IMPACT OF URBAN EXPANSION ON WATER DEMAND :

The case study of Nakhonrachasima city, Lam Ta Kong Watershed[1]

Saowanee WIJITKOSUM
Assoc. Prof. Dr. Thavivongse SRIBURI
i_am_saowanee@hotmail.com

ABSTRACT

This research analyzes the urban expansion of Nakhonrachasima City, the regional center of Northeastern Thailand, in terms of water demand and water usage in the Lam Ta Kong Watershed. Lam Ta Kong Watershed has had a severe water shortage problem for a long time. Nakhonrachasima City is a small city with 172,387 persons. The results show that the urbanization effect on changing land use rapidly and increases water consumption. The trend of the water consumption rate in Nakhonrachasima increases at a high rate. Presently, water consumption in the city is 64,336 cu m/d and the water consumption rate is 358 lcd, which is high when compared with the standard water supply design of Thailand. In terms of urban expansion, the agricultural area decreases by 2.76 sq km/yr on average and may soon be spent. The population decreases while the water usage tent to increases. Moreover, the urbanization also affects water usage in the city. The water consumption level per person in Nakhonrachasima City in 2024 was 513 lcd, which was a very high rate, 1.48 times higher than the standard water supply design of Thailand. Although the current water usage of Nakhonrachasima City is only 22.16 % of the overall usage of the Lam Ta Kong Watershed and will be 35 % in the future. However, the water allocation policy in Lam Ta Kong Watershed is set the first priority for Nakhonrachasima City will cause a conflict in water usage between the urban and the agricultural sector in the watershed and these problems may encourage to social conflict later.

Key words : Urban expansion / Water demand / Nakhonrachasima City / Lam Ta Kong Watershed

---

[1] *This article is a part of doctoral dissertation, Interdisciplinary Program of Environmental Science, Graduate School, Chulalongkorn University, 2008: "Integrated Water Resource Management in Lam Ta Kong Watershed". Advisor: Professor Dr. Thavivongse Sriburi.*

1. INTRODUCTION

Urban areas will be the main users of water in the next decade. Urbanization also reflects the level of water consumption in a river basin. Urban areas are the largest users of natural resources and produce economic value for raw material and consumption, which make urban areas the nation's economic center. Therefore, urban expansion directly affects the utilization of natural resources and economic development. It should be noted that the upstream area is likely to be an agricultural community while the downstream area tends to be urban. Urban expansion affects the increase of water demand and land requirements in the river basin level. In some areas the demand for water already exceeds natural supply and a growing number of countries are expected to face water shortage in the near future (Population Information Program, 1998). The pattern of water consumption and water demand in urban areas is important issues for sustainable urban development. In Thailand, government policy also emphasizes economic growth at the expense of available natural resources, especially water resources.

Nakhonrachasima City, the growth center of the Northeast Region of Thailand is located in the downstream of Lam Ta Kong Watershed. Although the city is relatively small (37.50 sq km), water usage has a very high consumption and growth rate. Water demand in the city effects water usage in other parts of Lam Ta Kong Watershed. Lam Ta Kong Reservoir is the only water resource in this watershed and supports all five districts in Lam Ta Kong Watershed. Water demand in the watershed will expand rapidly whereas water inflow in the reservoir may be decreasing. For these reasons, the water shortage frequently occurs and causes insufficient support for present and future activities. Furthermore, this could impact on economic development and human security in the long term.

This study is focused on the expansion of Nakhonrachasima City as the cause of increased water demand for the future and its effect on water usage in other sectors in the Watershed. Moreover, in order to establish a sustainable urban development plan in the future, urban expansion in terms of changing land use is also considered. Urban expansion occurs in several dimensions, e.g. increased urban population, water consumption patterns, change of land use type that will affects spatial growth etc. Urbanization has been considered the main sector that takes advantage of natural resources, therefore the planning of urban form, urban expansion patterns, land requirements and the requirement of natural resources are necessary to planning of urban development. Unplanned communities can cause several problems especially water shortage and the lost of suburban agricultural area and green areas due to rapid urban expansion.

2. HISTORICAL OF NAKHONRACHASIMA CITY

Nakhonrachasima City (popularly known as Korat) is located in the Muang Nakhonrachasima District, approximately 260 km northeast of Bangkok, Thailand. The city lies along the banks of the Lam Ta Kong River which runs through the southwest corner of a vast low lying plain (Figure 1). Nakhonrachasima City is an ancient city situated in the Korat plateau, which is the lower part of the Northeastern plateau of Thailand. The general area is high level terrain. An average range of elevations is 130-300 meters above mean sea level (MSL).

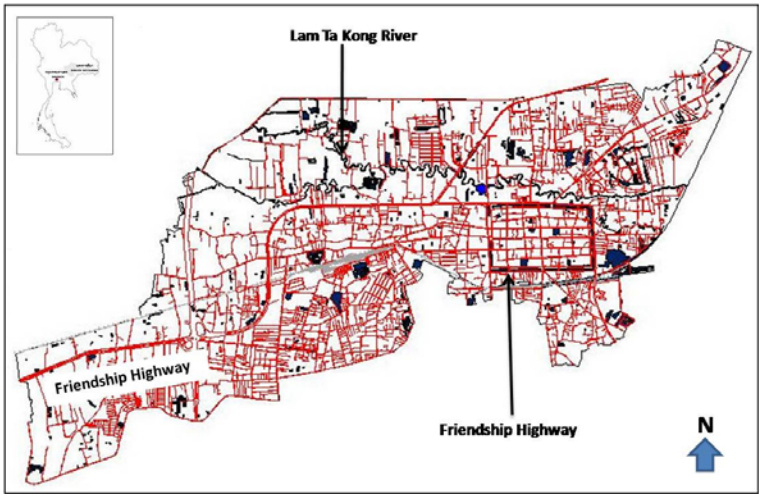

Figure 1 : Nakhonrachasima City

The city serves as the gateway to the northeastern region. As such, the city has become an important transportation hub. The city is also the center of business, education, administration and industry for the region. This center's servicing area is not limited to this province as some functions extend to the region. As a result Nakhonrachasima City has expanded rapidly.

The city is a 333 years old city and was historically important as a military center in northeastern Thailand. The city has grown rapidly and was rebuilt within ancient city walls on an area of 1.70 sq km. Most of the populations are military personnel and their extended families. During the reign of King Rama V (1868-1910) the military area expanded outside of the city wall to the south. In 1982 the area expanded from 4.40 sq km to its current area is 37.50 sq km. The city is characterized by urban sprawl, created to accommodate its large population. Nakhonrachasima City will continue as a hub of manufacturing, trade and the military and will extend its role as a major transport center.

3. CHANGE IN LAND USE AND THE URBAN GROWTH OF NAKHONRACHASIMA CITY

3.1 Changing in land use of Nakhonrachasima City

The present land use of Nakhonrachasima City comprises of residential areas, commercial buildings, government offices, and educational institutions. All are densely situated around the old city area, surrounded by an ancient moat. Furthermore, there are scattered commercial buildings and residential areas to the west along the Friendship Highway to Northeast railway station. Most of the government offices and educational institutions are scattered in the northern part of the city. Agricultural areas primarily occur in the outlying area of the city, north of the Lam Ta Kong River. Land use in Nakhonrachasima City and its proportions for 2004 are shown in Figure 2 and Figure 3.

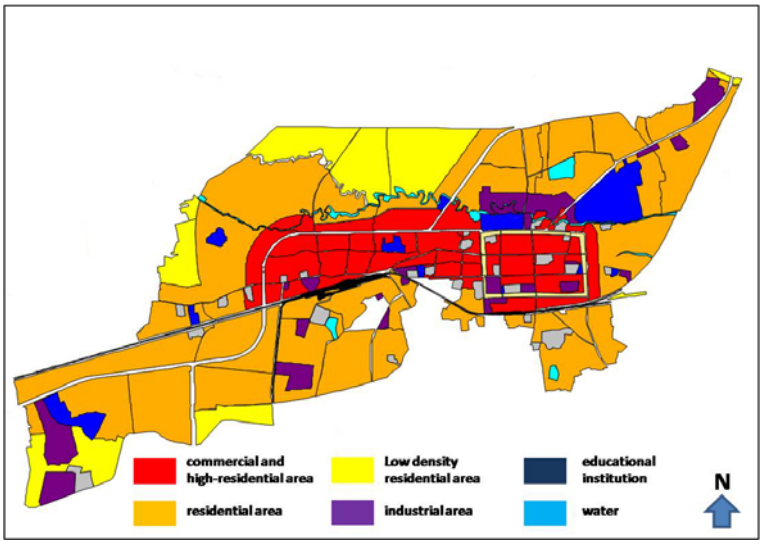

Figure 2 : Land use in Nakhonrachasima City in 2004

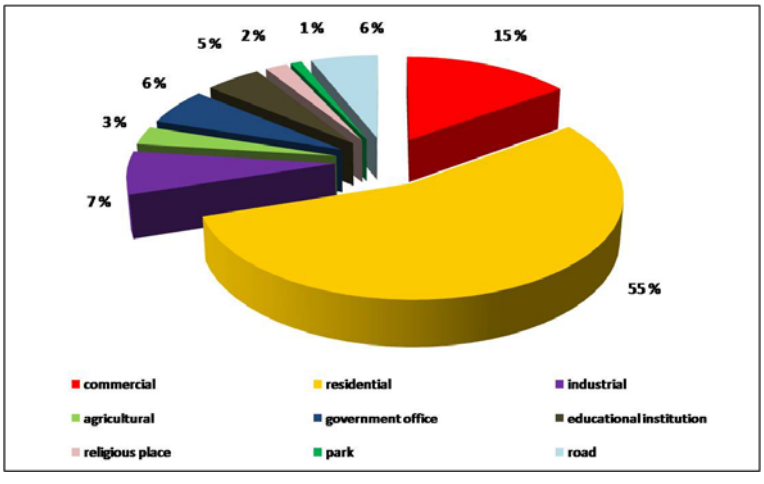

Figure 3 : Proportion of Land use in Nakhonrachasima City in 2004

Nakhonrachasima City's classified land use in 1969 was 7.35 % residential, 1.76 % commercial and 79.52 % agricultural. A survey of land use in 2004 found that this city had 55.23 % of residential areas, 15.23 % of commercial areas and 2.69 % of agricultural areas. The change of land use in Nakhonrachasima City during 1969-2004 is shown in Figure 4. The proportion of land use in Nakhonrachasima City was found to be concentrated in the city center.

Urban growth in Nakhonrachasima City has been rapid and disorganized, resulting in acute environmental deterioration. The rapidly increasing urban settlements continue to invade what previously was protected land, and land use has shifted from green areas to agricultural areas, to finally, urban.

An analysis of the change of land use found that residential areas grow rapidly and the growth of built-up areas destroys the precious remaining agricultural areas to the north part of the city. Agricultural areas decreased around 2.76 sq km/yr. Community settlements were confined

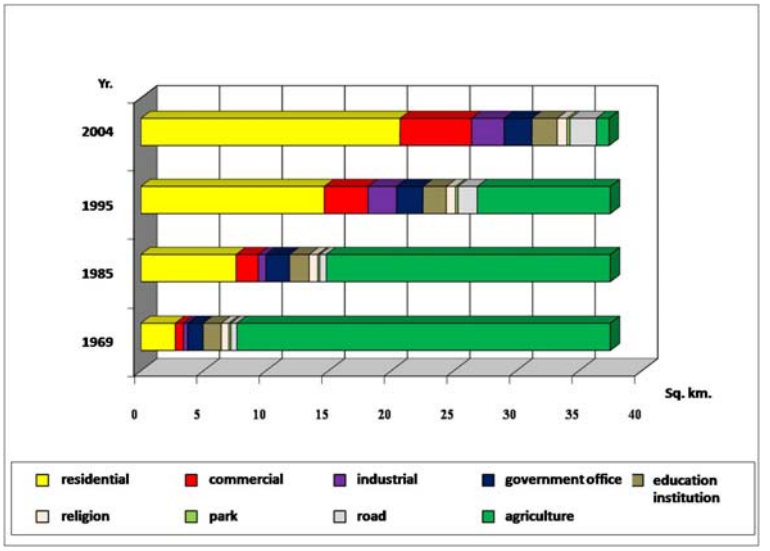

Figure 4 : Changing use of land in Nakhonrachasima City from 1969-2004

within the old city limits. In the old city and both sides of the road leading to the railway station have always been more densely populated than other areas. There is also a northern expansion along the main roads in the form of housing estates and especially since the development of the Friendship Highway. The southwestern expansion, in particular, was encouraged by a flood and the relatively short distance (5 km) from the city center. Although the urban area expands continuously, a political boundary still has the same area size as 37.50 sq km since 1982. So, the growth of built up areas expand over the political area. The expansion of residential areas to the northern part of city is the main problem for decreased agricultural areas. Urbanization has proceeded rapidly along the sides of the Friendship Highway in both northeastern and southwestern directions. As such, this expansion of Nakhonrachasima City can be understood as ribbon development.

3.2 The analysis of the pattern of urban expansion

From this study of the changing use of land and settlement, it is found that the urban expansion pattern of Nakhonrachasima City has finally changed from sector to ribbon form and urban sprawl. The changes caused by physical condition of the land and the biggest department store in the northern part of the city that is the attraction of job opportunities. Due to these reasons, even if the northern side of the city is unsuitable for settlement, the change of land use from agriculture to the residential area has finally occurred.

According to study of urban growth, the urban area might expand more than 10 sq km to support future population activities. Such an extension of urban area tends to be on the west and east side of the Friendship Highway which is the same as a past extension and an extension in the north part of the city (Figure 5). However, there are some limits on physical aspects of the area in the northern part of the city; that area still has space for future expansion by which the agricultural area will be occupied by the urbanization. In these terms, the agricultural area will be invaded by the municipality boundary and effect the use of water and land in the agricultural sector.

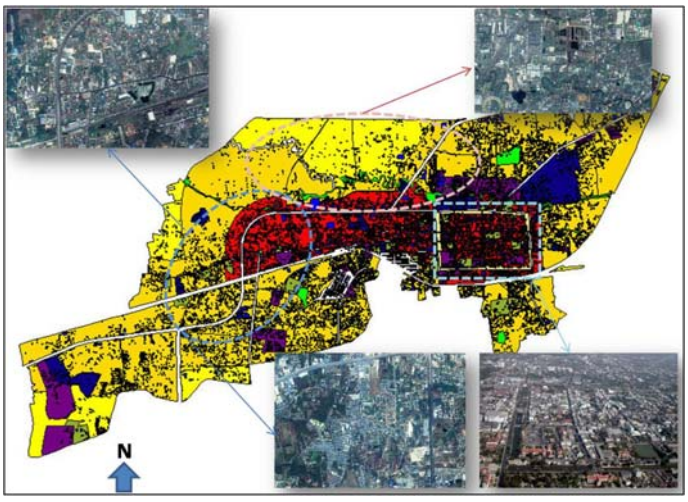

Figure 5 : Expansion of settlement in Nakhonrachasima City

Moreover, there is a possibility that the agricultural zone might disappear and this will affect food security. This area in the past was always the food source for supporting Nakhonrachasima City, which is the biggest vegetable bowl in the southern part of the North East Region. It will also destroy the old agriculture area which used to be the green belt of the city. If Nakhonrachasima City still cannot control the pattern of urban expansion effectively, the urban area will sprawl. Its effect on providing the infrastructure and damaging the environment will be similar to big cities around the worlds, such as Wisconsin.

The area of the northern part of the city is the low land of the Lam Ta Kong Watershed. The settlement in this area is trespass the Lam Ta Kong River and effects water flow and the drainage of Lam Ta Kong River. Problems from unsuitable use of land happened just as the long and heavy rains flooded this area in year 2007. It was the most critical flood of the city in the 12 years.

3.3 Changing of population in Nakhonrachasima City

The current registered population of Nakhonrachasima City is estimated to be approximately 172,387. The population of related areas (covering 6 subdivisions of Muang Nakhonrachasima District) that receive water from Nakhonrachasima Municipality Water Supply is 92,599 persons. There is about 16 % of the total population is a non-registered population and can be calculated as 27,306 persons. Population density is at 4,599 persons/sq km and the number of households at 57,427 or 1,531 households/sq km.

The study on the population's alteration in the past indicated that households have actually increased by 1.53 %/yr over the last 10 years. In the last 12 years, the population in the municipality and related areas decreased by 0.70 %/yr and 0.66 %/yr, respectively (Figure 6). Moreover, the settlement was found to increase around the boundary of the municipality while the change of the registered population in the municipality decreased continuously. This resulted in a very high density population for the municipality area and a high cost of land, especially in the inner city area (city center).

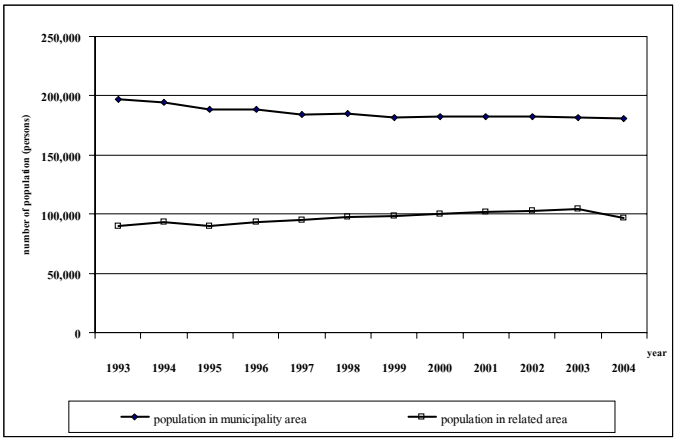

Figure 6 : Changes in the population of the municipality and related areas

The population forecasts of Nakhonrachasima City in year 2024 analyzed by population growth rate in 10 year periods will be at 282,801 persons (Figure 7). In this number, the population in municipality area is 181,045 persons (64.02 %) and the population in related area is 101,756 persons (35.98 %). The trend of population changes is the same as the past which is that the population in this area decreases every year at an average of 0.33 %/year. The population in the municipality decreases by 0.84 %/year whereas the population in related area increases by 0.79 %/year due to the highly saturated municipality area.

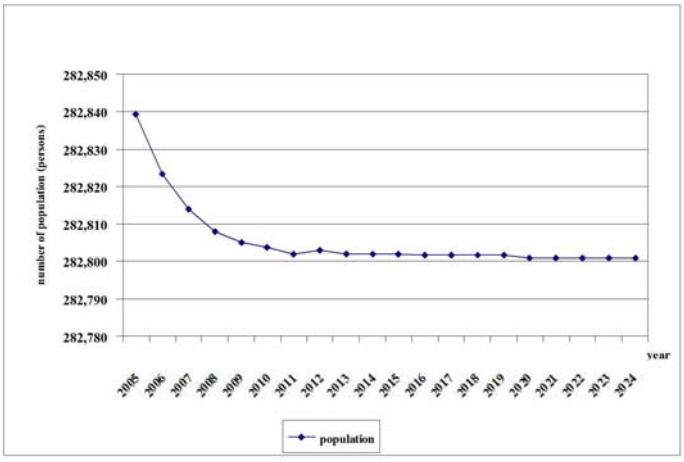

Figure 7 : The population forecast of Nakhonrachasima City

4. THE WATER SITUATION OF THE LAM TA KONG WATERSHED

4.1 The annual water inflow of the Lam Ta Kong Reservoir

Lam Ta Kong Watershed is sub-basin of Mun Basin that always faces the water shortage problems. The size of the watershed is 3,874 sq km which covers 6 districts of Nakhonrachasima Province. The origin of the Lam Ta Kong River is in Khao-Yai mountain range. The watershed can be divided into 2 areas by the Lam Ta Kong Dam: the upper area of the dam is Pak

Chong District and the lower areas are Sung Neon, Kham Talae Sor, Muang Nakhonrachasima and Chalearm Prakeate District. The Lam Ta Kong Reservoir is the only source of water to support all activities in these 5 districts. This reservoir is located at 62 kilometers before reaching the town on Friendship Highway. The capacity of the reservoir is 324.00 million cubic meters (MCM). Its primary purpose is to allocate water from the reservoir for irrigation only. But Nakhonrachasima Province has experienced rapid development in terms of the economy and urban expansion. So water in this reservoir must be supplied for agriculture, industry and consumption in five districts. Further to the water volume used for irrigation, industry and domestic needs, water in the reservoir is also used for supporting the Lam Ta Kong hydro power electricity plant.

According to study of the hydrological system of the Lam Ta Kong with the hydrological data (1970-2004), the average water asset of the downstream area is 251.00 MCM/yr and the maximum water inflow is 477.28 MCM/yr while the minimum water inflow is 86.30 MCM/yr. A chart of the water inflow to the Lam Ta Kong Reservoir during 1970-2004 is shown in Figure 8.

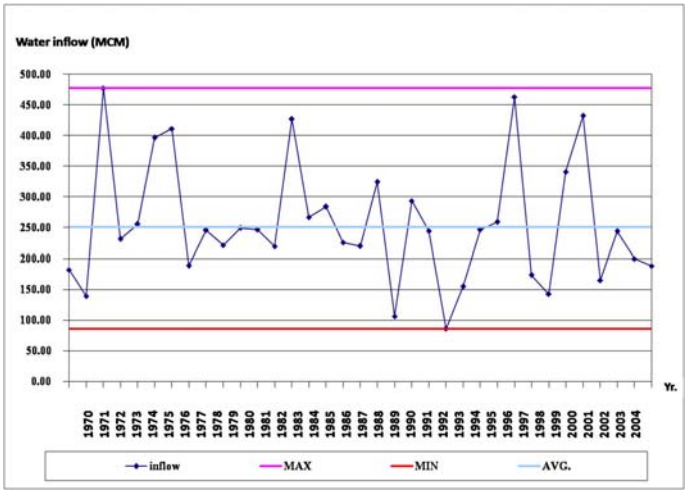

Figure 8 : Statistics of water inflow to the Lam Ta Kong Reservoir during 1970-2004

An analysis of the trend of water inflow shows that the water inflow to the Lam Ta Kong Reservoir may be decreasing while the water demand has expanded rapidly (Figure 9). The results show, the water in the reservoir frequently provides inadequate support for present and future activities. Moreover, a water shortage problem will occur in the watershed which can affect water usage and economic development in the downstream area.

Because of this situation, the local government set up a priority of water allocation for all sectors in the watershed. In the rainy season, water resources from the reservoir are impartially allocated for all activities. In this season water from the reservoir can be allocated for irrigation (204.06 sq km) under an irrigation plan; this is a basic principle demand of the agricultural sector. For the dry season, government must be set the priority for water allocation because a limitation on water in the reservoir must be employed for all activities. The first priority is the domestic consumption of Nakhonrachasima City. The second priority is the industrial sector and the third priority is the preservation of nature and the agricultural sector. The water situation of the Lam Ta Kong Watershed has shown that in the dry season the

amount of water in the Lam Ta Kong Reservoir is insufficient for supporting the first and second priority. The Lam Ta Kong Watershed has had water scarcity for a long time but now seems to more severe.

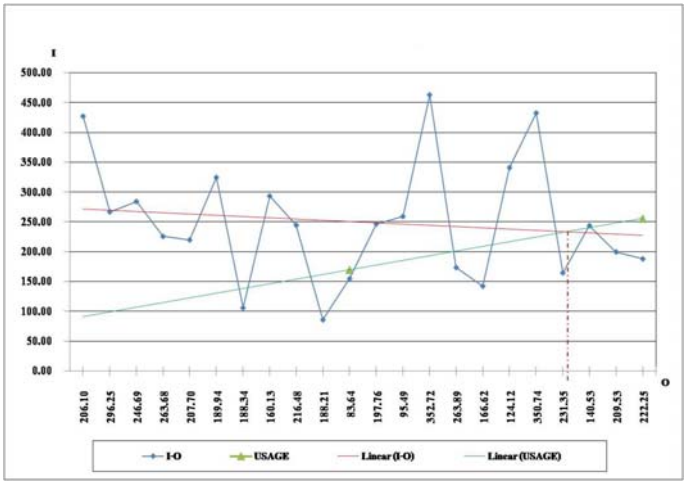

Figure 9 : Water inflow and water demand of Lam Ta Kong Watershed

4.2 Water usage in the Lam Ta Kong Watershed

The holistic study about water usage in the Lam Ta Kong Watershed divides water usage into 3 situations. In 1993, water usage is the usage in past situation. In 2004, present water usage which has critical water inflow and water usage in the future is in the year 2024. This study found that the total water usage in the year 1993 was 169.67 MCM and this can separated into 60.72 MCM/yr for the agricultural sector, 7.40 MCM/yr for the industrial sector, 44.91 MCM/yr for the domestic consumption (23.92 MCM for the domestic consumption of Nakhonrachasima City) and 56.64 MCM/yr for the preservation of nature.

In year 2004, the total water consumption demand for agriculture, industry and domestic use of five districts in the downstream area is 256.03 MCM/yr which can be separated into 133.25 MCM/yr for the agricultural use, 3.00 MCM/yr for the industrial use, 63.13 MCM/yr for the domestic use (34.70 MCM for domestic consumption of Nakhonrachasima City) and 56.64 MCM/yr for the preservation of ecosystem. This study shows that the amount water consumption demand in the present is more than the amount of the average water inflow to the reservoir (251.00 MCM), so it causes the water shortage in Lam Ta Kong Watershed. According to the calculation of the water balance of Lam Ta Kong Watershed, it found that in 2004 the amount water usage which is exceeding water budget was 33.78 MCM. Lam Ta Kong Watershed has faced serious water crisis in this decade especially in 2004 the Lam Ta Kong Watershed was noticed as the most critical drought area in Thailand. Water in the Lam Ta Kong Reservoir that can be used was only 16% from the total amount of water storage. For that reason, government decided to send military army into the area in order to regulate the water consumption along the Lam Ta Kong River since the adequate water must be supplied for the city. Moreover, the agricultural sector was not allowed to use water and these caused the conflict between urban sector and agricultural sector so government and agriculturist did.

Due to the forecasting of water demand in the Lam Ta Kong Watershed, it found that in 2024 the water demand will be 324.63 MCM and can be separated as follow; 174.49 MCM for the agricultural sector, 9.77 MCM for the industrial sector, 83.73 MCM for the domestic consumption which 59.18 MCM is for consumption of Nakhonrachasima City and 56.64 MCM for the preservation of nature. Therefore, according to the water balance, by 2024 water demand in the Lam Ta Kong Watershed will be 109.34 MCM which exceeded the water budget. The water demand in each sector of the Lam Ta Kong Watershed in 1993, 2004 and 2024 is shown in Figure 10.

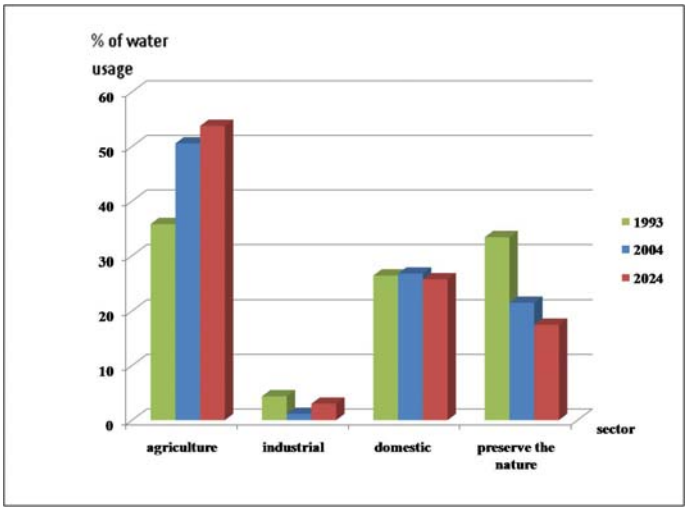

Figure 10 : The water demand in each sector of Lam Ta Kong Watershed in 1993, 2004 and 2024

Analysis of water usage in Lam Ta Kong Watershed found that the trend of water demand in the watershed is increased while the water availability is limited. Moreover, when the water demand is highest in year 2024 will cause highest shortage situation which make the conflict of water usage more aggressive through sectors. Because the water availability (water budget) is limited but all activities needs more water, that will cause the water sharing from other sectors to support their own sector. In this case, the sector that has more powerful reached to water resource will get more water like Nakhonrachasima City which has a direct pipe of raw water from the Lam Ta Kong Reservoir to the city. On the other hand, the water allocation policy in the watershed is set the first priority for domestic consumption of Nakhonrachasima City. When water budget in the Lam Ta Kong Reservoir has the water crisis, the agricultural sector was not allowed to use the water from the Lam Ta Kong River like the situation in year 2004. So the expansion of water demand of Nakhonrachasima City will affect the water usage in the other sector in the Lam Ta Kong Watershed.

5. ANALYSIS OF WATER CONSUMPTION AND URBAN EXPANSION OF NAKHONRACHASIMA CITY

5.1 The pattern of water consumption in Nakhonrachasima City

Water supply system of Nakhonrachasima City is under the supervision of The Office of Nakhonrachasima Municipality Water Supply, was started in 1934, which the supply area of 37.50 sq km. After twenty years, the water supply area was expanded to the outside of the municipality area. In 1952, the extended area from 37.50 sq km to its current area is 43.50 sq km. Raw water from Lam Ta Kong Reservoir is transmitted through closed conduit, which is 53 km length into the reservoir of the water treatment plant at Ban Makham Thao. Another route is delivered through Lam Ta Kong River into storage of the water treatment plant in municipality area.

The water consumption of Nakhonrachasima City in 1985 was 33,519.53 cu m/d and the numbers of water meters were 13,073 meters. Water consumption statistics was summarized in the Figure 11. The increment rate of water requirement per year and the number of water meters, using the data recorded of the year 1985 to 2004, indicated that the level of water consumption was actually increased by 4.98 %/yr and the numbers of water meters were increased by 12.59 %/yr.

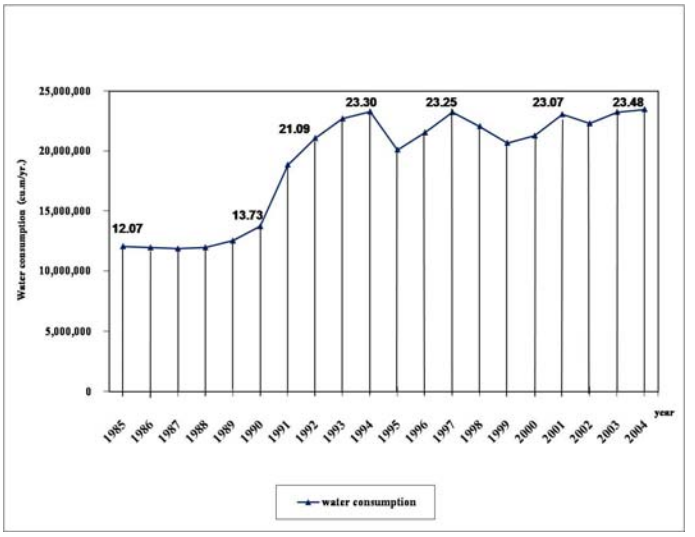

Figure 11 : The statistic of water consumption of Nakhonrachasima City during 1985-2004

In 2004, based on the water supply data mentioned earlier, the existing water demand in Nakhonrachasima City is indicated that, the water consumption rate was 64,336 cu m/d and the numbers of water meters were 546,304 meters. Allocation of water supply for the municipality area was 17,639,437 cu m/yr (81.38 % of total water consumption), the government offices was 2,131,567 cu m/yr (11.19 %) and the related area was 1,417,404 cu m/yr (7.44 %). The allocation of water supply in Nakhonrachasima City is shown in Figure 12.

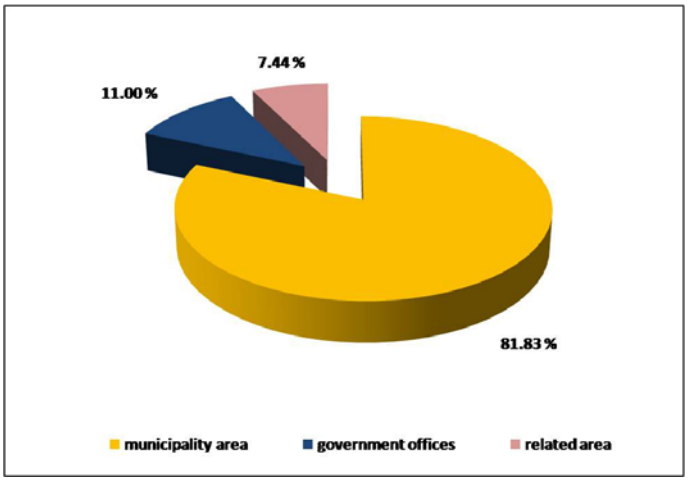

Figure 12 : The allocation of water supply in Nakhonrachasima City in 2004

Residential is the largest user of water consumption (approximately 55 % of total water consumption) follow by educational institutions, government offices and commercial, respectively. Water demand in Nakhonrachasima City is approximately 84 % of total domestic consumption of the Lam Ta Kong Watershed.

Urbanization increases water use dramatically. Water consumption level per person of Nakhonrachasima City in 1993 was 331 liters/capita/day (lcd) compared with 358 lcd in 2004. The increment rate of water consumption/person/day, using the data recorded of the year 1993 to 2004, indicated that the level of water consumption per person was actually increased by 0.75 %/yr. (Table 1).

Year	N0. of Population	Water Demand	
	(persons)	(MCM./yr.)	(ldc.)
1993	197,052	22,705,808	331.07
1994	194,175	23,300,667	360.90
1995	188,374	20,115,800	404.97
1996	188,519	21,556,500	402.37
1997	184,261	23,245,500	401.12
1998	184,827	22,077,000	396.43
1999	181,501	20,689,900	381.78
2000	182,272	21,290,200	370.44
2001	182,550	23,067,300	384.97
2002	182,030	22,309,200	351.79
2003	181,294	23,263,200	354.73
2004	180,523	23,482,700	358.43

Table 1 : The level of water consumption per person of Nakhonrachasima City during 1993-2004

Analysis the change of water consumption level found that the trend of water consumption level increase with a high rate. The atomizing national family is pushing up demand – average per capita consumption moves from 331 to 358 lcd as household size fall from 4 to 3 persons per household.

5.2 Water consumption and land use analysis

The office of Nakhonrachasima Municipality Water Supply divided the total area (43.50 sq km) in 20 blocks, the area of water allocation of Nakhonrachasima City is illustrated in Figure 13, this indicate that the block 1 to block 15 and block 17 are the area in municipality, block 16 is the block of government offices and block 18 to block 20 are relative area around the boundary of the municipality area.

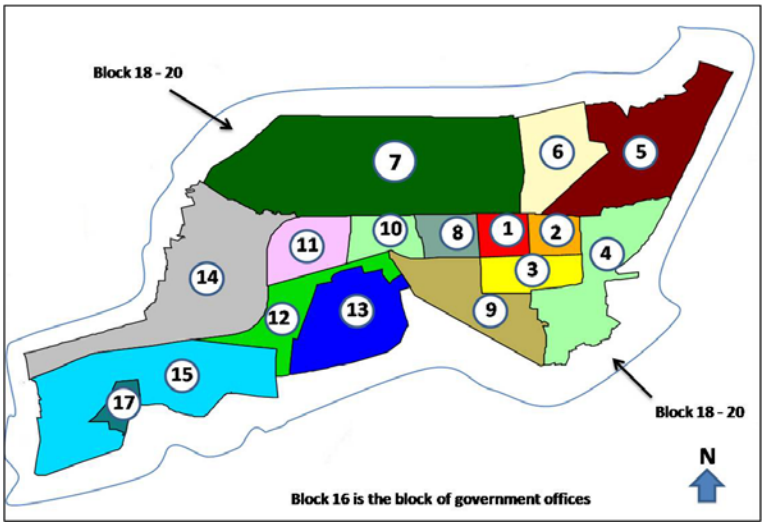

Figure 13 : The area of water allocation of Nakhonrachasima City

According to the area of water allocation analysis by Remote Sensing technique, GIS technique and field survey in 2004, it was found that the block 1, block 2 and block 3 are the Center Business District (CBD) of Nakhonrachasima City that is the old city area or the center city. This area have always been heavier populations than other areas which high density of residential and commercial building. The block 7 is the new sub-business center of the city which growth of built-up areas destroys the precious remaining the agricultural area and open space to the north part of the city. These expansion areas are in the form of housing estates after the development of the largest supermarket of the Northeast Region (The Mall Supercenter). Block 15 is the new sub-residential center of the city (Figure 14). Block 16 is block of the government offices which are hospitals, schools, universities, a prison and the government offices in the regional level. Block 18, block 19 and block 20 are the relative area around the boundary of the municipality area. These areas are the low density of commercial and residential area.

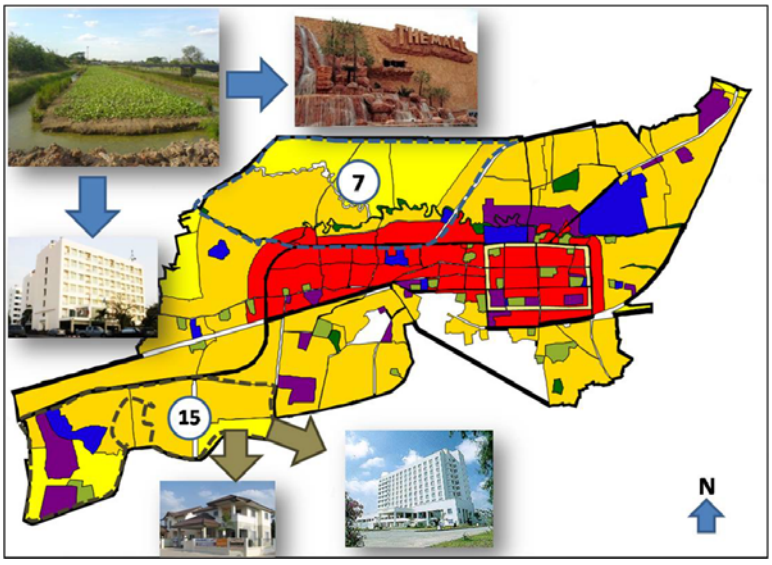

Figure 14 : Changing of land use of Nakhonrachasima City

5.3 Water demand and population analysis

The growth rate of water demand has been projected for 20 years by using the data recorded during 1984-2004 from the office of Nakhonrachasima Municipality Water Supply. Water consumption growth rate is 4.73 %/yr, analyze by average consumption growth rate with in 20 year periods. Water demand in the next two decades will increase up to 162,135 cu m/d or 59.18 MCM/yr. The increment rate of water requirement is 7.03 % annually. The projected water demand during 2005-2024 is represented in Figure 15. The allocation of water demand is 44.45 MCM for municipality area, 3.57 MCM for government offices and 5.37 MCM for related area. The numbers of water meters are 492,852 meters.

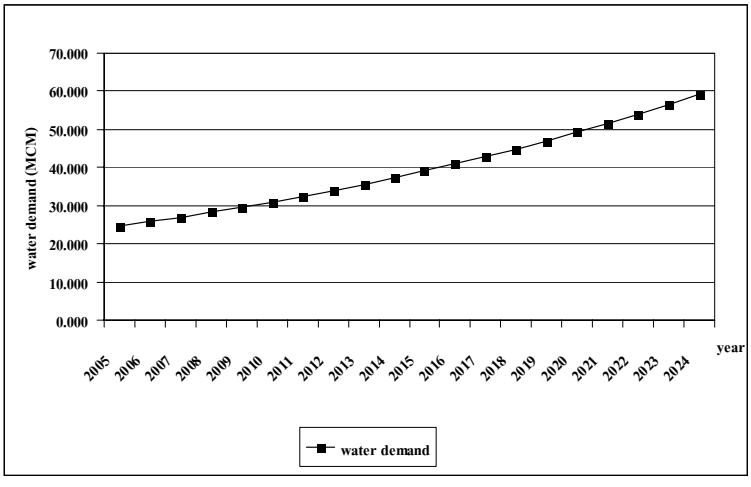

Figure 15 : The projected water demand of Nakhonrachasima City during 2005-2024

Analysis the change of water demand and the numbers of population of Nakhonrachasima City found that the trend of water demand is increasing while the numbers of population change decrease (Figure 16). Water consumption level per person of Nakhonrachasima City in 2024 was 513 liters/capita/day compared with 358 liters/capita/day in 2004. When comparing this number with the standard for water supply design of Thailand, 250 liters/capita/day, it discovered that, the water consumption rate of Nakhonrachasima City was much higher than the standard about 1.48 times. This number indicates that, Nakhonrachasima City has very high rate of water consumption in Thailand.

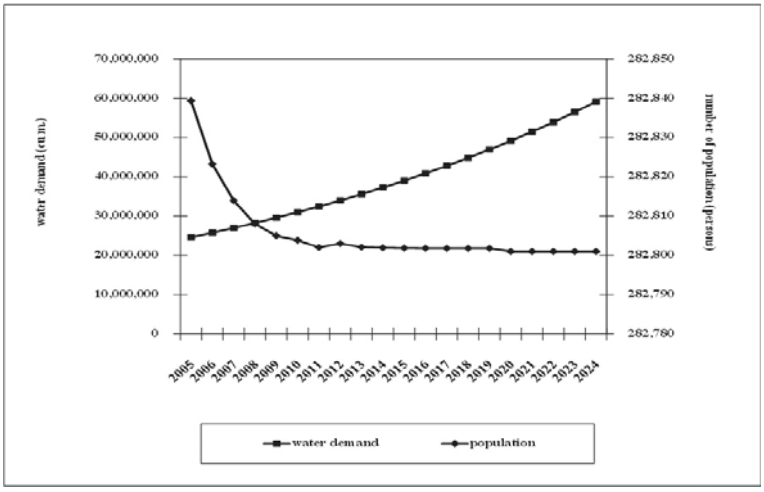

Figure 16 : The change of water demand and the numbers of population of Nakhonrachasima City

According to the analysis of the water consumption rate of people in Nakhonrachasima City and water availability, it's found that the trend of water availability (water inflow in Lam Ta Kong Reservoir) is decreasing whereas the water consumption rate is increasing continuously. Although Nakhonrachasima City still doesn't show the water crisis due to the policy of water allocation in Lam Ta Kong Watershed that set the first priority for water consumption of Nakhonrachasima City. However, this water consumption pattern will effect on the other user in the watershed especially agricultural sector that is the poor. Moreover, if population in Nakhonrachasima City still has the water consumption pattern as it was, this city will certainly face the water problem that will effect on urban development, human security, WHO-Healthy City Statement (The World Health Organization (WHO) funded Healthy City Concept was introduces in Korat in 1998 under the direction of the Thai Department of Health (DOH)). Furthermore, this pattern will disturb other usage in Lam Ta Kong Watershed. For that reason, local government should specify acceptable rate of water consumption for initial water demand management of Nakhonrachasima City and setup the measures for reduce the water consumption rate in order to avoid the water crisis. Therefore stakeholder should prepare the measures to defense with this crisis. In order to avoid the obstacle to urban development, the developed pattern should concern about available water resource for sustainable development. High efficiency urban planning and integrated water resource management are urgently required in order to prevent the water crisis.

6. CONCLUSION

Nakhonrachasima City has been considered as the center of prosperity of Northeast Region in Thailand due to the potential of the site and governmental policies. For that reason, Nakhonrachasima City expands rapidly. According to the study, it found that Nakhonrachasima City has a high rate of urbanization which effect on increasing on water consumption of population of Nakhonrachasima City as well as decreasing average annual inflow to Lam Ta Kong Reservoir. Due to the result of the study, it can conclude that;

1) The expansion of water demand in each sector in Lam Ta Kong Watershed while the water availability is limited. Moreover, the trend of water inflow to Lam Ta Kong Reservoir which is the only source of water for support all activities in downstream area are decreasing. In this situation, expansion of water demand of Nakhonrachasima City will effect on water usage in the watershed level.

2) Although, the proportion of water usage of Nakhonrachasima City is very small when compared to the agricultural sector but the water allocation policy and high growth rate of water consumption actually will make conflict on water usage between urban and agricultural sector in the future and those problems may encourage to social conflict later. Moreover, this policy will cause the migration of labor from rural to urban which will certainly be the problem for the urban sector soon.

3) The urbanization affects the water usage pattern and the living standard of the people, very high and continuous increase water consumption rate.

4) Urbanization of Nakhonrachasima City effects on changing of land use in the city that is transferred from agriculture to residential area. In near future, agriculture area could be reduced and disappeared. Unless urban area has been considered as the resource consumer, it also is the biggest waste producer that passes on the environment. The urbanization takes an impact on spatial use of agricultural sector. Moreover, agricultural areas where use to be the boundary of urban expansion has been destroyed therefore build-up area of Nakhonrachasima City will connect to suburban and will cause the un-bounded city problem. Changing of land use from agricultural to residential area affect the increasing of water demand. Together, expansion of urban settlement to the north part of the city is unsuitable use of land. It also flooded the north part of the city especially the critical flood in year 2007.

5) Although, the water shortage problem in the watershed is still clear but Nakhonrachasima people are not concerned about this problem. Since Nakhonrachasima City has more power than other water users in the watershed to reach the water resource. By powerful budget and supporting government policy, Nakhonrachasima people are not aware of the water shortage problem and water situation in the watershed, the effects and suffering are clearly impacted on the poor agricultural sector.

7. RECOMMENDATIONS

The following recommendations have been suggested for water management in urban area.

- **Effective of water usage:** This solution is an approach that aims to conserve water and less water use, managing consumptive demand itself to postpone or avoid the need to develop new sources. According to the trend of water demand and the pattern of water consumption rate of population in Nakhonrachasima City, it's found that the control of water demand of population is very imperative for the city. Local government should set up the measures for reduce the water consumption rate of people in the city in order to avoid the water crisis. Less water use may involve a wide range through various strategies which include: behavior change that ensures long-term sustainability of water resource**;** technologies that increase the efficiency of water use; a communication strategy, including a community education campaign; and enabling policies. In addition local government should have a policy and measure for control of water consumption of Nakhonrachasima City to avoid endless of new water resource construction that is the unsustainable solution of water resource management of this city.

- **More water storage:** The current source of water is only Lam Ta Kong Reservoir. This solution is emphasis on development of new sources of water. Finding new water supplies to support the growing of water consumption demand can be considered as the solution of water shortage problem**.** But, the cost of developing new sources or expanding existing sources is getting higher and higher as the most accessible water resources have already been tapped. The real cost of water per cubic meter in second and third generation projects in some cities have doubled between a first and the second project and then doubled again between the second and third. At the same time, governments are becoming reluctant to pay the rising investment costs as long as utilities are unable to meet these costs from user charges.

- **Pricing structure reform:** Low water prices are a known offender within increased water consumption. Appropriate pricing of water should be used for controlling demand for water. When municipal water users will pay realistic water prices, utilities will be able to maintain these systems, minimize losses and maximize the quality and the level of service.

- **Land use plan implementation:** Urban growth and economic development usually require more water resources for economic development and resident. Analysis of potential of water resource asset is very important for planning of spatial and economic development. Due to the past economic development of Thailand, there was not concern about the potential of water resource asset and available water resource therefore it causes the water shortage problem. This problem is an obstacle of sustainable urban development so the trend of spatial development in future should be considered the potential of water resource as the high priority factor and the development should be planed and analyzed for urban level and river-basin level which has the same water asset by using the integrated analysis.

ACKNOWLEDGEMENT

This research was funded by the 90 th Anniversary of Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) and Environmental Research Institute, Chulalongkorn University. The author is grateful for the data support given by central offices and local offices especially The Office of Nakhonrachasima Municipality. And special thanks for Nakhonrachasima people for information interview.

REFERENCE

Angel, S., Sheppard, S.C., and Civco, D.L. (2005) The Dynamic of Global Urban Expansion *Transport and Urban Development Department,* The World Bank, Washinton D.C.

Bhatia and Falkenmark. (1993) *Water Policies and Agriculture,* The State of Food and Agriculture. Rome, Food and Agriculture Organization of the United Nations.

Chappells, H., Klintman, M., Linden, A., Shove, E., Spaargaren, G., and Van Vliet, B. (2000) Domestic Consumption, *Utility Services and the Environment* Final Domus report, Wagenigen: Universities of Lancaster Wageninge and Lund, 1399p.

Department of Town & Country Planning. (1996) *Nakhonrachasima Urban Paln 2nd* Improvement. Ministry of interior (Bangkok, Thailand)

Department of mineral resources. (2004) *Geology Characteristic of Nakhonrachasima Province* (Bangkok, Thailand, Mimeographed).

Jensen, J. O. (2001) *Lifes Style, Dwelling and Consumption* Ph. D Thesis, Statens Byggeforskningsinstitit og Aalborg Universitet (Denmark, in Danish, English Summary).

Keller, A., Keller, J., and Seekler, D. (1996) *Integrated Water Resource System: Theory and Policy Implications. Research Report 3* Int. Water Management Institute (Columbo, Sri Lanka).

Office of Commercial Affairs, Nakhonrachasima. (2005) *The Report of Economic State of Nakhonrachasima Province.* Nakhonrachasima Province, Thailand, (Unpublished Manuscript).

Office of The National Economic and Social Development Board. (1997) *National Economic and Social Development Plan 4 (1997-1981),* Bangkok, Thailand. 356p.

Office of The National Economic and Social Development Board. (1981) *National Economic and Social Development Plan 5 (1982-1986),* Bangkok, Thailand. 433p.

Office of The National Economic and Social Development Board. (1987), *National Economic and Social Development Plan 6 (1987-1991)* Bangkok, Thailand. 452p.

Office of The National Economic and Social Development Board. (1992) *National Economic and Social Development Plan 7 (1992-1996)*, Bangkok, Thailand. 253p.

Office of The National Economic and Social Development Board. (1996) *National Economic and Social Development Plan 8 (1997-2001)*, Bangkok, Thailand. 187p.

Office of The National Economic and Social Development Board. (2002) *National Economic and Social Development Plan 9 (2002-2006)*, Bangkok, Thailand. 243p.

Office of The National Economic and Social Development Board. (2006) *National Economic and Social Development Plan 10 (2007-2010)*, Bangkok, Thailand. 185p.

Population Information Program. (1998) *Population Reports: Solutions for a Water-Short World. Series M No. 14. Center for Communication Programs*, The Johns Hopkins School of Public Health (USA)

Miranda, L. and Hordijk, M. (1998) *Let's Build Cities for Life – the National Campaign of Local Agenda 21 in Peru*, Environment and Urbanization, V 10, No. 2, 69-102.

Schilling, K. E. and Porter, E. (1990) *Urban Water Infrastructure. Kluwer Acadamic Publishers*, London, UK, 305p.

Swedish National Committee for Agenda 21. (1997) *Agenda 21 in Sweden*, Report from the Committee, Stockholm, Sweden.

Nakhonrachasima Provincial Operation Center. (1996) *Master Plan and Implementation Plan of Environmental Management for Water Resource Revival in Lam Ta Kong Watershed*, Nakhonrachasima Province, (Thailand).

Nakhonrachasima Provincial Operation Center. (2004) *Nakhonrachasima City, Nakhonrachasima Province*, Thailand. Nakhonrachasima. (Mimeographed).

Nakhonrachasima Provincial Statistical Office. (1995) *Statistical report of Nakhonrachasima Province*, National Statistical Office, Bangkok, Thailand. 138p.

Srinivas, H., (n.d.) *An Integrated Urban water Strategy*, http://www.grdc.org/uem/water/urban-water.html.

Surender, K. (2004) *Analyzing Industrial Water Demand in India: An Input Distance Function Approach*, National Institute of Public Finance and Public Working Paper No. 12/2004.

TDRI. (1990) *Water Shortage; Demand to Expand Supply* The 1900 TDRI Year-End Conference, Thailand Development Research Institute Foundation, Bangkok, Thailand. 96 p.

Thongplew Kongjun. (2003) *Multicritiria Decision Making for Multireservoir Water Allocation: A Case Study of Upper Mun Basin*, Doctor of Engineering (Irrigation Engineering). Major Field: Irrigation Engineering, Department of Irrigation Engineering, Kasetsart University. Bangkok, Thailand.

Troy, P. and Holloway, D. (2004) *The Use of Residential Water Consumption as an Urban Planning Tool: A Pilot Study in Adelaide* Journal of Environmental Planning and Management, Volume 47, No. 1, 97-114.

United Nation Asian Development Institution. (1997) *Regional Development of Nakhonrachasima- A Comprehensive Planning Study,* Volume 1, Book 1, Regional Analysis. 226p.

World Health Organization Regional Office for South-East Asia. (2000) *Report and Documentation of the Technical Discussions Held in Conjunction with the 37th Meeting of CCPDM,* New Delhi, 31 August 2000