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Research paper

The necessity of water resources inventory in Vietnam

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Abstract: Water resources inventory has become one of the important issues in many countries including Vietnam in order to build a database on the quantity of water sources, of water amount, water quality, current status of exploitation and polluted discharge into the water sources, economic value of water, so as to serve national water resource reports and information needs on water resources for socio-economic activities, national defense, security, science, education, training and other needs, etc., and serve as a basis for formulating and adjusting master plans and plans on water resources, as a basis for adjusting policies and laws on water resources. Till now, a number of countries have carried out activities for water resources inventory, but the inventory of water resources in Vietnam has not been officially implemented due to lacks of scientific basis in developing the inventory indicators and limitation of other resources. This article presents the contents related to water resource inventory in some countries and the current status of national water resource inventory activities in order to provide a system inventory criteria and methodology to be used in the inventory of water resources in future development.

Keywords: Water resources; Water resources statistics; Water resources inventory; Sets of inventory indices; Water planning.

1. Introduction

Over the past few decades, the inventory of water resources has become one of the important issues in many countries around the world, because it is the basis for proposing and building water resource planning, socio-economic activities, national defense and security. A series of inventory criteria on the quantity and quality of water resources, exploitation and use of water resources as well as statistical indicators to assess the sustainability of water resource have been developed. According to the availability of documents and the needs for information provision, the system of statistical indicators, methods of calculation, synthesis and inventory, statistics of water resources in research as well as in international organizations and countries are different. The statistics of international organizations often focus on basic indicators of water resource including the total amount of water inside and outside the country, the total amount of rainwater and annual evapotranspiration in countries [1]. The Food and Agriculture Organization (FAO) has issued a guidance on statistics, inventory and audit of water resources [2]. This is a comprehensive document that introduces the steps, methods and tools used in water balance analysis, providing information and quantification of flows and the distribution of water reserves over space and time. Four groups of indicators are related to statistics, inventory and assessment of the water sector, including the group of characteristics of water resources, the process of and use, the efficiency of water exploitation and water policies [3]. The United Nations

Statistic Division has also developed a technical report [4] to update and strengthen its water resource information systems for integrated management of water resources and introduce selected criteria for national measurements, including indicators related to water storage capacity; indicators on the potential of water sources, indicators on water exchange between surface water and ground water, surface water and surface water, groundwater and groundwater; indicators on water exploitation; indicators on water sources between economic fields; and indicators of water return.

In the US, the statistics of the physical characteristics of a river basin, its area, the proportion of each type of land, the type of landuse, the area and the ratio of the reservoir area; surface water flows, underground flows, targets on exploitation and use of water, indicators on flow quality, and environmental quality have been implemented [5], while in Australia, water surface is inventoried according to the average annual water volume, water distribution, average salinity, average current flow, scientific and technical level [6]. The countries in West Asia have based their inventory on factors: river basin characteristics, rainfall changes, annual fluctuations and trends in surface water sources, flow regimes, and water reserves on basins and in dams, water quality and environmental impacts, linkage of groundwater with surface water, water management in countries in the region [7]. In China, water resource statistics have also been carried out. The indicators of water resource inventory include: quantity of water, movement, quantity of water supplied, used, drained and discharged, exploitation and use of water resources, quality of water resources, natural disaster situation. It can be seen that international organizations (FAO), developed countries (the UK, USA, Australia, etc.) have all made statistics and provided information on the country's water resources for scientific research and socio-economic development. The information includes runoff, precipitation, monthly/ yearly evaporation, changes in groundwater and surface runoff during the year, floods, droughts, temperature, and annual precipitation. Most of them are published on the websites of professional organizations and are not restricted to different users. However, statistical and inventory information on water resources is quite limited. Particularly, there is very little information about research, inventory methods or indicators used for water resource inventory.

In Vietnam, water resources are considered as a kind of public property, possessed by the people, and managed by the Government as the only management unit [1]. Therefore, water resources are managed, exploited, protected, and fully assessed in terms of quantity and use value. According to the Article 38 of the Law on Management and Use of Public Property [8]: "Public property must be assessed timely and adequately in terms of the values according to the the law on statistics, accounting and related laws. State agencies assigned to manage and use public assets are responsible for inventorying assets at the end of the annual accounting period and making inventories according to the Prime Minister's decision on inventory and re-evaluation of public assets". Another study [9] has built a system of statistical indicators of water resources, which includes 06 statistical indicators of rain water resources, 11 statistical indicators of surface water resources, 14 statistical indicators of groundwater, 07 statistical indicators of water exploitation and use; and 04 groups of statistical indicators related to water quality and discharge into water sources. The document "Vietnam Water Resources and Management" [10] also provides information and knowledge on water resource management, and refers to the system of water resource management indicators such as socio-economic, water resource, ecological environment and synthetic criteria. Some indicators such as total surface runoff, total reservoir capacity and water stress index in 16 major river basins in our country were also evaluated [11].

2. Water inventory activities in Vietnam

The water resource inventory is guided in Article 7 of Decree 201/2013/ND-CP dated November 27, 2013 of the Government guidance on the the Law on Water Resources [12],

whereby the water resource statistics shall be made uniformly nationwide, once every five (05) years, in accordance with the national socio-economic development plan and the responsibility on the inventory of water resources [12]. At present, Vietnam has carried out several projects on measuring and drawing hydrogeological maps, maps of surface water and underground water at various scales and other water resources investigation and assessment projects. However, the projects on inventory of surface water and groundwater resources have not yet been implemented [1]. The Department of Water Resources Management (Ministry of Natural Resources and Environment) has proposed to expand the system of statistical indicators on groundwater resources to better serve the state management of water resources [13] with specific contents as shown in Table 1.

Table 1. Inventory of groundwater resources

No.	Inventory Indicator	Scope	Term	Methodology
1	**Group 1** Investigation, evaluation and development of maps for groundwater resource with the ratio is 1:200.000, in km^2, value 10^6đ	Nationwide	5 years	Cummulative, chart
2	Investigation, evaluation and development of maps for groundwater resource with the ratio of 1:100.000, in km^2, value 10^6đ	Nationwide, large river basin	5 years	Cummulative, chart
3	Investigation, evaluation and development of maps for groundwater resource with the ratio of 1:50.000, in km^2, value 10^6đ	Nationwide, river basin, locally	5 years	Cummulative, chart
4	Investigation, detail evaluation of groundwater resource, km^2, value 10^6đ	Nationwide, river basin, locally	5 years	Cummulative, chart
5	**Group 2** Underground natural dynamic reserve, static reserve, m^3/day	Nationwide, river basin, locally	5 years	Cummulative
6	Exploitable underground water reserves (potential reserves), m^3/day	Nationwide, river basin, locally	5 years	Cummulative
7	Exploited underground water reserves investigated and evaluated, m^3/day	Nationwide, river basin, locally	5 years	Cummulative
8	**Group 3**			
	Hydrogeological units	Area investigated	1 time	Chart
9	Physical data of hydrogeological units, thickness: m; permeability coefficient: m/ng; water release coefficient: %...	Area investigated	1 time	Arithmetic average, median
10	Characteristics of underground water quantity: pressure column, m; flow rate, l/s; flow rate, l/s.m; water depth, m…	Area investigated	1 time	Arithmetic average, median
11	Characteristics of underground water quality: TDS, g/l; primary ions; PH; EH, mv; Mn, Fe, As… annual and multi-year average, mg/l.	Area investigated	1 time	Arithmetic average, median
12	**Group 4** Report on the construction of monitoring networks, buildings and stations	Aquifers in regions (networks), the whole country	5 years	Cummulative
13	The quantitative dynamics include the maximum and minimum water level (or flow) of groundwater, the average daily, monthly, yearly and multi-year;	Monitoring works, aquifers in the region (network)/province	1 year and 5 years	Arithmetic average
	The minimum volume of monthly average water level (flow) with frequency of 85, 90 and 95%.	Typical monitoring works		Calculated variation

No.	Inventory Indicator	Scope	Term	Methodology
14	The qualitative dynamic features include the annual average data of water quality monitoring factors, the seasonal average of many years.	Monitoring works, aquifers in the region (network)/province	1 year and 5 years	Average value

According to studies and projects, those have been carried out at local and international levels, it can be seen that the methodology of statistics and inventory of water resources is diverse by province/city, river basin, and country, transnational and territorial areas. In the field of water resources, the subject of inventory is often separated from surface water and groundwater because the relevant characteristics of these two types of water resources are different. That leads to the inventory indicators of these two categories are also different [1].

In general, the study of water resources including rainwater, surface water and groundwater for the socio-economic development, basin management, and sustainable management of water resources has been conducted in Vietnam. In which, the assessment of natural resources and conditions in terms of hydrometeorology, demand for water use and the ability to exploit water supply, statistics of water resources and so on have been discussed and mentioned in many studies with varying degrees and details. These results make an important contribution to the management of water resources. However, the establishment of statistical and inventory methods, especially the development of criteria for the inventory of water resources, applied to river basins with different features are not covered in the reviewed studies. Therefore, the study and development of criteria for the inventory of water resources for different river basins to show the change of water resources compared to the base year is important for the state management of water resources. Accordingly, it is applied to a specific basin to clearly see the change of water resources in the context of rapid socio-economic development as well as the change in hydrological regime due to the impacts of upstream exploitation (most of the main river basins in Vietnam are transboundary basins), internal changes in the supply and demand for water use in the basin.

From the above analysis, it can be seen that each country has a different inventory approach, most of the water resource assessment methods usually focus only on individual water source, or many resources from different regional or national scales. Many findings have raised questions about the potential of water resources, changes in water resources over time, water quality, and the exploitability of water sources. Through the research objectives, it is clear to see that these studies only focus on looking at statistics on water resources, assessing the influence of these data on water resources and water balance calculation. In addition, in Vietnam, current studies only focus on the statistics on water resources, methodology and criteria for statistics on water resources. Therefore, finding a comprehensive approach to the assessment of water resources that considers the effects of many factors at different regional scales and stages will be better for water resources management [1].

Currently, the inventory of water resources has not been officially implemented in Vietnam. Particularly, in Decision No. 81/2006 QD-TTg on National Strategy on Water Resources vision to 2020 [14] emphasized the implementation of “periodic inventory; periodic assessment on the exploitation and use of water resources, discharge of waste into water sources…”. Decision No. 305/2005/QD-TTg [15] on the promulgation of the National Statistical Indicator System, which contains a number of indicators related to water resources and environment. On the basis of Decision No. 305/2005/QD-TTg, on November 5, 2007 the Minister of Natural Resources and Environment (MONRE) issued Decision No. 18/2007/QD-BTNMT [16] on the System Statistical indicators of the natural resources and environment sector, with 231 indicators related to land, environment, measurement and cartography, hydrometeorology, water resources, geology and minerals, of which there are 09 statistical criteria on water resources, including: (1) natural reserves of underground water;

(2) underground water reserves have been investigated and assessed; (3) the natural area that has been mapped of underground water resources; hydrogeological map; (4) total amount of rainwater; (5) total amount of surface water; (6) numbers of large reservoirs (with design capacity greater than 1 million m^3), total capacity of large reservoirs; (7) total amount of wastewater; (8) ratio of extracted surface water to total surface water; (9) the ratio of exploitable groundwater to total exploitable reserves (Table 2).

Table 2. Governing documents related to statistical indicators of water resources

Decision 18/2007/QD-BTNMT Promulgating a system of statistical indicators for the natural resources sector		**Circular No. 29/2013/TT-BTNMT Promulgating the system of statistical indicators for the natural resources sector** [20]		**Circular No. 02/2014/TT-BTNMT Regulation on reporting regime for statistics of natural resources industry**		**Circular No. 73/2017/TT-BTNMT Promulgating the system of statistical indicators for the natural resources sector** [21]		**Circular No. 20/2018/TT-BTNMT Statistical reporting regime for natural resources and environment sector**	
Code	**Group, target name**	**Code**	**Group, target name**	**Code**	**Group, target name**	**Code**	**Group, target name**	**Code**	**Group, target name**
N198	Natural dynamic reserve of underground water	201	Area to be investigated and assessed for ground water	0201/BTNMT	Area to be investigated and assessed for ground water	0201/BTNMT	Area to be investigated and assessed for ground water	0201/BTNMT	Area to be investigated and assessed for ground water
N199	The underground water reserve has been investigated and evaluated	202	Water level, temperature, physical properties and chemical composition of underground water	0202.1/BTNMT	Ground water level	0202.1/BTNMT	Ground water level	0202.1/BTNMT	Ground water level
N200	The natural area has been mapped of underground water resources; hydrogeological map			0202.2/BTNMT	Ground water temperature	0202.2/BTNMT	Ground water temperature	0202.2/BTNMT	Ground water temperature
N201	Total amount of rain water	203	Total surface water volume of some main river basins	0202.3/BTNMT	Physical properties and chemical composition of groundwater	0202.3/BTNMT	Physical properties and chemical composition of groundwater	0202.3/BTNMT	Physical properties and chemical composition of groundwater
N202	Total amount of surface water	204	Change of ground water level	0203/BTNMT	Total surface water volume of major river basins	0203/BTNMT	Total surface water volume of major river basins	0203/BTNMT	Total surface water volume of major river basins
N203	Large number of reservoirs (with design capacity greater than 1 million m3), total capacity of large reservoirs	205	Change of total surface water in some main river basins	0204/BTNMT	Change of ground water level	0204/BTNMT	Change of ground water level	0204/BTNMT	Change of ground water level
N204	Total amount of wastewater	206	Total volume of exploitation, use of water resources, discharge of wastewater into water sources of some main river basins	0205/BTNMT	Change of total surface water in major river basins	0205/BTNMT	Change of total surface water in major river basins	0205/BTNMT	Change of total surface water in major river basins
N205	Ratio of exploited surface water to total surface water			0206/BTNMT	Total amount of exploitation, use of water resources, discharge of wastewater into licensed water sources in the main river basins	0206/BTNMT	Total amount of exploitation, use of water resources, discharge of wastewater into licensed water sources in the main river basins	0206/BTNMT	Total amount of exploitation, use of water resources, discharge of wastewater into licensed water sources in the main river basins
N206	Ratio of exploitable groundwater to total exploitable reserves								

From 2007 to 2018, MONRE has three times issued the system of statistical indicators for the natural resources and environment sector including water resources (in 2007, 2013, 2017) and twice issued the system of statistical natural resources and environment sector (in 2014, 2018). Recently, Circular No. 20/2018/TT-BTNMT [17] on Statistical reporting regime of natural resources and environment sector was issued to replace the Circular No. 02/2014/TT-BTNMT [18].

The statistics and inventory of water resources of the Ministry of Natural Resources and Environment have not been implemented synchronously at all levels. The main reason is that the concepts, contents and methods for statistical indicators and inventory of water resources have not been unified and standardized in calculation, moreover, the indicators do not reflect the relationship between water resources and exploitation process, etc. Especially, in the context of climate change, most of Vietnam's rivers have had construction projects to exploit and regulate water, therefore the regularity and natural law of hydrometeorology and water resources have also changed. Statistical criteria of water resources (Table 2) of the natural resources sector in Circular 20/2018/TT-BTNMT [17] are the major and necessary criteria for the management at the national scale. However, they are not detailed, do not fully reflect the natural feature of water resources, including quantity and quality, and reflect the water

resources of a basin/ region in terms of its development over time, space, extremes, exploitation effects, environmental factors and water quality, etc.

There have been no legal guidance or studies on how to calculate and produce the most accurate data that fully reflects water resources at all levels of river basin, region, nation, etc. However, to do statistics of the required indicators in the appendix tables attached to the instructions, it is necessary to synthesize statistics from the reports of the Department of Natural Resources and Environment and the data from the hydrological stations at the estuary. This is a difficult task because collecting all data is impractical and if there is no agreed method, the results will be very different between localities and watersheds. Currently, the guidelines on the content or inventory forms, and reports on the results of water resource inventory are not adequate, leading to difficulties for agencies in the inventory of water resources.

3. Future indicators for water resource inventory in Vietnam

In the study of water resources inventory, the selection of criteria related to water quality and quantity of the basin is necessary. Besides, human exploitation activities in river basins, especially water tranfering from the reservoirs to other basins have a significant impact on the reserve and distribution of water reserves in the nature of the river, so these indicators show the extent of affected water resources, the remaining resources can be exploited without seriously affecting the inventory and quality of the water over a period of 5 years based on the national socio-economic development plan period. In addition, selecting some specific criteria for rivers (or river basins) whose typically specific characteristics and actual exploitation and use of water is also a necessary task.

The guidance of river basin water resource planning in the Law on Water Resources 2012 [19] of the Government clearly stipulates that the first step of river basin planning is: "Assessment of natural, economic, societal and environmental characteristics of water sources, the current status, exploitation, usage and water resource protection and prevention, from the harmful consequences". According to the Law on Water Resources 2012 [19], water resources include surface water, underground water, rain water and sea water in the territory of the Socialist Republic of Vietnam. However, the inventory of water resources focuses on surface water, underground water, and rain water. For sea water, the inventory will focus on the exploitation and the use of seawater, discharging waste into seawater sources belonging to the territory of Vietnam.

"Indicators" mean (1) the required levels to be achieved; or (2) the expression levels of a feature, a function. In the inventory of water resources, an "indicator" is understood in the second term, the latter. Thus, the water resource indicator system is a collection of indicators on various types of water resources, including rainwater, surface water, groundwater resources, and seawater resources (if any). They are expressed in terms of (i) numbers of water sources, numbers of monitoring stations; (ii) amounts of water; (iii) water quality; (iv) fluctuations and trends (variations in space and time between years and within the year; changes due to human impacts, including socio-economic activities, pollution, depletion, etc); (v) capacity and current status of exploitation and use; and (vi) economic value of the water.

An indicator must include (i) a name code and name of that indicator; (ii) quantitative value; (iii) reflection space; (iv) subjects of reflection; and (v) measurement/ calculation time. Quantitative data can be expressed as absolute numbers or ratios. Thus, indicators are always associated with certain numbers and a certain time frame. An indicator can be measured by many indices. Sometimes there are indicators that are not quantifiable. It should be noted that in order to manage by results, the number of indicators should not be too many, and more attention should be paid to indicators for specific goals. It is recommended to gradually move from single indicators to integrated indicators that combine many variables [1].

Table 3. Proposed water resource inventory indicator system.

No.	Water inventory indicators	Water resources		
		Rainwater	**Surface water**	**Groundwater**
1	Quantity	×	×	×
2	Quality	×	×	×
3	Variation	×	×	×
4	Use and exploitation	×	×	×
5	Economic value	×	×	×

Note: × = Yes, to be characterized by indicators.

Therefore, through international experience and the actual situation in Vietnam, we have introduced a systematic indicator for the inventory of water resources including rainwater, surface water and groundwater resources with a set of indicators representing quantity, quality, variation, use and exploitation as well as econominc value of water resources as described in Table 3. Specific contents and methods to determine inventory indices will be presented in another paper.

4. Conclusion

The article presents the water resource inventory in some countries and the current status of water resource inventory activities at national levels to provide a system of criteria and methods. The results show that each country has different statistical approaches, most of the statistical methods and assessments usually focus only on separate water source, or several resources in regional or national scale or on the basis of an annual inventory, the article determines the potential of water sources, changes in water sources over time, water quality, and the exploitation capacity of water sources. In addition, in Vietnam, practical studies and topics only focus on the statistics of water resources, giving methods and criteria for statistics on water resources in Vietnam. In order to manage the water resource planning in the river basin and a plan for the exploitation and use of sustainable water resources, the inventory and assessment of water resources is very necessary. Through international experience and the actual situation in Vietnam, the authors have systematized and proposed a system of standards/ indicators for water resource inventory and the inventory of rainwater, surface and underground water resources include the quantity, quality, fluctuations, exploitation, use and value of water resources, thereby serving the development of relevant circulars and guidelines.

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Reference

1. Don, N.C. Research proposal on "Scientific basis for establishing a system of indicators for water resource inventory. Application to the Ba River basin". Coded TNMT.2019.02.01, 2019 (in Vietnamese).
2. Charles, B.; Jippe, H.; Jean-Marc, F.; Livia, P. Water accounting and auditing: A sourcebook. FAO Water Report 43, **2016**, pp. 232.
3. UN-Water "UN-Water Task Force on Indicators, Monitoring and Reporting: Final report", **2006**, pp. 44.
4. United Nation. International Recommendation for Water Statitics. Statistical papers Series M, No.91. ST/ESA/STAT/SER.M/91, 2012.
5. USGS and ERSI. An online geographic information system that provides information on watersheds in the United States. Online available: https://streamstats.usgs.gov/ss/. Assessed 15/06/2021.
6. Bureau of Meteorology. Information on Water Resources, at Website http://www.bom.gov.au/water/, Assessed **15/06/2021**.
7. United Nations Economic and Social Commisssion for Western Asia (UN-ESCWA) và German Federal Institute for Geosciences and Natural Resources (BGR). Inventory of Shared Water Resources in Western Asia. Online available: https://waterinventory.org/.
8. Law on Management and Use of Public Property. No. 15/2017/QH14, dated 21 June, 2017, **2017** (in Vietnamese).
9. Dung, N.K. Project "Research on scientific and practical basis to determine content, methods of calculation, synthesis and statistics of water resource indicators", MONRE, **2010** (in Vietnamese).
10. Xuan, T.T. và Tuyen H.M. "Vietnam's water resources and management". **2012** (in Vietnamese).
11. ADB. Project on technical support for water sector assessment for Vietnam, 2005-2009.
12. Decree 201/2013/ND-CP dated November 27, 2013 of the Government guiding the implementation of a number of articles of the Law on Water Resources, 2013 (in Vietnamese).
13. Water Resources Management Department, MONRE. Research and propose to expand the system of statistical indicators of underground water resources to better serve the state management of water resources, 2012 (in Vietnamese).
14. Decision No. 81/2006/QD-TTg dated April 14, 2006 of the Prime Minister approving the National Strategy on water resources until 2020, 2006 (in Vietnamese).
15. Decision No. 305/2005/QD-TTg on the promulgation of the National Statistical Indicator System, 2005 (in Vietnamese).
16. Decision No. 18/2007/QD-BTNMT promulgating the System of Statistical Indicators of the Natural Resources and Environment Sector, 2007 (in Vietnamese).
17. Circular No. 20/2018/TT-BTNMT on Statistical reporting regime of natural resources and environment industry, 2018 (in Vietnamese).
18. Circular No. 02/2014/TT-BTNMT stipulating the regime of statistical reporting of the natural resources and environment sector, 2014 (in Vietnamese).

19. Law on Water Resources 2012, No. 17/2012/QH13, 2012 (in Vietnamese).
20. Circular No. 29/2013/TT-BTNMT Promulgating the system of statistical indicators for the natural resources sector, 2013 (in Vietnamese).
21. Circular No. 73/2017/TT-BTNMT Promulgating the system of statistical indicators for the natural resources sector, 2017 (in Vietnamese).