【学位論文審査の要旨】

This thesis is the first attempt to propose a groundwater sustainability assessment framework based on Analytical Hierarchy Process (AHP) method, and the framework is successfully applied for Hanoi, Vietnam from the environmental, social, and economic perspectives, in which all the groundwater sustainability components are clearly defined and described.

Achieving sustainable groundwater development is one of the essential objectives in water resources management for many developing countries. The rapid groundwater exploitation without an adequate institutionalized management has caused serious adverse problems such as drying up of shallow wells, decline of groundwater level, land subsidence and groundwater pollution. Similarly, the groundwater situation in Hanoi is disastrous suffering from those problems, where the communities almost entirely depend on the groundwater resource for their water use for domestic, agricultural, and industrial purposes. There are large number of studies dealing with those specific groundwater problems, none of them, however, have dealt with a holistic approach of sustainability assessment. Regarding sustainability assessment methodology, although the indicator-based AHP is one of the most popular and powerful method due to its ability to cope with multifaceted and unstructured problems, this method has not yet been applied for groundwater problems.

Based on the above-mentioned background, this thesis first proposed an indicator-based AHP for sustainability assessment of groundwater resources, hereafter it is referred to as AHP-SAG This AHP-SAG was specifically developed for Hanoi as a targeted area under the environmental, social, and economic criteria. For each criterion, groundwater sustainability of Hanoi was comprehensively evaluated using the AHP-SAG.

The main outcomes by this thesis are summarized as follows:

(1) A sustainability assessment framework for groundwater resources based on the AHP method (AHP-SAG) was successfully developed for the first time, in which the highest level of the framework is the groundwater sustainability. The three environmental, social, and economic criteria were considered as the second level, and each criterion consists of three aspects of quantity, quality, and management as the third level. In each aspect, the sustainability indicators were clearly defined as the lowest level.

(2) The weighting process in the AHP-SAG, the most tedious step in the conventional AHP applications, was modified to make it simple to cope with the limited data

availability and reliability, and insufficient financial supports in the developing countries like Vietnam.

(3) The concept of sustainability index function (SIF) was introduced in the developed AHP-SAG to make a clear relationship between an indicator value and its sustainability index, which has remained unclear in the conventional sustainability assessment. In this AHP-SAG, not only the linear SIF case, but also the non-linear SIF case were investigated to find out a reasonable sustainability assessment for groundwater resources.

(4) The proposed AHP-SAG successfully evaluated the groundwater sustainability in Hanoi. In the application for Hanoi, the environmental, social, and economic criteria were composed of twelve, thirteen, and nine (34 in total) core sustainability indicators, respectively. It was found that the sustainability indices assessed by the combined linear and non-linear SIF case were more reasonable than the conventional linear SIF case alone because the sustainability indices properly reflected the current groundwater problems in Hanoi.

(5) The environmental, social, economic criteria were appropriately assessed at acceptable, acceptable, and good sustainability levels, respectively, resulted in the acceptable level for the final sustainability index. The variable characteristics of the sustainability indices in each criterion were also described and discussed.

In brief, this thesis proposed a framework for sustainability assessment on groundwater resources and evaluated its applicability for Hanoi, Vietnam. The thesis thus made a notable contribution to groundwater hydrology and sustainability science. Therefore, this thesis is acknowledged to hold a highly satisfactory content for conferring the Doctor of Philosophy in Engineering.