

CONJUNCTIVE USE OF SURFACE WATER AND GROUNDWATER IN CHUOSHUI ALLUVIAL FAN

USAGE COMBINE DE L'EAU DE SURFACE ET DE L'EAU SOUTERRAINE DANS LE CONE ALLUVIAL DE CHUOSHUI

Chien-Pang Liu¹, Wen-Hao Tesi² and Fang-Tse Tao³

ABSTRACT

Chuoshui alluvial fan is the major place of paddy production in Taiwan. The irrigation water resource allocation is the most critical issue in this area. Due to the uneven distribution of precipitation on this 2,000 km² area, people rely on groundwater to supplement the insufficient surface water supply during dry season. Excessive withdrawal of groundwater leads to serious environmental impacts, which include groundwater contamination, land subsidence and seawater intrusion, causing immense losses in land and property. Therefore, appropriate water resource management strategies are imperative in the region. This paper introduces several major water resource management strategies being applied in the Chuoshui Alluvial Region. The major focus is on conjunctively using groundwater and surface water and artificial recharge program. The effects of these water resource management strategies will be monitored, evaluated, and modified if necessary, in order to achieve the goals of curtailing land subsidence and ensure sustainable use of groundwater resource.

Key words: *Conjunctive water use, Groundwater quality, Aqua culture, Groundwater recharge, Land subsidence, Taiwan.*

RESUME

Le cône alluvial de Chuoshui à Taiwan est la région principale de la production du paddy. L'allocation des ressources en eau d'irrigation est la question critique dans ce secteur. En raison de la distribution inégale de la précipitation sur une superficie de 2 000 km², le peuple dépend de l'eau souterraine pour compléter la fourniture insuffisante de l'eau de surface lors

1 Manager of Hydraulic and Ocean Department ,Sinotech Engineering Consultant , Tel: 886-2- 8761-1595, E-mail: liupang@sinotech.com.tw

2 Technical Manager of Hydraulic and Ocean Department ,Sinotech Engineering Consultant, Tel: 886-2- 8761-1595, E-mail: wenhao@mail.sinotech.com.tw

3 Senior Engineer,Hydraulic and Ocean Department ,Sinotech Engineering Consultant, Tel: 886-2- 8761-1595, E-mail: taur@mail.sinotech.com.tw

de la saison sèche. Le prélèvement excessif de l'eau souterraine exerce des impacts négatifs sur l'environnement tels que la contamination de l'eau souterraine, l'affaissement de la terre et l'intrusion de l'eau de la mer, causant des pertes immenses à la terre et à la propriété.

Donc, il est nécessaire de formuler les stratégies appropriées pour la gestion des ressources en eau. Ce rapport présente plusieurs stratégies de gestion des ressources en eau appliquées dans la région alluviale de Chuoshui. L'accent est mis sur l'usage combiné de l'eau souterraine, de l'eau de surface et du programme de recharge artificielle. Les effets de ces stratégies de la gestion des ressources en eau seront contrôlés, évalués et modifiés si nécessaire, pour réaliser les objectifs de réduire l'affaissement de terre et d'assurer l'utilisation durable des ressources en eau souterraine.

Mots clés : Usage combiné de l'eau, qualité d'eau souterraine, Aqua culture, recharge de l'eau souterraine, affaissement de Terre, Taïwan.

1. INTRODUCTION

The Chuoshui creek flows through the parts of Changhwa, Yunlin, Nantou, and counties in the downstream delta region. The Chuoshui Creek alluvial fan is the major groundwater district in Taiwan (Figure 1). Unfortunately, owing to the fact that the Chuoshui Creek has a strong sedimentation problem, and regional surface water storage options are inadequate, presently, the in-stream diversion and the inland groundwater wells abstraction is applied as the major method for water resource augmentation and utilization.

Due to its peculiar topographic configuration, rainfall is unevenly distributed both in space and time. In the dry season, rainfall is generally scarce in most areas. Under this situation, water resources planning and use is a difficult issue.

As a result of continuous economic growth, rapid increase of population, booming industrial development, and highly improved living standard, we see a continuous increase on water demand during the past decades. This increased demand on water renders water supply management more difficult at present than in the past. This is especially true in groundwater management.

The major water supplies in Chuoshui alluvial fan are surface water and groundwater. Water resource statistics is shown in Figure 2. It shows that the annual surface water supply is about 2.66 billion m³, amounting to about 72% of the total 3.66 billion m³ water used. The annual groundwater supply is about 1.0 billion m³, and constitutes about 28% of the total water use. It thus becomes obvious, that groundwater resource plays a very important role in the overall utilization of water resources.

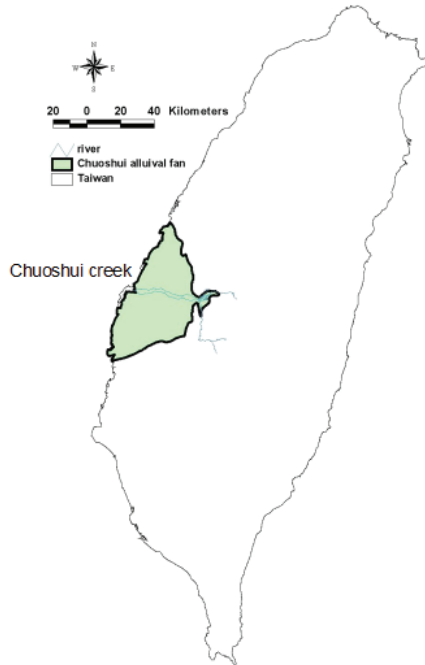


Figure 1. Region of Chuoshui alluvial fan

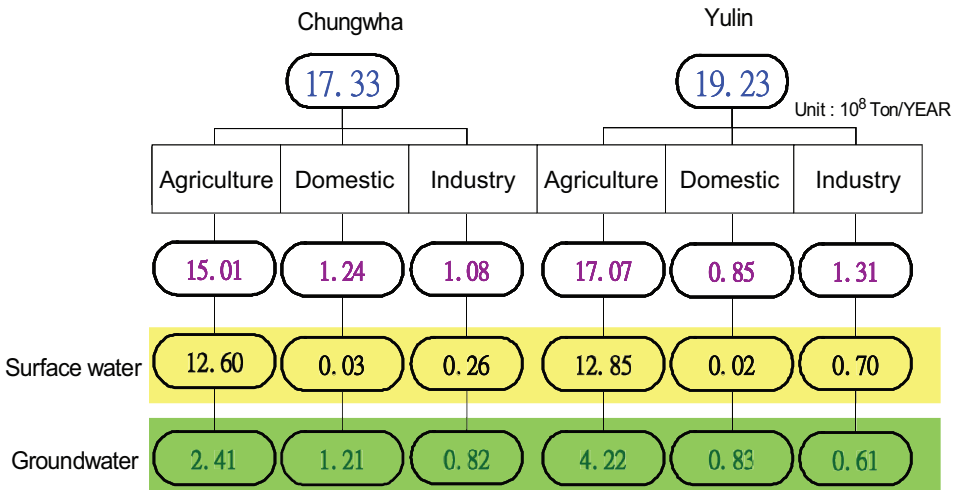


Figure 2. Statistics of water usage

People utilize groundwater not only because of its good quality, constant water temperature, ease of retrieval, and low cost, but also because of its reliability during the dry season. People can generally count on groundwater to supplement the deficit in surface water supply. In the past, the manner of groundwater utilization was mainly based on the users' demand. Since these users were so widely scattered it was very difficult, if not impossible, task in attempting to monitor and control groundwater utilization. Hence, although there are already 188 installed

observation wells for monitoring the groundwater table, the management of groundwater remained very primitive and relevant information are lacking.

In the past two decades there has been a boom in aqua-culture industry in several coastal areas, resulting in a tremendous increase in the demand of water in the recent years. Since there was insufficient surface water to meet the increased demand, the aqua farming industry began to draw groundwater as a supplementary measure. Their demand on groundwater was so large that excessive quantity of groundwater was withdrawn, and caused serious land subsidence due to aquifer dewatering. Well-known areas where land subsidence occurred due to the withdrawal of groundwater are mainly coastal areas of Changhwa, Yunlin. The consequences of land subsidence are the loss of precious land and property, expensive drainage control systems, high expenditure on dike rehabilitation and high risk of dikes. Frequent flooding in the wet season worsens the situation. Thus, the society and the general public paid hefty cost for the consequences of land subsidence induced by careless groundwater withdrawal. It thus stands to reason that, in order to prevent land subsidence and ensure the sustainability of water resources, proper utilization and management of groundwater is an urgent task for the water resources sector.

This paper discusses the current issues on groundwater management in Chuoshui alluvial fan. Action plans for improving groundwater management and the sustainable use of groundwater are also discussed. It is expected that these management strategies when introduced will be effective measures that would curtail the practice of excessive groundwater withdrawal, and gradually, but eventually reduce the amount of land subsidence, and also achieve the goal of sustainable use of water resources.

2. CURRENT ISSUES ON GROUNDWATER MANAGEMENT

Utilization of groundwater has its advantages and drawbacks. Using groundwater means low cost and readily available water for agricultural, domestic and industrial uses. On the other hand, excessive use of groundwater has imposed some serious problems. During the past forty years, the use of groundwater has created some critical issues on the management of groundwater resources.

The result of our water resources utilization analysis shows the total groundwater recharge is around 0.9 billion ton/year, and abstraction amount is around 1 billion ton/year. That is to say the over-abstraction is approximately 0.1 billion ton/year on an average. Owing to lesser recharge than abstraction, the groundwater level has been going down in these years.

The key issue related to groundwater management in this area is that there is no bona fide management body for groundwater use. Traditionally, surface water is managed by the farmer organizations. In this connection, groundwater is only a supplemental water resource for the farmer organizations that distribute water to the farms. Under this system, groundwater management was wholly neglected during the last several decades. By legislature, the direct management authority for groundwater is the local government of each county, and there are commonly just a few clerks who perform the chore of registration only. Under the Water Law, there is no need to enter a registration in the local county government if the use of groundwater is less than 144 m³/day. This leads to loss of information, albeit the groundwater drawn is of

small quantity in individual case, but the total cumulative quantity becomes quite substantial, which remains unknown. Another factor is that the farmers and private industries do not really understand the importance of groundwater cycle and the regulations of groundwater management. The combination of these factors explains why groundwater management is at best lax and ineffective, and sustainability remains a distant goal yet to be achieved. After forty years, the results show that only about 10% of water wells have been registered in the local county government. This indicates that the realistic information on groundwater consumption is not definitely clear.

The second issue related to groundwater management is that in the past forty years there has been no effective groundwater monitoring systems. In the last decade, only a few shallow wells were monitored in each groundwater basin, thus the results do not really reflect the groundwater characteristics of the corresponding basin. Recently, this situation has improved by installation of monitoring systems. Except Taipei basin, most groundwater basins do not have water meters on their wells. Hence, the actual groundwater consumption can only be estimated indirectly.

The third issue related to groundwater management is the incessant draw down of groundwater table and subsequent land subsidence. During the last forty years, groundwater has been over-drawn in most coastal plain aquifers because of the increased water demand and the insufficient surface water supply. The consequences of excessive groundwater use are the continuous draw down of groundwater table and the consequential land subsidence due to the consolidation process. The consequences of land subsidence are drainage problems on low land, beach erosion and high risk of dikes on the coastal areas. The consequences of land subsidence have caused huge losses in both territory and property to the society, especially in recent years, since there are floods almost in every year on the western coastal area due to typhoon.

3. CONJUNCTIVE USE OF SURFACE WATER AND GROUNDWATER

Several action plans have been drafted for the purposes of improving groundwater management in Chuoshui alluvial fan and achieving the goal of sustainable use of groundwater resource.

(1) Surface water resource development

Owing to overuse of groundwater, it's very important to develop surface water to reduce groundwater abstraction. There are two major water resources projects in this area.

The first one is construction of the Chi-Chi Weir Project. Major multipurpose functions of the Chi-Chi project include steady supply of agricultural water, meet the increased demand of 200,000 m³/day for the domestic water supply, and fully supply the 860,000 m³/day of water for industrial use in the wet season. During the dry season, the supply of the 300,000 m³/day industrial water demand is reallocated from agricultural water supply.

The second one is to implement the Yunlin Reservoir Project, the Hushan Reservoir. This reservoir provides 54 million cubic meters storage capacity for surface water during wet

season. The project will be completed in 2009. The water supply will be 430,000 m³/day in conjunctive use with the Chi-Chi Weir Project. The industrial and agricultural water supply will be well stabilized upon completion of this reservoir during this stage.

(2) Conjunctive allocation of surface water and groundwater

The whole water supply system including irrigation water and domestic water is shown in Figure 3. It includes surface water supply system and groundwater supply system. During the wet season from May to October, surface water is the main water supply, whereas during the dry season, from November to April, the water supply mainly comes from reservoir and groundwater wells. The core concept of the conjunctive use is to satisfy the water demand by conjunction of the safe yield of groundwater and the available surface water in a basin. In other words, the plan of conjunctive use of surface water and groundwater is to control the groundwater pumping rate, and supplement by the surface water supply scheme for the future sustainable use of water resources. Groundwater Management Index (GMI) is an index designed to display the groundwater storage situation in each sub zone in Chuoshui alluvial region (Figure 4). This index could supply a reference information for surface water allocation in each sub zone in order to avoid inadequate abstraction.

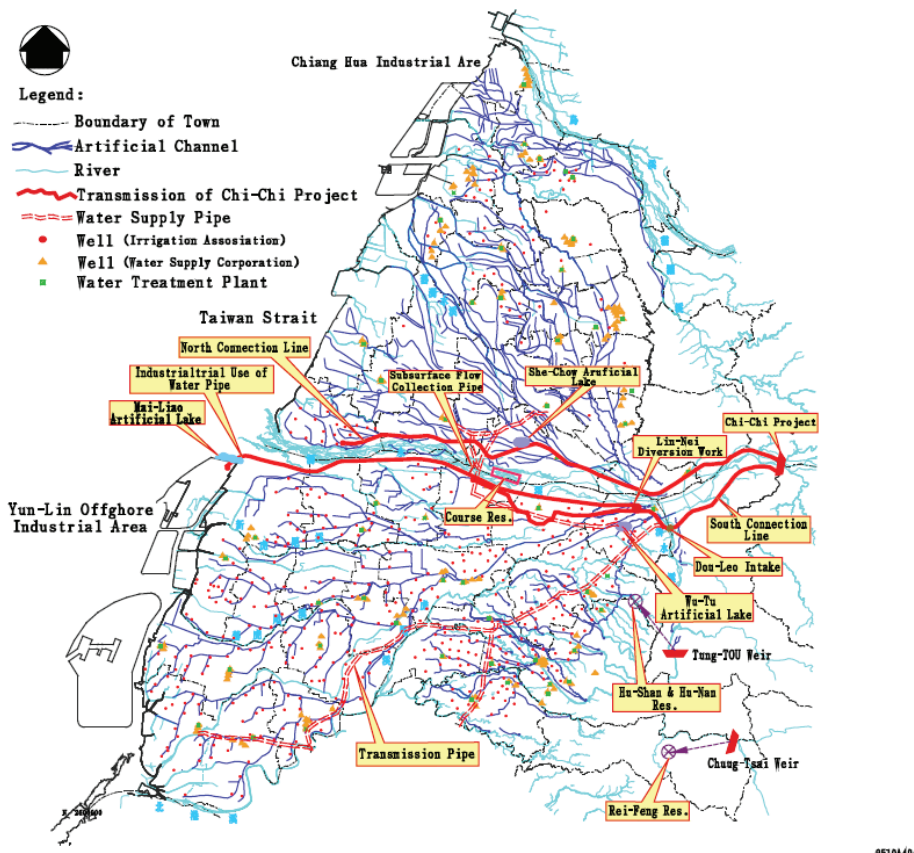


Figure 3. Water supply system in Choushui alluvial fan

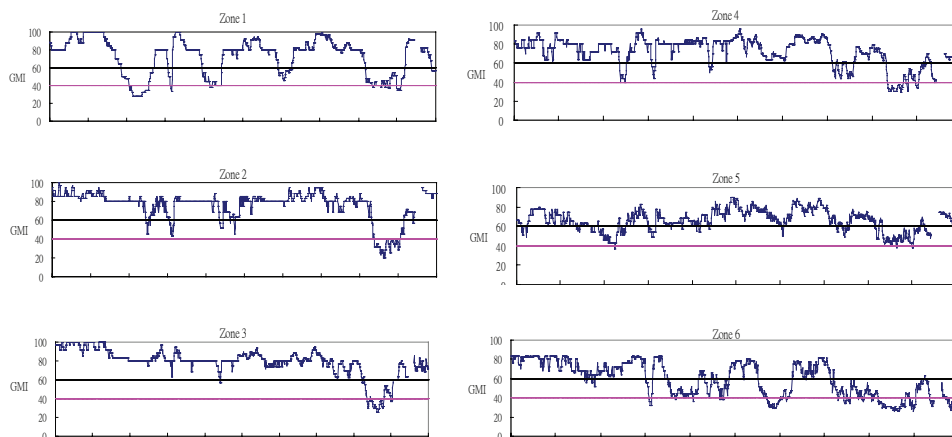


Figure 4. Groundwater management index in each sub zone

(3) Artificial recharge program

In the wet season, the residual water is diverted to the recharging pond, or recharging lake, for groundwater recharge. There are many ways to recharge groundwater, including artificial lake, river channel recharge and artificial storage recovery (ASR). Based on the geological formation of the Chuoshui alluvial Region, the artificial recharge program is to evaluate and select suitable places in the alluvial fan deposits areas for groundwater recharge. A field experiment of river channel recharge had been executed in the Chuoshui creek (Figure 5) and showed very good result.



Figure 5. Groundwater recharge in the river channel

(4) Land use adjustment

To adjust the land use scheme on the coastal zone to reduce the water resource demand is an important measure to achieve the goal for sustainable use of water resource. Recently, the development of Yunlin Offshore Industrial Estate and Changhwa Coastal Industrial Park are strongly influence the development of coastal areas of Chuoshui basin. Urbanization of coastal areas of these two counties is an inevitable trend and the result can definitely be observed in the near future. The land, originally used for agricultural purposes, will gradually be changed to urban use for industry, business and household. Urbanization of coastal areas will change the groundwater consumption pattern in Chuoshui Alluvial Region. The land, originally used for aqua-cultural purpose or as fish ponds, will gradually be changed to other purposes with higher economic profit. Hence, the large amount of groundwater withdrawal for fish growing will be reduced. Based on this development scheme, the amount of groundwater table draw down on the coastal areas will gradually be curtailed.

4. CONCLUSIONS

The utilization of groundwater has its advantages, such as providing cheap water for domestic, agricultural and industrial uses. However, serious land subsidence problem occurred in many zones due to inadequate withdrawal and excessive extraction of groundwater in these areas. During the last forty years, groundwater use in Chuoshui alluvial fan is not sustainable in several areas; this culminated in high cost to the society and future generations.

To improve groundwater management and mitigate the consequence of non-sustainable use of groundwater, several measures are installed and planned on the Chuoshui alluvial Region. The information of groundwater characteristics acquired through these measures will be transferred to the local county government, provincial government and central governmental agencies for the purpose of groundwater management.

The conjunctive use of surface water and groundwater is the best solution for increasing groundwater recharge and sustainable use of water resources. These major strategies including Surface water resource development, conjunctive allocation of surface water and groundwater, artificial recharge program, land use adjustment. These strategies are now operating in full throttle in the Chuoshui Alluvial Region Following establishment of conjunctive use of surface water and groundwater policy, groundwater use in Chuoshui alluvial fan will be sustainable in the future.

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