UDC 005:628.1(593)
Preliminary Communication

Knowledge Organization of Integrated Water Resources Management: A Case of Chi River Basin, Thailand

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Abstract

This study is a part of the research project on the Development of an Ontology-Based Semantic Search for Integrated Water Resources Management of the Chi River Basin (CRB), Thailand. The study aimed at developing the knowledge domain of water resources management for CRB. The research methods included document analysis and qualitative research by adopting Liou (1990)'s knowledge acquisition approach. Fifteen experts including ten experts in the areas of environmental engineering, water resources engineering, and GIS, and seven government officers who has been involving with water management in the CRB were interviewed. The experts also took part in the processes of developing the knowledge domain, classifying, and structuring the knowledge for water resources management in the CRB.

The results of this research were the knowledge domain of water resource management for CRB. An example of the water resources management knowledge domain which was structured by following concepts and processes of water resources management in Thailand is shown in this paper.

Keywords: Water Resources Management, Knowledge Domain, Knowledge Acquisition, Knowledge Organization, Knowledge Model, Chi River Basin Thailand

1. Introduction

Water is everyone's business. Beside a necessity for living, water has implications on public health and, most importantly, can cause social conflicts. This is because water is limited, is difficult to control, and can easily be polluted. The Integrated Water Resource Management (IWRM) process is considered worldwide as a means to reduce social conflicts from competing water needs as well as to facilitate effective and sustainable development of water resources. Effective implementation of IWRM however will require appropriate policy, regulation, and institutional frameworks which could facilitate cross-sectoral dialogue and cooperation among water users (The World Bank, 2011). IWRM is defined by the Global Water Partnership (GWP) as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment". In Thailand, IWRM has been technically recognized as a means to achieve sustainable water resources management and the concept has been incorporated in the national policy for more than 15 years, however clear institutional responsibility and introduction of the IWRM concept to local communities are relatively new (Global Water

Partnership, 2010).

Based on the economically and socially statistical data during the year 1989 - 2001, Thailand has been suffered from flood and drought periodically and the amount of damages sometimes was higher than 2,350 million US$ or 790 million US$ on average. The Royal Thai Government considers that flood and drought problems are the serious threats to the national development and significantly obstacles to the quality of life. Furthermore, water issue is very much interrelated with other natural resources such as forestry, land, ecosystem, etc. as well as human settlement which has an impact on the economic growth. As stated in the Johannesburg Plan, the IWRM is one of the perfect tools that should be applied in order to minimize the obnoxious problems. Therefore, IWRM approach has been adopted in Thailand and being applied in the twenty-five river basins in the country (Ministry of Natural Resources and Environment, Thailand, 2011).

Water resources in Thailand, with an area of about 513,000 km^2, can be hydrologically divided into twenty-five river basins. The average annual rainfall for all over the country is about 1,700 mm. The total volume of water from the rainfall in all river basins in Thailand is estimated at 800,000 million m.3, of which 75 percent or around 600,000 million m.3 is lost through evaporation, evapotranspiration and infiltration and the remaining 25 per cent of 200,000 million m.3 constitutes the runoff that flows in rivers and streams. The population of Thailand is around 60 million. Therefore, the availability of water resources is 3,300 m.3 per person each year which is statistically considered to be highly adequate. It is important to create and develop water resources information system which is now not standardized and scattered in different agencies. Information needed in water resources management includes the information of other related resources and activities such as land and land use, forest land, some other social and economic information etc. Network of information is necessary for planning and its implementation (International Commission on Irrigation and Drainage, 2012).

River basins are dynamic over space and time, and a change in any single component of a river basin system has implications for the whole system. To understand the system dynamics and help solve problems in a river basin, a holistic, multi-sector approach at the river basin scale is needed. A river basin approach is now recognized as a comprehensive basis for more economically, socially, and environmentally sustainable water resource management. Integrated river basin management (IRBM) emerged from the need to meet and alleviate the global water crisis (WWF 2011). According to the Global Water Partnership (2000), IRBM is defined as “the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximize the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems" (Columbia River Basin Research, 2013)

Chi River Basin (which will referred to as CRB in this paper), originating from the Phetchabun Mountains, is the largest and important river for the economic and social development of Northeastern Thailand. It covers an area of approximately 49,477 square meters across twelve provinces. The water of the CRB is used heavily in people’s everyday lives. It is also a resource for fishery, agriculture, industry, tourism, transportation, and electric power production. The CRB has always been in the interest of researchers who are recognized as experts on the CRB in monitoring and controlling the water condition that may be affected by water consumption, especially from agriculture and industry. The environmental and ecological damages to the CRB caused by agriculture and industry along the river have been a vital issue for several years (Hydro and Agro Informatics Institute, 2010). People living along the basin have faced problems caused by both floods and droughts every year. Although there are responsible organizations and researchers who are recognized as experts on the basin in monitoring and controlling the water condition, it is obvious that a lack of knowledge sharing still exists between them. In addition, the experts’ knowledge, which should be used for the water resource management of the basin, has not been captured, classified, or integrated into an information system for decision making.

This study is a part of the research project on the Development of an Ontology-Based Semantic Search for Integrated Water Resources Management of the CRB. It aimed at developing the knowledge domain, which integrated information from existing resources and knowledge from the experts in the fields. It is expected that the results will be able to support the decision making process of river operators intensively, furthering knowledge sharing among the experts and the use such knowledge as a resource for researches and studies on the basin in the future.

2. Related Studies

Instant personalized access to weather monitoring and warning systems is made possible by the revolution of information and communication technologies. The technology for collecting (e.g. remote sensing technology), recording and transmitting (e.g. telemetric systems), displaying (e.g. geographic information systems), and processing and analyzing data by the computer have become more developed and even more powerful (Parker, 2003).

Flood forecasting and warning signals have been a crucial component that can lead to major benefits in numerous aspects of national life, with considerable potential for improving the national economy. As such, these signs are recognized as highly cost effective, non-structural measures (BANCID, 1995). Implementations of a flood forecast, warning, and response system in order to reduce human, material, and cultural losses are carried out in Europe and South Africa (Parker, 1996; 2003).

Andreu et al. (2009) also expressed the opinion that the planning and management of water resource systems must be done with emphasis on drought preparation and mitigation. The use of models and Decision Support Systems (DSS) has played an important role in the development of the Jucar Basin Plans for almost two decades, as well as for the development and implementation of the Special Drought Awareness and Mitigation Plans (SDP). They include long term (planning), medium term (alert), and short term (emergency and mitigation) measures that are activated using Standardized Drought Monitoring Indicators (SDMI) based on the combination of data provided by the ASAS on precipitation, storage in reservoirs, groundwater levels, and flows in rivers.

Beran and Piasecki (2009) also developed an ontology-aided search engine named Hydroseek that allows users to query multiple hydrologic repositories simultaneously using keywords. The knowledge base has been developed, which covered the water quality, meteorology and hydrology domains and provided the linkage between scientific/everyday language and variable codes, which was eventually used to resolve semantic heterogeneity issues between the data repositories and clustering of search results. Ames et al. (2012) also developed open source software tool called HydroDesktop that can be used for discovering, downloading, managing, visualizing, and analyzing hydrologic data. It was created as a means for searching across and accessing hydrologic data services that have been published using the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Hydrologic Information System (HIS).

Moreover, Ceccaroni et al. (2004) studied the integration of ontology with case-based and rule-based reasoning into an environmental decision-support system. This integration improved the modeling of the information about wastewater treatment processes and resolved existing impasses in the reasoning cycle. They presented an ontological representation of two kinds of cause-effect relationships to improve the communication among different elements and agents of an environmental decision-support system, thus reducing any ambiguities.

As far as the semantic search systems of water resources information are concerned in Thailand, the major limitation of existing research was on the data integration for identifying the water problem, which often resulted in an analysis of the data from multiple sources. Between these information sources, there are also the limited supports for users to find the data related to their interests.

The word disaster is defined by the United Nations as a severe failure of community planning, causing an extensive loss of human life and materials and devastation to economic growth, and the environment. Usually, the affected community is unable to handle such disasters using its own resources. Solutions to minimize risks from natural disasters were greatly advanced in the last decade (1990-1999), which was named the “International Decade for Natural Disaster Reduction” by the International Community. Visualizing the international dimensions of disasters, agreements were settled so that the relief from the International Community can be most effective.

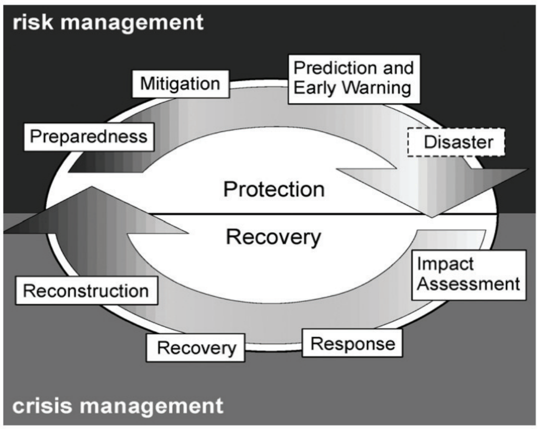

Figure 1. The Cycle of Disaster Management
(Source: National Drought Mitigation Center, University of Nebraska-Lincoln (Wilhite, 2002).

The principles of risk management can be boosted in many ways, such as: 1) Encouraging the improvement and application of seasonal and shorter-term forecasts. 2) Developing integrated monitoring and drought early warning systems and associated information delivery systems. 3) Developing preparedness plans at various levels of government. 4) Adopting mitigation actions and programs. 5) Creating a safety net of emergency response programs that ensure timely and targeted relief, and 6) Providing an organizational structure that enhances coordination within and between levels of government and stakeholders (Wilhite, 2002).

As the vulnerability to droughts has increased globally, greater attention has been directed to reduce risks associated with its occurrence through the introduction of planning to improve operational capabilities and mitigation measures that are aimed at reducing drought impacts. This change in emphasis is long overdue. Mitigating the effects of drought requires the use of all components of the cycle of disaster management (Figure 1), rather than only the crisis management portion of the cycle.

This paper presents an example of how to apply the cycle of disaster management model. By studying journal articles and research papers, several examples of water resources management methodologies or processes were discovered. One of examples is the flood management by Plessis (2002), who did a review of effective flood information systems for application in South Africa and found that the sustainable prevention and mitigation strategies should be achieved within a holistic integrated catchment management approach, namely a food forecast, warning and response systems, which contribute to the prevention and mitigation of flood losses.

The process of weather forecasts involves the collection of metrological information to alert about potential flood events in terms of location and the nature of event. It is similar to what was done by Parker (2003), who studied and designed flood systems from a societal perspective involving three processes: forecasting, warning, and response. As part of this research in the previous paper of Kaewboonma (2012), the researchers used Plessis (2002) and Parker (2003) concepts to design the knowledge domain of flood management information system of the Chi River Basin. However, when expanding the knowledge domain covering all the aspect of water resources management : Flood, Drought, and Waste water, the concept of Plessis (2002) and Parker (2003) had been found limited. This research which based on the literature reviews and experts, therefore, used the cycle of disaster management for water resources management (Wilhite, 2002; Figure 1.) which is more suitable for the knowledge domain of all three aspect of water resources management.

This research consolidated information from various areas, for example meteorology, hydrology, hydraulic engineering, and the human behavioral, sociological, and organizational disciplines to develop modeling and interpretation for forecasting. Thus, it can be concluded from the research that it is essential to collect specific types of information for each process of water resources management in order to future develop the information system.

Knowledge domains are important to the management of water resources in the sense that they define the scope of information systems and knowledge, following the strategies of water resources planning. In the process of setting knowledge acquisition, the essential knowledge framework for work process must be determined, according to the cycle of disaster management. Currently, no research paper exists, which categorizes the knowledge for managing water resources and combines it with the disaster management model in order to manage water resources in Thailand.

Knowledge is present in any water resources management organization and can take various forms. Nevertheless, government offices have difficulties in creating a system for the acquisition, retention, and access to knowledge, especially in the case of highly specialized knowledge. When this knowledge belongs to a physical person, it is also referred to as expertise or experience. Sometimes, however, knowledge also resides within non-human objects, either in a straight and formal way (e.g. expert systems), or in a conceptual way. Design information, for example, can be seen as an expression of knowledgeable choices made by the designer (Gebus, 2009). In other words, knowledge exists as soon as humans interact and can be available at any step of product development.

The knowledge acquisition process is the key process to build a complete knowledge base, in this case, managing water resources. The process employs the idea of compiling the entire knowledge necessary to identify the water resources problems and to solve them. The knowledge that must be acquired is not only concerned about how the water managers deal with their river basin real problems but also about how scientists think that water management should be improved based on the knowledge of stream ecosystem structures and functionality. Three types of knowledge can be distinguished from this process: literature, experts, and databases. The general knowledge of the process is mainly extracted from literature, while the heuristic knowledge is obtained mainly from both water management and domain-experts.

This study used the concept of knowledge acquisition in the context of expert systems by Liou (1990). There are three major concerns to the knowledge acquisition task: the involvement of appropriate human resources (including primarily domain experts and knowledge engineers, sometimes end users and managers), the employment of proper techniques to elicit knowledge, and a structured and systematic approach to performing the knowledge acquisition task (Liou, 1990). A knowledge engineer commonly carries out the acquisition relevant to knowledge and expertise. Extracting the knowledge from the expert and representing it in a knowledge base using a proper conceptualization, however, cannot take place without first overcoming some obstacles (Gebus, 2009).

In this sense, the water resources management becomes a typical complex and ill-defined problem, whose optimal management requires an integrated and multidisciplinary approach. This approach can be reached with an intelligent tool built upon the concepts and methods of human reasoning (Comas, 2002).

3. Research Methods

The research methods used in this study included the employment of document analysis and qualitative methods. The knowledge acquisition approach by Liou (1990) was adopted for acquiring knowledge from the domain experts. The study was comprised of four steps (See Figure 2): 1) Document analysis to identify the concept and domain knowledge of water resources management. 2) Drafting the classification by the concept of hierarchical categorization, considering both common and different attributes by evaluating the data types and the characteristics of the data with a hierarchical clustering of water resources management information. Table 1 gives example of instrument for classifying the data on groundwater resources domain, which composed of the following data: Domain/Concept, Sub-domain, Attributes, Relationship, Meaning in Thai language, Synonym, and Source. 3) Interviews with ten experts who were researchers in the areas of environmental engineering, water resources engineering, and GIS in the CRB from four universities located on CRB in the northeast of Thailand, and also interviews with seven government officers who has been involving with water management in the CRB, and 4) Summarizing the knowledge domain and reconfirming the results from the experts.

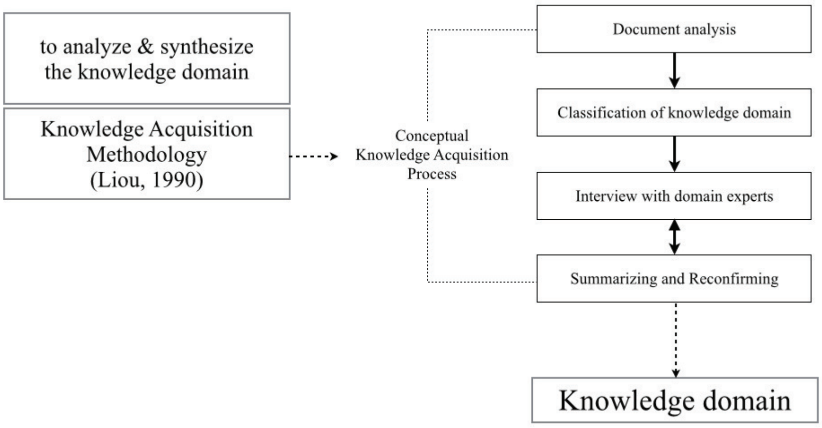

Figure 2. Key Components of the Knowledge Acquisition Process
(Adapted from Liou (1990) and Payne et al. (2007))

Based on the analysis of the data from the literature reviews and the experts, the knowledge domain on water resources management should be classified using two main concepts: 1) The practical classification of knowledge domain in the organizations responsible for CRB management in Thailand, which divide the process of water resources management into three processes: Planning, Response, and Recovery; 2) The classification of knowledge domain using the cycle of disaster management (Wilhite, 2002) which comprise 6 of processes: Forecasts, Monitoring, Planning, Alert, Emergency, and Recovery. In conclusion, the design of knowledge domain of water resources management can be classified as follows: 1) Planning (Forecasts, Monitoring, and Planning) 2) Response (Alert and Emergency) and 3) Recovery (Recovery) (Figure 3.)

Domain/ Concept	Sub-domain	Attributes	Relationship	Meaning in Thai	Synonym	Source	Decision making?	
							Yes	No
Groundwater Resources	Groundwater Quality	- Cl (Chloride) - Fe (Iron) - NO3 (Nitrate) - pH -TDS (Total Dissolved Solids) - TH (Total Hardness)	*is-a*	น้ำใต้ดิน น้ำบาดาล น้ำบ่อ	Underground water Well	Department of Groundwater Resources	/	
	Ground Water Quality Standards	- Acidity - Alkalinity - Biochemical Oxygen Demand	*is-a*	คุณภาพน้ำใต้ดิน	N/A	Department of Groundwater Resources		

		- Chemical Oxygen Demand - Chloride - Conductivity - Dissolved Oxygen - Harness - Heavy Metal - Nitrogen - Oil and Grease - pH - Phosphorous & Phosphate - Sulfate - Sulfide - Total Solids					/	
	Groundwater Level							
	Groundwater Site Location							
	Groundwater Map							
	Groundwater Usage							
	Groundwater Control Area							

Table 1. Example of Instruments Used

4. Research Results

In the CRB in Thailand, problems coordinating the water typically follow the guidelines of government agencies and the district and local-layered approach in terms of the communication structure. Most of the information coordinating with water resources is processed at the Provincial Administrative Organization, and many of the key strategic and tactical decisions are made at this level. District level coordination poses significant challenges as it represents many disparate groups and agencies. These sectors require a great deal of coordination but often have had little exposure to each other in the past. Among the agencies are the Royal Irrigation Department, Land Development Department, Department of Agricultural Extension, Department of Water Resources, Department of Disaster Prevention and Mitigation, Electricity Generating Authority of Thailand, Provincial Administrative Organization, Community Development Department, Department of Groundwater Resources, Thai Meteorological Department, Regional Centre for Geo-Informatics and Space Technology, Northeast Thailand, Department of Environmental Quality Promotion, Regional Environmental Office, and the Royal Thai Survey Department.

Each agency is a member of the water resources management committee, and the district office at the district level manages the committee. Since water resources management operations involve multiple agencies in collaboration, the water problems related to information must be organized in most efficient way, as shown in Table 2.

Agency's Name	Role	Resource
Royal Irrigation Department	Develop the potential of the basin water balance. Oversee effective water management in a thorough, fair, and sustainable method. Promote participation in the process of development and water management at all levels of integration, prevention, and relief of disasters caused by water.	- GIS - Water Storage Volumes and Levels in Rivers and Storage Information - Telemetry System - Water Prediction by ANN's Method

Land Development Department	Assist farmers in soil and water conservation practices and soil improvement, seed production for cover crops and soil improvement materials, transfer technology from its research of soil development and soil science for multiple purposes and uses.	- Soil and Land Information - Land Use Planning
Department of Agricultural Extension	Promote and develop farmers to be self-reliant, to produce agricultural products with good quality, and to engage in their farm occupation in a sustainable manner.	- Plant Information - Agriculture Land Use Information
Department of Water Resources	Suggesting the preparation of plans and policy measures related to water resources. Management, conservation, restoration, and development of directed supervision, monitoring, evaluation, and coordination problems associated with water resources.	- Hydro Information - GIS - Water and Landslide Information - Water Storage Volumes and Levels in Rivers and Storage Information - CCTV - Khong-Chi-Moon Water Monitoring Information - River Basin WRM Plan
Department of Disaster Prevention and Mitigation	Provide preliminary assistance and relief to victims and recover basic infrastructure, which is damaged and a danger to the public.	- Victims Information - Rescue and Evacuation Information
Department of Disaster Prevention and Mitigation	Provide preliminary assistance and relief to victims and recover basic infrastructure, which is damaged and a danger to the public.	- Victims Information - Rescue and Evacuation Information
Electricity Generating Authority of Thailand	Generate, acquire, and transmit electric energy to the Metropolitan Electricity Authority (MEA), the Provincial Electricity Authority (PEA), other electric energy consumers under the law thereon and neighboring countries.	Dam and Water Storage Volumes and Levels Information
Provincial Administrative Organization	Prevent and mitigate public and environmental dangers as well as provide aid to victims and coordinate with authorities for holistic assistance.	- Rescue and Evacuation Information - Victims Information
Community Development Department	Support, develop and sustain the local economy by preparing information for the community.	National Rural Development Information

Agency's Name	Role	Resource
Department of Groundwater Resources	Develop and manage groundwater resources to their full potential so as to promote the growth of the nation's development in a sustainable manner.	Groundwater Resources Information
Thai Meteorological Department	Provide a meteorological information service and governmental units against natural disasters.	Meteorological Information

Regional Centre for Geo-Informatics and Space Technology, Northeast Thailand	Provide data services relating to space technology and geo-informatics.	Geo-Informatics and Space Information
Department of Environmental Quality Promotion	Provide an environmental information service and to carry out analytical research, development, and technology transfer to quality control the environment.	Environmental Information
Regional Environmental Office	Conduct environmental quality management, evaluations, and monitoring as well as to publish environmental information.	Water Quality Monitoring Information
Royal Thai Survey Department	Survey ground and air to prepare map for country's security and development.	Geo-Informatics and Map Information

Table 2. Agencies involved during water resources management operation

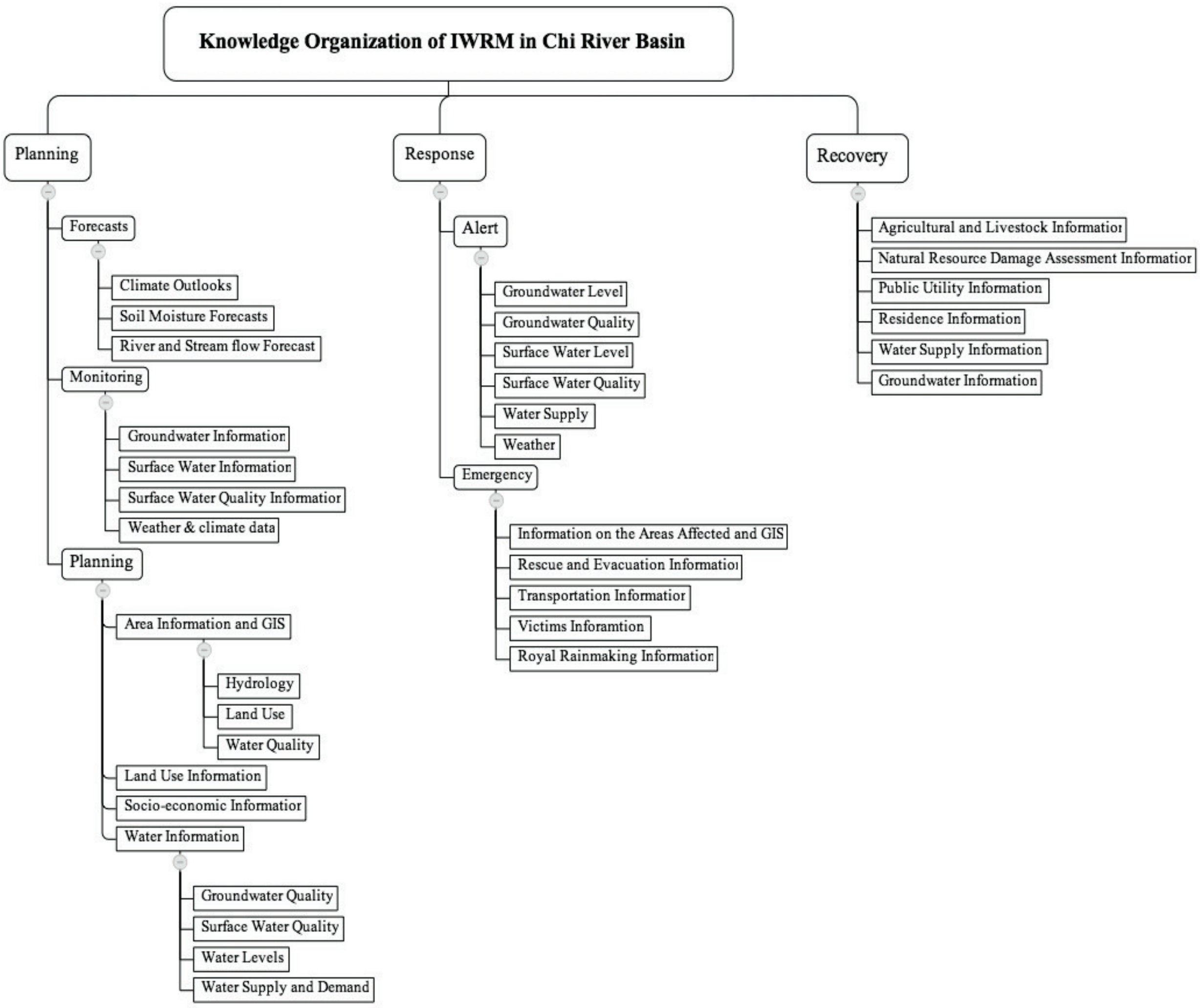

Figure 3. Hierarchical structured of IWRM: A case of the CRB

The results of this research were the knowledge domain of water resource management for CRB. An example of the water resources management knowledge domain (Top Levels) was hierarchical structured by following the concepts of the three processes in the management of water resources in Thailand: 1) The Planning process was comprised of three sub-domain, Forecasting, Monitoring, and Planning Information. For example, in the planning process, the water information were integrated of Groundwater Quality, Surface Water Quality, Water Levels (Dam, Reservoir and Lake and River and Stream Flow, and Water Supply and Demand from multiple agencies. 2) The Response process was a combination of two sub-domains, such as Alert and Emergency information to support the officers who working to rescue the victims of disaster from the river basin, And 3) The Recovery process illustrated the summary of natural resources damage, public utility damage and so on that help the officers to recover the infrastructure such as the public utility, water supply and groundwater system. The knowledge domain for water resources management can be seen in Figure 3 and Appendix A.

5. Conclusion

This paper presented the knowledge domain of integrated water resources management which has been studies on the case on CRB in Thailand. The knowledge domain will be further developed into an ontology-based semantic search information system which will be useful for information retrieval of the CRB management in the future. The research findings can be concluded as follows:

1) The knowledge acquisition of this research was conducted by integrating the explicit knowledge which were information on the water resources management currently used by the government offices responsible for the CRB management, and the tacit knowledge from the experts who were involving with the CRB's research and management. Therefore, the knowledge domain developed under this research is original and can be practically used for the development of integrated information system for the CRB resources management.

2) From the literature reviews, there have been several concepts being used on the studies of integrated water resources management. However, in this research it was suggested by the experts that the development of knowledge domain for the CBR should follow the risk management cycle because it is the real practices of the related government offices and also suitable for the CRB resources management condition. The research found that in the Thai context, in the needs for risk management of water resources, especially for the CRB resources, there are only three processes concerned: Planning, Response, and Recovery. This finding is completely new for the Thai concerns and different from the previous studies of international contexts.

3) In the next step, an ontology of the CRB resources management will be developed by using the knowledge domain from this study, followed by the development of an ontology-based semantic search on the web and knowledge-based DSS for water resources management of CRB. This will enable the information retrieval functions of the system operated automatically, efficiently and accurately. The number of searches and the time of search can also be vastly reduced.

Acknowledgements

This research is supported by The Graduate School, Khon Kaen University, Thailand.

Appendix A: Classification Structures (Top Levels) of the knowledge domain structure for the design of water resources management information system.

Planning

Forecasts

- Climate Outlooks
- River and Streamflow Forecast
- Soil Moisture Forecast

Monitoring
- Groundwater Information
  - Groundwater Level/Flow
  - Groundwater Quality
- Surface Water Information
  - Dam
  - Reservoir and Lake
  - River and Stream Flow
- Surface Water Quality Information
  - Point Source
    - Agricultural Wastewater
    - Domestic Wastewater
    - Industrial Wastewater
  - Physical, Chemical, and Biological
    - Ammonia-Nitrogen
    - BOD
    - Conductivity
    - Discharge
    - DO
    - Nitrate-Nitrogen
    - pH
    - Soluble Reactive Phosphorus
    - Temperature
    - Turbidity
- Weather and Climate Data
  - Rainfall
  - Temperature
  - Evaporation
  - Wind
  - Sunshine
  - Cloud
  - Air Pressure
  - Weather Map

Planning
- Area Information and GIS
  - Hydrology
    - Groundwater Levels
    - Surface Water Levels
    - Rainfall
  - Water Quality
    - Groundwater Quality
    - Surface Water Quality
  - Land Use
- Land Use Information
  - Agriculture Area
  - Forest Area
  - Urban Area
  - Watershed Area
- Socio-Economic Information
  - Population Growth Rate

Total Population
National Rural Development Information
Water Information
Groundwater Levels
Groundwater Quality
Surface Water Levels
Dam
Reservoir and Lake
River and Stream Flow
Surface Water Quality
Water Supply and Demand
Domestic Consumption
Tourism Industry
Ecological Balance
Irrigation Agriculture
Hydropower

Response

Alert
Groundwater Level
Groundwater Quality
Surface Water Level
Dam
Reservoir and Lake
River and Stream Flow
Surface Water Quality
Reservoir and Lake
River and StreamFlow
Water Supply
Weather

Emergency
Information on the Areas Affected and GIS
Rescue and Evacuation Information
Transportation Information
Victims Information
Royal Rainmaking Information

Recovery

Agricultural and Livestock Information
Natural Resource Damage Assessment Information
Public Utility Information
Residence Information
Water Supply Information
Groundwater Information

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