participate. 6. The process should offer participants an exit option.
SPEED	7. The process should create prospects of concrete gains and incentives for cooperation. 8. External developments may be used to speed up the process (new projects or opportunities). 9. Conflicts should be transferred to the periphery (a special committee) of the process.
SUBSTANCE	10. The roles of scientific and technical experts should be clear—providing information, not deciding 11. The process should result in alterative actions, and the final selection is participatory.

2. Technical Approach

2.1 Methodology: Background and Justification for Method

Public participation in river basin management seeks to incorporate concerns of all tiers of civil society (corporate or public) in decision-making processes on water resource management issues that affect the society or community concerned. The aim is to build capacity to ensure the involvement of stakeholders and local community in decision-making on water resource management issues. Participation ranges from being given notice of public hearings to being actively included in decisions that affect communities. Notices per se do not in any way build capacity on specific issues on water resource management. It must be understood that before a society or community can be involved in decision making processes in watershed management issues, it needs to be capacitated in a way. Public participation therefore should always be put in context.

The role and involvement of stakeholders changes at different stages of the river basin management process. As a general rule, stakeholders should be involved as early as possible.

2.2 Practical and Legal Reasons to Encourage Participation

Effective water resource management requires working in partnerships with diverse groups of stakeholders. Often, a consensus-based decision process will be most effective in motivating the broad support for decisions and participation in the solutions which are needed in water resources. In Armenia, participation in river basin planning and decision-making is not only recommended, but it is required by law. A number of legal acts is in place (including multilateral international agreements adopted by RA) referring to public participation.

There are numerous references in both the RA Water Code and the National Water Program to public participation. The last paragraph of Article 11 of the National Water Code states, *"Citizen's representatives, representatives of water user associations and other organizations may be involved in Water Basin Management Bodies with the right of advisory vote".* Nevertheless, neither the Water Code nor the National Water Program make specific reference to mechanisms for public participation.

Armenia has ratified the Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, and its requirements supersede the national legislation.

2.3 Defining the Stakeholders in the River Basin

The stakeholders are all the groups, inside and outside of government, which may have a strong interest in the result of river basin planning. These include the following types of persons or organizations (HarmoniCOP, 2005):

I) Stakeholders that possess expertise, creativity or local information.

II) Stakeholders who possess important resources for implementation: funding, legal authority, good personal connections.

III) Stakeholders who can block decision-making or implementation, by withholding approval, by legal action, by political pressure, or by subverting decisions.

IV) Stakeholders, such as the local rural population, and basin landowners, who may not have power, but who must be involved in making implementation a success.

In river basin planning, it is particularly important not to exclude the third and fourth groups. Water resource decisions typically affect a very broad range of the population, because everyone is a water user at some level. Groups that are excluded from the planning and decision-making process can easily withhold their future cooperation, making success in improving water resource management difficult at best.

In general, the stakeholder groups for river basin planning, at a minimum, will include: irrigators and other water user groups, operators of hydro-power and other hydraulic facilities, business and industry representatives in the basin, non-governmental groups (environmental groups, neighborhood or citizen groups), local and national government agencies working in agriculture, health, planning, territorial administration, and local municipalities (village or town mayors).

The leader of the river basin planning work must make a concerted effort to invite all the pertinent groups to participate. Obvious stakeholders can identify other stakeholders who are less known or less obvious. If groups appear after the process has started, and ask to be included, it is likely best to accommodate them.

2.4 Levels of Public Participation: Information, Consultation & Decision-making

Public involvement varies from sharing information, to consultation on ideas and direction, to actual participation in key decisions. Stakeholders who are enthusiastic and engaged in the basin planning process expect to be more deeply involved. In fact if they are engaged in early stages of planning, and then excluded from key decisions, they may become frustrated, or even angry and uncooperative. If the future cooperation of certain stakeholders is required, in most circumstances it is advisable to have them involved in key decisions. Therefore, it is best to be clear with stakeholders about their level of involvement from the beginning. Levels of involvement are:

- Information sharing
- Consultation on definition and prioritization of issues and options
- Participation in decisions: choosing the best options for management

2.5 Approaches to Issues using Public Participation

Participation in the river basin planning process should be used to reveal several aspects of the water resource issues in the basin:

I) Priority water needs and concerns of each stakeholder group.

II) Relationships between stakeholders, including conflicts which exist.

III) Different perceptions of the same problem by various stakeholders.

IV) Resources which stakeholders can provide (information, skills, money, power)

V) Understanding of how different measures (education, policy or infrastructure) might be effective or ineffective in the local situation

It is important for river basin planning leaders to consult with stakeholders both individually and in groups. First, the planning leaders, and eventually all stakeholders, must develop a better understanding of each aspect mentioned above. As the river basin planning process proceeds, the stakeholders should learn more about the basin, about the concerns and resources of the other stakeholder groups, and about how each of the groups may perceive the same issues somewhat differently. This learning process should be encouraged by the river basin planning leaders.
To encourage this mutual learning process, it may be worthwhile to use such approaches as:

- individual interviews
- interviewing focus groups of 6-10 people at one time
- group forums and workshops to learn, discuss topics of mutual interest
- field trips to observe how water is managed by distinct stakeholders
- providing technical data and maps on websites and electronic/written reports
- questionnaires or survey

Developing better information and understanding requires analysis and synthesis of both technical and institutional data, as well as local knowledge. The community or stakeholders should be involved in the identification of the problems in the basin. This will create the necessary awareness of the issues at stake to the people and will therefore encourage them to participate in the implementation of solutions.

2.6 Public Participation Strategy and Techniques

The river basin planner must lay out a strategy for involving the stakeholders in each phase of the basin planning process, including issue identification, setting objectives, and selecting measures. Usually the issue identification will be done in the first few months of a basin planning exercise, so it is important to have a public participation strategy in place at any early date.

The strategy can be developed based on answers to several key questions:

- Who is going to participate?

- What will they be asked to do?
- When should each group be involved?
- What kinds of issues will be addressed, or not addressed?
- Is there going to be an organization formed, and who will lead or facilitate?
- What methods or techniques will be used?
- What resources are necessary?

Usually stakeholders should be involved as early as possible in the planning. By asking selected stakeholders to participate in the definition of issues, it is implied that they will be involved in future steps of defining specific problems and solutions.

Although we have said that a broad open group of stakeholders should be formed, in truth, the group can be too large. Groups which are too large are slow, and many people can become disenchanted and leave the process. Smaller groups can build trust and come up with effective ideas more rapidly. So the basin planner will have to balance the need for diversity with a need to limit the size of a group. Generally basin planning groups of more than 25 persons can be awkward, unless they are broken down into committees. Groups of 10-25 persons, with flexible options for including larger numbers in some aspects of the work, are more effective.

2.7 Analyzing Issues and Options with the Public

In the stage of definition of issues and options, the key process is sharing of information and ideas. Technical personnel are involved in gathering technical information and analyzing the basin's characteristics. From this process they form ideas of what are the key issues. The basin planner should, at the same time, be initiating his participation strategy, interviewing stakeholders, and perhaps beginning some focus groups or forums. Some basin planners hire a social scientist to gather information from stakeholders on their view of the issues.

At a certain point, it is important to involve the wider group of stakeholders in analyzing the issues with input from technical specialists. This process is known variously as "synthesis of issues" or in the case that both technical and social diagnostic studies have been undertaken, "marrying the diagnostics."

For this purpose, a workshop or series of workshops should be arranged in which technical specialists give carefully prepared interpretations of the issues in the basin. The institutional and private stakeholders are consulted about the technical issues, and through a process of mutual learning and dialog, the issues are refined and adjusted to reflect the understanding of the major local water users and agencies. It is extremely important that the basin planner, at this stage, use good facilitation techniques (or a professional facilitator) to ensure that stakeholders' concerns are fully integrated in the final interpretation of issues and opportunities.

Analyzing options for environmental objectives or options for measures to address problems are similar tasks in that they require the basin planner to share information, solicit ideas, synthesize good ideas, and secure approval of priority ideas from the group.

2.8 Organizing a Stakeholder Meeting

Before sending the official invitation letters the stakeholders should be already contacted on a personal level i.e. face-to-face, telephone, etc. There are multiple purposes that this can serve:

- Make stakeholders aware of the benefits and rewards they would gain from participating i.e. contributing to local decision-making, an opportunity to share their knowledge and concerns, etc..
- Clarify what their individual role would be
- Identify stakeholder expectations before the event itself so that they can be used to feed into improving the overall outcome
- Different work positions and hierarchy levels of the invited persons should be considered once inviting – e.g. it may become a demanding task to motivate certain persons to speak up in front of "high level people".

2.9 Interpreting the Technical Data

River basin planning is both a technical and a social process. Technical information is critical to understanding the water resource problems and their causes, as well as the efficacy of certain solutions. But informal actors, especially local water users, have an in-depth understanding of how water is actually managed in the basin. Often their understanding is much more in-depth than that of water managers and scientists who do not live in the basin. Therefore to properly understand the problems, and design effective solutions, a blend of technical and local knowledge is needed.

Technical specialists will provide data and analysis of water resource issues like water quality and water quantity shortage. This information must be interpreted in a form that is understandable for local decision-makers and water users.

To be useful in participatory river basin planning technical data must be interpreted in a form understandable to all stakeholders. Frequently, technical specialists and engineers are not used to interpreting their information for non-specialists. If this is the case, the river basin planning leaders must take an active role in data interpretation.

This becomes a learning process for the stakeholders. However, technical specialists must also listen closely to local water users and local officials as they explain the constraints imposed on water management by local tradition, agreements, and practices. The job of the river basin planning leaders is to blend the technical analysis with local knowledge to clarify the real water resource problems, their causes, and existing constraints to their solution.

To be useful in participatory river basin planning, and particularly at early stages of issue identification, technical data must be interpreted in a form understandable to all stakeholders. Frequently, technical specialists and engineers are not used to interpreting their information for non-specialists. If this is the case, the river basin planning leaders must take an active role in data interpretation.

Water quality data, whether biological or chemical, is often complex and difficult to understand if only presented as numeric data. Planners should insist that all data sets be interpreted as "violation of water quality standards," or with qualitative ratings, such as "good, fair, or poor." Presenting water quality data as maps, with color coding on different reaches of rivers to show the relative water quality in different areas, is very useful.

Water quantity data, such as drought data, is difficult to understand unless interpreted carefully. The probability of low water flows (droughts) should be clearly explained using return periods. Drought-prone areas can also be mapped to give a visual interpretation of areas with "high" "medium" or "low" risk of drought. Data on geologic hazards such as flooding and landslides should be presented only in map form to stakeholders (although quantitative data are in reports for other technicians to consult). Data on aquatic biology, such as benthic invertebrate data, should such be interpreted in qualitative terms, such as "good, fair, poor." Fish population data, if it exists can be expressed in quantitative terms, as that is easy for all types of stakeholders to appreciate.

Technical information should be synthesized, so that the public can understand several major categories of information, and dialog with technicians about issues:

- Water quality data: qualitative information on violation of national norms should be summarized in tables and maps. Tables should also show the technician's proposed root causes (sources) of contamination so these preliminary conclusions can be shared and consulted with knowledgeable stakeholders.

- Drought and water shortage data should be presented as simple probabilities, so that frequency of water shortages can be consulted and confirmed with key water users.

- Flood and landslide data should be mapped, and maps presented to stakeholders for confirmation and improvement. Suggestions of locations of hazard areas from the public should be carefully noted on maps.

- Biological data, especially data on edible fish and crustaceans, should be presented with maps, and stakeholders consulted about details of where fish species migrate, spawn, over-winter, and when they are most frequently caught. Also information on when fish kills occur (due to pollution), or when certain fish disappeared from the river system is key data.

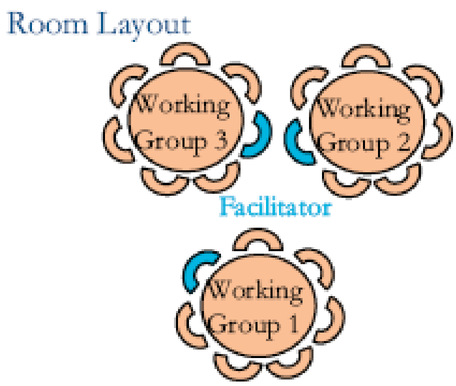
2.10 Maps

Maps are not only a means to communicate end-results. Maps also form a model of reality, and thereby serve as a visual language among participants during their discussions.

Below are some specific functions of maps that can be used during basin planning:

- To clarify issues and mechanisms: explain arguments and concerns by localizing and describing them with help of map images, e.g. link spatial patterns of water pollution to changes in local land-use
- To identify stakeholders concerned by the defined area on the map.
- To articulate and specify spatial issues
- To synthesize arguments and designs: summarize a design, an analysis result or a viewpoint as an argument in the debate, e.g. argue for more space for water with a map of several flooding scenarios
- To consolidate findings, views, options and decisions: location related decisions and visions become concrete when they are defined and described. Laid out on maps, this knowledge is being fixed and captured in "black on white".

Following is an example of use.
Tools: Maps + Workshop
Validation of draft inventory of water bodies



STEPS:
Before the workshop
1) Maps preparation (A3 format, 1 by sub-basin)
2) Maps duplication (1 by working group)

During the workshop
3) Put maps on the table
4) Facilitator presents the draft status of each water body and collects comments, if any

After the workshop
5) Synthesis report (with all the comments)
6) Maps and report dissemination

Below are some recommendations on using maps:
- Do not limit the map content to technical data from an existing database, introduce local expertise and knowledge. It improves the content and encourages transparency
- Explain how to read a map (scale, orientation, legend), encourage spatial reasoning (show examples of spatial interactions). It helps participants to better understand interdependencies.
- Produce draft "opened" maps, invite participants to draw, to comment
- Clearly represent the "no-data" or uncertain areas
- Spend time on the legend to build up an understandable visual language

3. Diagram of Approach (Flow Chart for first part of participation in river basin plan)

Designation of the basin management plan team and its responsibilities (WRMA and BMO)

⇩

Initial identification of stakeholders. Explain the river basin planning process to stakeholders. Develop a participation strategy for the river basin plan. Assign tasks for basin characterization.

↓

Collect and analyze technical data for basin characterization (physical, geographic, socio-economic, biological, water use, water balance, geologic hazards). Have technical team define issues and opportunities.

↓

Collect institutional, management and social data through interviews and focus groups (or a social science contractor). Analyze and consolidate issues manifested by stakeholders.

↓

Compare issues from technical team and management/social issues from stakeholders. Do initial synthesis of two types of issues. Have technical team prepare interpretation of technical data. Prepare presentations and methods for synthesis workshop(s).

↓

Conduct workshop introducing river basin planning methodology. Explain participatory strategy. Provide presentations on interpreted technical data and management/social data. Dialog with stakeholders. Strive to reach agreement on the major issues with stakeholders. Plan future events with stakeholders (field trips, vision development).

4. Example of Method (applied to Meghriget)

Two *Stakeholder Forums* were organized in the Southern basin; informational products, supporting increased public awareness in the basin, have been developed and provided to the BMOs, relevant trainings were provided to the BMO staff.

Southern BMO made significant efforts to involve local communities, including water sector partner institutions, NGOs, WUAs, village heads in basin characterization exercise. On May 17, 2007 the first stakeholder liaison meeting was held in Kapan, at the Southern BMO premises. Hands-on training on organization of multilateral stakeholder forums and outreach was provided to the Southern BMO staff during the preliminary trips to the basin by PA Program Specialists. Representatives from the Water Resources Management Agency and local stakeholders were present in large numbers. Twenty-seven representatives from local Water User Associations, the EIMC, the SEI, NGOs, the Marz Administration, rural community heads, as well as, mining companies including Zangezur Copper Molybdenum Mining Company, Dino-Gold Mining Company, and *Sipan-1* Gold Mining Company, attended the forum. Local television stations and print media widely covered the event.

The work and achievements of the BMO over the last two years and planned upcoming activities were presented to the forum. The purpose and process of developing river basin plans, as well as the role and importance of the stakeholders in this process was highlighted. Interactive work was organized in two groups in order to reflect on the leading water sector issues that affect the local stakeholders in the Southern Basin and how the issues relate to the role and function of the BMO.

Each group was assigned three questions to review and discuss:

- What are the leading water related issues in your area/community/business?
- Identify specific examples of these issues/concerns and highlight locations, where possible, on enlarged basin maps provided by the Program.
- What specific questions would you like to direct at the BMO or what information do you lack or need from the BMO?

After the completion of the working group assignments, the results were summarized and jointly presented.

Group One Results: Leading Issues

1. There are drinking and irrigation water shortages seasonally because of the limited number of water reservoirs.
2. There is an absence of drinking water purifying stations.
3. Many communities suffer from poor quality drinking water.
4. Pollution of the water in the *kyahrizes* caused by industry and agriculture.
5. The necessity for new reservoir construction.
6. Rural communities are contracting as a result of water shortages.
7. Lack of water quality data.
8. Deterioration or absence of irrigation and water supply systems.
9. Absence of industrial wastewater purification stations.
10. Absence of solid/domestic waste removal.
11. Lack of environmental education and awareness in the Basin.

Group Two Results: Leading Issues

1. Uneven seasonal water distribution in Kapan and Meghri Regions leads to drinking and irrigation water shortages.
2. Zangezur Copper Molybdenum Mining Company and Dino-Gold Mining Company discharge industrial waste water (tailings) into the Voghji River and the Achanan Tributary.
3. Degradation of the fish population, as well as other aquatic flora and fauna, due to poor water quality.
4. Uneven distribution of wells that are not serviced by water supply companies.
5. Lack of human resources and technical equipment in water purifying facilities leads to deterioration in the drinking water quality.
6. Pollution of water resources because of inappropriate distribution of sites for domestic and industrial solid waste accumulation.

Both groups also marked maps to show “the problem areas” linked to the issues they listed. They also marked infrastructure needs, e.g. new water reservoirs, irrigation links, etc.

Questions directed at the BMO were mainly geared toward its function and role, its authority and the nature and process of water use permitting.

Two local television stations, “Khustup TV" and “Sosi TV” were present at the event and taped news stories on water sector management. A reporter from the newspaper “Syunyats Yerkir” also wrote a story on the stakeholder forum.

The function of the BMO was little known in Southern Basin - moreover, stakeholders did not know much about the water use permitting process. There were numerous questions, concerns and issues regarding how, why, and where to acquire a permit.

The BMO needs informational materials to distribute regarding its general function and relationship and role in integrated water sector management in Armenia.

The BMO staff and basin stakeholders were enthusiastic about further collaboration and emphasized the need of these types of forums, as they are useful and information exchange is much needed.

5. References:

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EU WFD, 2002, "Guidance on Public Participation in relation to the Water Framework Directive," http://forum..europ.eu.int/Public/irccenv/wfd/library

Conservation Technology Information Center, 2008, "Know Your Watershed: Building Local Partnerships," published by Purdue University, South Bend, Indiana, USA: http://www2.ctic.purdue.edu/KYW/Brochures/BuildingLocal.html

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STEP 6. FORMULATION OF RIVER BASIN MANAGEMENT CONCEPT PLAN

Introduction to Step 6: Formulation of River Basin Management Plan

The sixth step in river basin planning is to combine specific environmental objectives with the pressure/impact analysis and the program of measures, to make up a river basin management concept plan. A modern river basin plan is a practical approach to sustainable management of water resources. It focuses on resolving critical water resource problems in a given basin, guided by concrete water resource objectives. This type of river basin concept plan is neither a complete water resource management plan, nor an mathematically optimized formula for water management. It is essentially a structured list of problems, root causes, and proposed solutions which will lead to quantifiable improvements in water quality and quantity in the river basin.

The concept plan is a practical tool, developed as a response to actual issues identified by the stakeholders. It is not a "centralized planning" approach to water management, but an "adaptive planning" approach. It allows the water management agencies to respond to new proposals, such as new water users or new industrial developments, with a clear set of "rules" and "expectations" for sustainability—that water quality and water quantity must continue to meet certain environmental objectives in the river basin.

The concept plan does not have fully developed alternatives, with dimensions, costs, and benefits. These aspects will be developed in Step 7.

1. Development of the River Basin Management Concept Plan

A river basin management concept plan must be prepared for each river basin in Armenia. It must provide clear guidance for the sustainable use of water resources in the basin, based the need for economic development while minimizing risks to human health and aquatic life. The planust encompass the milestones of river basin management planning: basin characterization, classification of water bodies, setting environmental objectives, analyzing impacts and developing measures, and evaluating measures..

It should be noted that the river basin management plan is essentially a snapshot in time and is the subject of continual review. Essentially, the first-generation river basin management plans represent the transition between the initial analysis and implementation of the requirements of Armenian legislation and EU Water Framework Directive. Their cyclical updating is a refining process based on improved data and understanding and allowing for real changes of circumstances in the river basins. The principal mechanism for achievement of the legislation's requirements is through the implementation of the proposed program of measures.

There are two important features of the planning process before the river basin management concept plans can be finalized.

1. Stakeholders, including local government agencies, and the general public must be aware of and support their content and the proposals in them.
2. The appropriate government minister must approve them, so that fully-developed projects can be developed for each proposed measure.

A guide to the content of the river basin management plan document is summarized below. The information required is very extensive covering every aspect of the river basin planning process and, if requested by the Government of Armenia, access to supplementary information must be made available by the Ministry of Nature Protection.

Essentially the river basin concept plans perform the following functions:

- They act as an inventory and documentation mechanism for water resource information including: environmental objectives for surface and ground waters, quality and quantity of

- waters, the impact of human activity on water bodies, and a set of proposed conceptual solutions (measures) to problems encountered in the basin.
- They co-ordinate program of measures and other relevant program within the river basin district (such as development programs of health, agriculture, energy agencies).
- They form the basis for river basin projects plans, which will have full details of costs and benefits of each proposed measure, and institutional responsibility clarified.
- They form the main progress reporting mechanism to the Government of Armenia or its authorized body.

The first river basin management concept plans must be published by the end of 2010 and will indicate the quality and quantity objectives to be achieved by 2015. Based on the Guidelines provided in this document, the Program will develop a pilot River Basin Management Concept Plan for the Meghriget River by February 2009 that will incorporate and complement all the practical application examples shown above.

2. Summary of the Issues to be Covered in the River Basin Management Concept Plan

The River Basin Management Concept Planfor each River Basin District should include the following:

1. A synthesized river basin characterization. This includes all the aspects covered in characterization: physical and biological resources, socio-economic trends and activities, land use, water use, water balance, geologic risks, and summary of major water issues. Maps of natural resources in the basin.
2. Classification of water bodies by types, including surface water and ground water. Maps showing the types of surface water bodies and groundwater aquifers within the basin.
3. Status of the surface water bodies and ground water bodies in the basin, especially in regards to water quality, ecological flows, aquatic life, and water balance of aquifers, and environmental objectives for all water bodies—quality and quantity desired in future.
4. Analysis of impacts caused by human intervention on water bodies, including root causes of these negative impacts. A set of conceptual measures which will enable all water bodies eventually to meet environmental objectives by addressing root causes.
5. Summary of proposed measures, with preliminary analysis indicating priorities and recommendations for interinstitutional cooperation (full scope and cost of measures is not included).
6. Proposed monitoring program
7. Register of any more detailed water resource programs and management plans and a summary of their contents.
8. Summary of the public information and the consultation measures taken, their results and the changes to the plan as a consequence.
9. List of competent authorities.
10. Contact points and procedures for obtaining background documentation and information, including actual monitoring data.

3. Public Information and Consultation

Active involvement by interested parties is a core principle of the river basin planning process. In particular during the production, review and updating of the river basin management plans, understanding and commitment from key stakeholders is vital.

The involvement of interested parties in Armenia began with the public consultation process in Meghriget River basin that preceded the basin characterization. In Southern Basin respondents to this process, and other notable stakeholders, were invited to join a Stakeholder Group to act as a sounding board on implementation issues. Similar arrangements should be in place in other river basin areas.

Proposals for engaging the wider general public are still at the formative stage. There is as yet no prescriptive procedure as to what kind of materials should be published for public information. However, in line with EU WFD requirements it shall be ensured that for each river basin area, input from the public (including users)cover the following:

- A timetable and work program for the production of the plan, and the consultation measures to be taken, at least three years before the beginning of the plan period.
- An overview of the significant water management issues identified in the river basin, at least two years before the beginning of the plan period.
- Draft copies of the river basin management plan at least one year before the beginning of the plan period.
- On request, access to background documents and information used for the development of the draft plan.

To allow active involvement and consultation with interested parties, including stakeholders and the public, the WRMA and BMOs must allow six months for written comments on these documents to ne ascertained.

STEP 7. PROJECT PLANNING

Introduction to Step 7: River Basin Project Planning

The seventh step in river basin planning is development of a projects plan. The projects plan transforms the concept plan into a concrete set of projects with scope and dimensions, estimated costs, cost-benefit analysis, and institutional responsibilities. The concept plan is a general document indicating general strategies, actions and priorities, usually over a long period, for example for five or ten years. The projects plan is a more specific proposal about how to put the concept plan into effect. It usually has a shorter time-frame (3-5 years) and is based on realistic budgets and implementation strategies. In order to complete a projects plan, the planning agencies like Water Resources Management Agency, must have "buy-in" from the key local agencies who have authority for implementation. Those agencies must insert key elements of the river basin projects plan into their own annual workplans. In some cases, parts of the Projects Plan may be integrated into other development plans, for example Marzpetan development plans. Every few years the river basin projects plan must be renovated, but in accordance with the overall river basin concept plan and its objectives.

1. Components of River Basin Projects Plans

The following are activities undertaken to develop three- to five-year projects plans:

*Developing scopes of work for education or extension programs
*Developing strategies for policy development
*Developing scopes of work for infrastructure design.
*Initial feasibility studies or evaluations for infrastructure
*Developing initial estimated budgets for all programs and proposed projects
*Developing coordination and communication strategies for institutions
*Designing studies of water resource problems
*Developing monitoring and evaluation programs and their budgets

2. Stages of River Basin Planning—the Role of Projects Plans

The development of the river basin management plan consists of four phases (**Figure 7.1**). Most of these phases run in parallel in order to ensure the timely completion and publication of the River Basin Management Plans. In developing and harmonizing methodologies and approaches the Guidance Documents presented in previous sections are taken into account and supplemented by guidance for special issues (e.g. the economic analysis). The river basin projects plan is immersed in the Phase IV activities.

PHASE I: Definition of river basin areas, definition of the institutional frame and mechanisms for coordination (2009)
In this phase it is important to clarify organizational issues and to agree on methodologies, e.g.

- agreement on the cooperation mechanisms,
- definition of the River Basin areas,
- agreement on maps and scales,
- agreement on mechanisms for data exchange,
- reporting formats.

PHASE II: Analyses of river basin characteristics, pressures and impacts and the economic analysis, establishment of the register of protected areas (until 2010)
Phase II runs more or less parallel to phase I. Most of the tasks are carried out on the national level. One of the major issues for coordination is to agree on common criteria and methodologies in order to achieve comparable results in the various basins. This includes agreements on:

- the amount of detail in the analysis of river basin characteristics,

- the criteria for the designation of significant pressures and impacts,
- suitable indicators for the economic analysis of water uses, as well as exchange of economic information
- the typology of surface waters and reference conditions.
- setting the environmental objectives.

PHASE III: Development of monitoring networks and programs (until 2010)
The monitoring networks and programs need to be based on the results of the analysis in particular on the results of the risk of failure to meet the environmental objectives. Monitoring networks and programs need to be designed

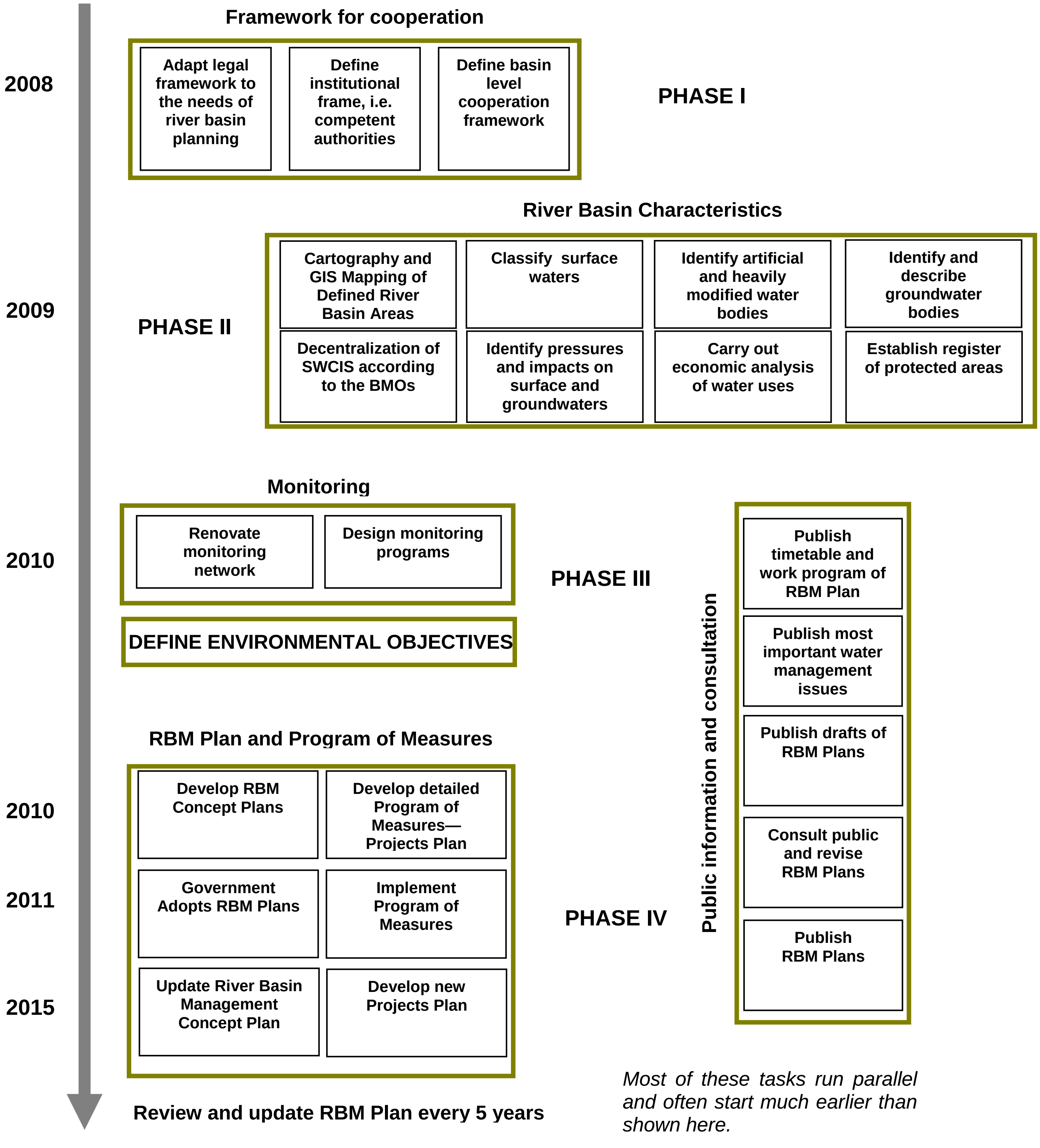
- for surveillance monitoring, including the definition of the necessary hydromorphological, chemical and biological parameters,
- for operational monitoring, including the choice of the necessary quality components, and
- for cases for investigative monitoring (bio-monitoring).

The existing monitoring programs should be adapted to fulfill the requirements of the WFD and needs of river basin planning. Most of the tasks for the operational and investigative monitoring will be carried out on the national or basin level.

PHASE IV: Development of the River Basin Management Plan including the conceptual program of measures, and the detailed projects plan (until 2011)
Based on the results of the analysis carried out in phases I and II, in particular the results of the assessment of water status, and on the monitoring results of the ecological and chemical status of the water bodies in phase III the River Basin Management Plans needs to be developed. First, the environmental objectives need to be defined for those water bodies that did not attain the “good” status. Second the program of measures is identified and proposed as part of the concept plan.

Finally, the program of measures should be developed in detail based on an economic cost-effectiveness analysis. Public information and consultation is required on the development and revision of the river basin management Plan. The process includes several steps and should begin as early as 2008 with the publication of the timetable and work program of the RBM. The WRMA should develop a strategy on public participation at the River Basins and hold the first Stakeholder Forums in 2008. The procedure of adoption of River Basin Management Plans is provided by the provisions of national legislation.

Figure 7.1 Development of the River Basin Management Plans in Armenia



STEP 8. APPROVAL OF RIVER BASIN MANAGEMENT PLANS

In terms of coordination the development of the River Basin Management Plans must be viewed as an inter-agencyeffort managed by the Water Resource Management Agency (WRMA), with local coordination by Basin Management Organizations (BMOs) . **Figure 8.1** shows the necessary coordination steps in the development of the River Basin Management Plans in Armenia. The first step is for the river basin concept plans to be approved and adopted by stakeholders---this signals their commitment. Then the WRMA should select the River Basin Management Expert Company to develop detailed projects plan to design and execute the proposed measures.. A number of **elements and tools** have to be introduced to ensure the necessary coordination and to facilitate the implementation on this inter-institutional river basin management plan.

a. Strategic Paper for the development of a River Basin Management Plan

At the outset it is important to develop a strategy for the coordination process. The Strategic Paper deals with most issues identified in Phase I of the river basin management plan, i.e.

- the definition of the River Basin and its sub-basins,
- the coordination mechanisms between WRMA and other agencies,
- outline of the River Basin Management Plan (see Step 6),
- reporting to the National Water Council or to the Government.

b. Work plan

The River Basin Management expert group has to develop a work plan for producing appropriate River Basin Management Plans. Therein, the main tasks for 2009 are identified for the tasks relating to Phase I and II.

c. Support from Expert Group (EG)

Considering the current low level of development, professional capacities, skills and resources of BMOs, it is clear that the WRMA and BMOs alone will not be able to carry out the whole volume of work on development of RBM Plans. The WRMA proposes to include the financial costs of the development of RBM plans in its medium-term expenditure program to be adopted by the Government. This possibly envisages the hiring of an expert company to develop issue papers on special RB topics. However, the BMOs will need also to involve appropriate basin stakeholder groups. The term “Expert Group” refers to a qualified water resources consulting company, as well the stakeholders of a basin.

In order to concentrate efforts on certain targets the RBM EG has to take over certain tasks e.g. related to typology and the definition of reference conditions, prepare an issue paper on the role of wetlands in the River Basin, develop a GIS and thematic mapping, make economic analysis, etc. Furthermore, it should develop issue papers (“drafts”) for each stage of the river basin plan.

d. Issue papers

Issue papers deal with issues that need special attention in the defined river basins, that require harmonization of methods to ensure comparability of results and that need to be dealt with in the introductory part of the river basin management plan. Issue papers are based on the relevant Guidance Documents developed in this report. Issue papers played an important role in Phase II and later on in the public participation process of Phase IV. They should be developed by expert companies in close collaboration with WRMA and BMOs.

Some of the special topics are:

- delineation and classification of water resources,
- evaluation of ecological status of water bodies according to water quality,
- the economic analysis of water uses and the cost-effectiveness of measures,

e. Role of WRMA in approval process

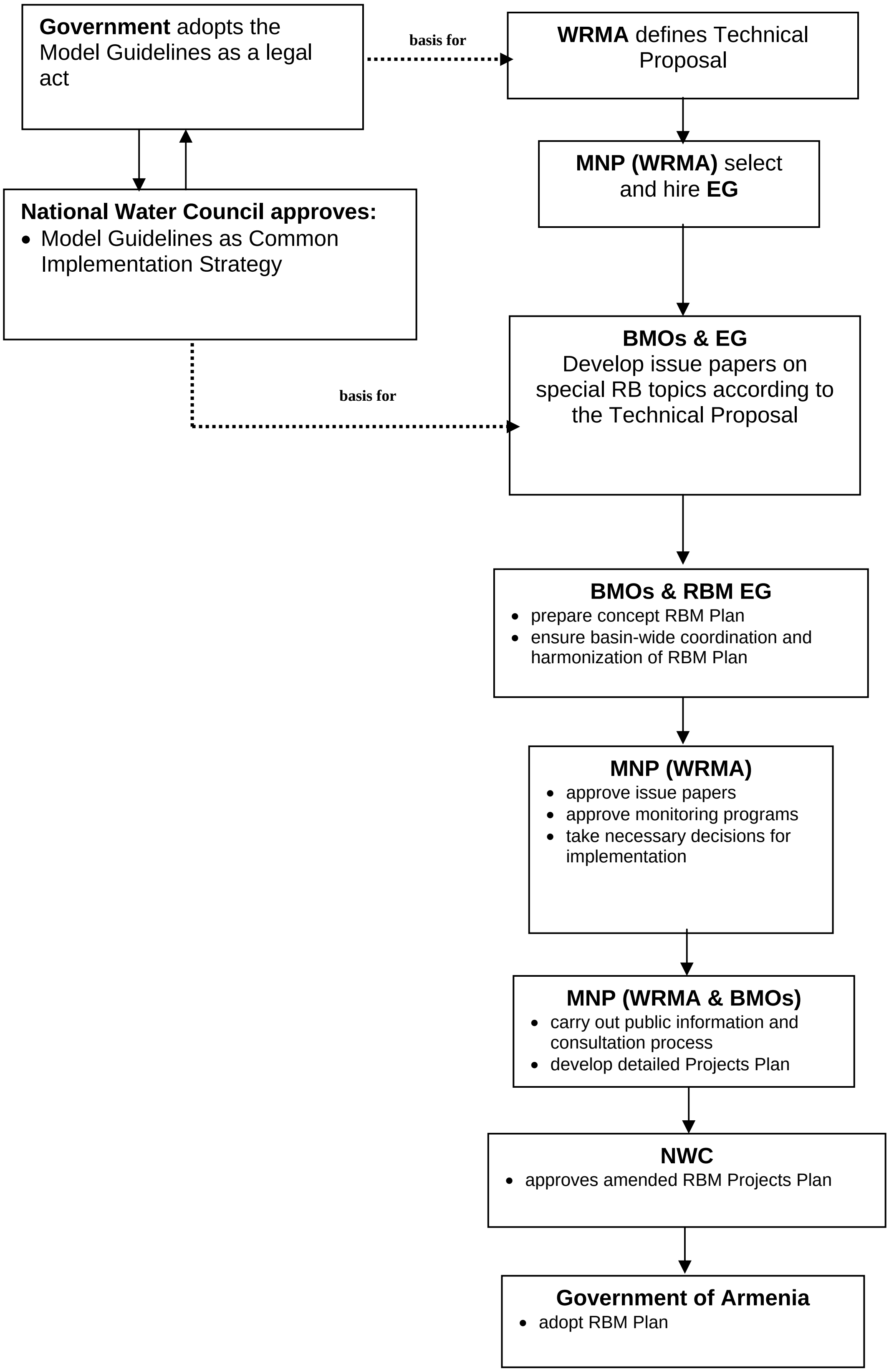
The WRMA must act as the coordinator for the approval of the river basin management plans. First, the WRMA, through the BMOs, will coordinate the development of the river basin management concept plan. This plan must be developed in coordination with other competent authorities including local governments and the non-government organizations and local water users. The concept plan must be signed by all the principal stakeholders as a sign of their long-term commitment to the river basin plan. The WRMA will take the signed concept plan to the national government authorities, through the appropriate channels, to request budget for development of the river basin management projects plan. The required studies will be done by the expert companies or local authorities, to provide all the input (costs, etc.) to the projects plan.

The components of the projects plan will then be sub-divided among the competent executing authorities (local government, national agencies), and they will submit budget requests for these activities as part of their annual workplans and budgeting. Some components of the projects plan may be assigned to non-governmental agencies. These agencies then are responsible for raising the funds needed to execute their portions of the plan.

Monitoring of the execution of the river basin management plan will be done by WRMA. They will hold periodic (annual?) meetings to review the progress of approval, funding, and execution of distinct parts of the river basin projects plan. Monitoring of environmental objectives (water quality and quantity) will be done by the Ministry of Nature Protection agencies like EIMC.

- public information and consultation,
- identification of pressures and impacts,
- typology and the definition of reference conditions of surface water bodies,
- identification of artificial and heavily modified water bodies.

Figure 8.1 Strategy for the approval of River Basin Management Plans



STEP 9. IMPLEMENTATION

Table 9.1 below recommends the tentative deadlines for implementation of River Basin Management Planning in Armenia.

Table 9.1 Timetable for implementation

Activities	**Deadlines**
Legal implementation	
-Adopting statutory provisions	June 2009
Status review	
-Analysis of characteristics of river basin areas	Dec. 2009
-Reviewing and assessing significant pressures and impacts	Dec. 2009
-Economic analysis of water use	Dec. 2009
-Updating of reviews and analyses	Dec. 2015
Regulation of groundwater	
-Adoption of measures to protect groundwater	Dec. 2009
-Criteria for chemical status and trend	Dec. 2009
-Criteria on a national basis (if necessary)	Dec. 2009
Monitoring programs	
-Setting up networks and putting them into operation	Dec. 2010
Public information and consultation	
-Publication of a timetable and work programme for river basin plan	Dec. 2009
-Publication of the most important water management issues	Dec. 2009
-Publication of drafts of the management plan	June 2010
Management plan and program of measures	
-Drawing up and publishing the management plan	Dec. 2010
-Drawing up a programme of measures	Dec. 2010
-Draw up first action plan	Dec. 2011
-Implementing the measures	Dec. 2015
-Updating the management plan	Dec. 2015
-Updating the programme of measures	Dec. 2015
Achieving objectives	
-Good surface water status	Dec. 2015
-Good groundwater status	Dec. 2015
-Compliance with objectives for protected areas	Dec. 2015
-Extension of deadlines to meet objectives	Dec. 2020/2025
Lists of priority substances	
-Proposal of limit values for substance exports and imports	Oct./Nov. 2010
-Updating of the priority substances list	Dec. 2011
-Phasing out discharges of priority hazardous substances	in 20 years
Recovering the costs of water services	2015

STEP 10. UPDATING OF RIVER BASIN MANAGEMENT PLANS

Guidance on updating the appropriate parts and data of RBM Plans is provided below in Table 9.1.

Table 10.1 Terms for update of necessary information materials for river basin planning in Armenia

NAMES OF THE INFORMATION MATERIALS	TERMS FOR UPDATE	NOTE (information sources)
I. DESCRIPTION OF RIVER BASIN **1. BIOLOGICAL, PHYSICAL AND GEOGRAPHICAL INDICATORS**		
Climate: a) precipitation, potential evaporation, air temperature	a) implemented once in a five-year period	Armstatehydromet
Topography: a) topography maps	a) implemented once	Topography maps
Geology: a) collection of geological data	a) implemented once	Topography maps, reference books
Hydrographs, Hydrology, Hydrogeology: a) hydrographical characteristics of watersheds, b) monthly average flows of main watersheds, c) maximum flows of rivers studied, d) minimum flows of rivers studied, e) characteristic of ground aquifer, f) flows of springs, g) general characteristic of water quality	a) implemented once b) implemented once in a five-year period c) implemented once in a year d) implemented once in a year e) implemented once f) implemented once g) implemented once	Armstatehydromet, archive of RGF, WRMA, Armecomonitoring

Land Resources: a) collection of data on land use (general irrigated, salinity and wetlands, erosion and landslide hazard areas)	a) implemented once in a three-year period	Land use division of regional administration, Territorial and Agricultural administrations
Biodiversity: a) natural plants b) plant and animal diversity c) aquatic biodiversity	a) implemented once b) implemented once c) implemented once	Bioresources management Agency of MNP, regional administration, unions of Hunters, field visits
Owned Land Use on Community Lands in The Basin	implemented once in a five-year period	Land use division of regional administration, Territorial and Agricultural administrations
Land Title	implemented once	Land use division of regional administration, Territorial and Agricultural administrations
Protected Areas	implemented once, till the establishment of a new territory	Regional administration, Bioresources management Agency of MNP
2. SOCIO-ECONOMIC CHARACTERIZATION		
Demographics: a) population and demographic growth b) age structure and average life expectancy c) immigration and emigration d) population density	a) implemented once in a ten-year period b) implemented once in a ten-year period c) implemented once in a ten-year period d) implemented once in a ten-year period	Regional administration, National statistic center of the marz
Water and Sanitation Facilities:	implemented once in a five-year period	Armenia Water Supply and Sewerage company CJSC
Economy: a) description of major sectors of economy, b) description of major infrastructures, c) production by sectors	a) implemented once in a ten-year period b) implemented once in a ten-year period c) implemented once in a five-year period	Regional administration, National statistic center of the marz

d) agricultural production by sectors, e) irrigated and dryland crop acreage	d) implemented once in a five-yearperiod e) implemented once in a three-year period	
Cultural/Historical Aspects of River Basin: a) historical settlements and land use	a) implemented once	National statistic center of the marz
3. WATER USE CHARACTERIZATION		
Water Use by Sectors: a) public drinking water supply, b) irrigation water supply, c) hydropower water use, d) industrial water use, e) water use for recreation and fisheries	a) implemented once in a three-year period b) implemented once in a three-year period c) implemented once in a three-year period d) implemented once in a three-year period e) implemented once in a three-year period	Armenia Water Supply and Sewerage company and Yerevan Jur CJSCs, communities, village councils, WRMA
Water Withdrawal/Discharge Permits: a) inventory of water withdrawal, b) inventory of waste-water discharges	a) given once in a three-year period b) given once in a three-year period	WRMA
II. BASIN WATER BALANCE		
Water Balance: Gaged river basins a) monthly and annual precipitation, b) monthly and annual evaporation, c) monthly and annual average river discharge, d) monthly and annual values of deep flow, e) preparation of monthly water balance, Ungaged basins a) monthly and annual precipitation and evaporation, multiyear average river discharge, monthly and annual average river discharge,	a) Once every five yearsOnce every five yearsOnce every five yearsOnce every five years Once every five years b) implemented once a year	Armstatehydromet, hydrological reference books, hydrological atlas

b) preparation of monthly water balance		
III. ECONOMIC WATER BALANCE OF RIVER BASIN		
Economic Water Balance: a) water withdrawal data collection, b) estimation of return flows, c) bringing actual river discharge to the level of natural flow	a) implemented once a year b) implemented once a year c) implemented once a year	WRMA, Institute of Water Problems and Hydrotechnic
IV. WATER BALANCE OF AQUIFER		
Estimation of Groundwater Resources: a) collection of data on precipitation, evaporation, springs and rivers discharges, b) preparation of balance	a) implemented once b) prepared once	Armstatehydromet, RGF
V. ESTIMATION OF MAXIMUM FLOW (FLOOD)		
Maximum Flows: For the basins having gagging station a) collection of data on maximum river discharges, b) estimation of maximum river discharge For the basins not having gagging station a) to determine the maximum river discharge form the map	a) implemented once b) implemented once a) implemented once	Armstatehydromet, hydrological reference books, hydrological atlas
VI. DELINEATION OF SURFACE WATER RESOURCES		
Delineation of the River into Discrete Sections: a) to place on the map altitude and basin drainage topography, drainage network, settlements, water systems, large industrial facilities, HPPs, reservoirs, large canals,	a) implemented once	GIS maps, WRMA,

b) summarize and delineate	b) implemented once (till the existence of a new large water use structure)	regional administration
VII. CLASSIFICATION OF SURFACE WATER RESOURCES		
Classification According to EU WFD: a) collection of data (absolute altitude of the river basin, basin drainage topography, geological indicators, hydrological characterization of the lakes)	a) implemented once	GIS maps, hydrological reference books, literature
Classification According to RA National Water Program: a) collection of data (significance, feeding source, length, water content level, flow distribution during a year, sector of use, level of sediment concentration, mineralization and stability levels of the river bed, hydrological indicators of the lakes)	a) implemented once	Armstatehydromet, WRMA, hydrological reference books, literature
VIII. CLASSIFICATION OF GROUNDWATER RESOURCES		
Classification According to RA National Water Program: a) collection of geological and hydro geological characterizations (geological conditions and transmissibility of the rocks, location of water bodies, their depth and vulnerability in respect to pollution, water pressure character, groundwater sources, wells, etc.) b) collection of meteorological data	a) implemented once b) implemented once	RGF, Armenia Water Supply and Sewerage company and Yerevan Jur CJSCs, Institute of Geological Sciences of NAS RA
IX. ESTIMATION OF SURFACE WTAER RESOURCES BY QUALITY		
Determination of Canadian index: a) collection of monitoring indicators, b) calculation of Canadian index,	a) implemented once a year b) implemented once a year	Armecomonitoring

c) classification of water quality according to Canadian index	c) implemented once a year	
X. ESTIMATION OF ECOLOGICAL FLOW		
Determination of ecological flows of the rivers: For the gaged river basins a) determination of the average flow for the period of 10 consecutive days having the minimum flows during the winter season b) calculation of monthly and annual ecological flows For the ungaged river basins a) calculation of monthly and annual ecological flows	a) implemented once a year b) implemented once a year a) implemented once a year	GIS maps, hydrological reference books, hydrological atlas