Strengthening Hydromet and Early Warning Services in Belarus
A Road Map
This road map was prepared by the World Bank Group/Global Facility for Disaster Reduction and Recovery (GFDRR) under the “Enhancing Disaster and Accident Preparedness in the Republic of Belarus” technical assistance. It presents a potential pathway to strengthen the country’s national hydrometeorological (hydromet) and Early Warning Systems and services, forest fire forecasting, and radiation monitoring and forecasting services based on the needs of the user community. The road map is based on a technical evaluation and detailed assessment of the needs and capacities of Belhydromet which, as the main service provider in the country, issues weather, water, forest fire and radiation-related information, forecasts and warnings.

Other government agencies that are responsible for the provision of advisory services related to weather, climate, hydrology, forest fire, radiation, disaster management and agriculture to end-users are considered as key stakeholders of the Belhydromet information and services. Some important stakeholders include the Ministry on Emergency Situations; Department of Crop Production at the Ministry of Agriculture and Food; State Institution for Forest Protection and Monitoring; Forest Institute; National Statistical Committee of Belarus; Belarusian Nuclear Power Plant; and State Aviation Rescue Institution. This road map identifies gaps and challenges in the production and delivery of weather, climate, hydrological, forest fire and radiation-related information and services, and proposes a strategy for improving the country’s institutional capacity in support of saving lives, protecting property and livelihoods, and social and economic development. The road map authors consulted a number of government institutions and agencies (including several among the above-listed). The road map is the result of a collaboration between the Government of Belarus and the World Bank Group.

The authors wish to extend their appreciation to and acknowledge the national agencies, ministries and organizations, in particular the Ministry on Emergency Situations and Belhydromet, for their support and assistance in granting access to information, for providing support and being available for discussions during the process of preparing the road map.

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**Design:** Johanna Mora

**Cover photo:** Belhydromet
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<th>Description</th>
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<tr>
<td>ATM</td>
<td>Atmospheric Transport Model</td>
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<tr>
<td>AWS</td>
<td>Automatic Weather Station</td>
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<td>BSSR</td>
<td>Belarusian Soviet Socialist Republic</td>
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<td>CAP</td>
<td>Common Alerting Protocol</td>
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<td>CDM</td>
<td>Collaborative Decision Making</td>
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<tr>
<td>CONOPS</td>
<td>Concept of Operation</td>
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<td>CRICUWR</td>
<td>Central Research Institute for Complex Use of Water Resources</td>
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<tr>
<td>DRM</td>
<td>Disaster Risk Management</td>
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<td>DSS</td>
<td>Decision Support System</td>
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<td>ECMWF</td>
<td>European Center for Medium-Range Weather Forecasts</td>
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<td>EFFIS</td>
<td>European Forest Fire Information System</td>
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<td>EMMA</td>
<td>European Multi-Service Meteorological Awareness</td>
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<td>EPS</td>
<td>Ensemble Prediction System</td>
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<td>ERA</td>
<td>Emergency Response Activity</td>
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<td>ERCC</td>
<td>European Response Coordination Center</td>
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<td>EUMETNET</td>
<td>European Meteorological Service Network</td>
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<td>EUMETSAT</td>
<td>European Organization for Meteorological Satellites</td>
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<td>EWS</td>
<td>Early Warning Systems and Services</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>FCS</td>
<td>Fire Chemical Stations</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GFCS</td>
<td>Global Framework for Climate Services</td>
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<td>GFDRR</td>
<td>Global Facility for Disaster Reduction and Recovery</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<td>G2B</td>
<td>Government-to-Business</td>
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<td>G2G</td>
<td>Government-to-Government</td>
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<td>GPRS</td>
<td>General Packet Radio Service</td>
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<td>GTS</td>
<td>Global Transmission System</td>
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<td>HA</td>
<td>Hectares</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>IPCC</td>
<td>International Panel on Climate Change</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<td>KM</td>
<td>Kilometers</td>
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<td>LRF</td>
<td>Long-Range Forecasts</td>
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<td>M</td>
<td>Meters</td>
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<tr>
<td>MM</td>
<td>Millimeters</td>
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<td>MEPA</td>
<td>Ministry of Environment Protection and Agriculture</td>
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<td>MES</td>
<td>Ministry of Emergency Situations</td>
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<td>MIAC</td>
<td>Main Information and Analytical Center</td>
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<td>MoE</td>
<td>Ministry of Energy</td>
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<td>MoU</td>
<td>Memorandum of Understanding</td>
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<td>MNREP</td>
<td>Ministry of Natural Resources and Environmental Protection</td>
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<td>MPO</td>
<td>Main Physical Observatory</td>
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<td>NCMC</td>
<td>National Crisis Management Center</td>
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<td>NEMS</td>
<td>National Environmental Monitoring System</td>
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<td>NFCS</td>
<td>National Framework of Climate Services</td>
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<td>NMHS</td>
<td>National Meteorological and Hydrological Service</td>
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<td>NPP</td>
<td>Nuclear Power Plant</td>
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<tr>
<td>NWP</td>
<td>Numerical Weather Prediction</td>
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<tr>
<td>O&amp;M</td>
<td>Operations and Maintenance</td>
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<tr>
<td>PSW</td>
<td>Public Weather Services</td>
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<tr>
<td>QA/QC</td>
<td>Quality Assurance/Quality Control</td>
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<td>QMS</td>
<td>Quality Management System</td>
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<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>SODAR/RASS</td>
<td>Radio-Acoustic Sounding System</td>
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<td>SOP</td>
<td>Standard Operating Procedure</td>
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<td>SSD</td>
<td>Strategy for Service Delivery</td>
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<tr>
<td>REMRC</td>
<td>Republican Emergency Management and Response Center</td>
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<tr>
<td>RERC</td>
<td>Republican Emergency and Response Center</td>
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<tr>
<td>RSMC</td>
<td>Regional Specialized Meteorological Center</td>
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<tr>
<td>USSR</td>
<td>Union of Soviet Socialist Republics</td>
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<td>WFD</td>
<td>Water Framework Directive</td>
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<td>WFS</td>
<td>Weather Forecasting Service</td>
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<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
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<tr>
<td>WRF</td>
<td>Weather Research and Forecasting Model</td>
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<td>WWW</td>
<td>World Weather Watch</td>
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<tr>
<td>ZAMG</td>
<td>Zentralanstalt für Meteorologie und Geodynamik, Central Institute for Meteorology and Geodynamics (Austria)</td>
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</table>
EXECUTIVE SUMMARY

Purpose of Road Map Development

The purpose of this road map is to assess the current capabilities of the Belarus Hydrometeorological Service to produce and deliver products and services based on the user needs. The analysis identifies gaps and challenges in producing and delivering fit-for-purpose weather, climate, hydrological, forest fire and radiation-related information and services. The road map aims to provide the Government of the Republic of Belarus with a technical strategic framework to improve hydromet, forest fire, radiation monitoring and early warning services and systems, and the resulting socioeconomic benefits. The expectation is for Belarus to improve its capability and capacity to: (i) produce, manage, translate and communicate hydromet, forest fire and radiation-related data and information, including forecasts and warnings for stakeholders and end-users; (ii) assist stakeholders and end-users in accessing, interpreting and utilizing the generated data and information; (iii) improve the dissemination of and response to warnings for public safety and economic security; (iv) inform planning and decision-making for cost-effective investments in sustainable development and adaptation to climate change; and (v) make optimum use of all investments from the government and development partners.

The road map first lays out the current context of hydromet in Belarus, identifies the principal stakeholders and end-user community, and weighs these two factors against Belhydromet’s long-term strategy and the Law of the Republic of Belarus No. 93-3 (2006) “About Hydrometeorological Activities. Here, the question is: Does the principal hydromet service provider meet the country’s expectations and needs? And, the findings indicate: a gap exists.

The road map then drills down on the financial and technical infrastructure to determine if Belhydromet has the tools to match the country’s expectations and needs for services. And, the findings indicate: more robust tools can transform Belhydromet into a technically modern and sound hydromet service.

To this end, the road map articulates three scenarios to transform Belhydromet to better deliver hydromet, forest fire and radiation-related information and early warning services and systems. The scenarios are based on realistic possibilities and priority activities and provide expected timeline and resource commitments.

Ultimately, the road map supports the Government of the Republic of Belarus in ensuring the country’s hydromet, radiation-related and environmental safety, safeguarding its population’s livelihoods and properties, and using robust hydromet and early warning systems and services to attract new investors and to protect its economic investments.

Geographical Features and Hydromet Hazards

Belarus has a total area of 207,600 square kilometers (km²). It is a landlocked country and is a part of the East European lowland, with the highest point at 345 meters (m) above sea level. It is bordered in the northeast and east by the Russian Federation, in the southeast and south by Ukraine, in the southwest by Poland and in the northwest by Lithuania and Latvia. For administrative purposes, the country is divided into the city of Minsk and 6 provinces (oblasts): Brest, Gomel, Grodno, Minsk, Mogilev and Vitebsk. There are around 20,800 rivers in Belarus with a total length of 90,600 km. The climate of Belarus is moderate continental, with cool humid winters and warm summers. Average temperatures vary across Belarus from -4.5° to -8° Celsius in January to 18.5° Celsius in July. At least 50 percent of Belarus experience sub-zero temperatures for about a third of the year, with the east being covered with snow for up to 120 days per year. Belarus has an average annual rainfall of 600–700 millimeters, with about 70 percent of the
precipitation falling from April to October.

Extreme weather events occur in Belarus primarily in the summer months in the form of high winds, extreme rainfall, hail, heat waves, drought, wildfires and, in rare instances, frost. In winter, the natural hazards include extreme low temperatures, blizzards, ice and wind.

**Socioeconomic Impact of Hydromet Hazards**

Atmospheric hazards include wind, localized rain, hail and extreme temperatures and cause losses of about 0.4 percent of gross domestic product (GDP) every year. Over 40 percent of Belarus’s GDP is weather-sensitive, primarily in the agriculture, forestry, fuel, energy, construction, transport, communications, housing, and utilities sectors. On average about 100,000 people are affected and about 1 percent of GDP is lost to flooding every year. A very damaging flood in Belarus occurred in 1993, affecting approximately 40,000 people and causing at least US$150 million in damage. The biggest flood in recent memory took place in 1999, when the floodplain of the Goryn and Uborot Rivers in the Polesie Area was 1.0–3.3 meters under water.

**Status of hydromet, forest fire and radiation-related services**

Belarus has a long history of meteorological observations. They started in the 19th century and are closely related with the development of the hydromet service in Russia. The hydrological observations on Belarusian rivers started at the beginning of the 18th century. The State Hydrometeorological Service was formed in 1924 and by 1941, a technically well-equipped state hydromet network existed on the Belarusian territory, numbering 464 hydromet stations and posts as an integral part of the Union of Soviet Socialist Republics (USSR) Hydromet Service. In 1948, the Belarusian Hydromet Service became a Member of the World Meteorological Organization (WMO). After the proclamation of the sovereignty of Belarus in 1991, the Law of the Republic of Belarus “On Hydrometeorological Activity” established the legal basis for the National Meteorological and Hydrological Service.

In 2001, the Department for Hydrometeorology was established within the Ministry of Natural Resources and Environmental Protection. It consisted of the Republican Hydrometeorological Center, Republican Aeronautical and Meteorological Center, and Republican Center for Radiation Control and Environmental Monitoring. In 2015, the Republican Hydrometeorological Center and the Republican Center for Radiation Control and Environmental Monitoring were merged into the Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring (Belhydromet). Finally, in 2017, Belhydromet was reorganized, incorporating the hydromet and environmental monitoring centers in the 6 oblasts. As of 2019, Belhydromet is a division of the Ministry of Natural Resources and Environmental Protection, with its Headquarters at Minsk and 6 regional offices in each oblast. Belhydromet is the principal hydromet, radiation information and early warning system and services provider.

The main budget of Belhydromet is provided by the government. However, Belhydromet through its commercial activities earns equivalent of 40 percent of its budget. There is no donor or international development agency assistance with the budget. All such assistance is limited to technical advice and guidance. The budget for 2018 was US$10,304,333.

The hydromet observation network of Belhydromet consists of 54 full meteorological stations, 43 Automatic Weather Stations (AWS), 5 agrometeorological stations (agrometeorological observations are also performed at 40 meteorological stations), 7 civil aeronautical meteorological stations, 1 wind profiler, 4 radiosonde stations, 4 radars, 114 gauges (of which 35 hydrological posts equipped with continuous water-level recorders and 7 posts equipped with automatic recording gauges and automatic data transfer).

Discharge is measured at 90 gauges, where rating curves exist. Remote space-based observations are obtained from a polar-orbiting satellite and the European Organization for Meteorological Satellites
(EUMETSAT) geostationary satellites to estimate moisture reserves in snow and their dynamics and to determine snow cover deposition borders in river basins.

Radiation monitoring of the air is conducted at 41 observation points of which 24 points perform sampling of radioactive fallout and 10 points perform sampling of aerosols. Radiation monitoring of surface waters is performed at 12 observation points, including 7 transboundary points. Radiation monitoring of soils is performed at 39 reference sites and 18 landscape and geo-chemical grounds. Environmental monitoring is conducted through 66 air quality monitoring stations, the soil chemical pollution monitoring network, and 297 surface water monitoring points and 4 labs (surface water, soil, air, physical and chemical parameters).

Belhydromet produces 7-day public weather forecasts for the territory of Belarus and 3-day forecasts for each oblast. These are disseminated via the Belhydromet website and mass media. Seasonal forecasts using information from different sources are issued, but Belhydromet does not produce its own seasonal forecasts. Warnings are issued and updated as needed. The weather forecast service produces fire hazard forecasts using a 5-level scale. Forecasts of hydrological characteristics of water bodies are issued with a strong focus on the forecast of maximum water levels. No drought forecasts are produced. Monitoring of drought emergence and spread is conducted in the vegetation period. A forecast of most common crops in Belarus is made once per season. Belhydromet is the official designated aeronautical service provider for 6 airports in the country. Climate services are limited to the production of statistical data and some analyses of historical data, but no climate indices or forecasts are produced. During the fire risk season, Belhydromet issues a daily forecast indicating the most fire risk areas in Belarus.

Databases for meteorology, hydrology and radiation are separate but a software allows their re-integration into 1 central database. Belhydromet is beginning the process of moving from this traditional system to an automation of data collection and storage. International data is exchanged through the Global Transmission System (GTS). Data from 10 out of 54 synoptic stations are used for this purpose. Belhydromet owns and operates a high-performance computer.

Assessment of User Needs

Several of the main stakeholders of Belhydromet were consulted regarding their use and requirements for Belhydromet products and services. The level of engagement and the use of Belhydromet products and services is varied. Some government institutions such as the Republican Emergency and Response Center (Ministry on Emergency Situations); Crop Production Department (Ministry of Agriculture and Food); State Institution for Forest Protection and Monitoring; and Belarusian Forest Institute depend heavily on the information and advice from Belhydromet. For the National Statistical Committee of Belarus, Belarusian NPP and the State Aviation Rescue Institution the information provided by Belhydromet seems to be less critical.

Proposed Modernization of Hydrometeorological and Early Warning Services

The modernization proposed in this road map intends to help Belhydromet fulfill its public service obligations by strengthening institutional and technical capabilities and capacities. The purpose of modernizing hydromet, fire risk forecasting, radiation and early warning services is to reduce the socioeconomic risks of weather, climate, hydrological, forest fires and radiation events, and thus to protect lives and economic/development gains.

A typical NMHS is comprised of a “system of systems” as shown in Figure 1. This generic illustration of a weather, climate or hydrological system of systems can be used to identify the current status of any NMHS and to visualize investments required component-by-component in each system to achieve a particular level of improvement. The complexity of each system and its sub-systems varies depending on the size, level of development and resources of an individual NMHS (Figure 2). The system’s building blocks are
inter-dependent. User requirement is an essential ingredient for the design and implementation of the entire system. The first requirement is to have staff with the capacity to understand and operate the system. The road map uses a system-of-systems approach to arrive at three scenarios for modernizing Belhydromet.

**FIGURE 1. SCHEMATIC OF AN NMHS AS A SYSTEM OF SYSTEMS**

![Diagram showing a schematic of an NMHS as a system of systems](image)

**FIGURE 2. SUB-SYSTEMS WITHIN EACH SYSTEM**

<table>
<thead>
<tr>
<th>Monitoring and observing systems</th>
<th>Modeling systems</th>
<th>Objective and impact forecasting and warning systems</th>
<th>Service delivery systems</th>
<th>Actions, service monitoring and feedback systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global data system</td>
<td>Global NWP systems</td>
<td>Severe hazard forecasting systems</td>
<td>Public weather services system</td>
<td>Service systems for public</td>
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<tr>
<td>Surface obs systems</td>
<td>Regional NWP systems</td>
<td>Nowcasting systems</td>
<td>G2G Disaster management service system</td>
<td>Service systems for national and provincial governments</td>
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<td>Radar system</td>
<td>Limited Area Model system</td>
<td>Very short range forecasting system</td>
<td>G2G Agriculture service system</td>
<td>Service systems for businesses</td>
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<tr>
<td>Data management and archiving systems</td>
<td>Nowcasting Model system</td>
<td>Short range forecasting system</td>
<td>G2G Water &amp; power management system</td>
<td></td>
</tr>
<tr>
<td>External data systems</td>
<td>Hydro Modeling system</td>
<td>Medium range forecasting system</td>
<td>G2G and G2B Aviation services system</td>
<td></td>
</tr>
<tr>
<td>Quality management systems</td>
<td>ICT systems</td>
<td>Long range forecasting system</td>
<td>G2G and G2B Climate services system</td>
<td></td>
</tr>
<tr>
<td>Institutional management systems</td>
<td>Data comms systems</td>
<td>Technology infusion systems</td>
<td>Public-Private cooperative services systems to key businesses</td>
<td></td>
</tr>
<tr>
<td>Operational management systems</td>
<td>Computing hardware and software systems</td>
<td>External Research and Development systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Communication systems</td>
<td>Internal research and development systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cloud computing systems</td>
<td>Transition Research to Operations systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Building</td>
<td>Stakeholder institutions training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Met/Hydro institutional education and training</td>
<td>End user training and outreach</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Blue: production systems; Green: delivery systems; Red: support systems; yellow: capacity building.
A substantial modernization program for any National Meteorological and Hydrological Service should include three components, namely: (i) enhancement of service delivery system; (ii) institutional strengthening and capacity building; and (iii) modernization of observation, information and communication technology (ICT) and forecasting infrastructure. The development of the road map is in line with this principle. The activities proposed aim to strengthen Belhydromet’s institutional basis and to enhance the capacity of staff; to technically modernize those elements of the basic infrastructure and facilities (observation, ICT, data management and hydromet forecasting) that require upgrade; and, most importantly, to advance the delivery of hydromet and EW services to the population of Belarus and weather-dependent sectors.

A high-level overview of the major requirements for each component is presented below. It should be noted that, this collection of activities will need to be adjusted to reflect the actual needs and the situation of Belhydromet at the time of implementation. It is reasonable to expect that other activities may be added to or removed from the list as required.

**Enhancing Service Delivery:**

- Developing and implementing a national Strategy for Service Delivery that draws on guidance from the WMO Strategy for Service Delivery and its Implementation Plan;
- Establishing and/or strengthening communication channels and developing stronger relationships with hydromet users to specify users’ needs and priorities and to gather feedback, for improving the visibility, utility and credibility of the hydromet and early warning systems and services (EWS);
- Developing EWS, including streamlining the mechanism for issuing and disseminating early warnings among the main agencies responsible for EWS provision;
- Enhancing services, including information on severe weather, hydrological hazards, fire weather threats and radiation exposure;
- Improving access of vulnerable communities to weather, water, and climate information through multiple dissemination and communication channels and socially relevant modes and communication formats;
- Delivering specialized services to critical weather-dependent sectors, including but not limited to:
  - Agriculture services, including an agriculture advisory service with drought monitoring;
  - Hydrological information services for integrated water resources management; and
  - Services to strengthen infrastructure resilience in sectors such as energy, transport and urban environment.
- Developing a common standard for service delivery; and
- Developing a national framework for climate services (NFCS) guided by the principles of the Global Framework for Climate Services (GFCS).

**Institutional Strengthening and Capacity Building:**

- Developing a Concept of Operation (CONOPS) to guide and support the transformation of Belhydromet in line with the strategic vision of the Department and this road map;
- Building the capacity of staff of Belhydromet in technical and management aspects, including modern observing networks; utilization of innovative tools in forecasting; application of downscaling methods for long-range forecasting and climate change prediction; and
- Establishing an institutional mechanism between Belhydromet and the users for sharing data and information, for joint product development and for shared capacity enhancement.

**Improving Observing Network, ICT Infrastructure and Forecasting:**

- Designing new, as necessary, and rehabilitating existing observation networks;
Streamlining and enhancing data management systems;
- Strengthening the ICT infrastructure as required;
- Enhancing the Early Warning System;
- Introducing modern forecasting tools and methodologies, including ensemble prediction systems (EPS) and probabilistic forecasting for weather and hydrological forecasting to produce forecasts with increased accuracy and the required lead time, and spatial resolution depending on end-user requirements;
- Enhancing forecast verification methods;
- Introducing downscaling techniques for long-range forecasts and climate prediction; and
- Introducing impact-based forecasting to cover severe hazards (e.g., floods and droughts).

This road map lays out three scenarios for modernization. Each contributes in different degrees based on the time and resources available to a system capable of producing and delivering: (i) timely warnings of extreme and hazardous events and their potential impacts; and (ii) forecasts for operations and planning in weather and climate-sensitive economic sectors, particularly agriculture, forestry, transport, water resources, and disaster risk management.

**Scenario 1: Technical Assistance.** Provision of technical assistance for high priority activities to improve basic public services by introducing affordable new technologies into and training the staff of Belhydromet for heightened capacities and capabilities. The approximate cost of implementation of this scenario is expected to be US$829,000 (immediate to short term: 2 years).

**Scenario 2: Intermediate Modernization.** Investment to achieve a modest improvement in the capabilities to provide weather and hydrological services to meet the needs of the most important user communities, for example, agriculture, forestry, transport, water resources, and disaster risk management. This scenario is expected to cost US$2,147,000 to implement (medium term: 4 years).

**Scenario 3: Advanced Modernization.** Investment to bring the capabilities for providing fit-for-purpose data, forecasts and warning services for the safety of the public and support to develop the most important socioeconomic sectors. This scenario is expected to cost US$2,964,000 to implement (long term: 7 years).

**Socioeconomic Benefits of Improved Hydromet Services and Early Warning Systems**

It is now a common practice for hydromet service providers to undertake a cost–benefit analysis to secure and optimize the use of investment resources. In all of the cases where such analyses have taken place, the benefits of hydromet services are significantly larger than the capital and operational costs needed to modernize, produce and deliver them.

With the purpose of optimizing investment benefits, the Belhydromet modernization must focus on delivering services using all possible mechanisms and channels to meet the goals and requests of end-users and ensuring that users can productively apply those services.

Recent assessments have applied different methodologies as described in the publication, Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. This includes further-refined, sector-specific and benchmarking approaches (*WMO et al 2015*).

It is clear that any enhancement in the capacity and capability of Belhydromet will lead to improvements in the generation of services and thus will lead to benefits both from reducing risks to life and property and from generating economic development. The benefit to cost ratio as the result of modernization of Belhydromet varies for each scenario.
1. INTRODUCTION TO GEOGRAPHICAL FEATURES AND WEATHER, CLIMATE AND HYDROLOGICAL HAZARDS

The Republic of Belarus (Belarus) is a landlocked country in Eastern Europe with a total area of 207,600 square kilometers (km²). It is situated in the center of Europe (56°10’ and 51°16’ north latitude, 23°11’ and 32°47’ east longitude) and extends for 560 km from the north to the south and for 600 km from the west to the east. The capital is the city of Minsk. The country is bordered in the northeast and east by the Russian Federation, in the southeast and south by Ukraine, in the southwest by Poland and in the northwest by Lithuania and Latvia (Figure 3). It declared independence from the Union of Soviet Socialist Republics (USSR) on August 25, 1991.

Belarus is part of the East European lowland, covered with young glacial formations, mainly gravel and sand. From the southwest to the northeast, the moraine Belarus rampart, where several larger rivers originate, crosses the country. In the south is the vast, marshy land of Polesye. The highest point is 345 meters (m) above sea level; the lowest point is 90 m above sea level. The country averages 160 m above sea level.

FIGURE 3. OROGRAPHIC MAP OF BELARUS
The climate of Belarus is moderate continental, with cool humid winters and warm summers. The west is characterized by the transitional climate between maritime and continental; the climate in the central and eastern parts is continental. Average temperatures vary across Belarus from -4.5° to -8° Celsius in January to 18° to 19° Celsius in July. At least 50 percent of the country experiences sub-zero temperatures for about a third of the year. Belarus has an average annual rainfall of 600–700 millimeters (mm), ranging from 550 mm in the southeast to 750 mm in the highest areas in the center of the country. About 70 percent of the precipitation falls from April to October. The east is covered with snow for up to 120 days per year, the west for fewer than 80 days.

In 2015, the total population of Belarus was about 9.5 million, of which around 25 percent live in rural areas. The population density is 46 inhabitants per square kilometer. The population is rather evenly distributed across the country.

The agricultural area is estimated at 8.7 million hectares (ha), which is 43.7 percent of the country’s total area. It consists of arable land with variable crops (27.2 percent of the country), permanent crops (0.6 percent only) and permanent meadows and pastures (15.9 percent). In 2013, the total physical cultivated area was estimated at 5.7 million ha. The country’s main agricultural products are potatoes (being the world’s eighth largest producer) and cereals. Other agricultural products include vegetables, fruits, meat and dairy products. Much is exported to neighboring states, with the Russian Federation being a major market. The total forest area is about 8.4 million ha, representing 39 percent of the country’s total area; 50.5 percent of the total forest area is Scotch pine. In 2014, the gross domestic product (GDP) was US$76,139 million and agriculture accounted for 9 percent of GDP while in 1994, it accounted for 10 percent.

Most of the main rail lines and highways, oil and gas pipelines, air routes and waterways between Western Europe and Asia converge in Belarus. The shortest routes from the central and eastern Russian regions to Western Europe, as well as between the Baltic and Black Seas, go through Belarus. There are around 20,800 rivers with an overall length of 90,600 km. Seven major rivers have a total length of more than 500 km each: Western Dvina, Neman, Vilia (or Viliya), Dnieper, Berezina, Sozh and Pripyat. All, except Berezina, are transboundary rivers (Figure 4).
Belarus can be divided into four main transboundary river basins:

- **Dnieper Basin** covers about 81.5 percent of the country. The Dnieper River rises in the Russian Federation and crosses the border of Belarus in the northeast. Within the country, it flows to the south and, after flowing along the Belarus–Ukraine border some 100 km, it enters Ukraine, and eventually enters the Black Sea. The largest tributary of the Dnieper in Belarus is the Pripyat, which rises in Ukraine, enters the country in the south, flows east and leaves the country again in the southeast to flow into the Dnieper in Ukraine just north of Chernobyl. Other main tributaries of the Dnieper are the Berezina River, originating within Belarus, and the Sozh River, originating in the Russian Federation. A major tributary of the Pripyat River is the Ptich River, originating within Belarus south of Minsk.

- **Western Dvina (Zapadnaya Dvina) Basin** covers about 10 percent of the country. The Western Dvina River rises in the Russian Federation and flows into Belarus in the northeast. It then flows to the west and leaves the country in the northwest to flow into Latvia, where it is called the Daugava, flowing to the Baltic Sea.

- **Neman (Nieman) Basin** covers about 6 percent of the country. Its main source is in the center of the country, south of Minsk. It flows to the west and enters the territory of Lithuania, where it is called the Nemunas River, and flows to the Baltic Sea. The Vilia River, also rising in Belarus to the north of the Neman River, flows west into Lithuania, where it becomes the Neris River and flows into the Nemunas River. Some smaller tributaries rise in Poland and flow east into the Neman River in Belarus.
• **Western Bug (Zapadny Bug) Basin** covers about 2.5 percent of the country in the southwest. The main Bug River rises in Ukraine, and forms the border, first between Ukraine and Poland and then between Belarus and Poland, before entering Poland’s territory.

Long-term total renewable water resources are estimated at 57,900 million cubic meters per year (m$^3$/year) but can vary from 92,400 million m$^3$/year in wet years to 37,200 million m$^3$/year in dry years. The renewable groundwater resources are estimated at about 15,900 million m$^3$/year. There are about 10,800 freshwater lakes with a total area of 1,600 km$^2$ (or 0.8 percent of the total area of the country) and a total capacity of 6,000–7,000 million m$^3$. Seventy-five percent of the lakes are classified as small, having a surface area up to 0.1 km$^2$. The largest is Lake Naroch, with an area of 80 km$^2$ and an average depth of 9 m, followed by Lake Osveyskoye, with an area of 53 km$^2$ and an average depth of 2m. There are also about 1,500 small and shallow natural ponds in the country with a total area of 350 km$^2$ and a total capacity of 0.5 km$^3$. There are 153 reservoirs constructed in Belarus with an overall volume of 3,100 million m$^3$ and an effective storage of about 1,240 million cubic meters. Due to the climatic conditions, there is a need for drainage rather than irrigation in the country, except in areas where the groundwater level has fallen too much due to excessive drainage.

According to ThinkHazard! wildfires, river floods and urban floods are the three natural hazards with the highest risk levels in Belarus. Spring flooding is the most dangerous. In large rivers, the water rises 8.6–12.8 m above the normal water level. In middle-sized and small rivers, the water rises approximately half as high. The flood period lasts 30–120 days. The shortest flood occurs on rivers in the Neman Catchment Area (30–50 days), the longest within the Pripyat Catchment Basin (90–120 days).

The recession of spring waters lasts 30–60 days. Spring river flooding is followed by a period when water levels are at their lowest in summer. This low-water period lasts 120–140 days on the rivers of the Western Dvina Catchment Area, 135–165 days on the Pripyat and 190–205 days on the remaining rivers. In dry years (as in 1939, 1951 and 1952), rivers and canals with catchment areas exceeding 1,000 km$^2$ may even dry up. Rivers stay frozen for 80–140 days, starting in November. During intense winters, some small rivers may freeze to the bottom for a period of up to 4.5 months. No river freeze-up occurs during mild winters.

For administrative purposes, the country is divided into the city of Minsk and 6 provinces (oblasts): Brest, Gomel, Grodno, Minsk, Mogilev and Vitebsk.

The Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring of the Republic of Belarus (Belhydromet) and the Republican Emergency Management and Response Center (REMRC) of the Ministry for Emergency Situations of the Republic of Belarus monitor for flooding and early flood warning. Belhydromet observes hydrological and meteorological variables and produces meteorological and hydrological forecasts. The REMRC receives real-time data and meteorological forecasts from Belhydromet and issues alerts for areas that are likely to flood.

Fire hazard also is high in Belarus. Half of the country’s forest cover is pine, and pine is susceptible to fire. One quarter of the country’s forest cover is contaminated as a result of the 1986 Chernobyl Nuclear Power Plant disaster, and the contamination exacerbates forest fire risk. For this reason, forest and peat fire monitoring and firefighting capacities have increased in recent years, reducing damages. However, in extreme weather conditions, burned areas can be significant. **Figure 5** shows the number of fires and the burned area from 1991 to 2017.
A general lack of biodiversity conservation programs has led to an increase of pine dieback caused by bark beetles. Dieback can increase the forest fire risk, but there is no evidence in Belarus of a such a correlation. In fact, by law, once a pest affects a forest, the damage has to be cleared in 1 month. In 2018, 450 ha of forest were destroyed by forest fires and 47,000 ha were destroyed by extreme weather and dieback, of which 45,100 ha were due to extreme weather alone.

Today, the remaining radioactive contamination restricts the use of agricultural areas and forests in the country, especially in the Gomel Region (Figure 7). In addition, the negative impact of forest fires in territories within and beyond Belarus is further increased due to such contamination. According to the Ministry of Foreign Affairs of the Republic of Belarus, the Chernobyl disaster cost Belarus approximately US$235 billion through 2009. Belarus continues to spend 3 percent of its national budget, or about €1 billion (approx. US$1.1 billion) per day, to address the Chernobyl consequences, with a major focus on recovery and development of impacted territories. About 97 percent of the radioactive fallout from the Chernobyl disaster landed in Belarus (Figure 6).
Belhydromet is tasked with providing forecasts for the Belarusian territory contaminated by Chernobyl until 2046 (Figure 7). Maps of the prevailing radioactive contamination are updated every 5 years based on the monitoring data. The main users of this information are the Ministry of Emergency Situations, the Ministry of Forestry and the State Institution for Radiation Monitoring and Radiation Safety (Bellesrad), which is a division of the Ministry of Forestry.

**FIGURE 7. MAP OF CS-137 CONTAMINATION IN GOMEL REGION IN 2016 (LEFT) AND FORECAST FOR 2056 (RIGHT)**

The closest nuclear power plants (NPP) in neighboring countries are listed in Table 1. Belhydromet operates a network of automated radiation measurements with stations close to the Belarusian border near these NPPs.

**TABLE 1. NUCLEAR POWER PLANTS IN NEIGHBORING COUNTRIES**

<table>
<thead>
<tr>
<th>Nuclear Power Plant</th>
<th>Net Generation Capacity (gigawatt/GW)</th>
<th>Distance to the Belarusian Border (kilometers/km)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignalina (Lithuania)</td>
<td>-</td>
<td>5 km</td>
<td>Decommissioned, shut down in 2009</td>
</tr>
<tr>
<td>Chernobyl (Ukraine)</td>
<td>-</td>
<td>15 km</td>
<td>Decommissioned, shut down in 2000</td>
</tr>
<tr>
<td>Rovno (Ukraine)</td>
<td>2.7 GW</td>
<td>60 km</td>
<td>Operating</td>
</tr>
<tr>
<td>Smolensk (Russia)</td>
<td>2.8 GW</td>
<td>70 km</td>
<td>Operating</td>
</tr>
<tr>
<td>Kursk (Russia)</td>
<td>3.7 GW</td>
<td>265 km</td>
<td>Operating</td>
</tr>
</tbody>
</table>

The first Belarusian NPP (2.4 GW) is expected to start operation in 2020 in Ostrovets. Belarus stress-tested its NPP using European methods and standards in 2018 in close cooperation with the International Atomic Energy Agency (Table 2).
TABLE 2. NUCLEAR FACILITIES IN BELARUS

<table>
<thead>
<tr>
<th>Facility</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostrovets NPP</td>
<td>Start of operation planned in 2020</td>
</tr>
<tr>
<td>Giatsint facility (critical assembly)</td>
<td>Operating</td>
</tr>
<tr>
<td>Yalina booster facility (sub-critical assembly)</td>
<td>Operating</td>
</tr>
<tr>
<td>Yavor facility (storage of non-irradiated nuclear material)</td>
<td>Operating</td>
</tr>
<tr>
<td>Yavor facility 1</td>
<td>Planned</td>
</tr>
<tr>
<td>Kristal facility (critical assembly)</td>
<td>Extended shut-down</td>
</tr>
<tr>
<td>Iskra facility (storage of spent fuel)</td>
<td>Decommissioned</td>
</tr>
</tbody>
</table>

2. WEATHER AND CLIMATE RISKS

Extreme weather events occur in Belarus primarily in the summer months in the form of high winds, extreme rainfall, hail, heat waves, drought, wildfires and, in rare instances, frost. In winter, the natural hazards include extreme low temperatures, blizzards, ice and wind. During the 2015–2016 winter, a series of storms caused heating and power interruptions and roof collapses. Between 2006 and 2015, there were 136 extreme weather events in Belarus. A severe drought and heat wave impacted the critical late summer growing period (with only 14 percent of normal rainfall in August) and increased the areas at risk of forest and peat fire.

Under these circumstances, rising temperatures are projected to lead to more extreme events. Since 1989, Belhydromet has observed an 1.3° Celsius increase in the average temperature (Figure 8) and a 40 percent increase in droughts. Projections indicate that this trend will continue, with an increase in average temperatures of 1° Celsius by 2030, 2° Celsius by 2060 and up to 4.4° Celsius by 2099. During this century (to 2100), the International Panel on Climate Change (IPCC) projects a continued increase in the frequency and intensity of warm days, leading to more frequent, intense and prolonged heat waves. Further, associated increases in the atmospheric convective potential are projected to lead to more frequent and intense extreme events, including wind, thunderstorms and hail.

FIGURE 8. DEVIATION OF AVERAGE ANNUAL AIR TEMPERATURE FROM CLIMATIC NORMAL, 1881–2011

![Graph showing deviation of average annual air temperature from climatic normal, 1881–2011.](image-url)
As a result of rising winter temperatures, the flooding period is changing as are annual river flows. Floods are expected to occur more frequently in winter and less so during the spring. This can be attributed to increases in winter precipitation as well as to higher temperatures. More of the winter precipitation is expected to fall as rain, as opposed to snow that is stored until the spring melt season (Figure 9). Already, melting snow combined with rain leads to flooding of agricultural areas and associated infrastructure, including critical roads and bridges, disrupting transport and hampering the access of emergency services. Floods can last up to 4 months. The IPCC projects an increase in heavy winter precipitation, with some potential for increased precipitation intensity in the summer.

Concerning forest fires, there is no evidence that increasing temperatures lead to increased forest fire risk.

**FIGURE 9. CHANGES IN AVERAGE SNOW COVER**
3. SOCIOECONOMIC IMPACTS OF HYDROMET HAZARDS

Atmospheric hazards include wind, localized rain, hail and extreme temperatures and cause losses of about 0.4 percent of GDP every year. Over 40 percent of Belarus’s GDP is weather-sensitive, primarily impacting the agriculture, forestry, fuel, energy, construction, transport, communications, housing and utilities sectors. On average about 100,000 people are affected and about 1 percent of GDP is lost to flooding every year. Damaging floods in Belarus have occurred 10–12 times over the last 50–70 years, with the heaviest ones in 1956, 1958, 1974, 1979, 1993 and 1999. The most damaging flood in Belarus since its independence in 1991 occurred in 1993, affecting approximately 40,000 people and causing at least US$150 million in damage. The latest happened in March 2013, when thousands of buildings were flooded. Figure 10 shows the impact of flooding on the oblasts’ GDP, represented as a percentage of annual average GDP affected, with greater color saturation indicating higher percentages. The bar graphs represent GDP affected by floods with return periods of 10 years (white) and 100 years (black). The horizontal line across the bars shows the average annual GDP affected by floods.

FIGURE 10. AFFECTED GDP BY FLOODS WITH RETURN PERIODS OF 10 AND 100 YEARS FOR OBLASTS IN BELARUS

A 100-year return period flood event would currently cause losses of the order of 4 percent of GDP, or US$2 billion. Climate change projections indicate that an event of similar frequency would cause losses in the range of US$5–8 billion in 2080, as shown in Figure 11.
At the household level, beyond immediate casualties and asset losses, disaster and climate risks contribute to the longer-term erosion of welfare. This includes, for example, negative impacts on food security, commodity prices, unemployment, health (including heat stress, pests, pathogens and acute enteric infections), air and water quality, and a general erosion of certain livelihoods. These long-term impacts clearly show that efforts to reduce poverty and disaster risks are complementary.

4. ASSESSMENT OF USER NEEDS FOR WEATHER, CLIMATE, AND HYDROLOGICAL SERVICES AND ENVIRONMENTAL MONITORING

In order to deliver fit-for-purpose hydromet services, the first step is to gather first-hand information about the users’ requirements. To this end, several of the main stakeholders of Belhydromet were consulted (Photo 1) regarding their use and requirements for Belhydromet products and services. The level of engagement and the use of Belhydromet products and services is varied. Some government institutions depend heavily on the products and advice from Belhydromet. For other institutions, the information seems to be less critical.

The following describes the users and their particular information requirements for Belhydromet data, products, and services:

1) National Statistical Committee of Belarus receives data from Belhydromet with a special focus on indicators for sustainable development.

2) Native Nature Magazine: was represented by a journalist who also represented a member of the public. She stated that weather forecasts up to 6 days ahead were needed for their work, but this information was not obtained from Belhydromet. They use other
channels and mostly the Internet for obtaining warnings and forecasts. The magazine publishes stories on hydromet topics which are aimed to inform and educate the public. On the whole they find the Belhydromet forecasts too general and not location-specific, but they have no problem in understanding the terminology.

3) Republican Emergency and Response Center (RERC) receives Belhydromet warnings by telephone followed by written text. These are used to warn the public through mobile platforms (phones and apps). RERC receives primary data of meteorological observations in Excel format every 24 hours via email and precipitation data in 12-hour intervals. In case of adverse and hazardous weather event warnings, the information is color coded. In addition, RERC also uses other web-based resources. Using interactive maps, RERC warns the public of spring floods and forest fires. Weather forecasts for 3 days ahead are received in Excel format in maps and parameter lists for oblasts and oblast centers, while 7-day forecasts are provided in text format. RERC receives daily hydrological observations data in Excel format; hydrological forecasts are provided in text format; analytical information on the state of water bodies is provided every 5 days and on a daily basis during flood season. As part of the fire season preparations, RERC uses the forecasts for the entire vegetation season and historical actuals to identify areas of highest probability of forest (also peat and grass) fires. Seasonal outlooks for the entire season are received twice per year from Roshydromet. The Emergency Center does not use geographic information system (GIS) maps for identifying vulnerable areas in the country but does use maps which indicate the location of infrastructure, such as the nuclear power plan (NPP) or factories that could pose risk to the population.

4) State Aviation Rescue Institution at the Emergency Center receives weather data for operations.

5) Belarusian NPP operates a meteorological and radiation monitoring network around the NPP site in cooperation with Belhydromet.

6) Department of Crop Production at the Ministry of Agriculture and Food is one of the most dependent sectors on hydromet information and forecasts.

7) State Institution for Forest Protection (Bellesozaschcita) focuses on pest and disease (forest health monitoring) and on radiation monitoring in the forests. It receives data from and in return provides forest-monitoring data to Belhydromet. Belhydromet bulletins are received every 10 days in the summer and monthly in other seasons. The bulletins use the average temperature and precipitation data and their deviation from normal, and they calculate the hydrothermal and aridness coefficient. Since the observation network does not cover all forests, Bellesozaschcita uses GIS-based methods to calculate the hydrothermal coefficient over the territory of Belarus. Bellesozaschcita requires groundwater data to better diagnosis the health of the forest; this is important because groundwater amelioration efforts in the 1960’s and 1970’s had negative impacts. However, Belhydromet does not carry out groundwater observations. Bellesozaschcita also requires electronic warnings for fire hazard classes early in the morning and information on wind speed. Belhydromet does not provide this information. Flood effects are less drastic than drought for this sector.

8) Ministry of Forests conducts annual field surveys and documents are shared with and checked by Belhydromet before being distributed to the forest agencies. In the approx. 350,000 ha of radioactively contaminated forest, Belhydromet monitors Cs-137 in the soil, air, vegetation and timber in the forests. Belhydromet monitors other radionuclides in the most affected zones, with focus on settlements. Cooperation between the Ministry of Forests and Belhydromet is well established for monitoring radioactivity and the sampling methods are harmonized. Quality is assured by International Organization for Standardization (ISO) accreditation and data exchange is ensured. Belhydromet is responsible for the storage of all monitoring data.
9) **Belarusian Forest Institute** provides scientific support to forest fire activities, including regulations on forest zoning and methodology to determine fire hazards. The Institute works with Belhydromet to determine forest fire hazard risks depending on weather conditions. At present, Belhydromet provides forest fire profiles and class warnings by 12 p.m. (12.00) each day. It would be helpful to receive these warnings earlier and to include the wind speeds in the fire warnings. Fire warnings are launched for 54 meteorological observation sites, but information is needed for all 96 organizations involved in forest operations.

10) **Department of Forestry** plans prevention activities and mobilizes resources.

11) **National Academy of Sciences Climate Research Center** collaborates with Belhydromet on scientific projects. It also represents Belarus State University.

5. **INSTITUTIONAL AND ORGANIZATIONAL ANALYSIS**

5.1 **HISTORY OF BELHYDROMET**

Belarus has a long history of meteorological observations. The observations started in the 9th century and are closely related with the development of the hydromet service in Russia. The Main Physical Observatory (MPO) of Russia was established in St. Petersburg in 1849 and began publishing meteorological observations in the “MPO Observations Collection” in 1850. From 1865 to 1910, Belarusian observations were regularly placed in “The MPO Chronicles”. In 1886, there were 45 meteorological stations, belonging to various institutions in Belarus. These gradually increased until the end of the 19th century when weather observations were carried out at almost 100 points.

The first hydrological observations on Belarusian rivers started at the beginning of the 18th century with the development of waterways and navigable canals. More systematic hydrological analyses began with the establishment of the Main Administration of Water Communications of Russia. Observations on the opening and freezing of rivers started in 1808. The first stationary hydrological posts were opened on the large rivers of Belarus for shipping purposes in 1876. The first official publication of observations from Belarusian hydrological posts was in 1881: “Information on Water Level Conditions on the Rivers and Lakes of European Russia on Observations at 80 Water-Measuring Posts.” Subsequently, from 1881 to 1910, Belarusian hydrological observations were published in “Information on the Water Level on the Inland Waterways of Russia.”

In 1914, 27 meteorological stations, 65 rain-gauge stations and 63 water-measuring posts existed in Belarus. During the First World War and the Civil War, the hydromet network location in the Belarusian territory changed significantly: many meteorological stations and posts ceased to function or were destroyed, and hydrological observations ceased. A new hydromet service began after the October Revolution in 1917. The Council of People’s Commissars of the Russian Soviet Federative Socialist Republic issued a decree in 1921 that clarified the tasks of the Russian hydromet service. Similar work was carried out in all republics that had been included in the Union of Soviet Socialist Republics (USSR) since 1922, including in Belarus which became the Belarusian Soviet Socialist Republic (BSSR).

In 1919, only 7 meteorological stations existed in Belarus; in 1921, 8 water-measuring and 2 rain-gauge posts resumed operation. The hydromet observation stations were mainly a division of the People’s Commissariat of Agriculture and the People’s Commissariat of Transport. The weather stations in Gorki, Vasilevichi, Maryina Gorka and the Novoe Korolevo remained under the MPO’s control.
The Belarusian Hydrometeorological Service was established on July 1, 1924. From that date, the Belarusian Meteorological Office began its work under the authority of the Experimental Department of the People's Commissariat of Agriculture. The primary task of the Meteorological Office was to secure the operation of BSSR hydromet units, collect and process received materials, deliver hydromet information to the respective departments and organizations, and develop a scientific, evidence-based network of stations and posts. The first Belarusian Weather Bulletin was issued in April 1925. The first pilot balloon was launched in Minsk in July 1926. In the same year, agrometeorological observations were launched, and research work on the study of hail started.

At the beginning of 1927, the Meteorological Office was attached to the Belarusian Research Institute of Agriculture and Forestry under the Council of People's Commissars of the BSSR and became part of the Belarusian Geophysical Service organized by the Institute. In 1928, it was transformed into a Department of Weather Stations of the Belgeophys, which checked and processed the observational data of 80 meteorological stations and issued monthly weather surveys. In the same year, the management of hydrological works was entrusted to the hydrological section of the People's Commissariat of Agriculture. In 1930, the Belarusian Hydrometeorological Institute was established. It comprised the Belarusian Geophysical Service of the Research Institute of Agriculture and Forestry with its meteorological network, the People's Commissariat of Transport weather stations network, the People's Commissariat of Agriculture experimental stations and hydrological operations (water-measuring posts and rain gauges), as well as a network of water posts belonging to the Dnieper River Transport Authority and other institutions. In 1931, 40 meteorological and 23 hydrological stations and posts were operated under the jurisdiction of the Belarusian Hydrometeorological Institute.

In 1941, a technically well-equipped state hydromet network existed on the Belarusian territory. There were 464 hydromet stations and posts, and they were an integral part of the USSR Hydromet Service. The BSSR Hydrometeorological Service ceased with the occupation of BSSR by Germany in 1941. Restoration of the observation network began in December 1943 in accordance with a plan by the Western Administration of the Hydrometeorological Service of the Belarusian Military District for restoring hydromet stations and posts was, in general, completed by the end of 1944. By the beginning of 1945, 46 stations and 185 posts were operating in Belarus. In addition, the forecasting services and the Belarusian Geophysical Observatory were operational. In 1948, the Belarusian Hydrometeorological Service became a member of the World Meteorological Organization (WMO).

In 1974, the Belarusian Hydrometeorological Service consisted of the Belarusian territorial hydromet center, 3 observatories, 34 meteorological stations, 6 specialized stations (swamp, lake, forest and 3 agrometeorological), 7 hydrological and 16 aero-meteorological stations, 201 hydrological posts and about 700 collective farm and state farm agrometeorological posts.

In 1991, after Belarus proclaimed sovereignty, the Law of the Republic of Belarus "On Hydrometeorological Activity" established the legal basis for the National Meteorological and Hydrological Service. The service was reorganized into the Main Department of Hydrometeorology under the Council of Ministers. In 1995, it was reorganized into the Committee on Hydrometeorology of the Ministry on Emergency Situations and Protection of Population from the Impacts of the Accident at the Chernobyl Nuclear Power Plant. In 1997, it was reorganized into the State Committee on Hydrometeorology of the Republic of Belarus.

In 2001, the State Committee on Hydrometeorology was liquidated by presidential edict. The Department for Hydrometeorology was established within the Ministry of Natural Resources and Environmental Protection. The Department included the Republican Hydrometeorological Center, the Republican Aeronautical and Meteorological Center, the Republican Center for Radiation Control and Environmental Monitoring, 6 oblast hydromet centers, 54 weather stations, 86 meteorological posts, 3 hydrological stations, 136 hydrological posts, 6 agrometeorological stations, 1 background monitoring station, 1 lake station, 1 swamp station, 2
inter-district centers for hydrometeorology and environmental monitoring, and 8 aeronautical meteorological civil stations.

In 2015, the Republican Hydrometeorological Center and the Republican Center for Radiation Control and Environmental Monitoring were merged into the Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring. Since 2016, this hydromet service has participated in the Integrated Environmental Monitoring Program for the Belarusian Nuclear Power Plant.

In 2017, Belhydromet was reorganized, incorporating the hydromet and environmental monitoring centers in the 6 oblasts.

As of 2019, Belhydromet is a division of the Ministry of Natural Resources and Environmental Protection, with its Headquarters at Minsk and 6 regional offices in each oblast. Belhydromet is the principal hydromet, radiation information and early warning system and services provider. Its activities in the fields of meteorology, hydrology, agrometeorology and civil aviation are governed by the Law of Belarus “On Hydrometeorological Activity” (2006), which is under revision. The revised Law “On Hydrometeorological Activity” and the World Bank-supported road map will guide the future development of Belhydromet.

A data-sharing protocol exists in Belarus but, in practice, the ministries have bilateral arrangements. As a rule, data are provided to the government agencies free of charge but contractual arrangements govern cases where a fee is charged.

There is a strategy to develop hydromet and environmental protection through 2030. Based on this long-term strategy, short-term plans guide the work of Belhydromet. Belhydromet is the only government source of hydromet observation data and forecasts.

The main budget of Belhydromet is provided by the government. The budget covers staff costs, equipment, costs of developing services and running costs. Belhydromet, through its commercial activities, earns the equivalent of 40 percent of its budget for paying staff bonuses, purchasing additional equipment and making repairs. Revenue-generating activities include the provision of information to economic sectors, contracts with mass media, the provision of pollution information for the pre-design stage of projects, and radiation monitoring. The information is provided free of charge to the insurance sector (in accordance with national legislation) and to civil aviation.

There is no donor or international development agency assistance with the budget. All such assistance is limited to technical advice and guidance. The budget for 2018 was US$10,304,333, which was exceptionally high due to the funds allocated to purchase a radar and other equipment. The budget allocation 2015–2019 is contained in Table 3, which shows relative stability with modest growth.

### Table 3. Belhydromet Budget, 2015–2019

<table>
<thead>
<tr>
<th>Year</th>
<th>BYN</th>
<th>US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>12,786,742</td>
<td>5,924,176</td>
</tr>
<tr>
<td>2016</td>
<td>12,435,694</td>
<td>5,761,533</td>
</tr>
<tr>
<td>2017</td>
<td>13,052,931</td>
<td>6,047,503</td>
</tr>
<tr>
<td>2018</td>
<td>22,240,874</td>
<td>10,304,333</td>
</tr>
<tr>
<td>2019</td>
<td>17,742,425</td>
<td>8,220,174</td>
</tr>
</tbody>
</table>
The main responsibilities of Belhydromet are:

• Regular environmental monitoring, information gathering and analyses;

• Provision of all types of hydromet and radiation-ecological information to government agencies, other organizations, the economic sectors and the public in accordance with established procedures;

• Production of hydromet information, compilation of hydromet forecasts, provision of information on actual and expected weather conditions, warnings about hydromet hazards;

• Ensuring prompt response in the event of accidents or incidents related to environmental pollution;

• Maintenance of the climatic information and the inventory of surface waters;

• Study of climatic, agrometeorological, and hydrological conditions in the territory of the Republic of Belarus, and analysis of regional climate changes; and

• Interstate exchange of information on the state of the environment in accordance with the recommendations of the WMO and UNESCO.

Belarus’ hydromet service is based on a state-owned network of hydromet observation posts.

As of November 30, 2017, Belhydromet had 1,143 staff, of which 725 are female (63 percent). The qualification structure is as follows: 211 executives (18 percent), 771 specialists (68 percent) and 161 technicians and general staff, including hydro-observers (14 percent). In total, 716 staff members have higher education (63 percent) and 308 staff members (27 percent) have specialized secondary (vocational) education. The number of working pensioners is 207 (18 percent), of which 56 (5 percent) are men and 151 (13 percent) are women (Figure 12).

The average age of employees is 45 years; 372 employees (32 percent) have up to 5 years of experience in hydromet; 162 employees (14 percent) have work experience between 5 and 10 years; and 609 employees (54 percent) have over 10 years of work experience at Belhydromet.
THE SUB-STRUCTURE OF BELHYDROMET’S DIFFERENT DEPARTMENTS IS AS FOLLOWS:

- Head;
- First deputy head;
- Deputy head;
- Deputy head; and
- Chief engineer.

Lead Engineer on Quality:
- Sector on State Secrets Security;
- Legal Department;
- Personnel Department;
- Paperwork Unit;
- Logistics Unit; and
- Sector on Occupational, Industrial and Fire Safety.

Financial and Economic Service:
- Accounting and reporting unit; and
- Planning and economic unit.

Meteorological and Climate Monitoring, Methodological Support of Data Bank Service:
- Unit for meteorological monitoring;
- Unit for climate change studies; and
- Unit for state data bank.

Capital Construction, Repairs and Economic Support Service:
- Unit for Civil Works and Repairs;
- Economic Support Sector;
- Transport Sector; and
- Unit for Electrophysical Measurements and Energy Supply.

International Cooperation and Public Relations Service:
- International Cooperation Unit;
- Public Relations Unit; and
- Analytical Work and Science Service.

Meteorological Forecast Service:
- Unit for short-term weather forecasts, adverse and hazardous events;
- Unit for of long-term forecasts;
- Unit for provision of hydrometeorological information to clients; and
- Meteorological forecasts support sector.
Hydrology and Agrometeorology Service:
- Unit for hydrological forecasts;
- Unit for the study of water regime; and
- Unit for agrometeorology.

Environmental Information Service:
- Unit for environmental information analysis; and
- Unit for provision of environmental information.

Environmental Monitoring Service:
- Unit for air monitoring;
- Unit for surface water monitoring;
- Unit for physical and chemical measurements; and
- Unit for land monitoring.

Radiation Monitoring Service:
- Unit for radiation monitoring;
- Unit for radiometry and radiochemistry;
- Unit for radio spectrometry; and
- Unit for operational data of radiation monitoring and monitoring of emergency situations.

Communications and Telecommunications Service:
- Unit for technical facilities servicing;
- Unit for telecommunications; and
- Unit for operational and duty work.

Measurement Service:
- Unit for metrology, standardization and verification; and
- Unit for instruments and equipment servicing.

Software Service:
- Unit for numerical forecast simulation;
- Unit for software development; and
- Unit for software maintenance.

Aviation and Meteorological Support Service:
- Unit for organizational and methodical work;
- 1st class aviation meteorological civil station, Minsk;
- Unit for aviation and meteorological forecasts;
- Unit for meteorological tracking;
- Unit for aviation and meteorological observations; and
- Unit for technical support.

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FIGURE 13. GOVERNMENT BODIES AND ORGANIZATIONS FOR NUCLEAR AND RADIATION SAFETY ASSURANCE
6. CURRENT STATUS OF BELHYDROMET

Modernizing a National Meteorological and Hydrological Service (NMHS) is highly complex and costly. Therefore, the approach to such an endeavor should follow a structured and long-term plan based on a sound strategy reflecting the needs of the stakeholders and the end-user community.

The first step in the development of such a plan is to study and analyze the current systems comprising the organization. A typical NMHS is comprised of a “system of systems” as shown in Figure 1. This generic illustration of a weather, climate or hydrological system of systems can be used to identify the current status of any NMHS and to visualize investments required component-by-component in each system to achieve a particular level of improvement. The complexity of each system and its sub-systems varies depending on the size, level of development and resources of an individual NMHS.

The building blocks of a system of systems are inter-dependent. As has become evident in the case of Belhydromet, the most important requirement is human resources in sufficient number and with the capacity to understand and operate a particular system. This road map uses a system-of-systems approach to arrive at three possible scenarios for enhancing the capabilities of Belhydromet.

6.1 SERVICE DELIVERY SYSTEMS

6.1.1 Public Weather Services System

Belhydromet produces public weather forecasts for 7 days. The forecasts and warnings are posted on the Belhydromet official website: www.pogoda.by in Russian. The public also can directly reach the forecasters by telephone. It is recommended to set up a call-in system on a commercial basis to generate revenues and also to bring efficiencies to the forecasters’ time.

Belhydromet does not have a television studio and does not produce its own media presentations. The state television channel, Belarusian Television, uses its own graphics to broadcast (and post on YouTube) Belhydromet’s forecasts. Commercial television stations can broadcast these forecasts, but most use their own graphics and model-based forecasts downloaded from the Internet. Hence, different channels broadcast different forecasts and use different graphics. Belhydromet has tried to discuss this issue with the television companies, but freedom of information permits the broadcasters to continue the practice. Belhydromet warnings, however, are broadcast without any change.

Belhydromet is mandated to verify forecasts against observations and to inform the Ministry of Natural Resources and Environmental Protection on the performance rate of the forecasted indicators. The verification results show a relatively high level of performance of over 80 percent for the 24-hour temperature forecasts. Performance is somewhat lower for the precipitation verification.

There are no private weather service providers operating in Belarus and while this is not prohibited by law, it is mainly due to lack of interest to set up commercially operated weather companies. Independent entities post weather information on the Internet.

Belhydromet uses social media to maximize the dissemination of its information. It has a presence on Facebook, Instagram, Odnoklassniki, Telegramme, Twitter, VKontakte, Vyber and YouTube. It also has and regularly updates a mobile app, «ПОГОДА В КАРМАНЕ» (Weather in Your Pocket). While Belhydromet does not use Short Message Service (SMS) for forecast dissemination, the Ministry of Emergency Situations uses SMS for distributing alerts and warnings.

Outreach activities are rather limited to group visits by children and the public to Belhydromet, where its systems and functions are explained. Belhydromet does not hold special events. Although Belhydromet holds a media conference before World Meteorological Day, there has not been much interest expressed by the
media. There are no blogs or weather-related stories published on www.pogoda.by. Belhydromet could clearly benefit from guidance on improving their public outreach and education activities as a means of increasing the public awareness of the roles and functions of the main hydromet service provider in the country.

6.1.2 Disaster Management Services System

Belarus has a structured disaster risk management (DRM) system. In 2001, Belarus established the State System of Prevention and Elimination of Emergency Situations, which serves as the UNISDR National Platform for Disaster Risk Reduction. Guided by an Emergency Commission under the Council of Ministers, the Ministry on Emergency Situations (MES) coordinates the government’s disaster risk management activities, including ensuring the functioning of this State System. The MES holds lead responsibility for risk management of natural and man-made disasters. During emergencies it assumes a lead role for civil protection and response.

DRM responsibilities are shared across agencies and administrative levels. The State System operates at the national, oblast, and local levels. It integrates the MES, other ministries, state agencies, local executive and administrative bodies, and organizations to plan, prepare and implement measures to protect the population and territories from natural and man-made emergencies. Risk reduction measures are included in the Republic of Belarus Population and Territories Protection Plan, relevant regional and sectorial plans, and the National Economic and Social Development Plan 2016–2020.

Both short- and long-term planning and emergency management require standardized multi-hazard risk assessments. While Belarus has made some progress in detailed flood risk assessment, it does not yet cover the entire country and lacks risk assessments for other hazards. Modern approaches are needed for a high-resolution probabilistic assessments of natural hazard risks to inform DRM planning and to optimize emergency preparedness. The system for national early warning of hydromet hazards requires more efficient data exchange between institutions and with the public. Activities to strengthen risk assessment, early warning and outreach would increase awareness of natural disaster risk and support improved risk management.

Concurrent investment in the Ministry of Emergency Situations and the Ministry of Natural Resources and Environmental Protection would holistically strengthen national DRM. An integrated system for risk assessment, monitoring, forecasting, early warning, preparedness, needs assessment and risk financing for hydromet and radiation-ecological risks would reduce disaster risks and impacts on people and the economy, supporting poverty reduction and economic growth. Investments in DRM support the government’s priority of constructing and operating Belarus Nuclear Power Plan (BelNPP).

6.1.3 Water Management and Flood Forecasting Services System

One of the main tasks of Belhydromet is to work toward the country’s hydrological security, precluding or mitigating the effects of dangerous hydrological phenomena. Providing reliable and comprehensive information, forecasts and warnings about hydrological hazards to help ensure the safety of life, to protect property and to prevent damage to the economy is essential.

Belhydromet provides forecasts of the different hydrological characteristics of water bodies with a strong focus on forecasting maximum water levels. The forecasts are mainly based on observations from a hydrometric network (hydrological posts and stations) and expert knowledge of past conditions based on long series of regular observations, assessments of similarities with situations in the past and statistical relationships (e.g., between snow storage and the expected water levels of spring flooding).

Belhydromet forecasts are used by the MES and several other ministries and are published on its website and display maps of the level, thermal and ice conditions of water bodies. During floods, the situation is
shown on three levels: normal water level, the level at which water enters the flood plains, and dangerously high water level, when with riverside areas are flooding. During summer and autumn, low-flow conditions in terms of navigation, the water levels are divided into two levels: normal water level, a water level impeding operation of river transport.

Overall, hydrological forecasts can be categorized as follows:

Flood forecasts
At the beginning of March, Belhydromet prepares a long-term prognosis for the coming spring floods, indicating the maximum water levels at different locations of the main rivers. Belhydromet provides the hydrological and meteorological conditions of the prior autumn/winter period, a forecast of the maximum water levels and a comparison of the expected levels with the potential deviation from seasonal norm. The expected forecast of the highest water level for spring flooding is formulated for 40 points on 16 rivers, based on the accumulated snow and the current runoff conditions. The uncertainty in the forecasts is expressed as a range of the expected values. To compare the expected flooding with the situations in previous years, statistical data from multi-year observations (maxima, averages and minima) are provided together with forecasts. The MES informs communities that could be inundated and mobilizes resources for flood protection. Besides forecasting the maximum water levels, Belhydromet provides projections of the flooding's end.

River ice conditions
In spring, Belhydromet issues a consultation of the probable ice breakup for the main rivers and their tributaries. The forecast period is 9–28 days. To compare the forecasts with situations in the past, the range of dates with the beginning of the ice drift derived from long observation series is listed in the forecast. At the end of October, the timing of ice formation on rivers is forecasted. In 2018, the forecast was made for 4–5 weeks ahead, with an uncertainty range of 5 days.

Inflow into reservoirs during springtime
To support planning for seasonal water management, Belhydromet provides forecasts of spring inflows into reservoirs. For 10 reservoirs, the surface runoff height in millimeters and the surface runoff volume in millions of cubic meters is provided together with observed minima, averages and maxima from long-term observations.

Low-flow conditions
Belhydromet prepares forecasts of minimum levels for each month of summer–autumn low-flow conditions. The expected minima are forecasted at 11 posts at the Western Dvina, Neman, Dnieper, Sozh, Beresina and Pripyat Rivers (three tributaries of the Dnieper River). The forecasts are prepared at the end of each month, and the last forecast is issued for October. These forecasts are mainly used for navigation.

At the end of the year, the meteorological, agrometeorological, hydrometeorological and hydrological conditions of the last year are summarized in an annual report, highlighting the differences between the year’s winter and spring (flooding season) and summer and autumn (low-flow season).

The hydrological information (mainly the hydrological bulletins but also special analyses for emergencies) is distributed regularly to following recipients:
Belhydromet has no regular, direct contact with end-users of hydrological information.

6.1.4 Agriculture Services System
Belhydromet issues agrometeorological bulletins every 3–10 days and posts other agrometeorological reviews on its website. The bulletins include agrometeorological conditions (i.e., weather, moisture and temperature of soil, crop development rates and conditions) and an assessment of the opportunities for agricultural field work in different regions. Belhydromet also can produce customized agrometeorological information for clients (e.g., for insurance cases regarding crop loss). No drought forecasts are prepared. However, in the vegetation season, a 10-day integrated estimate of the occurrence and spread of drought is carried out based on field observation data. This method of predicting droughts should be developed into a modern drought forecasting process. Yield forecasts for the most common agricultural crops in Belarus are prepared once per season. Frost forecasts and frost warnings are prepared by the weather service.

6.1.5 Aviation Services System
The Ministry of Natural Resources and Environmental Protection has authorized Belhydromet to ensure
support to civil aviation and as such Belhydromet is the official designated aeronautical service provider in Belarus. There are 6 airports in the country, with the international airport in Minsk and 5 national airports in the oblasts. All airports are operated based on International Civil Aviation Organization (ICAO) and WMO regulations. It is planned to improve aeronautical service provision in the next 3–5 years, including the establishment of a large forecasting center in Minsk, where forecasts will be prepared for all 6 airports. Aviation Meteorology Services operate with 6 people at the Minsk office (head, deputy head and 4 specialists) who provide methodological guidance for airports operations, make administrative and technical decisions, interact with Civil Aviation and the Ministry of Transport, participate in accident investigations, provide information to the Belaeronaigation (which manages Civil Aviation), and oversee quality management systems (QMS), including ISO certification. Belhydromet has the 9001-2015 ISO certificate and keeps the certificate up to date. The ICAO officials visit Belarus every 3 years to carry out checks on the quality and standards of the aeronautical meteorology operations. In addition, the Aviation Committee of the Ministry of Transport audits all airports on an annual basis.

There are 41 staff at the Minsk International Airport, including 12 observers and 10 forecasters, who together with the staff in Minsk coordinate the aviation activities at all airports. A newly created unit with 10 forecasters monitors all air transport information up to a 20 km altitude. A group of 8 engineers is responsible for the maintenance and repair of observing equipment at the airports. A total staff of 131 of Belhydromet provides services to Civil Aviation. All the usual products such as Terminal Area Forecast (TAF), Significant Meteorological Information (SIGMET) and Meteorological Terminal Air Report (METAR) are provided to airlines are provided by Belhydromet.

Aeronautical aviation services are considered public services and, by law, are provided free of charge. However, the Ministry of Natural Resources and Environmental Protection has expressed interest in introducing cost-recovery, as is practiced by the majority of aeronautical meteorology service providers. Although Belhydromet has access to WMO guidance materials on this subject, Belhydromet would like WMO’s assistance to start negotiations with the relevant stakeholders on cost-recovery. Steps were taken by the World Bank mission to put Belhydromet in touch with the appropriate WMO officials.

Belhydromet has competency requirements for aeronautical meteorology personnel and implements education and training to achieve them. It mandates and provides six months of on-the-job training for new recruits before they can work autonomously. The staff also receive training at institutions abroad (e.g., St. Petersburg) and through e-learning before they are certified. Feedback is obtained from the users in the form of satisfaction surveys for pilots. Belhydromet is actively working on implementing Aircraft Meteorological Data Relay (AMDAR). They have attended three workshops on the subject.

6.1.6 Climate Services System

Belhydromet’s climate services include the production of statistical data, analysis of historical data, calculation of climate indices, and participation in state programs and research. The climate norms (1960–1991) are used for reporting to the WMO and for climate change estimations; the new climate norms (1981–2010) are used for internal purposes only (i.e., analysis of the current climate situation and service provision to economic sectors).

Belhydromet has not yet established a National Framework for Climate Services. Services to economic sectors are provided upon request. Regional engagement in climate surveys is mainly with the Russian Federation; the information for the WMO and the North Eurasian Climate Center is provided on a regular basis. Climate-change monitoring is done by Belhydromet climatologists who issue a climate characteristic for every decade, month and season indicating climate features of the respective period and hazardous events, if any. Climate monitoring also involves maintenance of the state climate cadaster by the unit for Climate Change Studies. The climate cadaster contains monthly and annual climate data; an annual review of climate features and hazardous hydromet events in Belarus, which is published in April; and
climate reference books. Belhydromet participates in the implementation of the Paris Climate Agreement. Apart from that, climate change research is conducted with Belarus’ National Academy of Sciences and Russian research institutes.

6.1.7 Forest Fire Services System

Before the beginning of the forest fire season, long-range forecasts are analyzed (Russian seasonal forecasts) for the forthcoming season of forest fires. During the forest fire season, Belhydromet produces a daily forest fire danger bulletin. It is sent to the prime minister, the Ministry of Forestry and the Ministry on Emergency Situations (MES). By law, the fire season is April 15 to October 15. Officially, however, the fire season starts after complete snow melt. (The snowpack’s height is measured twice a day at all meteorological stations). In case of complete snow melt before April 15, the MES can request Belhydromet to produce and disseminate a bulletin. The same consideration applies for snowfall after October 15.

The forest fire danger is calculated on daily basis. Figure 14 shows an example of fire danger calculated at the 54 meteorological stations.

The forest fire danger is calculated automatically every 12 hours. In areas characterized as high and extreme danger, the fire danger maps are updated at 9 a.m. (9.00), 12 p.m. (12.00) and 3 p.m. (15.00). Figure 14 shows an example of fire danger calculated at the 54 meteorological stations.

**FIGURE 14. FIRE DANGER MAP CALCULATIONS AT METEOROLOGICAL OBSERVATION STATIONS**
In case of emergency, operational room staff have the capacity to prepare a real-time text report with data from the station nearest to the burning area and forecasts for the next several hours. Fire danger information is transmitted by email, fax (for government organizations), social networks, official website (warnings for the general population) and mass media. The Ministry on Emergency Situation is able to provide alerts by SMS.

6.1.8 Environmental Monitoring Services System

According to the Law of the Republic of Belarus No 1982-XII dated November 26, 1992 “On the Protection of the Environment”, protection of the environment is an integral prerequisite of environmental safety and the sustainable social and economic development of society. The National Environmental Monitoring System (NEMS) was established in 1993. It is coordinated by the Ministry of Natural Resources and Environmental Protection. The NEMS’ main task is to provide environmental information to state agencies and organizations, legal entities and the general public.

The Main Information and Analytical Center (MIAC) and 11 information and analytical centers ensure collection, storage and provision of environmental information. In January 2017, Belhydromet became the MIAC of the NEMS. Quarterly and annual reports of the state of the environment are published, including analyses of trends and predictions. Belhydromet monitors the environment, gathers information and provides analysis and generalizations. It also has to ensure prompt response in the event of accidents or incidents related to environmental pollution.

Belhydromet monitors the environment through 66 air quality stations that cover 19 industrialized cities where 90 percent of the population lives, a soil chemical pollution monitoring network, 297 surface water monitoring stations and 4 labs (i.e., surface water, soil, air, and physical and chemical parameters). In the cities, concentrations of particulate matter, carbon oxide and nitrogen dioxide as well as specific pollutants such as formaldehyde, ammonia, phenol, hydrogen sulfide and carbon disulfide are monitored. In monthly samples of atmospheric precipitation, their acidity, components of the basic salt composition and the content of heavy metals are determined. While water quality sampling and measuring is done by Belhydromet or other entities, all data are collected at Belhydromet.

The Environmental Information Service prepares reports for relevant authorities using the above data. Daily reports on urban air pollution concentrations are published in a standardized format on working days only on the website (www.belgidromet.by). Furthermore, text information on exceedances of standards for ambient air quality is provided on the website. The air pollution data are routinely monitored and reports on unusual phenomena connected to air pollution (e.g., smell annoyance) are sent to the Radiation Monitoring team, which is on duty 24/7. In case of an event (e.g., chemical accident), the Ministry of Natural Resources and Environmental Protection is informed.

To date, no concentration maps and no air pollution forecasts are produced. Further information services could be developed to provide more understandable information on the state of the environment in Belarus to the public and to selected groups of users.

6.2 QUALITY MANAGEMENT SYSTEMS

A quality management system (QMS) is defined as the organizational structures, procedures, processes and resources needed to develop and successfully manage the delivery of products and services for users. A QMS is implemented by most NMHSs in the provision of services to the aviation sector in compliance with the requirements of the International Civil Aviation Organization. In general, the implementation of a QMS as part of the strategy to modernize an NMHS has a positive impact on the quality of services and management practices and the user/stakeholder perception.
6.2.1 Institutional and Operational Management Systems

Belhydromet is the only official producer of meteorological and hydrological observations and forecasts in the Republic of Belarus. Belhydromet has become ISO 9001-2015 certified for the entire organization since 2018 but has been previously ISO-certified for aviation services as well as for the operation of radiation laboratories (Photo 2).

6.3 CAPACITY BUILDING

Sustainable, effective capacity development and staff training are essential for Belhydromet. Capacity building is the foundation of any NMHS. A major challenge for all NMHSs is to create a professional meteorological and hydrological workforce with the required access to training opportunities to enable them to take advantage of rapid advances in many areas in meteorology, hydrology, information technology and meteorological and hydrological modeling and forecasting.

A continuous provision of qualification upgrading opportunities to meteorologists, hydrologists, engineers and IT specialists is essential to replace retiring staff. It is critical to provide in-house training to ensure that employees are familiar with new meteorological and hydrological tools and software. Attending training at the regional or international training facilities and twinning with more advanced NMHSs is also important.

Capacity building is generally guided by the needs of Belhydromet and not solely by WMO guidelines or templates for training. There usually is a succession planning and when staff are approaching retirement, replacements are hired from those trained in the national institutions such as Belarus State University. Belhydromet collaborates with the Belarus State University’s program in the launch of a post-graduate training for meteorologists and forecasters. Like most NMHSs in developing countries, Belhydromet experiences difficulties with retaining trained staff. While there is no formal or structured training plan for new recruits, they receive on-the-job support and instruction. A separate but modest budget is made available for staff training.

Educating stakeholders and partner organizations in the application of hydromet products for decision-making is also essential. Educating the general public to better understand warnings and probability forecasts is equally important. User education could be undertaken through many diverse means, including workshops, flyers, publications and public service videos posted on social media and educational materials posted on the Belhydromet website.

6.4 MONITORING AND OBSERVATION SYSTEMS

6.4.1 Global and Regional Data Systems

Belhydromet has access to observational data from certain global centers such as the European Center for Medium-Range Weather Forecasting (ECMWF). It also has access to satellite data via the European Center for Meteorological Satellites (EUMETSAT).
6.4.2 National Data Systems

Surface Meteorological Observations Network
Currently, there are 54 full meteorological stations, but this number is expected to increase to 67 by 2020. There are 43 automatic weather stations (AWS) making observations every 10 minutes. In 2018, 3 fully automated AWSs were added, with a plan to increase this number to 17. Surface meteorological and upper air observations were integrated in 2018 on a 24/7 basis. In addition to its headquarters in Minsk, Belhydromet operates 6 regional centers in the 6 oblasts and 3 inter-regional centers for hydromet and environmental monitoring, 5 agrometeorological stations, and 7 civil aeronautical meteorological stations. Belhydromet operates 1 wind profiler in Minsk which is used for boundary-layer measurements up to 1 km (See section 6.4.5). No global atmosphere watch stations are operated. There is no lightning detection monitoring at Belhydromet and no hail suppression or weather modification activities are conducted.

Surface Hydrological Observations Network
The hydrological observation network consists of 114 hydrological posts, of which 104 are located at rivers and 10 at lakes and water reservoirs. Discharge is measured at 90 hydrological posts. Staff measure discharge regularly (up to 3 times per month). The frequency of discharge measurements depends on the water regime of the surveyed river (i.e., on the nature of changes in water level and discharge during a year). There are 35 hydrological posts equipped with continuous water-level recorders and 7 posts equipped with automatic recording gauges and automatic data transfer. A map of the hydrological observation network is shown in Figure 15.
Hydrological posts are equipped with continuous water-level recorders “Waldai” GR-38 and GR-116, which were supplied between 1965 and 1988. The recording is done on paper and requires manual digitization. Angle decoders which would enable the digital storage of water-level data at hydrological posts are not available for continuous water-level recorders.

Discharge measurements are made with the area–velocity method by using GR-21M meters, which were supplied between 1969 and 1983. There are more than 180 of these meters and they are regularly checked. Belhydromet has 1 Acoustic Doppler Current Profiler (ADCP) ARGO-600, which is produced in Russia; however, its data transmission capabilities are insufficient.

In addition to water levels and discharges, hydrological posts monitor water temperature, ice conditions, ice thickness, snow height on the ice and precipitation at 64 hydrological posts. Water samples are collected at 11 hydrological posts on a daily basis to measure turbidity. Apart from that, water samples are collected to determine the size of suspended sediments; bottom sediment samples are collected to determine the size, specific and volumetric weights of bottom sediments. Water samples are measured for turbidity at Belhydromet.

6.4.3 Upper Air System
Belhydromet operates 3 radiosonde stations. At the station in Minsk, radiosonde operations were suspended in 1998 and resumed at the end of 2018 with the opening of a new meteorological observation points in the eastern part of Minsk, Gomel and Brest.

6.4.4 Radar System
Belhydromet operates 4 meteorological radars: 1 Soviet-era radar in Brest, which will be replaced in 2020; 1 Doppler radar in Gomel which was manufactured in Germany, installed in 2013; 1 Doppler radar in Vitebsk which was installed in 2018; and 1 radar at the Minsk airport, relocated to new location. In 2019 on three operating Doppler meteorological radars a uniform software “MeteoCell” developed by IRAM Russia are used. In 2020 it is planned to install the 5th Doppler meteorological radar in Grodno, manufactured in Russia. All radars are S-band and are used for monitoring convective activities, hail formation and thunderstorms to forecast weather conditions, to ensure flight safety, and to fulfill obligations under international projects (e.g., the advanced weather radar network for the Baltic Sea Region, BALTRAD).

6.4.5 Remote-Sensing System
The sparsely observed regions of Belarus are where satellite data can be particularly useful as a complementary data source to in-situ systems. The integration of satellite data into the country’s hydromet observing network would ensure maximum benefits and cost-effectiveness. This includes the use of remote-sensing data to produce precipitation, flood, extreme temperature, soil moisture, and evapotranspiration maps of Belarus in support of agriculture, weather and hydrological forecasting and EWS. Currently, forecasters use satellite data from a polar-orbiting satellite and the EUMETSAT geostationary satellites. Belhydromet recently started to use ground-based remote sensing systems for boundary-layer profiling. A radio-acoustic sounding system (SODAR/RASS) for boundary-layer profiling of wind and temperature (up to about 600 m above ground) has been operating in Markuny, which is 4 km northeast of the Belarusian NPP, since 2014 (Photo 3). The purpose of this boundary-layer profiling is the real-time provision of measured wind direction, wind speed and (near-ground) temperature gradient as input data for dispersion modeling of releases at the NPP.

A second SODAR for wind profiling was installed in January 2019 at the new meteorological station in the eastern part of Minsk.
6.4.6 Radiation

Radiological and environmental preparedness is critical for Belarus. Belhydromet is responsible for radiological and environmental monitoring and the MES is responsible for preparedness and response for nuclear accidents. Belhydromet is tasked with providing forecasts for the areas contaminated by Chernobyl until 2046. With the first Belarusian nuclear power plant (i.e., BelNPP) under construction, radiological and environmental monitoring and preparedness take on a new level of importance.

According to the International Atomic Energy Agency (IAEA) Safety Glossary, environmental monitoring comprises the measurement of external dose rates due to sources in the environment or of radionuclide concentrations in environmental media (i.e., air, soil and water). The results of these measurements are used to assess radiological hazards or doses resulting or potentially resulting from exposure.

Radiation monitoring in Belarus started in 1963. It is now part of the National Environmental Monitoring System (NEMS) and is responsible for:

- Monitoring natural radiation;
- Controlling radiation in the influence zone of potential sources of radioactive contamination (NPPs), including estimates of transboundary transport; and
- Controlling the radioactive contamination of air, soil, surface and underground waters in territories affected by the Chernobyl NPP disaster.

Belhydromet monitors radiation using 41 manned stations (manual measurements of the gamma dose rate once a day at 9 a.m. (9.00) local time); 24 sites equipped with sampling devices for radioactive fallout; 10 sites with radioactive aerosol samplers; 18 landscape-geochemical polygons; 39 reference sites for exposure monitoring of soil; and 12 surface water monitoring sites, including 6 observational sites for river surface water and bottom sediment monitoring (Figure 16). A total of 22 automated radiation monitoring stations operate in the areas near Chernobyl NPP, Ignalina NPP, Rovno NPP and Smolensk NPP, as well as around the Belarusian NPP. Observations are carried out for the dose rate of gamma radiation, the content of 137Cs, 90Sr, total α- and β-activity and the presence of 131I.
Belhydromet operates 3 information and analytical centers which collect, store, process and analyze the observational data.

The automated radiation monitoring system around the site of the Belarusian NPP consists of 10 automatic measurement points, measuring the dose rate of gamma radiation with BDKG-22 detectors, the spectral composition of radionuclides with BDKG-11M spectrometer sensors and 3 Vaisala automated weather stations (Figure 17). General Packet Radio Service (GPRS) technology is used for data transmission. As soon as a limit of gamma dose is exceeded, the system gives an alarm and changes to a more frequent transmission mode. The meteorological observations are used to forecast the airborne transport of radioactive materials for a radiation incident. Within 13 km of the Belarusian NPP, 5 sites conduct radiation monitoring of the following radionuclides: 134Cs, 137Cs, 90Sr, 65Zn, 58Co, 60Co, 54Mn, 59Fe, 94Nb, 95Nb, 51Cr, 95Zr, 131I, 3H, 40K, 232Th, 226Ra as well as total α- and β-activity.
Data transfer between the automated monitoring stations and the local response centers (LCR) is performed by radio transmission. The automated radiation monitoring system operates in two basic modes. In the normal mode, a cyclic interrogation of all sensors connected to the terminal controller at the LCR is conducted continuously in 10-minute intervals. The data values are compared to thresholds (dose rate or radiation increase) and alarm values are stored. In the case of a detected event, the system is set to emergency mode. The interval of data query increases to 1 minute. Transition to normal operation occurs as soon as the measured parameters decrease below the thresholds or if the mode is reset by a software command.

Modern approaches for radiation-ecological monitoring with enhanced observational technologies, data collection, processing, storage, transmission and presentation, including for emergencies, are needed to ensure radiation safety not only in the vicinity of the Belarusian NPP, but also for the whole country. For timely response to threats posed by radiation and nuclear accidents, it is recommended to expand the automated national radiation monitoring network. At present, 1 mobile radiation measurement unit is available. If this monitoring unit is in operation, for example, near the Belarusian NPP, it cannot monitor for emergencies in other parts of the country (e.g., during a fire in the contaminated area near Chernobyl). The acquisition of a second mobile radiation monitoring unit is therefore recommended.

Radiological laboratory analyses are undertaken at Belhydromet in Minsk as well as at 3 other laboratories in branches of Belhydromet. The branches send their measurements to Belhydromet headquarters on a monthly basis or upon request. All laboratories are accredited according to ISO 17025. All data are quality controlled. The acquisition and implementation of a state-of-the-art Laboratory Information Management System for all radiological laboratories belonging to Belhydromet is recommended to support their quality management and efficient organization.

At Belhydromet sampling, data evaluation and control are done by the staff members of the radiometric section, the radiochemistry section, the gamma-spectrometry section, and the head of the section. Besides specialized instruments developed by ATOMEX with online data-transfer to a computer, a series of sampling instrumentation is still in use which requires manual data reading. The data are first written down in tables,
entered into the database manually and finally checked and approved by the head of the section. For this purpose, a software is in use which was developed at Belhydromet. This software supports quality assurance: information on the full sampling process is included and data from measurements at the same location for previous month are listed. If sampling results are significantly increased compared to previous data, the operator is obliged to send the probe to be controlled by gamma-spectrometry. If visualization is needed, data are exported and plotted with other programs (e.g., Microsoft Excel). It is suggested to include simple plotting routines in the software to support the data control procedure.

Besides the official radiation monitoring network for Belarus, Belhydromet also offers paid services. The services include, for example, control of potentially contaminated soil during construction activities and the control of goods like timber, vegetation or building materials from contaminated regions for export trade.

A first analysis of the spatial distribution of radon contamination in Belarus was conducted in 2018. It is recommended to amend the radiation monitoring system by radon measurements at selected stations and to consider developing a service for indoor radon measurements.

The installation of carbon-14 and tritium air monitoring systems in the vicinity of a possible release site (NPP or waste storage site) are of particular urgency.

The modernization of the radiation monitoring system should be accomplished by the development of a training program. State-of-the-art training in the field of radiation measurements is necessary to optimize outcome from the available technical equipment. It is suggested to set up a partnership with an institution able to support training for new staff or to extend the know-how of experienced staff in the field of radiation monitoring as well as forecasting and to ensure this capacity building by assigning the appropriate budget.

6.4.7 Data Management and Archiving Systems: Data Collection System, Quality Control/Assurance System, Storage and Archiving System

Telecommunication and data handling are organized through 1 central core (Belhydromet in Minsk) and 5 nodes in the oblasts. All data from across the country as well as from neighboring countries arrive at a data collection center where they are quality controlled before reaching the forecasters. The forecasters are the internal users of data. The first level of quality assurance is automatic (e.g., checking the formats and data ranges). The second level is the quality control, whereby any doubt in the data is addressed. Raw data are collected every 3 hours and automatic data every 10 minutes.

There are separate databases for meteorology, hydrology and radiation data, and while the databases are decentralized, software allows their re-integration into 1 central database. Satellite data are also processed at the data collection center. The software was developed by a Russian company. Belhydromet is beginning the process of moving from this traditional system to an automation of data collection and storage so that when information is received from all collection points in different formats and codes, it is fed into a system and can be retrieved by staff in the format according to their need. Data are kept in the data collection center for up to 1.5 years, but long-term data archives are kept on a more powerful server. The database systems used are Oracle and Firebird (an open source Structured Query Language (SQL) relational database management system). An uninterrupted power supply ensures continuity of the operational systems, and in addition, a generator supports the electricity supply to all servers.

Forty-three AWSs work in the frequent reporting (10-minute) mode, and the rest send data every 3 hours. Only 1 fully automated hydrological post sends data every 10 minutes; the rest transmit data every 24 hours. The water levels from 96 stations, which are observed at 8 a.m. (8.00) and 8 p.m. (20.00), are transferred once per day before noon to the central unit in Minsk by telephone and stored in the operational database. The data transmission is based on modems (modulators-demodulators) that convert data between transmission media so that they can be transmitted from the transmitter to the receiver over telephone wires. The stations deliver their recordings (automatic and/or manual recordings on paper) to 1
of the 5 local branches of Belhydromet. The data are quality controlled, digitized and sent at the end of the month to the hydrological department in Minsk, where they are stored in a hydrological data management system which was developed by Belhydromet. Smart phone technology is also being introduced for data transmission.

6.5 ICT SYSTEMS: TELECOMMUNICATION SYSTEM (DATA EXCHANGE AND DISTRIBUTION SYSTEM, TRANSMISSION)

International data is exchanged through the Global Transmission System (GTS). Data from 10 out of 54 synoptic stations are used for this purpose. Belhydromet owns and operates a high-performance computer with a storage capacity of 64 terabytes and a computing capacity of 5 teraflops. The Internet speed is 100 megabits per second and the local speed is even higher.

6.6 MODELING SYSTEMS

6.6.1 Meteorological Models (Global and Regional NWP Systems)

EPSgrams from ECMWF are used to produce deterministic forecasts for 6 locations within Belarus only. This should be increased to the full range of EPSgrams provided by ECMWF for each country.

Belarus has access only to the graphical products from the global models it uses. The global models are the GFS (0.25°) GRIB fields through the FTP server, UK Met Office (0.56–0.86°), Roshydromet and Cosmo. Regional models include Cosmo at 7-km resolution from Roshydromet, which is trying to increase the resolution to 1.5 km (and hopefully will share this with Belhydromet) and from Poland. No nowcasting models or system are used, but all available data are used to produce a forecast for the immediate 2–3 hours during severe weather. No post-processing of model outputs and no objective verification are conducted, but daily verification of 24-hour forecasts against observations (i.e., maximum and minimum temperature, precipitation and wind speed) are carried out for a number of locations.

6.6.2 Limited Area Meteorological Models

A Weather Research and Forecasting (WRF) model is run in a pre-operational mode at Belhydromet at 15-km resolution for Europe and at 3-km resolution for Belarus. The initial conditions are derived from the GFS model. Data is assimilated for radio sounding and station data. The assimilation of radar data into the model is not realized yet although the respective module has been tested. The model set-up was decided by the Department for Numerical Modeling (part of the Software Division) based on recommendations from the Hydrological and Meteorological Center of the Russian Federation and from the WRF user-community. Model verification was undertaken from 2012 to 2014.

It is recommended to strengthen the information exchange between the model operators and the forecasters’ training through, for example, model verification workshops (statistically as well as for extreme events), utilization of the Extreme Forecast Index (EFI) from ECMWF; use of FLEXPART for dispersion modeling with ECMWF data as input; and application of the CHEM model for air quality analysis and forecasting.

6.6.3 Hydrological Models

Belhydromet does not use deterministic hydrological and hydraulic models. The forecasts are based on inferences by analogies with similar situations in the past which are derived from long observation series. Expertise in hydrological and hydraulic modeling exists in the Central Research Institute for Complex Use of Water Resources (CRICUWR), a commercial organization. CRICUWR participates in several national and international hydrological projects and could support the development of hydrological and hydraulic modeling at Belhydromet in the future.
6.6.4 Radiation Dispersion Models

At Belhydromet, the model system RECASS-NT is used for the analysis and prediction of the airborne transport of a radioactive plume in case of a nuclear release. RECASS-NT is a decision support system to model airborne transport of radiation and chemical releases based on a ‘client–server’ principle. The model runs are carried out on a server connected to a database where all needed meteorological information as well as radiation measurements and model results are archived. The meteorological input data (forecast and observation data) for the dispersion model are provided in GRID format by the Russian WMO-RSMC in Obninsk. The software is applied at Belhydromet with technical support from the software developers (Scientific and Production Association “Typhoon” of the Russian Federation Service for Hydrometeorology and Environment Monitoring Roshydromet). The dispersion model comprises stochastic approaches for transport modeling in air as well as for rivers. The atmospheric dispersion model does not consider wet deposition.

For training purposes, RECASS-NT is run at Belhydromet on a daily basis. The operator chooses a scenario according to the current wind field. A release from one of the NPPs close to Belarus is simulated and a 24-hour forecast of air concentrations is modeled. Model run-time for this application is about 1 hour.

In the future, Belhydromet could expand the radiation information considerably for relevant stakeholders. Atmospheric dispersion model results provided by Regional Specialized Meteorological Centers (RSMC) provide simulation results considering dry and wet deposition based on regional to long-range weather forecasts. Furthermore, dispersion calculations considering all relevant processes could be conducted by Belhydromet, for example, using the transport and dispersion model FLEXPART which is available as free software.

6.6.5 Forest Fire Models

The fire danger maps reported in the daily bulletin are based on the Dychenkov Index (1970). The Fire Danger Index for the current day is calculated from observations at 3 p.m. (15.00) local time, since it is considered the time of the day characterized by higher air temperatures. The Fire Danger Index map for today makes use of meteorological observations, while the maps for tomorrow and the day after make use of forecasts. The Fire Danger Index is calculated as follows:

\[ \Gamma = \sum_{1}^{n} \left( t - t_d \right) \]

where:

\( \Gamma \) – Fire Danger Index;
\( t \) – air temperature at 3 p.m. (15.00) (maximum warming up hour);
\( t_d \) – dew point at 3 p.m. (15.00); and
\( n \) – number of days since the last precipitation (<2.6 mm).
The Fire Danger Index $\Gamma$ is an incremental index expressed in degrees Celsius. During days when the dew point is greater than the air temperature, the increase of the index is set to 0. The Fire Danger Index has 5 danger classes considering the amount of precipitation over the last 10 days and the value of the Fire Danger Index. In case the total amount of precipitation is greater than 2.6 mm, the Fire Danger Index $\Gamma$ is set to 0. As shown in Table 4, the threshold value of $\Gamma$ among the first 3 classes is different considering the total amount of precipitation of the last 10 days as follow:

- 3–14 mm;
- 15–25 mm; and
- More than 26 mm.

The fire danger classes are defined as follows:

1. **1 class** – Complete non-flammability - forest visits are allowed;
2. **2 class** – Weak flammability - forest visits are allowed;
3. **3 class** – Medium flammability - forest visits are limited;
4. **4 class** – High flammability - forest visits are undesirable; and
5. **5 class** – Extreme flammability - forest visits are forbidden.

**TABLE 4. THRESHOLD VALUE OF $\Gamma$ AMONG THE FIRST 3 CLASSES**

<table>
<thead>
<tr>
<th>Precipitation for 10 days</th>
<th>1 Class Complete Non-Flammability</th>
<th>2 Class Weak Flammability</th>
<th>3 Class Medium Flammability</th>
<th>4 Class High Flammability</th>
<th>5 Class Extreme Flammability</th>
</tr>
</thead>
<tbody>
<tr>
<td>3–14 mm</td>
<td>&lt;150</td>
<td>151 – 500</td>
<td>501 – 4,000</td>
<td>4,001 – 10,000</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>15–25 mm</td>
<td>&lt;250</td>
<td>251 – 600</td>
<td>601 – 4,000</td>
<td>4,001 – 10,000</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>More than 26 mm</td>
<td>&lt;350</td>
<td>351 – 700</td>
<td>701 – 4,000</td>
<td>4,001 – 10,000</td>
<td>&gt;10,000</td>
</tr>
</tbody>
</table>
6.7 OBJECTIVE AND IMPACT FORECASTING AND EARLY WARNING SYSTEMS

6.7.1 Severe Hazard Forecasting Systems

In Belarus, heavy precipitation and prolonged dry spells are the primary hydromet hazards which lead to secondary and tertiary hazards (see Sections 2 and 3). The distinction of extreme weather hazards in a cascading manner is the first step in progressing from weather forecasts and warnings to multi-hazard, impact-based forecasts and warnings. Table 5 provides two examples.

**TABLE 5. EXAMPLES OF PRIMARY, SECONDARY AND TERTIARY HAZARDS CASCADEING FROM HYDROMET EVENTS**

<table>
<thead>
<tr>
<th>Event</th>
<th>Primary Hazard</th>
<th>Secondary Hazard</th>
<th>Tertiary Hazard</th>
</tr>
</thead>
</table>
| Thunderstorm | • Heavy rainfall  
• Strong winds  
• Lightning  
• Urban/flash floods | • Flash floods  
• River floods | • Damage to embankment, irrigation and drainage facilities, pumping facilities  
• Submerging fields  
• Loss of infrastructure systems and services (shelter, energy, transport, schools, hospitals, communications)  
• Widespread economic losses  
• Infectious disease  
• Insect and pest problems  
• Sand and silt deposition  
• Water borne disease  
• High sediment runoff into reservoirs |
| Drought | • High temperatures  
• Heat waves  
• Less rainfall | • Water scarcity  
• Low flow  
• Less inflow  
• Crop damage  
• Forest, peat and grass fires | • High evaporation loss in reservoirs  
• Shortage of storage water in reservoirs  
• Insufficient diversion in channels  
• Salt-affected soil  
• Food shortages  
• Energy shortages  
• Pumping system difficulties  
• Air pollution/haze  
• Smog/Dust |
Successful impact-based forecasting requires collaboration with others who have the expertise, resources, knowledge and data. Forecasting severe hazards and their impacts requires a well-established weather forecasting system on different time scales.

River and urban floods are the two natural hazards with high risk levels in Belarus. Spring flooding is the most dangerous phase of the river water regime in Belarus. In large rivers, the water rises 8.6–12.8 m above the normal (mean water) level. In middle-sized and small rivers, the water rises approximately half as high. The flood period lasts 30–120 days. Spring river flooding is followed by a period when water levels are at their lowest in the summer, and in dry years rivers and canals may even dry up.

Beside floods, Belarus is prone to wildfires. About 39 percent of the total area is covered by forests (a total area of 8.4 million ha). About 50 percent of the total forest cover is pine, which is susceptible to fire, and about 25 percent of the total forest cover was contaminated by Chernobyl NPP fallout, which exacerbates fire risk. In general, the climate of Belarus is not favorable to the ignition and propagation of wildfires. But in extreme weather, even a relatively low number of fires can have a large impact in terms of the burned area, as happened in 2015. Figure 18 shows the number of fires reported from 1991 to 2017. As is evident, better monitoring and improved fire-fighting capacities have decreased the number of fires and the areas damaged by fires.

### Figure 18. Yearly Burned Area and Number of Fires Reported, 1991–2017

![Figure 18](image-url)

#### 6.7.2 Short-Range Weather Forecasting Systems

There are 33 employees at the meteorological/weather forecast service (Photo 4). The main functions of the WFS are forecasting, issuing warnings and providing information to the government, economic sectors, the public, and the media. The main forecast office is situated at the headquarters in Minsk. Forecasters use data from surface observations and remote sensing, including 4 radars; satellite data from a polar-
orbiting satellite and the EUMETSAT geostationary satellites; and road sensor data. Forecasts are only deterministic, not probabilistic or impact based. It is recommended to initiate both probabilistic and impact-based forecasting.

Forecasts are prepared on a 24/7 basis by 2 shifts of forecasters for 1–6 days for Belarus and 3 days for each oblast. They are issued once per day and updated once per day. Warnings are prepared and updated as needed. Specialized forecasts for economic sectors and storm warnings are also issued.

The warnings use a color-coded system (with four colors), similar to Meteoalarm warnings. Warnings for government agencies, including the Ministry on Emergency Situations, are emailed and faxed; warnings for the general public are disseminated via mass media, social media and the Belhydromet website.

PHOTO 4. WEATHER FORECAST OFFICE

Aviation forecasts are produced by the Air Force, the State Rescue Institution “Aviation” of the Ministry on Emergency Situations and the Belhydromet Service for Aviation Meteorological Supply. Aviation forecasts are not the responsibility of the Weather Forecast Service.

The forecasters’ shift starts at 8 a.m. (8.00) with an analysis of the radar and satellite imagery. The Belarus territory observations are sent to Regional Telecommunication Hub (RTH) Moscow for input into the GTS and are returned to Belhydromet as part of the global data set to prepare forecasts. Upper air observation data from 3 stations are used in addition to surface observation data to produce the analyzed weather maps. Isobars display automatically on the maps while the forecasters insert the fronts. Surface weather maps and maps of 4 vertical levels of the atmosphere (850, 700, 500 and 300 millibars) are produced. The daily forecast is produced by 9 a.m. (9.00), discussed by the forecasters and disseminated by 10 a.m. (10.00). The offices at each oblast produce their own bulletins based on the forecast from Belhydromet.

The weather forecast maps are displayed through a visualization system with software provided by a Russian company. The software produces pre-defined images and does not input the observational data. Thus, weather forecasters need a software product that would allow working with all types and kinds of information.
Another important job of the forecast office is monitoring forest fires. Warnings are issued using a 5-level scale (from no hazard to extremely high). The official forest fire season is from April 15 to October 15. The forest fire warning scales have been in operation since the 1970s, long before the weather warning levels were introduced. It will be difficult to harmonize the different color schemes. But, since the fire hazard warnings are sent to the MES (which issues the public warnings), this does not cause public confusion. Actions are taken by the responsible authorities and could include closing forest access roads to the public. Relative humidity, temperature, maximum temperature and precipitation are used in the fire hazard index (not wind) for issuing warnings. A daily conference is held with the MES to discuss the overall weather and hazards situations for the entire country. These briefings are done separately by the meteorological and hydrological divisions; however, if there is a threat of severe weather, the hydrologists may join the forecasters.

### 6.7.3 Medium-and Long-range Weather Forecasting Systems

Medium-range forecasts cover up to 10 days ahead. Long-range forecasts (LRF) cover monthly and seasonal forecasts that are required for planning purposes in different sectors. LRFs are available on several websites. The ECMWF website includes EUROSIP products, which are multi-model seasonal forecasts from the ECMWF, Met Office, Météo-France, U.S. National Oceanic and Atmospheric Agency National Centers for Environmental Prediction (NOAA/NCEP) and Japan Meteorological Agency (JMA). The WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (https://www.wmolc.org/) provides access to the 12 Global Producing Centers for long-range forecasts. Regional Climate Downscaling provides projections with much more detail and more accurate representation of localized extreme events than a global climate model, which provides information on a scale of around 1,000 km². Downscaling is needed to support more detailed impact and adaptation assessments and planning in Belarus.

Belhydromet produces 7 forecasts. Seasonal Forecasts are published using information from different sources, such as the United States or Moscow. Belarus does not produce its own seasonal forecasts. No downscaling of global models is done, and staff have not received any training in downscaling.

### 6.7.4 Hydrological Forecasting Systems

Currently, hydrological forecasts are based on expert judgement and statistical relationships, for example, between the water storage in snow cover and the expected water levels of flood peaks. Based on the forecasts from Belhydromet, RERMC prepares forecasts for areas which are likely to be flooded for the short term (daily) and the long term (several months). RERMC is also responsible for issuing flood alerts. RERMC became a European Flood Awareness System (EFAS) partner in 2016 and has good interaction with hydromet services and civil protection in the neighboring countries. RERMC has an agreement to exchange hydrological data and information with and among Latvia, Lithuania, Poland, Russia, and Ukraine.

As described in Section 6.1.3, Belhydromet issues hydrological forecasts for water bodies depending on the season. These forecasts are based on knowledge of the past conditions. However, this basis is of limited value in view of the changing hydrological conditions due to climate variability and change. If the snow conditions change due to climate change, the statistical relationships between snow accumulation and the resulting spring floods are not valid anymore. The possible increase of the amount of rain or the decrease of precipitation falling as snow requires the introduction of mathematical hydrological models, which are able to consider both types of precipitation, to forecast floods effectively. A combination of numerical snow models with long-range weather forecasts could be very useful for spring flood forecasts, to determine the specific flood conditions resulting from the rain on snow. The current situation in flood monitoring and early warning in Belarus is characterized by the European Union as follows: “Flood warnings mainly rely on expert judgment, based on hydrological and meteorological observations and numerical weather forecasts. The current network is not sufficient for flood monitoring and early warning (lack of stations and lack of automatization of existing stations), but the more urgent needs for improved early warning would be
implementation of rainfall-runoff models on the major rivers. Better weather forecasts and training of the staff is also high on the priority list, together with new radars.”

6.7.5 Radiation Forecasting systems

In an emergency, the flow of information between the authorities responsible for the nuclear or radiological safety of Belarus is shown in Figure 19. The information flows by email or phone, but fax is still used as a technical back-up. No automatic sharing of information, for example, on a common web-based platform is in use.

**FIGURE 19. FLOW OF INFORMATION BETWEEN THE GOVERNMENT BODIES ON THE RADIATION SITUATION AND THE STATE OF THE ENVIRONMENT**

Republican Center for Emergency Management and Response

- Task/ request

Crisis Center of Belarusian NPP

- emission parameters
- radiation data from NPP observational network

Crisis Center at Ministry of Natural Resources and Environmental Protection Belhydromet

- Radiation data from the Belhydromet monitoring network

- Current and predicted meteorological conditions

- Predicted air concentrations of radionuclides and radioactive fallout

Crisis Center at Ministry of Health

Crisis Center at Ministry for Emergency Situations

Republican Center for Emergency Management and Response

National Academy of Sciences

Crisis Center of Belarusian NPP
An Emergency Preparedness Review was carried out by IAEA in 2018 at the request of the Government of the Republic of Belarus. The review concluded that Belarus has a robust overall emergency management organization involving national, local and facility-level entities. IAEA experts noted the following commendable practices in Belarus: a comprehensive program for international cooperation on Emergency Preparedness and Response, including for nuclear and radiological events; the authorities' experience in addressing the long-term, non-radiological consequences of a nuclear emergency; good training capabilities for (nuclear) emergency responders; and good capabilities for the treatment of contaminated or overexposed individuals. The Emergency Response Center of the Belarusian NPP is well prepared for emergency workers to implement mitigating actions. In the final report, the IAEA experts point out that more clearly defined processes and authorities for decision-making in the State System for Emergency Management and operational guidance for their implementation would further improve the system. It is suggested to conduct comprehensive full-scope exercises in order to test the effectiveness and efficiency of the emergency-response procedures, including coordination among entities.

Dispersion model products for nuclear and non-nuclear incidental releases into the atmosphere can be requested from the WMO in the framework of the Emergency Response Activity. Regional Specialized Meteorological Centers (RSMC) that specialize in the provision of Atmospheric Transport Model (ATM) products provide ATM products for environmental emergency response and/or backtracking. The RSMCs for the WMO Regional Association VI (Europe) are located in Exeter and Toulouse. At present, Belarus is not represented at the WMO by a national delegate.

### 6.7.6 Forest Fire Forecasting Systems

The forest fire warning service has been in operation for about 50 years. Its number of classes and color schemes of fire danger risk are, thus, not harmonized with more contemporary risk coding. However, the Ministry on Emergency Situations is the sole recipient of the forest fire warnings, thus precluding any public confusion. The MES is responsible for the management of forest fires, pit fires and shrub fires.

Belhydromet also issues a daily fire danger bulletin to the Office of the Prime Minister and the Ministry of Forestry (Figure 20).
Preventive actions are taken by MES local agencies and can include closing forest access roads to the public. In case of fire danger Class 5 (extreme flammability), it is possible to close forests to the public, except for the forest workers and people living in the forest. The decision is taken by a joint committee between local authorities and local decision-makers of the MES. Concerning the Ministry of Forestry, early detection monitoring is done every day using 580 lookout towers. The total number of forest guards is about 13,500. Early detection of forest fires from the lookout towers is efficient under no wind conditions. Unfortunately, the Fire Danger Index provided by Belhydromet does not consider the wind, which is considered important by the stakeholders. As regards the moisture content of vegetation and soils, data on groundwater levels are also needed. The MES checks the weather forecasts directly via meteoinfo.by/wrf3; it also uses the European Forest Fire Information System (EFFIS) for forecasts over 72 hours. In case of fire in 1 of the 98 forest enterprises, the Ministry of Forestry intervenes. It requests assistance from the MES only in case of uncontrollable fires.
The Ministry of Forestry has its own fire-fighting equipment depots and fire chemical stations for fire prevention and control. Fire chemical stations (FCS) can be either Class 1 or 2. Fire-fighting vehicles are available only in Class 2 FCS. Fire chemical stations are activated in case of peat fires.

6.8 METEOALARM

6.8.1 About Meteoalarm
Meteoalarm (meteoalarm.eu) is a product of the European National Meteorological Services Network (EUMETNET). Meteoalarm provides a one-stop shop and a repository for multi-hazard warnings to be used, for example, by professionals or tourists on a European scale. The Meteoalarm website has been successfully developed over the last decade by EUMETNET members to improve both national and cross-border warning services. The website integrates authoritative warning information for meteorological and hydrological hazards delivered by 37 (as of 2019) NHMSs across Europe. Meteoalarm provides a high level of overall visibility of the participating partners and their warnings through an impressive number of page visits to the website and strengthens the Single Authoritative Voice (SAV) principle.

FIGURE 21. EUMETNET METEOALARM WEBSITE METEOALARM.EU, EUROPEAN OVERVIEW

Meteoalarm provides the most relevant information needed to prepare for extreme weather and related hazards expected to occur over its European coverage area. The warnings are understandable by all actors from the private and public sector and are multilingual and harmonized as far as possible; whereas the 4-level color code is seen as an understandable “language.” This information is presented consistently to ensure coherent interpretation as widely as possible throughout Europe. Meteoalarm supports and provides a valuable framework for the transition to impact-based warnings.

Meteoalarm is well-accepted by the public and professional institutions, civil protection and first responders and interaction with professional users has provided valuable expertise to both sides. Meteoalarm is promoted at the national level via the contributing NMHSs and at the European level by the Meteoalarm program management in close cooperation with the members.

Meteoalarm has been operational since 2007 and the website has generated large public interest (Figure 21). Re-users acquire warning data from Meteoalarm RSS and CAP feeds. Since 2009, close cooperation with the European Response Coordination Center (ERCC) has enabled 5-day warnings to be communicated to the European Commission (European Civil Protection and Humanitarian Aid Operations, ECHO) for early warning purposes. Since 2010, flood warnings of National Hydrological Services have been integrated into
the Meteoalarm system.

WMO has endorsed the XML-based data format Common Alert Protocol (CAP) for exchanging public warnings and emergencies between alerting technologies, which is understood by NMHSs and end-users (Figure 22). The CAP allows a warning message to be disseminated simultaneously in a consistent manner to many users. Since 2014, CAP warnings have been listed on the Meteoalarm website via ATOM feeds and the alert hub. The process is still ongoing, as some members are still working to change to the new format. The number of warning regions is steadily increasing, as more and more members provide warnings in a higher spatiotemporal resolution (Figure 23).

The European Multi-Service Meteorological Awareness (EMMA) project, with the Meteoalarm system, represents one of the most successful and visible achievements of EUMETNET. The current phase of EMMA started in January 2019 and will last until the end of 2023. The coordinating EUMETNET member is the Austrian Meteorological Service (ZAMG).

FIGURE 22. EUMETNET METEOALARM WEBSITE METEOALARM.EU, COUNTRY LEVEL

Note: Example of a red warning situation (storm and rain) in Croatia. Warnings include information about the warning level, meteorological scenario and possible impacts.

FIGURE 23. EUMETNET METEOALARM WEBSITE METEOALARM.EU, REGIONAL LEVEL

Note: Example of a red warning situation (rain) in Gospic Region, Croatia. Warnings include information about the warning level, meteorological scenario and possible impacts.
6.8.2 Basic Requirements for Meteoalarm Members

6.8.2.1 Forecasting ability at the NHMSs

A set of capabilities should be available to forecast intensities, geographical spacing, and timing for critical hydromet parameters. This includes an adequate observing network with remote-sensing capacities, NWP models, post-processing techniques, nowcasting techniques and flood forecasting abilities. Additionally, it should include observations from a voluntary network (e.g., trusted spotters) and crowd-sourced information (e.g., reporting apps) as available in Belarus.

6.8.2.2 Definition of hazards/warning parameters/critical thresholds and colors

As a first step, it is necessary to identify the weather- and water-related hazards that have the greatest potential for harm. It is advised to work closely with partners such as the Civil Protection Agency to carry out such a study. Once the primary extreme weather hazards including extreme rainfall, high winds and extreme high and low temperatures have been identified, the secondary and tertiary hazards need to be identified. In addition, secondary and tertiary hazards such as floods should be considered. Once the hazards are defined, it is necessary to review the thresholds for each parameter. Thresholds should be linked as closely as possible to potential impact and damage which should be made clearly visible to end-users.

A straightforward 4-level color-coded system is used in Meteoalarm to define and connect the potential impact to hydromet criteria. This gives the civil protection organizations, the general public and targeted end-user groups of users a clear signal on potential danger. The colors green, yellow, orange and red are used to classify the levels of danger, to provide general advice on “what to do” and to indicate typical meteorological and hydrological conditions for these levels. The hazards and behavioral advice are generalized across Europe, even though the hydromet conditions change from one climatic region to the next. Each color has a specific meaning which can be understood by all European citizens independently of their own language.

To set a threshold for each hydromet parameter, climatologically determined return periods is used for each color as a starting point. Based on the typical damage/impact relationships of each region the foreseeable average frequency of usage for each parameter can be determined in a given climate (Figure 24).

FIGURE 24. METEOALARM WARNINGS PARAMETERS AND MEANING OF COLOR CODES
Of primary importance is the "What to Do" criteria – warning and alert level systems are effective if people react to them. In an effective system, the damage impact criteria are well met for each warning. At the same time higher levels of warnings or alerts are used cautiously and not too often. The meteorological thresholds are a result of these considerations. Some situations might be meteorologically extreme, but they should not be reasons for warnings if such situations do not cause any damage. On the other hand, some scenarios might result in higher warning or alert levels due to a combination of different parameters or increased vulnerability of the infrastructure.

6.8.2.3 Warning strategies – certainty/uncertainty of an event

Any warning should comply with the following criteria:

- It should be timely for a certain event (weather parameter), giving proper timing and geographical spacing and displacement of the phenomenon;
- It should describe the expected damage scenario (impact information), such as possibility of falling trees or flooded areas; and
- It should also include advice on actions to take.

These points imply a certain lead time between the issuance of the warning and the event expected to happen. The lead times depend on the NMHS capability and also on the parameters in question. For example, it is easier to give a warning for a large-scale synoptic wind scenario than for a freezing rain or convective event.

The provision of warning texts in English is required to reach international users. Color-coded warning information is also requested for Days 2-5. This information is needed by European users like the ERCC and re-users of the warning information.

6.8.2.4 Issuing of warnings

In order to properly issue severe weather warnings, it is advised to include all meteorologists on the shift in the final decisions. If necessary, experts from outside the shift can be involved. This is called Collaborative Decision Making (CDM), and it leads to more-balanced decisions on the issuance of warnings over time. It might also be useful and necessary within the warning system to involve other parties as required such as hydrologists and fire fighters during the operational phase. A common strategy should be defined, and cooperation should be established with organizations outside of the NMHS.

It has been proven wise to work closely with national civil protection agencies when issuing warnings, especially those of higher levels such as orange and red. The information that these agencies may have about increased vulnerability of certain infrastructure might be crucial for the determination of the correct warning message.

A good relationship with the media is equally important when issuing warnings. Mutual trust and a close relationship have to be established long before a crisis situation arises in order to be able to talk to well-informed media partners during a crisis.

6.8.2.5 Presentation and dissemination of warnings

The warnings should be presented in an easy-to-understand way, published on the NMHS website for the general public and disseminated to relevant media, civil protection agencies and other stakeholders (e.g., operators of critical infrastructure).

It is recommended to disseminate the warnings using the Common Alerting Protocol (CAP). Warnings can be published in real-time via CAP-feeds (RSS, Atom). The national CAP warnings should be sent to the Meteoalarm server in order to publish them on Meteoalarm and redistribute them to re-users. Warning information on Meteoalarm should be kept as much as possible consistent with the national warning webpage (e.g., resolution and update interval). Warnings can also be published via SMS-services, APPS (push notification) and CAP feeds. All warnings should be updated and be withdrawn at the end of a warning episode.
7. MODERNIZATION OF METEOROLOGICAL AND HYDROLOGICAL SERVICES AND EARLY WARNING SYSTEM

7.1 VALUE CHAIN APPROACH

The Belhydromet forecasting and warning services need to be raised to a level that can provide fit-for-purpose services to all users. A well-planned and organized NMHS should play a key role in early warning systems and services (EWS). Producing and disseminating warnings that are targeted to the impacted areas and populations are the main mandate of any NMHS. The introduction of impact-based forecasting and warning services is the way of future NMHS operations in collaboration with relevant government organizations. The public will need to be educated and the emergency management authorities will need to be trained on the potential impacts of severe hydromet events to take protective actions.

Modernizing a NMHS is a complex, time-consuming and costly task in any country. As an example, the modernization of the U.S. National Weather Service and the Japan Meteorological Agency took many years and cost hundreds of millions of dollars. The modernization of the Hydromet Service in Slovenia, a relatively small country, which was completed in 2015 cost €33 million (approx. US$27 million). To this end, before proposing modernization activities for Belhydromet, it would be reasonable to present a brief description of the main elements of a well-functioning NMHS.

The operation of an NMHS in any country is based on observations and data collection; data processing; telecommunications; preparation of forecasts, warnings and climate advisories; and dissemination of forecasts and other specialized information through the media and other channels to users (Figure 25). This is achieved through the combination of many networks, centers and hubs on global, regional and national scales to form the intricately inter-connected world of global hydrometeorology. The three components of observations, telecommunications and data processing, and forecasting together comprise the WMO World Weather Watch (WWW) system.

The Global Observing System, extremely complex, is perhaps one of the most ambitious and successful instances of international collaboration in the last 100 years. The System consists of a multitude of individual observing systems owned and operated by many national and international agencies. The Global Telecommunication System (GTS) is the communications and data management component that allows the WWW to collect and distribute information critical to its processes. The GTS is implemented and operated by the NMHSs of WMO members and by intergovernmental organizations, such as ECMWF and the EUMETSAT. The GTS also supports other programs, facilitating the flow of data and processed products to meet WMO members’ requirements in a timely, reliable and cost-effective way. It ensures that all members have full access to meteorological and related data, forecasts and alerts. The Global Observing System evolved into the WMO Integrated Global Observing System (WIGOS) and the GTS expanded into the WMO information system. The Global Data Processing and Forecasting System (GDPFS) encompasses all forecasting systems operated by WMO members. It enables members to make use of the advances in NWP by providing a framework for sharing data related to operational hydrology, meteorology and oceanography. The WMO information system is the main support for the exchange and delivery of these data.
The value of the products and services of NMHSs is manifested in the way they are used by the recipients. The generation of meteorological and hydrological value can be depicted in a “value chain” linking the production and delivery of services to user decisions and the outcomes and values resulting from those decisions (Figure 26). Potential value is added at each link of the chain as services are received by users and incorporated into or considered in decisions. Value-adding processes involve tailoring services to more specialized applications and decisions (i.e., making the information more relevant) or expanding the reach of an information product to ever-greater audiences (e.g., the public, decision-makers and clients). In a well-functioning NMHS, every link in this chain is strong, helping to deliver value to the society at the end of the chain. In contrast, in a less developed NMHS, the chain often stops at observation or forecasting without a robust modeling, ICT, and service delivery capability and a broken link somewhere in the value chain would result in producing sub-optimal, and in worst case, no value at all to the society.
Modernizing NMHSs cannot be piecemeal; however, it could be implemented in a phased approach stretched over a number of years as long as the initial plan takes into consideration every component of every system and the level of improvement needed. In the end of the implementation of the plan, the process should be transformative, ensuring NMHSs can deliver the services stakeholders expect. This includes new technologies for observation and data recording, data validation and archiving and, modern tools for forecasting, dissemination and communication of products and services (Figure 27).
Network design has to be an ongoing process based on user needs, with new stations being established and existing stations being discontinued as program priorities and funding evolve. Selecting the best technology for data sensing at a given location is a very complex task. There are many technologies available and for each combination of these technologies, there are numerous vendors and products available. Network operators must consider additional factors such as reliability, reporting accuracy, costs, operation and maintenance requirements, durability and site specifications. Data management ensures the proper storing, validating, analyzing and reporting of vast amounts of data and establishes the validity of the data by providing evidence of compliance with the quality management system. Finally, no investment in technology can compensate deficits in human capacities for which continuous training is essential. **Figure 28** gives an overview of the flow of data and information in modern hydromet services.
The socioeconomic benefits of modernization will be manifested in managing risk and aiding decision-making in weather-related disasters and economic development. This is especially the case for floods, which have the biggest impact on the poor and vulnerable populations. Improving the forecasting and early warning of hydromet hazards will contribute to building resilience for communities and sectors at risk. A substantial modernization program for any NMHS should typically include three components, namely: (i) enhancement of service delivery system; (ii) institutional strengthening and capacity building; and (iii) modernization of observation, ICT and forecasting infrastructure. The activities proposed in the subsequent sections are in line with this principle. They aim to strengthen Belhydromet’s institutional basis and to enhance the capacity of staff; to technically modernize those elements of the basic infrastructure and facilities (observation, ICT, data management and hydromet forecasting) that require upgrade; and, most importantly, to advance the delivery of hydromet and EW services to the population of Belarus and weather-dependent sectors.

7.2 DEVELOPMENT AND COOPERATION PARTNERS

There are a number of ongoing initiatives that aim at strengthening early warning systems and hydromet services in Belarus. It is therefore crucial that any new initiatives build upon the activities and achievements of ongoing projects.
The air quality monitoring network is being modernized in the framework of the United Nations Development Programme “Strengthening Air Quality Monitoring and Environmental Management” (SAQEM, 2018–2022). It is financed by the European Union and is being implemented in partnership with the Ministry of Natural Resources and Environmental Protection.

The radiation monitoring is conducted by Belhydromet (key entity of the monitoring system) together with partners (Ministry of Environment, Ministry of Forestry, Belarusian NPP). Therefore, further developments of the radiation monitoring system need to be aligned with these partners.

An important partner for any European NMHS is the ECMWF, assisting the member states in research, numerical weather predictions, supercomputing and training. New products and services of Belhydromet should take advantage of the developments planned in the ECMWF Strategy.

Any new project for modernizing Belhydromet could benefit from consolidating the achievements so far of the previous activities.

8. PROPOSED ROAD MAP FOR MODERNISATION OF BELHYDROMET

Recognizing that cultural change in institutions takes time; this road map represents the first step in a planned long-term engagement on hydromet enhancing the current capabilities of Belhydromet. The resulting project should lay a strong foundation that can be developed over time. The engagement of the relevant government authorities in this process and their understanding of the role that Belhydromet can play in many areas of the development of the country should also be strengthened.

A modernization/enhancement program for any NMHS should include the three inter-related groups of activities or components: (i) enhancement of service delivery system; (ii) institutional strengthening and capacity building; and (iii) modernization of observation, ICT and forecasting infrastructure. These components are described in the following sections. While a road map aims to present a comprehensive plan for the overall modernization process, Belhydromet may consider those elements of the road map that are most appropriate and applicable for its enhancement purposes and prioritize the proposed actions and the timeframe needed for their implementation.

8.1 DELIVERY OF SERVICES

Most NMHSs see their main role as making observations and providing data to certain users without much knowledge of the application of such data or the follow up as to their usefulness. The evolution from a data providing to a demand- and user-driven, knowledge-based organization that emphasizes service provision across many socioeconomic sectors is essential if NMHSs are to stay relevant in their respective countries. In the case of Belarus, capacity building should be carried out for the staff of Belhydromet to enable them to take advantage of new tools and technologies in the provision of services which will result in substantial benefits to the country.

Challenges that exist in most countries relate to a gap between providers and users of hydromet services resulting in miscommunications and misunderstandings between the two sides. To overcome this gap, it is essential to create and deepen the understanding of who the users are, what they need and how NMHSs can meet those needs. It is equally important that the users be aware of the capabilities and limitations of the service providers.

The Service Delivery system of Belhydromet should be able to correspond to the needs of various users who require different services from their national service provider, including a service-monitoring and feedback system (Figure 29 and Figure 30).
For service delivery systems, only some of the users and stakeholders are identified here; there could be many others, including aviation and road services.

Being an important component of investment in any country, it is critical that the design and upgrading of monitoring networks be coordinated with the user community, so as to achieve an integrated network that supports users’ requirements for services. Belhydromet has made efforts toward identifying users and their requirements for hydromet information and has developed dialogue with them to varying degrees.

The objective under this component of the road map is to enhance the Belhydromet’s current service delivery systems by developing a national Strategy for Service Delivery; enhancing public weather and hydrological services; strengthening end-to-end early warning systems and services, including developing impact-based forecast and warning services; developing agriculture and climate advisory services; and creating a National Framework for Climate Services. This provides for the implementation of a systematic upgrade of the weather, climate and hydrological-related end-to-end services provided to all agencies, communities and individuals. The WMO Strategy for Service Delivery and its Implementation Plan (the Strategy) provide in-depth and step-by-step guidance to enhance and develop service delivery. The Strategy describes a continuous cycle of 4 stages that define the framework for service delivery and identifies 6 elements that detail the activities required for high-quality service delivery (Figure 31).
The six elements necessary for moving towards a more service-oriented culture are:

1. Evaluate user needs and decisions
2. Link service development and delivery to user needs
3. Evaluate and monitor service performance and outcomes
4. Sustain improved service delivery
5. Develop skills needed to sustain service delivery
6. Share best practices and knowledge

Source: WMO 2014.
Annex 2 to this road map shows the Service Delivery Progress Model as illustrated in the Strategy. It should be noted that this model is applicable to all types of services provided by NMHSs.

Such a shift to user-based products and service delivery requires a mechanism to facilitate communication and understanding between service providers and the user sectors. Establishing a hydromet user group is a useful tool for this purpose. The user group needs to develop and implement a Strategy for Service Delivery with the engagement of service providers, stakeholders and end-users. The strategy should outline user needs; priorities for needed products and services (must-haves and nice-to-haves); design and generation of those products and services; dissemination of products and delivery of services; evaluation of the impact of the new products and services on the country; and improvement of products and services. Since user needs change periodically, existing and potential new key users should be surveyed on a regular basis. NMHSs need to engage the public and more specialized users through educating and informing them on how to make the best use of scientific advances. It is essential that a user database be maintained and updated. The products and services required by the users should become part of Belhydromet’s strategy.

Although both hydrological and meteorological services reside in Belhydromet, in order to respond to user requirements in a holistic manner, it is advisable to review their established working processes to ensure a collaborative approach between them resulting in the hydrology service providing the following services:

- Water-related data and observations obtained from hydrological observing network;
- Water-related information such as a comprehensive assessment of national water resources, the statistics of flood events or maps of spatial/temporal trends;
- A monitoring service designed to provide very specific data or information at a particular location for a particular user (e.g., to indicate when the remaining discharge, influenced by water extractions, falls below a specified minimum value);
- Knowledge and understanding of water-related phenomena and water resources (e.g., seasonal changes of the runoff regime as a result of ongoing climate change);
- Advice on decision-making, where information is developed into recommendations for response to certain conditions (e.g., estimation of inundated areas ahead of the spring flood season); and
- Setting up a model- and database-driven methodology to estimate water balances since reliable estimates of water balance are a service required by many users and should be developed through joint interdisciplinary efforts of experts in geo-informatics, hydrology, meteorology and water management. This requires an exchange of information between sectors and capacity building of staff.

Similarly, the meteorology service would be expected to provide the following:

- Weather-related data and observations from a meteorological observing network that provides specific data at a particular location based on established WMO standards;
- Weather forecasts at various timescales (nowcasting, very-short-, short-, medium- and long-range based on available capacity) based on user needs and severe weather warnings; and
- Advice on the impact of the weather conditions (both severe and routine conditions) on different stakeholders and decision-making guidance for users.
8.1.1 Strengthening Public Services for Weather, Climate, Hydrology, Forest Fire and Radiation

A public weather services (PWS) provides information on severe weather, hydrological hazards, fire weather threats and radiation exposure. It is the principal interface between the technical providers of weather and the related products and end-users (Photo 5). NMHSs utilize PWS to reach the broad end-users, including the public, economic sectors and mass media.

A PWS translates technical forecasts and other information into socially and economically relevant and understandable information and provides this information to the public at-large and various economic sectors. In most countries, the NMHS disseminates all forecasts and warnings through various channels, including mass media, the internet and increasingly social media. This information includes both weather and hydrological warnings, forecasts and advisories. Under a PWS program, standard operating procedures are needed.

Belhydromet should develop standard operating procedures in partnership with their key stakeholders for producing and delivering fit-for-purpose services. This is especially important for warnings: it ensures that such information is consistent among partners and stakeholders and permits clear decision-making and timely action. Implementing PWS services effectively at Belhydromet would ensure that all users receive timely information on all time scales available. Implementing formal and regular feedback mechanisms should also be part of the successful delivery of public meteorological and hydrological services.

The wide dissemination of hydromet forecasts and warnings to all users is a key element of modern delivery of public meteorological and hydrological services. An essential tool for access to important meteorological and hydrological as well as radiation and air quality information is the Belhydromet website.

PHOTO 5. MODERN PUBLIC WEATHER SERVICE DELIVERY IN INDONESIA

Credit: Haleh Kootval, World Bank.
8.1.2 Developing a National Drought Monitoring Service

Low-water periods resulting from meteorological droughts may result in the deterioration of the state of the environment and potential for recovery of surface water bodies and adjacent areas. In addition to the economic damage (mainly to the agricultural sector), the water supply may be put at risk in rural settlements which are not connected to the centralized water supply system because of a decline in the groundwater level and water shallowing in wells. In addition, the possible increase in the frequency and duration of dry seasons may increase the risk of a substantial reduction in the summer runoff of small rivers. This would result in lower water levels and deterioration of the water quality. During droughts, the risk of peat fires increases because the soil dries out.

Given that Belarus is, in general, a rather swampy country as a result of lowlands, no groundwater monitoring network exists in the country. However, there are drought problems in some regions as a result of meliorations which were (over) done during the Soviet era. Considering drought as one of the main weather- and climate-related hazards impacting Belarus, there is a need to develop more comprehensive agriculture and climate advisory services. This includes a drought-monitoring program which would coordinate meteorology and hydrology information and knowledge and establish the drought magnitude and potential drought-impact information that most farmers and the Ministry of Forestry use. It is important that a drought-monitoring program be developed by Belhydromet in collaboration with the Ministry of Forestry and the Ministry of Agriculture and Food given that production of drought forecasts is essential for their decision-making.

8.1.3 Developing a National Framework for Climate Services

A National Framework for Climate Services (NFCS) is defined as a coordinating mechanism enabling the development and delivery of climate services required at national and local levels. A number of NMHSs have developed a NFCS, guided by the Global Framework for Climate Services (GFCS), involving practicalities and specifics for the actual delivery of climate services at the national level. The NFCS would involve the key national institutions (if other than NMHS) collecting and compiling climate observations and other climate-related datasets as well as institutions undertaking relevant research and providing tailored information, products and expert advice. A NFCS in Belarus would potentially include support to major sectors such as agriculture, forestry, transport, water resources, and disaster risk management.

8.1.4 Developing a National Information System for Airborne Hazards

It is necessary to standardize and (as far as possible) automate the delivery of model results and expert assessments for natural and man-made emergencies with airborne hazards. Further, the model results need to be disseminated to all authorities involved in emergency management and response. It is suggested to set up a common web-based platform for information sharing.

The WMO’s Emergency Response Activities (ERA) program involves the application of specialized atmospheric dispersion-modeling techniques to track and predict the spread of airborne hazardous substances in the event of an environmental emergency. The ERA program was established to assist NMHSs, their respective national agencies and relevant international organizations to respond effectively to environmental emergencies involving large-scale dispersion of airborne hazardous substances. The WMO has implemented and maintains a system of 10 Regional Specialized Meteorological Centers (RSMCs) that provide real-time 24/7 specialized atmospheric dispersion model products for environmental emergency response and/or backtracking.
These specialized centers, providing complete global coverage are located in National Meteorological Centers at:

- Beijing (China);
- Exeter (United Kingdom);
- Melbourne (Australia);
- Montreal (Canada);
- Obninsk (Russian Federation);
- Offenbach (Germany) – backtracking only;
- Tokyo (Japan);
- Toulouse (France);
- Vienna (Austria) – backtracking only; and
- Washington (United States).

In order to take full advantage of this support, it is necessary to update the positions of the Belarus permanent representative with the WMO, the delegate authority for Belarus and the technical contact point for Belarus and to clarify how the products from the WMO RSMCs are retrieved and delivered to the responsible stakeholders in Belarus in case of nuclear or non-nuclear emergency.

It is recommended to set up an automated system of retrieval of model results provided by the WMO ERA in the event of a nuclear emergency (as well as during international exercises for training purposes).

8.2 INSTITUTIONAL STRENGTHENING AND CAPACITY BUILDING

8.2.1 Institutional Strengthening

In most countries, strategic policies that ensure effective integration of water resources and disaster risk management are needed for effective mitigation of the loss of life and livelihoods from droughts, floods and climate change.

The main objectives of NMHSs are to provide information on weather, climate and hydrological conditions and where required, to provide support to decision-makers in case of airborne hazards of natural or man-made origin for safety in the air, on land and at sea; to mitigate natural disasters; to provide services to weather-sensitive economic sectors; and to support national development. A modern NMHS performs these functions by acquiring:

- Comprehensive, high-quality and robust observational networks;
- Efficient data collection and management and rapid information exchange;
- State-of-the-art ICT and computing facilities within its technological, expert support and financial capability;
- Sophisticated data analytics schemes and powerful simulation and forecasting models;
- Improved understanding of meteorological and hydrological phenomena through ongoing scientific research;
- Expertise in delivering forecast and warning services based on impacts of hydromet phenomena, in partnership with relevant government organizations;
- Effective tailoring of services to user needs;
- Effective dissemination systems using multiple channels to assure wider dissemination of warnings, forecasts and advisory information;
- Efficient public and private service delivery arrangements;
• Effective communication of the science and practice of meteorology and hydrology, including limitations, uncertainties and applicability of the science and related technologies;
• Capacity building across the entire NMHS and for the users and stakeholders; and
• Improved methodologies and algorithms for use of meteorological, hydrological and related information in decision-making.

Modern NMHSs need to focus on understanding the user value chain to become better aware of users, the decisions they must make and how information related to weather, climate and hydrology is applied to minimize risk and to benefit the society as a whole (see Section 7.1). Effective service provision is a virtuous circle whereby as a result of improved service delivery, users will gain confidence in the capability of the NMHS; this will lead to improved relations and increased demand for services; better services to government agencies and departments will result in greater recognition of the NMHS as provider of vital services supporting the economy and society; and this will enable the NMHS to build a more convincing case for investment to sustain and further improve the range and quality of services.

A powerful tool for modern NMHSs to maximize the return on investment by ensuring optimum use of resources is a Concept of Operations (CONOPS). The CONOPS provides a conceptual overview of the system and sub-systems in an NMHS to achieve the capabilities listed above. The CONOPS is intended to support the evolution of a fully integrated, modernized and functional NMHS, which provides the level of services required by its users and stakeholders. A CONOPS describes the existing and future systems of an organization from the perspective of different users. It addresses:

• Design, procure, implement, operate, maintain, and replace the system; and
• Integrate sub-systems into a “system of systems.”

Figure 1 in this road map illustrates the system of systems of an NMHS supported by CONOPS.

At the moment, the Belhydromet activities mainly focus on observation and data collection and producing forecasts and services to varying degrees for users. Taking full advantage of the current technological and scientific progress and applying the best practices and standards would contribute to improved weather forecasts and service delivery. The step from data collection to information production demands a strengthening of most of the system of systems in an integrated manner, such as modeling, forecasting and service delivery systems supported by the ICT, QMS (Figure 32), capacity development and technology infusion systems (Figure 33). The institutional strengthening component of this road map will aim to focus on the improvement of institutional arrangements at Belhydromet for enhancing its performance in line with international best practices.
8.2.2 Capacity Building

Capacity building underpins the human resources within any NMHS and within the main users and stakeholders. Building capacity to improve the sustainability of the modernization of Belhydromet is indispensable and a foundation block for other systems and functions. Like most NMHSs, Belhydromet experiences difficulties with retaining trained staff, and will need to develop staff capacity guided by the needs of its various divisions. Effective succession planning and strengthening working relationships with the Belarusian State University is needed to launch a post-graduate program to train forecasters to ensure replacement of retiring staff. It is important to ensure the new recruits receive on-the-job support and instructions, while a regular program should be in place to offer refresher courses to existing staff to ensure their skills and knowledge are kept up to date (Figure 34).
Educating stakeholders/end users in the application of hydromet products for decision-making is equally needed to better understand warnings, probability forecasts and the impact of hazards. User education should include workshops, open days to encourage visits by the public, school visits, the distribution of flyers, publications and public service videos, and posting educational materials on the Belhydromet website.

8.3 MODERNIZATION OF OBSERVATION INFRASTRUCTURE, DATA MANAGEMENT SYSTEMS AND FORECASTING

This component aims to ensuring that meteorological, hydrological and radiation observations networks are well functioning and interoperable. It further focuses on modernizing data management, communications and ICT systems; improving weather, hydrological and radiation forecasting processes and numerical prediction systems. Modernization of each system should be broken down to manageable packages for phased implementation.

Monitoring and observing systems (Figure 35) have two distinct sub-systems. The first is the global data system, which includes all of the information received via the WMO information system or the Global Telecommunication System and data from unique sources, such as satellite products from specific providers. The second is national data, which is a combination of observations networks supported by different entities—public and private, and crowdsourced data associated with social networks.
8.3.1 Meteorological Observation Infrastructure

The increasing risks of floods and droughts because of climate change will require better forecasts and response. Infrastructure modernization should focus on rehabilitation of the existing synoptic network to safeguard compatibility and interoperability between different types of equipment and sensors; it also should introduce a higher degree of automation of observations to improve nowcasting and very-short-range forecasts. For any future plans regarding the expansion of observing stations in Belarus, it is necessary to keep in mind that a ground-based surface observation network only provides moderate value for investment (financial and human) from a weather and climate perspective. Satellite technology can now provide good analysis of snowpack and water resources relevant for many sectors. A ground-based surface observational network can become high value when assimilated into a common information layer through NWP that then offers a richer, more useable, sector specific output for forecasters, or when used as ground truth to calibrate radar data. Therefore, single (or even multiple) ground observation from an area of interest does not represent the full picture for, say, water management, without being used as part of a common information layer. Therefore, this road map strongly encourages a careful assessment of the future needs for data when planning an expansion or reorganization of the network, which should consider the requirements of the users and constraints of the operators. Regular preventative maintenance procedures to be carried out by trained personnel once the network expansion has been undertaken, will be a major condition for success.

8.3.2 Hydrological Observation Infrastructure

Currently, the hydrological activities of Belhydromet are mainly focused on observation and data analyses. Revisions of the observation network and the operating procedures are necessary to consider new requirements (e.g., to implement the EU Water Framework Directive or the EU Flood Directive). The future needs for operational data provided by automated data loggers should be assessed. The efficiency of the hydrological observation system is limited by outdated instrumentation.
A modernization of the gauges is necessary to ensure not only a full operational data availability of water levels and discharges which is essential to provide the input into hydraulic and hydrological models but also an automated data chain from gauges into modern data management and reporting systems. To ensure such an automated collection and transfer of hourly hydrological data, new self-recording gauges with electronic data storages and data transfer via GSM should be established. The extent and speed of network expansion should be proportional to the capacity of Belhydromet in operating and maintaining the stations. The utilization of new sensor systems, for example, an Acoustic Doppler Current Profiler (ADCP) for discharge measurements, could improve data quality and increase the efficiency of the observation network.

There is a strong need to enhance interoperability of hydrological and meteorological data, for example, to apply numerical models for growth and ablation of snow covers as regards spring flood forecasting. This requires a combination of hydrological models with ground-based and remote-sensed data and meteorological forecasts.

Strengthening the status of data logging and transmission will allow the provision of reliable end-to-end data communication, the delivery of forecast and warning services to users and the implementation of operational deterministic flood models. WMO’s recommended guidelines on establishing operating and maintenance programs of NMHSs should be taken into consideration. In a modernized hydrological observing system, all new stream gauge installations should also include recording rain gauges in the contributing watersheds. Real-time access to this rainfall data should be established and telemetry added to ensure that the data are automatic and operational at all times to trigger flood warnings.

**8.3.3 Radiation Monitoring Infrastructure**

The instrumentation necessary to control the exposure due to the Chernobyl disaster is step-by-step renewed and upgraded in the framework of the National Environmental Monitoring Program. With the start of the construction of the Belarusian NPP, additional radiation monitoring around the site became necessary and funding for this purpose was provided. In 2018, the IAEA carried out two missions; further investments will be required to follow the IAEA recommendations.

The laboratory radiometric infrastructure at Belhydromet partly consists of state-of-the-art technology but still requires further step-wise replacement of outdated instrumentation and acquisition of additional modern equipment (e.g., spectrometers). Further optimization of the tools for data processing and quality control (e.g., implementation of a Laboratory Information Management System) and replacement of all laboratory equipment which still requires time-consuming manual data retrieval will help to ensure data quality and reduce the work pressure on laboratory staff (see Photo 6).

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**PHOTO 6. LABORATORY EQUIPMENT AT BELHYDROMET (SAMPLE COUNTER) REQUIRING MANUAL DATA READING AND RECORDING (CREDIT: KATHRIN BAUMANN-STANZER)**
A new task for Belhydromet is monitoring of the natural radioactive gas which is realized to be an important health hazard if accumulated indoors in workplaces or dwellings. Radon is estimated to cause between 3 and 14 percent of all lung cancer cases, depending on the average radon level in the country. Therefore, traceable and quality assured in-situ and laboratory measurements of radon are needed to meet the governmental and public request for information.

**8.3.4 Data Management, Communication and ICT System**

A readily accessible, digital database of hydrological and meteorological parameters is needed to develop a range of warning and forecast services related to extreme weather and flood events that impact Belarus. To obtain the most benefit from modernization of Belhydromet’s observation network and improvements in forecasting and service delivery, it is essential to continue improvements in ICT capacity (Figure 36). A modern software/hardware environment at Belhydromet will depend on communications equipment and computers (Belhydromet already has a high-performance computer), harmonized database management systems for weather, climate, hydrological, radiation and air pollution data (Belhydromet is beginning the process of moving from the traditional system of data collection and storage to an automated system, including servers, software, web access and social media); remote sensing and GIS and, satellite downlink system. Such an environment will provide efficient and timely collection of data from the observational network and will speed up reception and processing of information products from leading international centers enabling higher resolution products and more information to be available to Belhydromet forecasters (Figure 37).

**FIGURE 36. INFORMATION AND COMMUNICATION TECHNOLOGY SYSTEMS**
8.3.5 Meteorological Forecasting

Numerical Weather Prediction (NWP), including ensemble prediction systems (EPS), coupled to an extensive observational network, is the foundation of modern forecasting. Weather forecast modeling is a cost- and resource-intensive process because its use requires well-developed computer infrastructure, often costing millions of dollars (with associated research and technical support) (Figure 38). Belhydromet has access to models from several developed NMHSs and with the increasing accessibility of different model outputs from different global and regional centers. With appropriate training, Belhydromet could extract optimum benefit from all the available and accessible tools. Modern weather forecasting and warning systems cover all time scales from nowcasting to seasonal. Production of forecasts for a certain range is often the responsibility of a particular forecaster. For example, severe hazard forecasting may be linked with a forecast of flood, drought or a combination of these (Figure 39).
FIGURE 38. MODELING SYSTEMS

Hydrological Modelling Systems

Limited Area Modelling Systems

Global NWP Systems

Regional NWS Systems


FIGURE 39. FORECASTING AND WARNING SYSTEMS

Hydrological Modelling Systems

Limited Area Modelling Systems

Severe Hazard Forecasting System

Nowcasting System/Flash Flood Guidance

Very Short-Range Forecasting System

Short-Range Forecasting System

Objective and Impact Forecasting and Warning Systems
Short-range, long-range and severe weather forecasting is currently performed by Belhydromet to produce forecasts for 1–6 days ahead for the entire country and 3-day forecasts for each oblast, using surface in-situ and remote-sensing data, including 4 radars; satellite data from a polar-orbiting satellite and the EUMETSAT geostationary satellites; and road sensor data. No nowcasting models or systems are used, but all available data are used to produce a forecast for the immediate 2–3 hours. Specialized forecasts for various economic sectors and storm warnings are also issued. The forecast map is displayed through a visualization system with software provided by a Russian company. It produces pre-defined images and does not ingest the observational data. There is thus a lack of a forecaster workstation at the Forecasting Office (Photo 7 showing a modern forecast office environment). No post-processing of model outputs and no objective verification are conducted but daily verification of 24-hour forecasts against observations (max and min temperature, precipitation and wind speed) are carried out for a number of locations.

Belhydromet also produces seven-day and seasonal forecasts using information from different sources (e.g., United States or monthly forecasts from Moscow but does not produce its own seasonal forecasts). No downscaling of global models is done, and staff have not received any training in downscaling.

As part of the longer-term modernization plans for Belhydromet, it is necessary to establish a comprehensive process for operational weather forecasting as is practiced in a well-functioning modern national forecast center. Such a modernization process will allow access to the NWP/EPS digital data and products from a global center (e.g., ECMWF); the required software for data handling (license); NWP post-processing and calibration (model output adjustment to country conditions); and production of regional and site-specific forecasts. Fortunately, Belhydromet enjoys access to uninterrupted broadband internet, which is essential for moving from deterministic to ensemble prediction systems (EPS), critical for estimating the uncertainty in the weather forecasts and the most likely outcomes, as well as the likelihood of an extreme event. Uncertainty is estimated by running a model many times from very slightly different initial conditions instead of running the NWP model once (a deterministic forecast). The range of different solutions in the forecast allows access to the uncertainty in the forecast, and the level of confidence in a deterministic forecast. The EPS is used to produce probabilistic forecasts and allows the application of techniques for impact-based forecasting, which is very important for decision-making.

Access to the ECMWF Global Model digital data (9-km resolution) will represent a great step forward for Belhydromet at a cost of €42,000 (approx. US$51,400) per year. An even better approach is for Belhydromet to become a Member State of the ECMWF, which will provide Belhydromet with full access to digital data (including archive), as well as to the ECMWF computing facilities, and associated training. It should be noted that the ECMWF membership costs include an entry fee of US$264,000 plus an annual fee of US$60,000. Other tools for the modernization of forecasting will include a forecaster workstation, implementation of real-time data management, forecast process monitoring and verification, NWP post-processing, nowcasting and impact-based forecasting techniques, as a matter of priority. Training is required both in the use and interpretation of these products and tools, as well as in the overall forecasting process supported by standard operating procedures (SOP).

In addition to the short-range forecasts, there is a need to develop (monthly and seasonal) long-range forecasts (LRF). Belhydromet should be able to access LRFs, for example on the ECMWF website, and on the WMO Lead Center for Long-Range Forecast Multi-Model Ensemble (at https://www.wmolec.org/) which provides access to LRFs from 12 Global Producing Centers. Belhydromet should eventually develop expertise also in Regional Climate Downscaling techniques, which will allow it to provide high resolution climate information on a national scale and with much greater detail and more accurate representation of localized extreme events.
PHOTO 7. MODERN FORECASTING OFFICE ENVIRONMENT IN THE AUSTRALIAN BUREAU OF METEOROLOGY AND THE FORECASTING OPERATION CENTER AT ZAMG

Credit: Haleh Kootval, World Bank.
8.3.6 Hydrological Forecasting and Decision Support System

Hydrological and hydraulic models have two main applications: (i) to specify the hydrological conditions and the resulting impacts, such as the inundated areas, for planning purposes under assumption of meteorological scenarios, such as rain events, snowmelt and droughts; and (ii) to provide operational forecasts. In general river flood hazard of Belarus is classified as high. Impacts of climate change tend to manifest themselves in more frequent and intense precipitation days in winter and an increase in the number of extreme rainfall events are expected in the future with high confidence. Some years ago, Belarus started activities to develop a planning approach for flood risk management to implement the EU Flood Directive.

In a pilot project, flood hazard maps for the Pripyat River were developed for floods of different probabilities. In addition, several other national and international projects were implemented in this basin which is a hot spot of flood risk. Other model-based risk assessments were done in 2015 for the Neman River Basin within the project “Strategic Framework for Adaptation to Climate Change in the Neman River Basin.”

The hydrological and hydraulic modeling in these projects was done by the Central Research Institute for Complex Use of Water Resources (CRICUWR), a commercial organization with no budget financing. Belhydromet does not use models for hydrological forecasting. As regards the dominating lowlands and the large extent of inundated areas, hydraulic models play a major role in flood risk assessments and forecasting in Belarus. Cooperation between CRICUWR and Belhydromet will be essential for implementing flood forecasting models in the future. Such a cooperation should be accompanied with the development of extended capacities for hydrological modeling in Belhydromet.

The hydrological conditions in Belarus requires a specific category of forecasting models. Special emphasis has to be placed on snowmelt in connection with synoptic rain events. This requires a strong cooperation of the hydrological department with meteorological forecasters. The assessments of inundations of lowlands requires hydraulic models to be driven by hydrological scenarios derived from forecasts of snowmelt and rain. The expected shift of seasonality in flooding from spring into winter, caused by rain induced floods in connection with high soil moisture in winter as a result of climate change should be considered.

The human and technical capacities to develop and implement hydrological and hydraulic models should be strengthened. As a first step, the existing knowledge which is based on personal experience and data analyses of long time series, could be extended by probabilistic analyses to improve the existing forecasting tools which are based mainly on comparisons with similar hydrological conditions in the past. It is recommended that for starting their own modeling activities, Belhydromet should implement and test free licensed software like HEC-RAS, HEC-HMC or HBV-Light. The opportunities for hydrological forecasting depend on the data availability in real time. Automated hydrometeorological stations (AHS) and hydrological gauges, embedded in a modernized ICT system are essential for this purpose.

8.3.7 Radiation Forecasting

At present, Belhydromet uses the model system RECASS-NT with data and support provided by the Scientific and Production Association “Typhoon” of the Russian Federal Service for Hydrometeorology and Environmental Monitoring Roshydromet.

It is recommended to take advantage of the meteorological products provided by ECMWF and to consider the use of a coupled meteorological forecast & dispersion model system such as FLEXPART with ECMWF forecast data. FLEXPART is a Lagrangian particle dispersion model developed and used by the scientific community. It can be driven by meteorological input data from a variety of global and regional models, including ECMWF analyses and forecasts. FLEXPART can either be run within the ECMWF computing environment which is accessible to all ECMWF members or be installed and applied locally at Belhydromet. This approach would enable Belhydromet to produce additional valuable information on air concentrations as well as (wet and dry) deposition values based on meteorological data of high quality on a regional to hemispheric or global scale.
8.4 IMPLEMENTATION OF METEOALARM

The implementation strategy of Meteoalarm covers the whole value chain, with a focus on three specific aspects: required operational systems, service delivery, and forecasting capacity for the provision of user-centric warning services. Therefore, implementation has to be carried out in close coordination and cooperation with other relevant development activities and should be considered in the CONOPS.

Membership in the EUMETNET EMMA project (Meteoalarm) is subject to approval by the EUMETNET Council.

For the implementation of Meteoalarm in Belhydromet, the following steps are needed:

- Joint review with Belhydromet, civil protection and other stakeholders of the hydromet parameters that have the potential to endanger the territory and citizens of Belarus;
- Review of the warning criteria and thresholds in use and establishing the link to potential impacts and damages;
- Generating proposals for generic damage descriptions and advisories based on existing work and input from Belhydromet for all hazards;
- Local technical implementation and configuration of the Meteoalarm system. This includes the installation of web-based tools for the generation of warnings, CAP file generation and processing at Belhydromet as well as setting up transfer of the warnings to the Meteoalarm servers;
- Pre-operational production of warnings according to the Meteoalarm standards; cross-border exchange of warnings through the Meteoalarm system; and establishment of contact with the forecasters of other European NHMSs;
- Support to the Belhydromet administrative steps required for participation in EUMETNET Meteoalarm;

8.4.1 Training and Capacity Building

Capacity building comprises the basics of the Meteoalarm system, technical background, use of the system and tools, overview of the system implementation at Belhydromet, implementation of the Meteoalarm guidelines, and practical exercises for the generation of warnings and the local maintenance of the system (Figure 40).
8.4.2 Pre-operational Phase

During the pre-operational phase, shift forecasters generate and transfer warnings in CAP format to the Meteoalarm test environment. Forecasters get used to the Meteoalarm tools and the warning procedures. Meteoalarm experts routinely check the test warnings and provide feedback for incorrect warnings or technical problems. During regular online sessions, open questions, technical issues and test warnings are discussed.

8.4.3 Operational Phase

The operational phase starts after the acceptance of a warning (technically and content-wise) by the Meteoalarm program management (Photo 8).
9. ROAD MAP SCENARIOS

This road map lays out three scenarios to modernize Belhydromet. Each contributes to a system capable of producing and delivering: (i) timely warnings of extreme and hazardous weather events and their potential impacts; and (ii) forecasts for operations and planning in weather- and climate-sensitive economic sectors such as agriculture, forestry, transport, water resources, and disaster risk management.

**Scenario 1:** Technical Assistance. Provision of technical assistance for high-priority activities to improve basic public services by introducing affordable new technologies into and training the staff of Belhydromet for heightened capacities and capabilities (immediate to short term: 2 years). The success of this assistance requires some basic investments to implement these new technologies.

**Scenario 2:** Intermediate Modernization. Investment to achieve a modest improvement in the capabilities to provide weather and hydrological services to meet the public service needs of the most important user communities, such as agriculture, forestry, transport, water resources, and disaster risk management (medium term: 4 years).

**Scenario 3:** Advanced Modernization. Investment to bring the capabilities for providing fit-for-purpose data, forecasts and warning services for the safety of the public and support to develop the most important socioeconomic sectors (long term: 7 years).

The first two scenarios build Belhydromet’s capacity to discharge its public service responsibilities. The third scenario provides the opportunity to build on public weather and hydrological services, radiation forecasting capacity and forest-fire services to provide additional tailored services either alone or in partnership with other institutions.

The steps outlined in this road map to modernize Belhydromet are based on discussions with the staff at various divisions and offices of Belhydromet and key stakeholders. These discussions reveal gaps between the requirements of the user community and the capabilities of Belhydromet to respond to those needs. The proposed steps are meant to guide the transformation of Belhydromet to a fit-for-purpose organization whose standards for products, services, and service delivery will be raised to the best possible level to discharge its public service duties to the satisfaction of the users. Clearly, Belhydromet strives to provide products of quality, diversity and coverage to users. However, in doing so, it faces many challenges in: (i) having a sufficient number of well-trained technical staff; (ii) accessing to appropriate new technologies, technical assistance and guidance; (iii) ensuring that their capacity can keep pace with and meet the ever-growing demand for their services; and (iv) securing adequate and sustained funding.

It is imperative for Belhydromet to demonstrate the importance of access to essential modern tools and technologies for observation, data processing, ICT, and forecasting infrastructure and of delivery of services and advisory guidance for users. It also should rigorously argue the case for the rate of return on investment based on the projected socioeconomic benefits of reduced losses from floods, fires and other hazards.

To compete for and optimally use scarce public resources, Belhydromet must justify the need for improving its operations and thus the investment of public funds to support its basic infrastructure and suite of services. To demonstrate the benefits to users, however, Belhydromet must first be able to provide fit-for-purpose services to the satisfaction of those users. Today, it cannot perform at an optimal level without a substantial upgrading of its forecasting and ICT infrastructure and its services. This gap in available resources and the ability to serve its mandate keeps widening for Belhydromet.

This road map and the scenarios it presents can guide Belhydromet toward a more systematic basis to set strategic and forward-looking priorities that are based on available (and potential future) financial and human resources to improve its service delivery. Future challenges may include the impacts of climate change and other factors on the provision of services.
change with resulting increases in the amount and intensity of natural hazards as well as the emergence of new technologies and economic evolution in the country.

Belhydromet should produce more relevant, location-specific, well-articulated and useable information not only on hazards but on their impacts on target areas and population. Provision of hydrological information should evolve and move forward from the basis of old data and methods, dating back to the Soviet era. This assumption has been the basis of the different scenarios proposed in this road map. Certain steps can be taken quickly and with rather limited investments and effort to enhance the utility of weather-, climate-, hydrology- and radiation-related information for users. Examples include training of the Belhydromet technical staff to access, understand and use readily available products and guidance from various regional and global centers for improved forecast and warning services; to streamline its forecasting and IT procedures and practices; and to develop a regular means of user communication and feedback. Other changes may require a series of actions over medium or long timescales and require more substantial investments. One example is introducing capacities for hydrological modeling.

As described in Section 7 of this road map, the modernization of Belhydromet is guided by three main components: (i) enhancement of service delivery; (ii) institutional strengthening and capacity building; and (iii) modernization of observation infrastructure, data management systems and forecasting.

The development of a Concept of Operations (CONOPS) as a living operational plan will be essential to guide and support the transformation of Belhydromet. A CONOPS is based on the principle of a system of systems (Figure 1) and proposes various alternatives, depending on the level of financial and human resources and other constraints, for the transformation of each individual system. The provision of the best possible products and services requires a full modernization program. This forms Scenario 3 in this road map and aims to bring Belhydromet up to the current level of a well-functioning, modern country with capabilities for providing data, forecasts and warning services to meet the needs of a spectrum of users.

The alternatives, however, should be considered for each system if there are not sufficient resources to provide this full modernization. It will be necessary to prioritize the most important changes in the systems to go forward and to consider where the program should be scaled back in favor of those priorities. The emerging solution may be to trim down from the full modernization to a relatively modest improvement in services in consultation with users, and matched with a corresponding reduction in their level of expectation. This is Scenario 2 in the road map: an intermediate level of investment to achieve a modest improvement in the capabilities to provide weather, climate and hydrological services to meet the public service needs of the most important users, such as agriculture, forestry, transport, water resources, and disaster risk management. Finally, if there are not enough resources for a moderate modernization, then it will be necessary to choose an alternative which will provide a minimum basic improvement through technical assistance. This is Scenario 1 in this road map and represents a set of high-priority activities option. It focuses on improving basic public services by strengthening Belhydromet’s capacity and introducing basic affordable new technologies. In this way, the CONOPS will be particularly useful in understanding the impact of any new activity on the existing system and will guide the process through considering a whole range of alternatives and finally choosing the one which is affordable and yet can provide the best possible services to users.

It should be noted that these scenarios are not exclusive of each other, but are inter-dependent and if conducted in phases, build on each other to contribute to the overall goal of the modernization progressing from Scenario 1 to Scenario 3. That is, Scenario 2 assumes the accomplishment of objectives in Scenario 1 and builds on them. Similarly, Scenario 3 assumes achievement of the goals in Scenarios 1 and 2 and builds on those. On the other hand, if resources are made available to undertake the modernization as a single package under Scenario 3, then this will also comprise the activities as described under Scenarios 1 and 2. Similarly, a complete modernization package under Scenario 2 will comprise Scenario 1.
9.1 SCENARIO 1: TECHNICAL ASSISTANCE FOR HIGH PRIORITY AND IMMEDIATE NEEDS

High-priority activities needed to achieve critical capabilities to provide improved weather, climate and hydrological services (focused on improving basic public services by strengthening Belhydromet’s capacity in the use and interpretation of available and accessible tools and technologies and introducing basic affordable new technologies) are indicated below. The activities focus on: developing a national Strategy for Service Delivery; establishing a hydromet user group; developing a CONOPS to guide the design of activities for Scenario 1; establishing/strengthening a collaborative approach for service provision to key government stakeholders; training; accessing and using NWP/EPS data and products from other centers; initiating an objective verification of NWP data and products from other centers against Belhydromet’s own observations; enhancing the use of remote-sensing products for hydrological services; initiating long-range forecasting and hydrological forecasting; revising seasonal river forecast methods, improving radiation monitoring and forecasting, and improving forest fire forecasting services. The list below offers a comprehensive range of activities to develop/enhance various functions under this scenario. The implementation of this scenario should be completed within at least 2 years.

Strengthening institutional capacity through:

1) Developing a CONOPS to guide the design of activities for different systems under this scenario; and

2) Developing a Business Plan to capitalize on the investment in Belhydromet’s modernization to provide sustained, high-quality, value-for-money government and commercial services throughout Belarus.

Strengthening service delivery by:

1) Developing and implementing a national Strategy for Service Delivery (SSD) based on the WMO Strategy for Service Delivery and its Implementation Plan. The WMO Strategy defines the various stages and elements of a continued process for developing and delivering services and guides NMHSs through the steps in assessing and improving their current service delivery. For Belhydromet, the initial step includes assessing its current level of service delivery using the Service Delivery Progress Model of the WMO Strategy document (Annex 2), followed by close consultation with Belhydromet’s key stakeholders (e.g., agriculture, forestry, transport, water resources, and disaster risk management) to gather their requirements. The next stages will involve designing the required services and delivering them to the user sectors;

2) Establishing closer collaboration with disaster risk management, such as establishing/strengthening Standard Operating Procedures (SOPs) and joint exercises, providing mirror computers to display weather information as seen by the forecasters and attaching a meteorologist to the disaster risk management office during severe weather events for improved EWS;

3) Applying the SSD and CONOPS for developing initial SOPs for the operation of the critical existing and new equipment, for the review and needed improvements in the production of forecasts and for meteorological and hydrological service delivery;

4) Establishing a hydromet user group to develop and enhance different services, to improve coordination among service providers and to improve the interface with and response to users;

5) Initiating in collaboration with key government stakeholders and agencies the provision of improved information and services; and

6) Increasing dissemination channels for enhanced provision of PWS and hydrological and radiation information services.

Improvement of short- and medium-range weather forecasting through:

1) Training to build on current capabilities of forecasters to enhance the understanding and full use of NWP/EPS data and products for short- to medium-range forecasts from leading global centers (e.g., ECMWF); training on the operation and maintenance of the forecasting systems, including
the use of any new techniques taught during the training;

2) Initiating an objective verification of NWP data and products from other centers against Belhydromet's own observations;

3) Introduction of improved techniques to verify public forecasts;

4) Initial trainings to introduce the ensemble prediction system (EPS) and the concept of probabilistic forecasting and its benefits;

5) Initial and follow-up training to introduce the concept and basic application of impact-based forecasting through interpreting forecasts and adding other information to demonstrate the impact of weather and associated hazards;

6) Purchase of a license for access to graphical products from a global center (e.g., ECMWF);

7) Best possible utilization of all relevant data for optimum forecast production; and

8) Upgrade of the tools for visualization and manipulation of data and products by forecasters.

**Improvement of long-range weather forecasting through:**

1) Training to build up knowledge and understanding of concepts related to long-range forecasting;

2) Access to the use of products from Global Producing Centers for long-range forecasts;

3) Tailoring long-range forecasts for specific applications and users; and

4) Introduction to concepts of climate models and downscaling.

**Improvements in ICT:**

1) Implement as a priority a complete operations environment, including observations, models, forecasts and products in an integrated data center; and

2) Speed up the automation of data collection and storage systems and convert all data into the standard format required for the functioning of an integrated ICT system, allowing the retrieval of data in the format required by staff and thus covering the needs of the meteorological and hydrological divisions as well as the requirements for improved data exchange between them.

**Improvements of the hydrological services:**

1) Improving the automatic flow of quantitative hydrological data by modernizing gauges and switching from mechanical to electronic recording systems, equipped with digital data storage and data transfer units as parts of a joint data management system, including quality-controlled historical data;

2) Validating hydrological tools and methods which date back to the Soviet era to specify the needs for new methodologies to provide updated hydrological information for the following main activities of water management:

   - Knowledge of water resources;
   - Statistical characteristics of hydrological time series;
   - Analyses of the current hydrological situation and forecasts of the hydrological conditions in the near future;
   - Forecasts and real-time data of hydrological extremes (i.e., floods and droughts);
   - Impact assessments of water management activities and land-use changes on hydrological conditions; and
   - Assessments of hydrological impacts of climate change, based on monitoring and simulations.

3) Strengthening the application of GIS in hydrology through a common database using interoperable software solutions with users of hydrological information and data providers. Such systems should provide access to national and global information systems, for example, to use remote-sensing data;
4) Improving hydrological flood forecasts by developing human and technical capacities to set up conceptual hydrological models. Special emphasis should be given to snowmelt modeling, which requires close cooperation with meteorological forecasters;

5) Developing human and technical capacities to implement GIS-based hydraulic models (in one-dimension and pseudo two-dimension) in close cooperation with CRICUWR; and

6) Implementing impact-based forecasting by specifying critical water levels at points of interests together with local authorities responsible for EWS.

**Improvement of radiation monitoring and forecasts through:**

1) Establishing new contacts at the WMO Emergency Response Activity Program and automating the request, receipt and dissemination of dispersion model products and radiation information services; and

2) Training forecasters to provide additional information to decision-makers on the reliability of the radiation forecasts by means of expert assessment and the use of products such as the EPS.

**Improvements of the Forest Fire Forecasting services:**

The improvements of the forest fire services need to be addressed in the context of the capacity to discriminate actual extreme fire weather conditions. The Fire Danger Index operationally used for providing the fire danger bulletin considers the number of days since the last rainfall (as the main driver of forest fires). It does not consider the effect of wind and relative humidity on fuel moisture content and potential rate of spread. The main limit of the current Fire Danger Index is that after days with no rain and increasing temperatures most of the country is classified in high danger, imposing potential limitations on access to forest areas and requiring large resources for monitoring. The fire danger decreases only in case of rain. This means that in case of high danger, the system is not able to identify anomalies in dead fire fuel moisture content and in fire ignition probability or in the increase in the potential rate of spread because of strong dry winds.

For this reason, the current Fire Danger Index needs to be validated considering the forest fires that have occurred in the last decades. This will help build the capacity to identify high-danger conditions. The validation phase should consider other fire danger indices, at least the Canadian Fire Weather Index which is available on the European Forest Fire Information System (EFFIS) platform. In this phase, collaboration with universities and/or other research institutes is recommended. Belarus can join the EFFIS network at any time, simply by requesting membership and informing who will attend the meetings of the Expert Group on Forest Fires. A training session can be organized through Skype or Webex or directly in the Joint Research Center of the European Commission.

Collaboration between Belhydromet and the Ministry of Forestry needs to be improved. Installing meteorological stations on existing, strategically located lookout towers is one possibility. This would allow the Ministry of Forestry to provide meteorological data, including wind speed and direction, to Belhydromet within the forests to augment the existing meteorological network; in return, Belhydromet could provide the Ministry of Forestry with more detailed fire danger indices.

Improving the capacity to identify high-danger conditions would better address monitoring and preparedness activities, thus save resources and improve the efficiency of fire prevention and fire attack.

Besides the improvements to the forest fire forecasting services, Belarus has great opportunities to be one of the best representative regions to study the impact of climate change on forest fire risk, including the impact of fires in contaminated areas. The main reasons can be summarized as follows:

1) The Belarusian forests are almost completely public property (Ministry of Forestry);

2) Of the total forest cover, 50.5 percent pine which is susceptible to fire and 25 percent is impacted by Chernobyl fallout which exacerbates fire susceptibility;
3) There is limited interface between wilderness and urban areas;
4) The country has a simple topography; and
5) Climate conditions can be monitored for study purposes.

In principle, Belarus is in a unique position to define a plan of experimental fire risk prevention and reduction strategies, to monitor the effect of such strategies and to select the most appropriate ones for other regions. In addition, monitoring by unmanned aerial vehicles of controlled fires in pine forests can be useful for reducing fire risk, training fire fighters and improving operational forest fire propagation models. The improvement of the monitoring network could be sustained and promoted through these activities.

The most urgent among the comprehensive list above have been selected for the implementation of this scenario, the cost of which is described below.

**For improved institutional capacity an estimated total funding of US$44,000 is needed as follows:**

1) Advisory services, including training to assist Belhydromet in developing a CONOPS for Scenario 1 to guide design of activities (1 month, US$22,000); and
2) Advisory services, including training to assist Belhydromet in developing a business model (1 month, US$22,000).

**For improved meteorological services an estimated total funding of US$316,000 is needed as follows:**

1) Advisory services to assist Belhydromet in understanding and documenting stakeholders’ requirements (meetings, workshops and surveys); establishing a baseline for user satisfaction with the current Belhydromet services through conducting a user-based assessment; developing a national SSD and applying the CONOPS for Scenario 1 to guide design of activities (3 months, US$66,000);
2) Training and advisory services for assessing the forecasts production procedure, introducing EPS and probabilistic forecasting; providing forecaster training to understand and use available global and regional NWP data and products, and perform forecast verification (9 months over 2 years, US$198,000);
3) Training to Belhydromet forecasters and DRM on the principles and practices of impact-based forecast and warning services (8 weeks over 2 years, US$44,000); and
4) Purchase of graphical (not digital) products license from a global center (2 years, US$8,000).

**For improved hydrological services an estimated total funding of US$165,000 is needed as follows:**

1) Advisory services to assist the hydrological department of Belhydromet in understanding and documenting stakeholders’ requirements (meetings, workshops and surveys) and development of a national Strategy for Hydrological Service Delivery (SHSD) and CONOPS for Scenario 1 to guide design of activities (2 months, US$44,000);
2) Advisory services to develop a modernization strategy of the hydrometric network through the replacement of mechanical gauges with new technical equipment, including flow meters (2 months, US$44,000);
3) Development of human capacities of Belhydromet through training in statistical methods with the aim of making probabilistic assessments of spring flood conditions, based on time series analyses of hydrological and meteorological data (1 month, US$22,000);
4) Training in conceptual hydrological and hydraulic modeling using free licensed software to understand the options and limitations of models, the required database and the operational aspects of modeling (1 month, US$22,000);
5) Training in snow modeling and snowmelt forecasting (15 days, US$11,000); and
6) Advisory services to implement model-based forecasts in operational hydrological services by an integrated hydrological monitoring and forecasting system considering the existing and future
data availability and the need for additional hydrological information in co-operation with end-users (1 month, US$22,000).

**For improved ICT-related systems an estimated total funding of US$232,000 is needed as follows:**

1) Advisory services and training for increasing the dissemination channels for PWS and hydrological services, including implementation of Common Alerting Protocol (CAP) at Belhydromet and disaster management (1 month over 3 months, US$22,000);

2) Advisory services, including training to address the issues related to the functioning of an integrated ICT system, and developing SOPs for the main ICT operations (3 months, US$66,000);

3) Upgrade of the visualization system, including hardware, software, and training for the forecast office for integration of all meteorological observations and model data and related training (US$100,000); and

4) Advisory services to develop an integrated system for data transfer, quality control, data storage and management considering the needs of embedded hydrological models, including linkages with meteorological forecasts (hydrological component of the ICT) (2 months, US$44,000).

**For improved radiation monitoring and radiation forecast an estimated total funding of US$22,000 is needed as follows:**

1) Advisory services to optimize the preparation and dissemination of user-tailored radiation analysis and forecast products to authorities based on all available data, dispersion model output and meteorological expertise (2 weeks, US$11,000); and

2) Training for forecasters on the use of radiation forecast products and on the assessment of the reliability of radiation forecasts (2 weeks, US$11,000).

**For improved Forest Fire Forecasting service an estimated total funding of US$50,000 is needed as follows:**

1) Validation of the actual Fire Danger Index and adoption of new fire danger indices (US$50,000); and

2) Enhancement of training on EFFIS platform (depending how it is provided).

**9.2 SCENARIO 2: INTERMEDIATE MODERNIZATION**

This is the intermediate investment scenario between Scenarios 1 and 3. This scenario aims to achieve improvements in capabilities to provide weather, climate, hydrological and radiation-related information services to meet the needs of the most important public service users such as agriculture, forestry, transport, water resources, and disaster risk management. This scenario builds on the activities of Scenario 1 (which are not repeated here). It should be noted that if this scenario is chosen as a starting point, then the cost of investment for activities under Scenario 1 should be added to this scenario as initial priorities.

**Under this scenario the following potential set of activities may be undertaken:**

1) Revising and further developing a national Strategy for Service Delivery (SSD) already initiated;

2) Establishing closer collaboration with disaster risk management for improved EWS;

3) Establishing a hydromet user group and revising and further developing the CONOPS to guide the Scenario 2 activities;

4) Maximizing the utility of the meteorological observation network following the introduction of new equipment (such as weather radar) for application in, for example, hydrological forecasting;

5) Providing linkages between the observing systems (hydrological and meteorological), data management systems and modeling systems in a common format to avoid multiple ICT systems;

6) Enhancing training on the EPS and probabilistic forecasting;

7) Enhancing training on impact-based forecasting;
8) Initiating long-range forecasting and hydrological forecasting for different forecast periods;
9) Procuring computing and communication equipment for modeling and forecasting;
10) Maximizing the utility of hydrological network by obtaining quantitative hydrological data for water management and other key stakeholders;
11) Enhancing the use of remote-sensing products for hydrological services;
12) Operationalizing quantitative hydrological forecasts by establishing a hydrological forecasting center to apply numerical models for forecasts at hotspots;
13) Assessing the state of water resources in the country, including a database of water uses and their impacts on hydrological conditions;
14) Training on drought forecasting and linkages with seasonal meteorological forecasts;
15) Training to establish modern methods to regionalize flood statistical assessments, which are based either on rain events and hydrological models or statistical analyses of long observation series;
16) Training of stakeholders and end-users to build their understanding and capacity in using hydromet information; and
17) Strengthening monitoring and feedback systems.

The budget for this scenario should include the estimated cost of any new equipment, tools, instrumentation and software. The operations and maintenance (O&M) budget for this scenario (approximately 10 percent of the initial capital expenditure) should be used for, among others, spare parts, consumables, fuel, increased communication, power and other operating costs. It is expected that the implementation of this scenario should be completed within 4 years.

In addition to the survey of the observation and the ICT systems to specify the existing gaps, outdated and incompatible components, the rest of the technical infrastructure of Belhydromet should also be examined to introduce new technical equipment and methodologies. The most urgent among the comprehensive list above have been selected for the implementation of this scenario.

For improved meteorological services an estimated total funding of US$418,000 is needed as follows:

1) Advisory services for updating the CONOPS to guide design of activities under Scenario 2 (15 days, US$11,000);
2) Advisory services for further developing the forecaster environment using the visualization system (e.g., development of a dashboard for the forecaster workstation) and related training (2 months, US$44,000);
3) Advisory services, including training, for downscaling of climate models and initiating seasonal forecasts (1 month, US$22,000);
4) Advisory services, including training, for post-processing of NWP output (2 months, US$44,000);
5) Advisory services, including training, for advancing the implementation of the EPS, probabilistic forecasting and impact-based forecasting to an intermediate level, including on-the-job support (6 months over 1 year, US$132,000);
6) Advisory services, including training, for further engagement with users through strengthening the monitoring and feedback systems and tools (surveys), and enhanced training of stakeholders and end-users (1 month over 1 year, US$22,000);
7) Advisory services to assist Belhydromet to conduct workshops with DRM to define warning thresholds and update knowledge of stakeholder needs (15 days over 1 year, US$11,000);
8) Advisory services and training to assist Belhydromet to conduct workshops and to develop a prototype warning system with DRM based on the likelihood and severity of an impact, using common color coding for warning thresholds for all hazard impacts (3 months over 2 years,
9) Advisory services to assist Belhydromet to conduct workshops and to develop SOPs for all partners involved in the delivery of the impact-based forecast and warning services (3 months over 2 years, US$66,000).

For improved hydrological services a total of US$461,000 is needed as follows:

1) Provision and installation of automated gauges at selected stations with electronic data storage and two-way access to water-level data (regularly from the station to the hydrological department and on-demand) (US$120,000) and advisory services and training (2 weeks, US$11,000);

2) Implementation of hydraulic models for the Pripyat River in cooperation with CRICUWR, including installation of technical pre-conditions, training of users, automated flow of input data, and assessments of uncertainties (6 months, US$132,000);

3) Advisory services to ensure the linkage of real-time data, numerical weather predictions and climatological data with hydrological and hydraulic models in a central server and a tailor-made design of hydrological forecaster interfaces (2 months, US$44,000);

4) On-the-job training for advancing hydrological analyses at ungauged sites by several methods (2 months, US$44,000);

5) On-the-job training for impact-based drought forecasting (data analyses, modeling, and utilization of seasonal meteorological forecasts) (2 months, US$44,000); and

6) On-the-job training for hydroclimatological analyses under consideration of changing impacts of water management activities to determine possible instationarities and to improve seasonal runoff forecasts (3 months, US$66,000).

For improved radiation monitoring and radiation forecasting an estimated total funding of US$22,000 is needed as follows:

1) Training for dispersion modeling with FLEXPART using the METVIEW interface at ECMWF (1 month, US$22,000).

For improved forest fire forecasting service an estimated total funding of US$100,000 is needed as follows:

1) Expanding the observation network in forests by installing new meteorological stations on strategic lookout towers (US$50,000); and

2) Implementing real-time EWS based on the evaluation of fire danger premised on the meteorological observation network; and piloting fire danger warning signs in strategic points to inform the public and stakeholders (US$50,000).

For improved ICT-related systems an estimated total funding of US$1,146,000 is needed as follows:

1) Design, procure and install a centralized data center to integrate and automate the flow of meteorological and hydrological data, and to store and visualize data, including advisory services and training (6 months, US$600,000); and

2) Become a member of ECMWF including payment of the annual fee for 5 years (US$564,000 comprising an entry fee of US$264,000 and an annual fee of US$60,000 for 5 years).

9.3 SCENARIO 3: ADVANCED MODERNIZATION

This scenario presents the investment needed to bring Belhydromet up to the current level of a well-functioning developing country’s capabilities for providing data, forecasts and warning services to meet various user needs, in addition to meeting the obligations for public service provision. This scenario is built on Scenarios 1 and 2. Thus, whether Scenarios 1, 2, and 3 are built in a stepwise manner or all are rolled into one scenario needs due consideration. This is the reason for including the full explanations for the three modernization components in sections 9.3.1–9.3.3. Under this scenario, most of the effort
is expended for the full utilization of all the systems that are in place. It is hence expected to result in a substantial increase in capabilities in forecasting, ICT and service delivery. The implementation of this scenario is expected to require up to 7 years.

9.3.1 Enhancement of the Belhydromet Service Delivery Process

Developing and implementing a national Strategy for Service Delivery, ensuring that users of meteorological, hydrological, forest-fire and radiation-related information and services are included in product planning and design from the outset and that the derived information and services respond to user needs. An action plan with well-defined milestones would then be created for responding to the unfulfilled user requirements. The establishment of a hydromet user group would be a useful mechanism for this purpose. The user group should be supported by:

- Establishing a coordination platform and communication channels between the service providers and users to support modernization, effectiveness and sustainability of the services;
- Supporting users to identify their respective data, product and service needs;
- Proposing improvements of exiting or development of new products and services to meet needs;
- Developing the capacity of users of products and services to maximize the benefits of data, products and services; and
- Supporting awareness and outreach programs targeted at decision-makers and sector users to highlight the benefits of the services.

Enhancement of Belhydromet’s service delivery process will focus on the improvement of public weather, climate, hydrological, agrometeorological and forest services as well as on the improvement of radiation information services. It will include among others and as required further enhancement and implementation of a national Strategy for Service Delivery as described above; development of new and improvement of an existing set of basic and specialized user-tailored products, including evaluation of forecast utility and user satisfaction; development and operationalization of Common Alerting Protocol (CAP) capability (if not implemented yet) to standardize the production and dissemination of warnings; improvement of dissemination mechanisms to communities; pilot testing and operationalization of impact-based forecast and warning services in selected vulnerable districts/cities; strengthening end-to-end EWS, including a regular post-event review process; development of an Agriculture and Climate Advisory Service (ACAS) portal, including provision of hardware and software; and completion of a digital library of climate-relevant information. In addition, based on an evaluation of Belhydromet, opportunities to initiate public–private engagement strategies will be explored to introduce new sustainable business models, such as fee-based service provision, and outsourcing of modeling activities, such as updating models.

The estimated budget under this scenario will cover the cost of any new equipment, tools, vehicles, instrumentation, software and facilities. As in the intermediate modernization option, the O&M budget under this scenario should be used for a proper life-cycle management of observation infrastructure and facilities which in this scenario will also require greater staff support. This includes the supply of spare parts, consumables and fuel; covering the increased communication, power and other operating costs; and quality control/quality assurance procedures.

9.3.2 Institutional Strengthening and Capacity Building

Under this scenario, it is crucial to have the key national, provincial and local government agencies to work in close cooperation if forecasting and warning services are to be fully effective. The inter-departmental relations also need to be strengthened through regular contacts and communication channels. Roles and responsibilities of each agency must be sufficiently well-defined to avoid ambiguities, especially during severe/hazardous weather-related events. Memoranda of Understanding (MoU) among service providers and key stakeholders need to be established (where not existing). Standard Operating Procedures (SOPs)
will enable Belhydromet to codify how alerts, warnings and other operational products are issued. They also enable stakeholders to define their responses to the various levels of alerts and warnings improving the response to meteorological and hydrological hazards. SOPs should be constructed to align with WMO guidelines and global good practices.

Institutional Strengthening and Capacity Building will aim to improve the performance of Belhydromet in line with international best practices through: development of a new concept of operations (CONOPS) aligned with this scenario; improvement of a legal framework for Belhydromet as needed, including human resources planning and management; evaluation of Belhydromet opportunities to develop a new business strategy for more sustainable operations; development of technical capacity and education through a professional training plan for Belhydromet to build/enhance the required skills to cope with innovations, modernization and sustainability of hydromet enhanced systems, and training of stakeholders; public education and outreach; publication of bulletins and annual reports, working with schools; and cooperation with universities and research institutes.

One example of institutional strengthening through the regulatory framework would be establishing a mandate for providing hydrological planning tools. The operation of the hydrological network and the description of the current hydrological conditions and short or longer-term forecasts are an important activity of Belhydromet. To transform the hydrological data into information, new hydrological planning tools are needed. For this purpose, Belhydromet responsibilities for country-wide assessments of hydrological conditions in the form of water balances, hydrological data for flood risk management, drought forecasts and warnings, and other derived information have to be specified as a priority.

9.3.3 Modernization of Observation Infrastructure, Data Management Systems and Forecasting

Modernization of the Observation Infrastructure, Data Management Systems and Forecasting is a substantial undertaking. The road map considers the need for a modernized data processing system, including communication and computer equipment for storage, archiving, processing and visualization for weather, climate and hydrological and radiation data (servers and workstations); data management systems for weather, climate, hydrological and radiation data (servers, software, web access and social media). Meteorological and hydrological modernization, including the required training and capacity building, may include use by Belhydromet of internationally available products where possible such as satellite products, numerical weather prediction/ensemble prediction systems (NWP/EPS) data and products and required software for data handling (i.e., license); flood forecasts from the Global Flood Awareness System (GloFAS) operated by the ECMWF; equipment for weather forecasting, including forecaster workstation software products and implementation of real-time forecast process monitoring, quality control of observations; introducing nowcasting using radar data; seasonal forecasts based on remote-sensing data and snow modeling, including servers, licenses for software, training, quality management and dissemination of products; flash flood warning and alert systems, including technical facilities for collecting data from new sensors; operational water balances for the main river basins; and any refurbishment of Belhydromet facilities and offices that may be required. It should be noted that this list is neither exhaustive, nor mandatory and is meant mostly to provide guidance and reflection on what may be needed in Belarus for modernizing the infrastructure and technologies with the ultimate goal of improving hydromet service provision to the population of Belarus.

This scenario includes the expansion of current technologies, including observation, forecasting, ICT, service delivery and the associated training. It is normal practice that the O&M costs range between 10 and 15 percent of the initial capital expenditure.
For improved hydromet services, including ICT-related systems, an estimated total funding of US$2,964,000 is needed as follows:

1) Building on the ICT design (centralized data center), procurement and installation of the full set of the hardware and software required for a modern forecast and warning system, a service delivery platform and applications, including data management, dissemination and service delivery (US$1,300,000);

2) A moderate expansion of the observation network to represent the “fit-for-purpose” coverage of the country which includes: Synoptic AWS; AWS Agrometeorological; AWS meteorological posts; automatic hydrological posts; ground-based, remote-sensing instrumentation, including implementation of procedures for data quality control and on-the-job training of staff in the use of the data and derived products (US$100,000);

3) Revision and updating of CONOPS, development of additional SOPs, to include the requirement of both Belhydromet and disaster risk management; operationalization of impact-based forecast and warning services (5 months, US$110,000);

4) On-the-job training of staff to support the implementation and application of upgrades for meteorological components, including user engagement and feedback (6 months over 7 years, US$132,000);

5) On-the-job training of staff to support the implementation of country-wide NWP downscaling and hydrological models with different components according to climatic conditions, upgrading procedures of models, their calibration and validation (9 months over 7 years, US$198,000);

6) Establishing a hydrological forecasting center which ensures hydrological forecasting, reporting and dissemination of forecasts to stakeholders and the public. This would include provision of computers, automated gauges, data storage and transfer, models and required software (US$900,000);

7) Adoption of a new platform for wildfire danger assessment and management, including automated services for fire danger bulletin delivery; and implementation and training activities (US$400,000);

and

8) On-the-job training of staff to support the implementation and upgrading of modeling and information tools to analyze and forecast the dispersion of radioactive material in air (e.g., implementation of FLEXPART at Belhydromet, operational model set-up with ECMWF model input), including user engagement and feedback (1 month, US$22,000).

10. SOCIOECONOMIC BENEFITS OF IMPROVED HYDROMET SERVICES AND EARLY WARNING SYSTEMS

According to the World Bank assessment, improved quality and timeliness of hydromet forecasts would reduce the impacts of hazardous hydromet phenomena and unfavorable weather conditions in Belarus by about 12 percent for direct economic losses (stock losses) and 10 percent for indirect losses (productivity disruptions). The same assessment indicates that a significant investment to modernize hydromet services would deliver a benefit/cost ratio in the range of at least 5/1. This estimate did not account for benefits associated with better economic performance at the household level and should therefore be considered as conservative.
11. CONCLUSIONS AND A WAY FORWARD

The strategic steps needed to modernize hydromet products and services in Belarus, including radiation information and forest fire services, are primarily driven by the needs of the user community. Discussions with the management and technical staff of Belhydromet and key stakeholders dealing with the most pressing issues in the country, such as emergency management and response, agriculture, forestry, transport, water resources, and disaster risk management have revealed a need for strengthening the provision of meteorological and hydrological information. Belhydromet should bolster its capabilities in accessing up to date technologies and tools for the production of forecasts and using best practices and standards in delivering services. Addressing these issues will require a joint approach involving stakeholders and ensuring that full consideration is given to include all meteorological and hydrological elements of a modern, well-planned organization with a clear strategy and goals and means of achieving those goals.

To respond to the needs of stakeholders for optimum services, Belhydromet should reach the level of a modern middle-income country NMHS and enhance its capabilities for EWS, use of NWP, nowcasting, agrometeorological forecasting, seasonal outlooks and climate projections, and flood forecasting based on hydrological models.

This implies building a robust data management system; a forecasting system with capabilities to allow forecast production on all time scales from very-short-range to short-range to long-range and seasonal forecasts, and impact-based forecasts; hydrological services and flood forecasting; improved radiation forecasting capabilities; improved forest fire services; an ICT system capable of transmitting, processing and storing data from all the different components of the observing network in a harmonized and efficient manner; and an effective service delivery system.

There is no obvious indication at the present of the existence of a private sector interested in collaboration with Belhydromet in the production and delivery of services.

Meteorological and hydrological activities across different institutions in Belarus need to be coordinated. There is a potential mutual benefit in closer collaboration with academic community.

Three scenarios to enhance the capabilities of Belhydromet have been presented. The level of complexity and required resources is different in each scenario.

**Scenario 1: Technical Assistance.** Provision of technical assistance for high priority activities to improve basic public services by introducing affordable new technologies into and training the staff of Belhydromet for heightened capacities and capabilities (immediate to short term: 2 years). The investment cost of this scenario is estimated at US$829,000.

**Scenario 2: Intermediate Modernization.** Investment to achieve a modest improvement in the capabilities to provide weather, hydrological and radiation information services to meet the public service needs of the most important user communities and stakeholders, for example, agriculture, forestry, transport, water resources, and disaster risk management (medium term: 4 years). The investment cost of this scenario is estimated at US$2,147,000.

**Scenario 3: Advanced.** Investment to bring the capabilities for providing fit-for-purpose data, forecasts and warning services for the safety of the public and support to develop the most important socioeconomic sectors (long term: 7 years). The investment cost of this scenario is estimated to be US$2,964,000.

The cost/benefit analysis indicates that all three proposed options are economically efficient, meaning they will produce socioeconomic benefits greater than their costs. In all cases, the generated benefits are significantly greater than the costs.
It should be noted that the implementation of each of the options offered in the three scenarios for the modernization of the Belhydromet observation, ICT and forecasting infrastructure and improvement of service delivery will result in an increase in the number of staff and the accompanying staff costs as well as a need to allocate additional financial resources to operate the modernized Belhydromet systems. Thus, an overall increase in the budget of Belhydromet by the end of the 7-year period (the most advanced scenario) will be inevitable.

Developing a Concept of Operation is essential for the detailed planning and implementation of each scenario.

/ANNEX 1. REQUIRED TRAINING AREAS

The following list is a guide and indicative of areas for which training is generally required by NMHSs. The precise details of training for Belhydromet will be defined at the time of designing implementation of the different scenarios presented in this road map. Other areas may be added to this list as needed.

- Project management;
- Business model planning;
- Change Management/Leadership training;
- Technical skills to support meteorological and hydrological observing networks;
- Instruments and sensors maintenance;
- Enhanced skills in weather forecasting using numerical prediction models (including ensemble prediction systems) on all time scales from very short- to long-range forecasting;
- Enhanced skills in weather monitoring based on in-situ and remote-sensing observational data; and in nowcasting by blending these data with NWP outputs to extrapolate to the immediate future;
- Enhanced skills to operate a flood forecasting center;
- Enhanced skills in flood forecasting using numerical models;
- Enhanced skills to operate a forest fire forecasting center;
- Enhanced skills in deterministic seasonal forecasting using snow models;
- Understanding the end-to-end early warning production and delivery;
- Impact-based forecasting and warning services, including for hazards such as floods, landslides, avalanches and droughts;
- Verification and statistics methods for model evaluation;
- Database management;
- IT management skills;
- Skills in the delivery of public weather and hydrological services, including user/stakeholder consultation, communication, negotiation and feedback gathering;
- Enhanced skill in climate prediction using numerical methods; and
- Public education and outreach.
ANNEX 2. SERVICE DELIVERY PROGRESS MODEL

The Service Delivery Progress Model is adapted from the WMO Strategy for Service Delivery and Its Implementation Plan (WMO 2014). The model can be used as a tool for assessing an NMHS’s level of development and for creating an action plan to improve service delivery. Full details can be found in http://www.wmo.int/pages/prog/amp/pwsp/documents/WMO-SSD-1129_en.pdf.

<table>
<thead>
<tr>
<th>Strategy Element 1: Evaluate User Needs and Decisions</th>
</tr>
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<tbody>
<tr>
<td><strong>Undeveloped</strong></td>
</tr>
<tr>
<td>The users and their requirements for products or services are not known.</td>
</tr>
<tr>
<td><strong>Development, Initiated</strong></td>
</tr>
<tr>
<td>Users are known, but no process for user engagement exists. User requirements for service delivery are not well defined.</td>
</tr>
<tr>
<td><strong>Development in Progress</strong></td>
</tr>
<tr>
<td>Users are able to contact the NMHS and their feedback is recorded. There are some formal processes for integrating the feedback received into the development of services. User requirements are defined with limited documentation.</td>
</tr>
<tr>
<td><strong>Developed</strong></td>
</tr>
<tr>
<td>NMHS seeks input on an ad hoc basis from users to facilitate the development of services. Requirements are defined in documents agreed upon with the user but are not routinely updated.</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
</tr>
<tr>
<td>An ongoing dialogue is maintained with users regarding their needs and the services they receive. Requirements are defined in documents agreed upon with the user and routinely updated using feedback from users.</td>
</tr>
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<table>
<thead>
<tr>
<th>Strategy Element 2: Link service development and delivery to user needs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Undeveloped</strong></td>
</tr>
<tr>
<td>No concept of service exists; products are simply issued.</td>
</tr>
<tr>
<td><strong>Development, Initiated</strong></td>
</tr>
<tr>
<td>Services do not adapt to changing user needs and new technology. Products are documented with limited descriptive information.</td>
</tr>
<tr>
<td><strong>Development in Progress</strong></td>
</tr>
<tr>
<td>Services are developed and changed as technology allows, but engagement with users is ad hoc. Products and services are documented, and the information is used to inform management of changes.</td>
</tr>
<tr>
<td><strong>Developed</strong></td>
</tr>
<tr>
<td>User feedback is used to inform management of changes and development of services. Products and services are consistently documented. Service-level agreements (SLAs) are defined.</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
</tr>
<tr>
<td>Users are consulted to facilitate development of products and services. The service defined in the SLA is agreed upon with the user based on user consultation.</td>
</tr>
<tr>
<td>Strategy Element 3: Evaluate and monitor service performance and outcomes</td>
</tr>
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<tr>
<td>No measures are in place for assessing performance, in terms of either accuracy or service delivery.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategy Element 4: Sustain improved service delivery</th>
<th>Undeveloped</th>
<th>Development, Initiated</th>
<th>Development in Progress</th>
<th>Developed</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>No concept exists of service delivery principles.</td>
<td>The concept of service delivery has been introduced and an assessment of current status has been undertaken.</td>
<td>An action plan has been created to improve the current level of service delivery, and resources have been identified to implement it.</td>
<td>The action plan is being implemented to improve service delivery, and the outcomes are being monitored.</td>
<td>The status of service delivery is reviewed on a regular basis. The action plan evolves in response to the outcome of the reviews.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategy Element 5: Develop skills needed to sustain service delivery</th>
<th>Undeveloped</th>
<th>Development, Initiated</th>
<th>Development in Progress</th>
<th>Developed</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>No concept or communication of service delivery principles exists.</td>
<td>No formal training in service delivery is provided, though service delivery principles are informally communicated.</td>
<td>Most staff of the NMHS are aware of the importance of service delivery. Some formal training is provided.</td>
<td>All members of staff are fully aware of the importance of service delivery. Formal training is provided. There is an ad hoc process for staff to offer ideas for improvements to service delivery.</td>
<td>There is a culture of providing best possible service delivery. Innovative ideas are routinely integrated into the continual service improvement process.</td>
<td></td>
</tr>
</tbody>
</table>

| Strategy Element 6: Share best practices and knowledge | | | | NMHSs are encouraged to share best practices in service delivery through formal training, twinning, mentoring and other methods. | |
## ANNEX 3. OBSERVATION AND TELECOMMUNICATION PROGRESS MODEL

<table>
<thead>
<tr>
<th>Observations and Telecommunications</th>
<th>Undeveloped</th>
<th>Development, Initiated</th>
<th>Development in Progress</th>
<th>Developed</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMHS has very few manual synoptic stations and hydrological stations. It does not share station data on the Global Telecommunication System (GTS).</td>
<td>NMHS has the capacity to support a synoptic meteorological network and hydrological network; it shares these data on the GTS; and it has sufficient staff to maintain its observing networks.</td>
<td>Automation of observing network with quality control is routine. NMHS accesses satellite data with (e.g.) the capacity to derive precipitation estimates. The observing network is sustainable with sufficient budget for operations and maintenance. The vertical structure of the atmosphere may be routinely measured.</td>
<td>Observations extend to smaller scales and include ground-based remote sensing techniques, such as radar. The NMHS may be able to take and integrate observations from other parties. It may access observations by outsourcing its observing requirements.</td>
<td>NMHS conducts research, introducing new observational technologies and techniques as needed. The observing network is comprehensive and sufficient to meet main user needs, incorporates external observations from other suppliers, for example, agro-meteorological network operated by a Ministry of Agriculture or hydrological network operated by a Ministry of Energy or Water Resources.</td>
<td></td>
</tr>
</tbody>
</table>
## ANNEX 4. FORECASTING PROGRESS MODEL

<table>
<thead>
<tr>
<th>Undeveloped</th>
<th>Development, Initiated</th>
<th>Development in Progress</th>
<th>Developed</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMHS provides up to two-days deterministic forecast based on graphical forecast products retrieved from different web sources. There is no verification of forecasts. The NMHS does not operate forecasting on a 24-hour, seven-days-a-week basis; and warnings are not issued.</td>
<td>NMHS can provide at least 3-days deterministic forecasts based on access to global and regional NWP data and products available on the GTS and/or graphical products available from WMO RSMCs; monitors the current weather and hydrological system; has basic data-processing and archiving systems; carries out subjective forecast verification. There is no research and development, and the quality management system is rudimentary. The NMHS may not operate forecasting on a 24-hour, seven-days-a-week basis. Warnings are limited.</td>
<td>The NMHs can provide 0 to 5 days forecasts using global and regional deterministic NWP and EPS data and products from GPCs; issues nowcasts and very-short-range forecasts up to 12 hours based on extrapolating NWP and blending remote-sensing observations.; is able to monitor major rivers and generate short-term flow and flood forecasts; has protocols for emergencies, back-up of data and products and offsite storage facilities; carries out verification and post-processing; has some R&amp;D and a QMS. The NMHS operates forecasting on a 24-hour, seven-days-a-week basis.</td>
<td>LAM systems are available locally or through regional centers. Using local data assimilation, high-resolution short-time scale forecasts are produced with emphasis on 0–6 hours for extreme events. The forecasting system extends from 0 to at least 7 days based on a combination of global, regional and national deterministic NWP and EPS data and products. The NMHS has the capacity to manipulate digital data and to tailor forecasts to specific users and operates a multi-hazard warning system; generates seasonal stream flow outlooks and specialized hydrology products; has full R&amp;D capability. There are well-established relationships with partner agencies.</td>
<td>NMHS has an extensive research program and introduces new forecasting technologies and techniques; has the capacity to support requirements of other NMHSs, is able to run global, regional and national NWP and EPS systems. Forecasts of weather and hydrological impacts on specific sectors are routine and generally developed with users of these forecasts. The NMHS has a well-developed education and training unit.</td>
</tr>
<tr>
<td>Climate Services</td>
<td>Undeveloped</td>
<td>Development, Initiated</td>
<td>Development in Progress</td>
<td>Developed</td>
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<td>NMHS may operate a limited national climate observing system; collects data in paper form; retrieves climate data from different sources to generate national climate products; participates in regional climate outlooks; and has very limited or no interaction with users. Typically, NMHSs in this category do not have staff dedicated to carry out climate services.</td>
<td>NMHS designs, operates, and maintains national climate observing systems; manages data, including QA/QC; develops and maintains data archives; monitors climate; oversees climate standards; performs climate diagnostics, climate analysis, and climate assessment; disseminates climate products; participates in regional climate outlooks; interacts with users; and performs the functions of national climate centers providing basic climate services. Staff are proficient in climate statistics, homogeneity testing techniques, and quality assurance techniques.</td>
<td>NMHS has the capacity to develop and/or provide monthly and longer climate predictions, including seasonal climate outlooks, both statistical and model-based; is able to conduct or participate in regional and national climate outlook forums; interacts with users in various sectors; adds value from national perspectives on the products received from Regional Climate Centers and in some cases Global Producing Centers for long-range forecasts; conducts climate watch programs; and disseminates early warnings. Staff are proficient in developing and interpreting climate prediction products and in assisting users in the uptake of these products.</td>
<td>NMHS generates subseasonal to seasonal forecast products, develops specialized climate products; downscale long-term climate projections as well as interprets annual to decadal climate predictions; covers all the elements of climate risk management (risk identification; risk assessment, planning, and prevention; services for response and recovery from hazards; information relevant to climate variability and change; and information and advice related to adaptation); builds societal awareness of climate change issues and provides information relevant to policy development and a national action plan. Staff have knowledge of climate modeling and methods for downscaling/calibration, risk and risk management, and financial tools for risk transfer.</td>
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</table>
# ANNEX 6. HYDROLOGICAL SERVICE PROGRESS MODEL

<table>
<thead>
<tr>
<th>Hydrological Services</th>
<th>Undeveloped</th>
<th>Development, Initiated</th>
<th>Development in Progress</th>
<th>Developed</th>
<th>Advanced</th>
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<tbody>
<tr>
<td></td>
<td>The NMHS may operate and maintain a very small hydrological observation network; collect data in paper format; and have very limited or no interaction with users. Typically, staff of NMHSs in this category are not trained in hydrology.</td>
<td>Functions of NMHS may include operation and maintenance of a small hydrological observation network; hydrological data management, with basic hydrological data processing, archiving, and communication system; little or no backup/off-site storage; and some interaction with users of hydrology data and products. There is no research and development, and a rudimentary quality management system. There are no relationships with partner agencies.</td>
<td>The NMHS is able to operate and maintain a hydrological observational network to monitor major rivers, and take and integrate some hydrological observations from other parties. The NMHS operates an interoperable hydrological data management system and has well-established protocols for emergencies, backup of hydrological data, and minimum off-site facilities. The NMHS carries out water-level and flow monitoring and is able to generate short-term flow forecasts (low flows), flood forecasting, and hydrological data products for design and operation of water supply structures. The NMHS is also able to generate seasonal streamflow outlooks and specialized hydrology products. There is a research and development unit and a quality management system. There are some relationships with partner agencies.</td>
<td>The NMHS operates and maintains a comprehensive hydrological observational network to monitor major and some smaller rivers, and takes and integrates most of the hydrological observations from other parties. The NMHS operates a well-developed interoperable hydrological data management system and has well-established protocols for emergencies, backup of hydrological data, and off-site facilities. The NMHS carries out water-level and flow monitoring, and is able to generate short-term flow forecasts (low flows), flood forecasting, and hydrological data products for design and operation of water supply structures. The NMHS has the ability to generate customized hydrological products, and to develop hydrological application tools.</td>
<td>In addition to the foregoing capabilities, the NMHS has an extensive research and development program; and strong relationships with partner agencies, taking a leading role in advice and decision support. NMHS has the ability to generate customized hydrological products, and to develop hydrological application tools.</td>
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</tbody>
</table>
REFERENCES


