

Does Transferring Water Present an Efficient Way of Solving Water Scarcity in China's Northeast?

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## Abstract

Faced by a severe water scarcity, in 2002 the Chinese government initiated the large-scale South-North Water Diversion Project (SNWDP), which was estimated at 62 billion U.S. dollars in cost and which presumably would solve China's northeast water scarcity problem. The Eastern Route was finished in December 2013, but the Central and Western routes of the project are yet to be finished. There is not yet sufficient evidence to determine whether the project is going to be successful in dealing with water scarcity of Northeast. Among major reasons for China's acute water scarcity is inefficient water use in agriculture, which wastes 36 percent of all water in China every year. In this research I utilize a Case Study method and look at five existing small -scale water transfer projects: Case 1: Water Transfer between Yiwu and Dongyang in Jinhua river; Case 2: Water Transfer from Zhangye City, Gansu province, to Heihe river; Case 3: Water Transfers in Ningxia Hui Autonomous Region; Case 4: Water Transfers in Inner Mongolia; and Case 5: Water transfers between Hebei and Beijing. Using these data I analyze whether the affected areas meet the UN thresholds of water scarcity ( $1000\text{m}^3$  per person/year) and water stress ( $1700\text{m}^3$ ). The research contributes to the understanding of water scarcity in China and provides an academic analysis that argues in favor of the SNWDP as a partial solution in dealing with China's water scarcity. I propose an argument supporting water transfer as a potential partial solution to the water scarcity.

**Key words:** Water scarcity, water transfer, water rights, the SNWDP, water scarcity threshold, water stress, Yiwu and Dongyang, 2002 water law, China's northeast water availability.

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## **Chapter 1: INTRODUCTION**

The 20<sup>th</sup> century was a time of a tremendous economic growth throughout the planet. The engine of that growth was predominately energy in the form of oil and other fossil fuels. The “Black gold” led to numerous wars and it continues to be a crucial determinant of the geopolitical power of developed and developing countries. Due to the higher standards of living the demand for water is also ever increasing. The irreplaceable significance of energy in 21<sup>st</sup> century will be further enhanced due to manmade water scarcity predicaments that are very likely to lead to either enhanced collaboration between countries or an increase of bloody wars. In this research I focus on China, which with its massive population is becoming the biggest producer and consumer of goods in the world. China’s economy is growing rapidly, which enhances its position as a geopolitical player, however its development is in danger because of severe water scarcity.

China established itself as an important geopolitical player on October 25<sup>th</sup> 1971 as the United Nations General Assembly passed Resolution 2758, which recognized the People’s Republic of China is the only lawful representative of China to the United Nations. Since then political importance of China has continued increasing. China is one of the 5 permanent members of the UN Security Council, which includes the United States of America, the United Kingdom, the Russian Federation and France. Being a permanent member of the Security Council provides China with the right of veto, which in itself presents a powerful leverage in projecting political power. At the end of the 1970s Deng Xiaoping came to power and initiated a new economical reform which

allowed capitalism to enter Chinese society while preserving communism as the ruling political ideology. After several decades of economic reforms China joined the World Trade Organization (WTO) in 2001 and after a decade of membership has achieved tremendous growth which is enabling hundreds of millions of its people to rise from poverty. China has become a major trade partner of the two world leading economies, that of the USA and Japan, while building up the trade cooperation with rising Russia.

The peaceful rise of China requires resources and among those are energy and water. Industrialization of 20<sup>th</sup> Century required machine power fueled by petroleum and coal. The contemporary world, characterized by the information revolution, almost universal access to the information, unprecedented interconnectivity and an ever-increasing number of devices, demands electricity. In China's case, coal has been the major source for generating electricity, but extracting coal requires water, another source that might become the transparent gold of the 21<sup>st</sup> century due to its increasing scarcity. Education, technology, cultural richness are important for a country that wants to play an important geopolitical role in the globalized world, but the train that would take a country into the prosperous future needs to be powered by the fuel of the 21<sup>st</sup> century, which is believed to be water and electricity (Johnston et al 2005).

China's numerous middle class expects to have conveniences, a certain unsustainable level of consumption. Swimming pools, household bathtubs, jacuzzis, private lawns, fresh vegetables, frequent meat in the diet, all of these lead to the increased stress on China's water resources. The country's renewable water resources amount to about 2,841 km<sup>3</sup> which is the world's 6th largest supply, however due to the high population per capita, availability is only 2,156m<sup>3</sup> (World Bank 2009). To put this in perspective, the

common threshold for water scarcity set by the UN is  $1000\text{m}^3/\text{year}$  per capita which means that on average per capita water availability is 115% above the scarcity level. However, as it is often the case, the capitals attract peripheral populations, which leads to the overpopulation of the area. As a result of overpopulation, China's capital, Beijing, has only about  $100\text{m}^3$  of water a year per capita, which forces it to make emergency water borrowing from surrounding areas (Wang et al 2005). This water borrowing (water transfer) within one water scarce area in itself may present an additional water scarcity problem, unless there is enough water resources to supply the entire region. Due to the uneven special and temporal distribution of water the Hai River Basin in northeast China accommodates a population of 120 million people who have only  $300\text{m}^3$  of water a year per capita (Xie 2009). Northeast China is the most populated, industrialized and water scarce region of China. Striving to secure strategically important part of the country, Chinese officials decided to deal with the big problem of the 21<sup>st</sup> Century via massive project.

It seems like China has an inherited passion for a massive projects, like the Chinese Great Wall and Grand Canal, or Three Gorges Dam. In the beginning of this century Chinese officials decided to take on attempt another challenging project, the South - North Water Diversion Project (SNWDP). The SNWDP is estimated at 62 billion U.S. dollars and the governments hopes it will solve China's northeast water scarcity problem. The SNWDP consists of three routes: the Eastern route, the Central route, and the Western route. It covers 3000 kilometers of canals and tunnels and crosses several Yangtze river basins making it complex. (Freeman, Carla 2011). More specifically, Chinese engineers hope to transfer 13 billion  $\text{m}^3$  of water through the Central line, and

around 8 billion m<sup>3</sup> via West route, while the Eastern line will have a capacity of transferring 14.8 billion m<sup>3</sup> (Keith et al 2013). The project is yet to be finished and it is unclear whether the project can alleviate water scarcity in the northeast overtime.

While the SNWDP is under construction, smaller water transfer projects across China could provide evidence on the efficiency of water transfer. In this research I am looking at already existing small scale projects hoping to extrapolate the conclusions of the five case studies of China's local water diversion projects on major project of Chinese government such as the SNWDP. I am going to utilize Case Study method and look at already existing small scale projects in five different provinces (three different Chinese regions), that took place since 2002 when the water right law was introduced, hoping to determine if water transfer in general and the SNWDP in particular could be the potential successful solution to China's water scarcity.

I measure success in terms of water availability, I am using 1000m<sup>3</sup>/year of water per person as threshold of water scarcity. If the small water transfer projects have increased water availability, then they demonstrate increased efficiency and success. I provide the actual numbers of water availability before and years after the implementation of the project. Basically, if I see that a water transfer project between Yiwu and Dongyang (southeast) brought the water availability in Yiwu city to a significantly higher level, I would also want to see if the positive effect of the water transfer still exists 12 years after the first transfer. In the very same way, I look at total of five cases and produce two sets of graphs indicating water availability in the chosen provinces.

Therefore, this study presents new sets of data on water transferring that suggests that it is an efficient partial solution/mitigating measure to the water scarcity in northern

China. Based on the available information **my hypothesis that water transfer is an efficient system in resolving/mitigating water scarcity in the regions it is applied.**

The purpose of this thesis is to contribute to the understanding of water scarcity in China and provide academic data that would predict what role does the SNWDP play in dealing with China's northeast water scarcity.

## **Chapter 2: Literature review**

China's water scarcity becomes an increasingly important issue due to the rapid population growth of already the most populated country in the world. As of now China's population exceeds 1.3 billion people and more than 40% of them work and live in the northeast China, which has four times less water per capita than China's South (Anderson et al 2013). The threshold for water scarcity commonly defined by the UN is 1, 000 m<sup>3</sup>/year per capita, but China's northeast has less than 700m<sup>3</sup>/year per capita with some places having less than 250m<sup>3</sup>/year (World Bank 2009). According to the World Bank 300 million people, majority of whom lives in rural areas of China's northeast, still do not have an access to clean tap water. Rural Chinese often have to procure water from the contaminated or drying wells that are far away from the households while urban Chinese also have to boil the tap water. I assume that solving water scarcity issue is going to be particularly difficult for the Chinese government as water availability in the northeast China is decreasing while its population is continually growing.

The serious water scarcity of northeast China is exacerbated by the environmental health problems and dangers coming from the usage of unsafe water. Unsafe drinking water and poor sanitation lead to infectious diseases such as diarrhea, hepatitis A, typhoid and effect more than 40 % (or 296 million) of China's rural residents and 6.2 % (46 millions) of the urban dwellers (Zhang et al 2010). Zhang's data show a striking difference between urban and rural population that are effected by the unsafe water. This shows that the lives of poor are in much bigger danger than those of an urban upper class due to the availability of clean and safe water. The biggest problem for the urban

population is the industrial pollution of water, which causes one million deaths a year from the digestive system cancer (WHO-UNDP 2001).

Lack of safe drinking water causes serious economic losses. Dealing with the lack of clean water is a costly issue, but Chinese government should keep in mind that the economic cost of water crises and associated with it diseases worth 2.3% of country's GDP (World Bank 2009). In the beginning of the 21<sup>st</sup> century China is puzzled with questions on how to reduce rural poverty, secure the nation's food and continue to improve its economy. All of these questions are directly correlated with the water scarcity, therefore China's number one priority should be the eradication of unsafe water issue, which could be partially achieved by the improvement of water use efficiency.

#### **Main causes of China's water scarcity**

Water quality deterioration in China has been recognized as one of the most serious environmental problem that the country is facing. The rapid growth of Chinese industries is often accompanied by bad environmental practices that include uncontrollable water pollution and inefficient use of fresh water resources. A Chinese scientist Jian Xie claims that lack of environmental regulations have led to contamination of two thirds of China's major lakes and reservoirs with litter and toxic chemicals (Xie 2009). As a result, poor quality water cannot be used for productive purposes and rural areas have the least access to the safe drinkable water (Tortajada and Shahnila 2011). Therefore, China's drinking water scarcity is partially caused by the industrial pollution.

Climate change is another contributor to the China's northeast water scarcity. Over the past century the country experienced a temperature rise equivalent in 0.5-0.8 degrees Celsius. China will experience further temperature rise of 3-4 degrees Celsius by the end

of this century (Lewis 2009). China's North is very vulnerable to climate change since its increasing temperature will decrease precipitation. Currently, northern parts of China already receive only 20% of the country's rainfall and snowmelt (Burgér 2012). Decrease in precipitation will very likely lead to more frequent droughts, which, in turn, will reduce previously available replenishment of water.

Wasteful usage of water in agriculture may further exacerbate country's water shortage. Half of the water used by agriculture does not reach the fields due to the poor and old infrastructure of irrigation channels. Many lateral channels are paved with flagstones, so a large amount of water is seeping into the soil (Dianxiong 2010). Low water productivity is often cited as a crucial contributor to China's water problem. World Bank researcher Xie Jian claims 65% of all water withdrawals are used for agriculture. He argues agricultural water efficiency is only 45% (Xie 2009). This means that agriculture alone wastes 35.75% of total water resources/year. Industrial usage accounts for 24% of all withdrawals, however industries recycle only 40% of their water intake (Xie 2009). The civil sector (households, hospitals, schools etc.) withdraws the remaining 11 % of available water, more than half of which is wasted (World Bank 2009). Based on this data the major reason for China's water scarcity is the low efficiency of water use in agriculture, which wastes 35.75 percent of all water available to China every year.

### **Proposed solutions to water scarcity**

Recognizing the scale of the Chinese water scarcity problem scholars proposed possible solutions to the problem. Jian Xie sees a great opportunity in recycling mechanisms (such as sewage water treatment) and claims that they are capable of substantially contributing to water scarcity relief if used in public sectors, as

municipalities are notorious for poor water practices where most of the sewage water is wasted (Xie 2009). Striving to ensure water availability, in 2002 Chinese authorities started to emphasize water saving technologies and policies. Andrew Burgér supports such solution and urges the construction of industrial plants that would treat water, ensuring that instead of wasting, industries systematically and properly recycle most of their water intake (Burgér 2012). Water saving policies and water saving technologies are often suggested to mitigate water scarcity, but in case of severe water scarcity it does not seem to be sufficient unless accompanied by the measures that increase a total water availability of an area/city (Jin et al 2011).

Desalination is often mentioned as a possible option to increase water supply. It is argued that increased water prices along with improved technological capabilities, makes construction of desalination plants a feasible and profitable endeavor (Schneider et al 2011). Desalination opens up great opportunities for using ocean water, which by no means is a scarce resource on our planet. The biggest challenge for desalination as a process is that it is highly energy intensive. Therefore, in order to be an effective measure in dealing with water scarcity the energy for desalination plants should not come from coal (most of which comes from the Inner Mongolia), which is a big contributor to the water scarcity in the already dry north of China (Jing 2013). Therefore, the solution to China's water predicament may be in creation of energy efficient desalination plants.

A different approach currently being implemented by the Chinese authorities is building vast channels, transferring water to dry regions (such as North and Northwest of China) from relatively more water abundant areas. Such projects are expensive to build and maintain, and these costs are passed on the consumer in higher water prices (Burgér

2012). However, a number of researchers argue, that driven by the increasing prices and enhanced governmental regulations the consumers will be using water more thriftily (Xie 2009). With the aspiration to force consumers (via an increased water that reflects the degree of water scarcity) to be more responsible about their water use, and with the establishment of the 2002 water law, water transfer becomes the major approach in dealing with water scarcity.

### **2002 water right law and water transfer**

To deal with water scarcity in northeast China, in the beginning of 21<sup>st</sup> century Chinese authorities are using a water transfer as a main approach. Water transfer in China means building the vast channels connecting dry regions (such as North and Northwest of China) with China's South where the deficit of water is absent (Young 2008). Water transfer projects include water reallocation to the areas with water deficit where it will be shared by all groups of people from local to national levels on the basis of equal access to water in order to meet the primordial needs of the population (Cai et al 2008). A number of Chinese authorities and academics claimed that as water management approach water transfer presents a number of economic benefits (Chong et al 2006) However, reallocation of a significant amount of water contains a number of problem.

The 2002 water law introduced a legal basis for water rights trade, which made water transfers an accessible tool in dealing with water scarcity. The water right law established the framework for the allocation and management of China's water resources (Speed 2009). Shen and Speed say the law provided rights at three levels: for a region, for abstractors and user-level (Shen et al 2009). Speed described these categories as:

regional water rights -“the right of an administrative region to allocate its share of common resource amongst water abstractors or to sub -regions” (2002 Water Law, Articles 44-47). Abstractor rights –“granted via a water abstraction permit system to entities (including factories, water supply companies and irrigation districts) as the rights to take water from river or groundwater system ” (2002 Water Law, article 48). User-level rights –“granted, for example, for farmers within an irrigation district to define their share of the district’s water allocation“ (Code of Practice for Technical Management of Irrigation and Drainage Engineering , 1999) (Speed 2009). The establishment of water rights enabled Chinese authorities across China to use water transfer to solve small and big scale problems of water deficit.

Even if water can be transferred and delivered at a reasonable cost there is an increased danger that transferred water will be polluted. There is a concern that implementation of the Middle Route of the South–North Water Diversion Project will bring disastrous consequences by exposing a vast amount of water from the South to the contaminated soils of the northeast China and instigate an algae bloom in the middle and lower reaches (Zhu et al 2008). On the other hand, a study conducted by Chinese biologists claims that the risk of northward spread of schistosomiasis japonicawill<sup>1</sup> will be decreased or eliminated as long as long-term reliable interventions for snail control are implemented, which makes a problem of toxic algae bloom<sup>2</sup> preventable (Liang et al

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<sup>1</sup> “*Schistosoma japonicum* is the only human blood fluke that occurs in China. It is the cause of schistosomiasis japonica, a disease that still remains a significant health problem especially in lake and marshland regions” [http://en.wikipedia.org/wiki/Schistosoma\\_japonicum](http://en.wikipedia.org/wiki/Schistosoma_japonicum)

<sup>2</sup> “Algal blooms occur when the nutrients getting into surface waters cause rapid growth in the algae present in the water. Algal blooms have caused sporadic problems in water treatment processes for decades. When water abstracted for drinking water treatment contains algal blooms, blockages can occur in filters and odours may develop in the treated water. Toxic algal

2012 ). Bringing drinkable water from the Yangtze (South) to Tianjin (North) would require construction of 426 sewage treatment plants and establishing of water pollution control mechanisms that will cost China more than 2 billion U.S. dollars (Official news agency: Xinhua). For the central route, the withdrawals are planned to be taken from the Han River, which is a cleaner source of water since it was not subjected to much pollution (Guo-ying 2005). Nonetheless, the main channel of the central route will cross 205 rivers and streams in the polluted industrial parts of China before reaching Beijing, which increases the likelihood of water pollution (Dai 2011). Based on the existing literature it is not completely clear if a massive water transfer is going to be compromised due to the water pollution.

Meanwhile, another serious concern of a big scale water transfer in China is in its destruction of river-side ecology. It is a common preoccupation that project of such a scale could destroy the ecology of the southern rivers which are planned to be connected with the lifeless Yellow River in the North (Naumberg 2005). On the other hand, since the middle route of a big scale project such as South-North Water Diversion Project (SNWDP) goes through the Northern China Plain, which experiences the most severe water shortages, including water used for the ecological purposes (parks, protected areas, forests), the water transfer could potentially benefit the environment that is starving due to water deficit (Chen et al 2008). Water transfer is believed to mitigate groundwater depletion, create artificial water niches along the channel that can be used for ecological purposes of feeding local flora and fauna (Jin et al 2011). Despite the research conducted

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blooms, which cause toxins to be liberated in the water, are caused by the cyanobacteria species of algae. These are commonly referred to as blue-green algae”.

(<http://www.fwr.org/drnkwaatr/algaltox.htm>)

on possible ecological impacts of the SNWDP, there is still seems to be a lack of convincing evidence for either prediction. An additional research of the fully operational eastern route (was launched in the end of 2013 ) and western route (will be launched in the end of 2014) would reveal the potential hazards and clarify how to capitalize on the possible benefits that water diversion project might bring.

The theoretical framework of the research is constituted by two competing approaches overseeing water transfer projects. The academic like Mark Rosegrant argues that market based approaches are the most efficient in dealing with water scarcity (Rosegrant et al 1994). Rosegrant claims that “The institutional requirements, potential and feasibility of developing markets in tradable water rights should receive increased attention from researchers and policy makers”. Easter agrees with such position and suggests that the water markets can be an efficient method for reallocating scarce water supplies (Easter et al 1999). However, Chinese leaders like Mao Zedong (1949-1976) and Hu Jintao (2002-2012) have assumed a State lead approach to be superior in China, because the state has more resources (Zheng 2010). Chinese government is believed to be more efficient in dealing with water scarcity because it is concerned with social stability and actual solution, while the markets and businesses are after profit (Feng, 2006).

Focusing on the issue of water transfer as an efficient way to resolve the water scarcity, He believes that government lead water transfer projects are successful in increasing water availability and could be a viable and environmentally sustainable way of mitigating China’s northeast chronic water shortage (He et al 2010). China’s State Council claims to generate larger projects and to more efficiently deal with water

scarcity (State Council, 2010). However, other scholars favoring market- driven approach, like Speed, suggest that the most efficient way to resolve the water scarcity is to create local water rights, enabling farmers, industry and individuals to trade water (Speed 2009). Cai suggests that government lead water transfer projects are miscalculated and are not capable of solving water deficit problem. China has chosen state run water solutions at the local and national level.

### **Hypothesis**

This literature review reveals the lack of a general agreement on whether water withdrawals for the SNWDP would instigate a water deficit problem in the South. Some data suggests the attempt to solve water scarcity by redistribution of water from the South to the North and from East to West substantially increases its price. An increased water price is predicted to push local authorities of Northern provinces to look for alternative options (Schneider et al 2011 ). Thus, it seems like efficient water management and redistribution of water between the regions could potentially be a step toward increased water availability in the water-scarce northeast. The English language literature review presented in this chapter reveals a lack of research analyzing the efficiency of the previous small scale water transfer projects in China. In my research I examine five cases of small scale water projects in China that took place since 2002 when the water rights legislation was introduced. This enables me to present arguments that either support or not the SNWDP efficiency. I extrapolate the results of the case studies of the small scale water transfers onto the big scale SNWDP and determine if there are factors that speak in favor or undermine the ongoing project of “borrowing” water from the south

in order to deliver it to the north. My hypothesis is that water transfer is an efficient system in resolving water scarcity in the regions it is applied.

### **Chapter 3: METHODS**

This research utilized a case study method to examine five existing water transfer projects. It then analyzes hydrological data to determine how these projects meet the goal of addressing water scarcity. Using secondary English sources I determine how efficient analyzed projects are. I utilized data collection and simple calculations to unite data on these five water transfer projects. I looked at the reports of China's Water Resources for the total internal water resources of provinces in which my cases took place. Then I consulted the most recent primary data on China's population from the China Statistical Yearbook 2012. Knowing each provinces' population and its total water availability I calculated current per capita water availability using the formula:  $X/Y=Z$ , where X is total water available, and Y is a province's/city's current population. To calculate the effect of a water transfer(s) in each given case, I used the formula:  $(X+T)/Y = Z1$ , where X is total water available to the city/province, T is an amount of water transferred to the province, while Y is a province's/city's current population, and Z1 is a per capita water availability that is effected by the water transfer.

To obtain the data, I also used the scholarly literature that talked about water use issues in China, including scarcity, water management practices, water rights, water trade, the pilot water transfer projects and the volumes of diverted water. The literature analyzed World Bank reports, China's water policy papers, UN reports, statistical yearbook of the Republic of China (2012), China Census 2010 and World Watch Institute. I examined water conferences reports and scholarly books, the most recent of

which is “Integrated Water Resources Management in the 21st Century: Revisiting the paradigm” published on March 2<sup>nd</sup> 2014. This last resource gave me a holistic picture of total amount of renewable water in each of China’s provinces.

A significant part of utilized methodology relied on the analysis of the academic sources. The access to the authentic data produced by the Chinese authorities was restricted due to my lack of competence in Chinese language, therefore I collected crucial data from English language sources.

### **Case Sample Selection**

In this research I looked at five already existing small scale water transfer projects in this order: 1. Water Transfer between **Yiwu and Dongyang** by the Jinhua river 2. Water Transfer from **Zhangye city** (Gansu province) to Heihe river, 3. Water Transfers in **Ningxia** Hui Autonomous Region 4. Water Transfers in **Inner Mongolia** 5) Water transfers between Hebei and Beijing. Since the water law was introduced in China only in 2002, all of the transfers have occurred since that time. These cases were chosen, because they had been the most well known as they were designated by the Chinese Government as the pilot projects testing water transfer. The cases are taking place in three regions: Southeast, North, and Northeast, which helped to reduce the regional bias of the research. The case of water transfer between two counties (Yiwu and Dongyang) is the most famous one since it was the first case of water transfer regulated by the water rights legislation. The second case took place in the water scarce northwest of China in the Zhangye city (Gansu province). This case presented a good opportunity to look at the water transfer from the commercial point of view. It enabled me to understand the mechanism of pricing for transferred water. The next two cases took place in the

northeast China and were initiated by the Chinese government as trial projects. The fifth case is significant because eastern and western routes of the South –North Water Diversion project are aimed at supplying Hebei and Beijing, and because it was important to see if the current water transfers of a smaller scale have been successful.

### **Analysis**

I analyzed the data using UN thresholds of water scarcity ( $1000\text{m}^3$  per person/year) and water stress ( $1700\text{m}^3$  per person/year). I calculated how much water the transfers moved and measured the success in terms of water availability. To calculate water availability I was looking for a) Population of an area (city), b) Amount of annually renewable water resources ( $\text{m}^3/\text{year}$ ) c) amount of water transferred ( $\text{m}^3/\text{year}$ ). If water transfers brought the population's water availability above the water stress threshold ( $1700\text{m}^3$ ), then the water transfer is determined to be a ***complete solution*** (“A” ***Category***) to local water scarcity. If a water transfer increased target population water availability above  $1000\text{m}^3$  but less than  $1700\text{m}^3$  I determined the water transfer to be a ***partial solution*** (“B” ***Category***) to the local water scarcity. If a water transfer increased water availability of the population, but its present water availability is still below  $1000\text{m}^3$ , I determine such water transfer to be only a ***mitigating measure*** (“C” ***Category***) of the local water scarcity. If a water transfer failed to be maintained due to the water pollution or over extraction, or rapid population growth and did not increase water availability of a target area I determined such water transfer ***to be a failure*** (“D” ***Category***).

To get the data I needed, I calculated as follows: Dongyang's population is 785 800 people and Yiwu is 80% of that, which would be  $785\ 800 / 100 * 80 = 628$

640. Dongyang has  $2126 \text{ m}^3$  per capita per year, therefore they have  $785\,800 * 2126 \text{ m}^3 = 1\,670,610$  million of  $\text{m}^3$  of water per year. When a source says that Yiwu has half of per capita water that is available to Dongyang, it means that they have  $2126 \text{ m}^3 / 2 = 1063 \text{ m}^3$  per person or  $628\,640 * 1063 = 668,3$  million  $\text{m}^3$  available every year. These calculations are important to conduct, because this way, when an author says, that “50 million tons of water resources can be transferred into Hengjin reservoir” it means that Yiwu would have  $50 \text{ million } \text{m}^3 / 628\,640 = 79.5 \text{ m}^3$  per person per year in addition to  $1063 \text{ m}^3$  which would give the dwellers of Yiwu  $1063 \text{ m}^3 + 79,5 \text{ m}^3 = 1142,5 \text{ m}^3/\text{year}$ . When the source concluded that the project was successful I was able to add: Because on top of the environmental benefits it added an x amount of previously unused water per capita for the citizens of Yiwu.

## **Chapter 4: Results and Analysis**

In this chapter I analyze five cases of water transfer that took place in China:

1. Case 1: Water Transfer between Yiwu and Dongyang in Jinhua river.
2. Case 2: Water Transfer from Zhangye city Gansu province to Heihe river.
3. Case 3: Water Transfers in Ningxia Hui Autonomous Region.
4. Case 4: Water Transfers in Inner Mongolia.
5. Case 5: Water transfers between Hebei and Beijing.

These cases are among the best known once since the establishment of a new 2002 Water Law that enabled water rights trade/transfer. In my analyzes of the cases I was looking at the geography of a case place, per capita water availability based on the internal renewable water resources, reasons for water transfers, the amount and timeframe of water/water rights transfers. To determine the rate of success of every given case I used a threshold of water scarcity ( $1000 \text{ m}^3$  of water per capita/year) and a threshold of water stress ( $1700 \text{ m}^3$  of water per capita/year), both of which have been established by the United Nations. If water transfer led to an increase in water availability of a target population (or of a Heihe River in case 2) without endangering water quality, I determined a water transfer to be considered as successful in dealing with water scarcity. However, the rate of success varied, therefore I used four categories described in the methodology chapter to determine the rate of success/failure of a project: ***“A” Category -Complete solution, “B” Category –Partial solution, “C” Category-Mitigating Measure, “D” Category - Failure.***

## Case 1: Water Transfer between Yiwu and Dongyang in Jinhua river (2000 - ongoing)

Figure 1: Zhejiang province on the map of China and its per capita water availability



The first case took place in the Zhejiang Province in the Southeast of China. This province is situated in a water abundant area. The Jinhua river watershed is located in the middle of Zhejiang province, covers 200 km<sup>2</sup> (125 square miles) and supplies Pan'an county, part of Jinhua county, Jinhua city, Dongyang city, Yiwu city and a couple of towns. The Jinhua watershed supplies about 3.2 million people (Zheng et al 2006).

Figure 2: Geographic location of Dongyang and Yiwu (Zhejiang province)



Zhejiang province is part of the Yangtze water basin and it has 139.86 billion m<sup>3</sup> of renewable water per year (Ministry of Water resources, 2010). The population of the province has increased from 45,930,651 people in 2000 to 54,426,891 people in 2010 (China Statistical Yearbook 2012). Given its population and the total water available per year it is possible to conclude that current average water availability in the province equals about 2570m<sup>3</sup> per person/year which is far from water scarcity (1000m<sup>3</sup>) threshold. It is also far above the water stress threshold (1700m<sup>3</sup>). Despite significant water availability, the problem of Zhejiang province comes from the uneven water distribution. The water availability in the neighboring cities Dongyang and Yiwu was significantly unbalanced, which led to the initiation of the talks between local municipalities of water transfer possibilities in 2000. The actual annual water transfer from Dongyang city (population 785,800, water availability 2126m<sup>3</sup> per person/year) and Yiwu city (population 628,640, calculated water availability 1063m<sup>3</sup> per person/year) started in 2006 and resulted in a tremendous success of water transfer in China which inspired a number of other cases throughout the country (Zheng et al 2006).

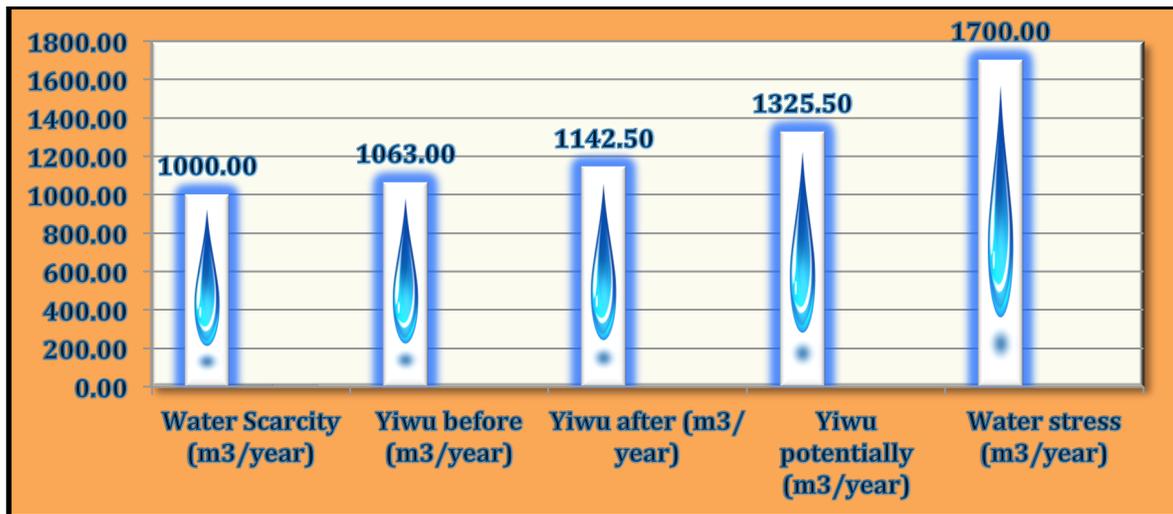
After reaching the agreement in 2000, according to which the regional government of Dongyang agreed to supply Yiwu with at least 50 million m<sup>3</sup> of water per year, the

construction of the water pipe took place (Speed, Robert 2009). By the time the water transfer project began (2006), Dongyang had 165 million m<sup>3</sup> of water available for trade (Zheng et al 2006). The construction was financed by the more economically developed Yiwu was finished in 2005, which made it possible to start supplying Yiwu with addition 50 million m<sup>3</sup> per year. In exchange, less affluent Dongyang is receiving 25 million (\$) flat payment annually plus 1.25 cents usage fee per m<sup>3</sup> of water supplied every given year (Zheng et al 2006). Chinese authorities and the academics called this project a win-win since Yiwu gets water needed for its development while Dongyang receives money with which it has been improving water quality via careful monitoring complemented by an additional water treatment plant. Moreover, with the additional income from the water trade Dongyang implemented a number of policies that encourage water preservation (Ma et al, 2013). Given that Dongyang's government is successfully maintaining the water safety standards which are complimented by the new water saving policies, it can be argued that Dongyang-Yiwu water transfer has the capacity to be mutually beneficial for the years to come.

Scholars agree that the Dongyang and Yiwu water transfer project is a success because it achieved not only building the water pipe from one city to another, but also provided the safety of the transferred water. It also increased water efficiency in Dongyang and improved its economy through an additional 25 million (\$) flat payment annual fee + 1.25 cents for the amount of water, that was actually transferred. Given that according to the contract Yiwu receives at least 50 million m<sup>3</sup> of water annually, Dongyang is benefited with \$31.25 million every year (25 +6.25 million). On the other hand, Yiwu increased its water availability by 79.5 m<sup>3</sup> having 1142.5 m<sup>3</sup> per person/year (1063

+79.5) in the very first year it got 50 million m<sup>3</sup> of water. The most important part is that this trade is sustainable and has a potential to grow by more than 300% (if Yiwu's population does not increase dramatically) giving Yiwu's citizens an additional 262.5 m<sup>3</sup> water per year, bringing the total to 1325.5 m<sup>3</sup> per person per year. This qualifies the project for a **“B” Category -Partial solution.**

Figure 3. Effect of water right transfer on per capita water availability in Yiwu



## Case 2. Case study in Zhangye city (Gansu province), the middle reaches of Heihe River (2002 -ongoing)

Figure 4: Gansu province and Zhangye city with its per capita water availability on the map of China



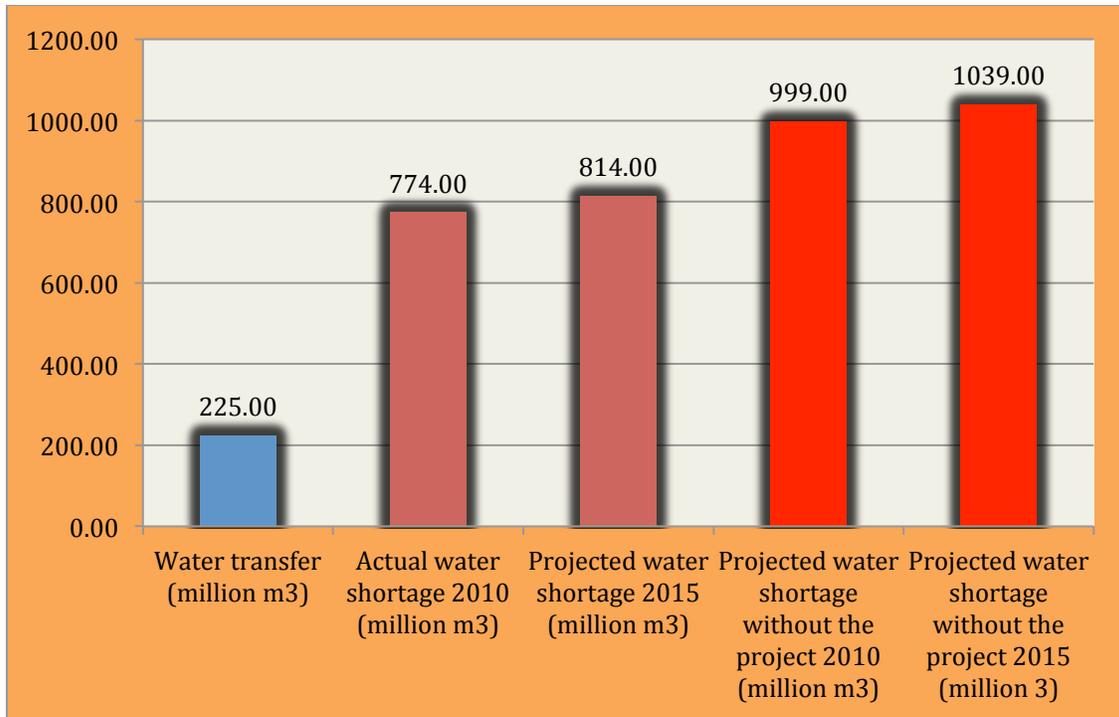
The second case took place in Zhangye city in the Northwest of China. Zhangye city belongs to the Gansu Province, which has 74.11 billion  $m^3$  of water/year with an average per capita water resource of a staggering 13, 225  $m^3$  per person/year. However, the city is an oasis located midstream of the Heihe River, an inland river that flows across Qinghai Province, Gansu Province and the Inner Mongolia Autonomous Region (Ministry of Water resources, 2010). The population of the province has increased only slightly from 25, 124, 282 people in 2000 to 25, 575, 263 people in 2010 (China Statistical Yearbook 2012). Gansu is far from the proclaimed water scarcity ( $1000m^3$ ) threshold, it is also far above the water stress threshold ( $1700m^3$ ). However, significant average per capita water availability ( $13\ 225\ m^3$ ) Gansu province suffers from uneven water distribution. To deal with this problem and to gain experience in water-saving irrigation systems, China's Ministry of Water resources initiated a pilot water saving project in the Zhangye city.

Figure 5: Zhangye city



The project is located in midstream of the Heihe River, in the middle part of Hexi corridor. The middle stream of Heihe River is between the Yingluoxia station and Zhengyixia station is 185 km long, and has the area of 25,600 km<sup>2</sup> (Ke et al 2011). The main problem in Heihe River Basin is the water shortage which in 2010 reached 774 million m<sup>3</sup>/year while it is expected to grow to 814 million m<sup>3</sup> /year. (Ke et al 2011). This water shortage is caused by the drastic population growth in the second half of the 20<sup>th</sup> century and the development of low-efficiency irrigation of farmland in the middle of basin over the previous decades (Li et al 2010). In order to resolve the problem the State Council developed a master plan for Zhangye city to annually discharge additional 225 million m<sup>3</sup> of clean water to the lower basin of the Heihe river basin. (Jiang 2008). According to the Master Plan, in 2002 Zhangye city was forced to discharge/transfer total 950 million m<sup>3</sup>/year (including 225 million m<sup>3</sup> of additional water transfer ) (Li et al 2010). To illustrate the impact of this pilot project on the water shortage in the Heihe river basin I compiled a graph that summarizes shortages.

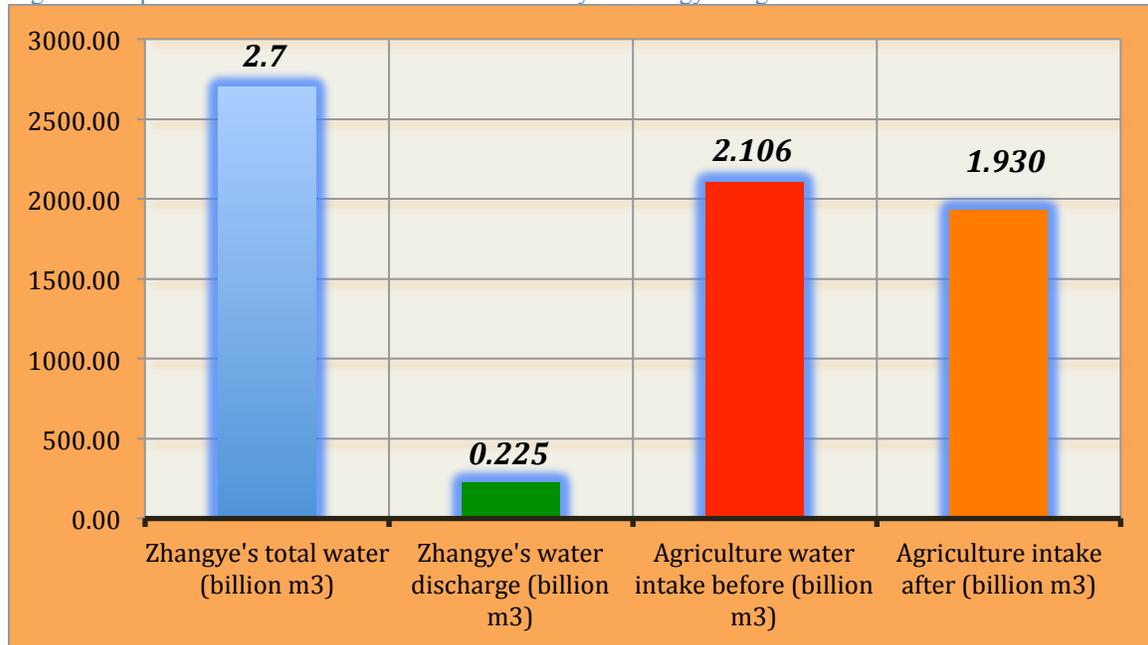
Figure 5: Water transfer impact on water shortage in Heihe river



From the Figure 5 we can see water transfer did not solve the water shortage problem of Heihe river, but significantly mitigated it and lowered the pace of water shortage increase. On the other hand, it decreased water availability for the citizens of Zhangye. According to the Master Plan of this pilot project, the city was asked to introduce water quotas and allow water trade between the farmers. Agriculture in Zhangye is responsible for 78 % of water use and therefore the hope was to encourage farmers to save water so they could sell. (Ke et al 2010). However, the survey conducted by Zhang indicated that “despite the development of the output market, no significant water trading emerged” (Zhang et al 2014). Zhang’s survey of 350 farmer’s households in 2009 showed that “only 27.9% of the interviewed households were aware that they were allowed to swap water with others, while only 10.8% knew that they were allowed to buy or sell water against payment” (Zhang et al 2014). Knowing that total amount of water available to Zhangye is 2.7 billion m<sup>3</sup> (Martinez-Santos et al 2014) and that agriculture is responsible

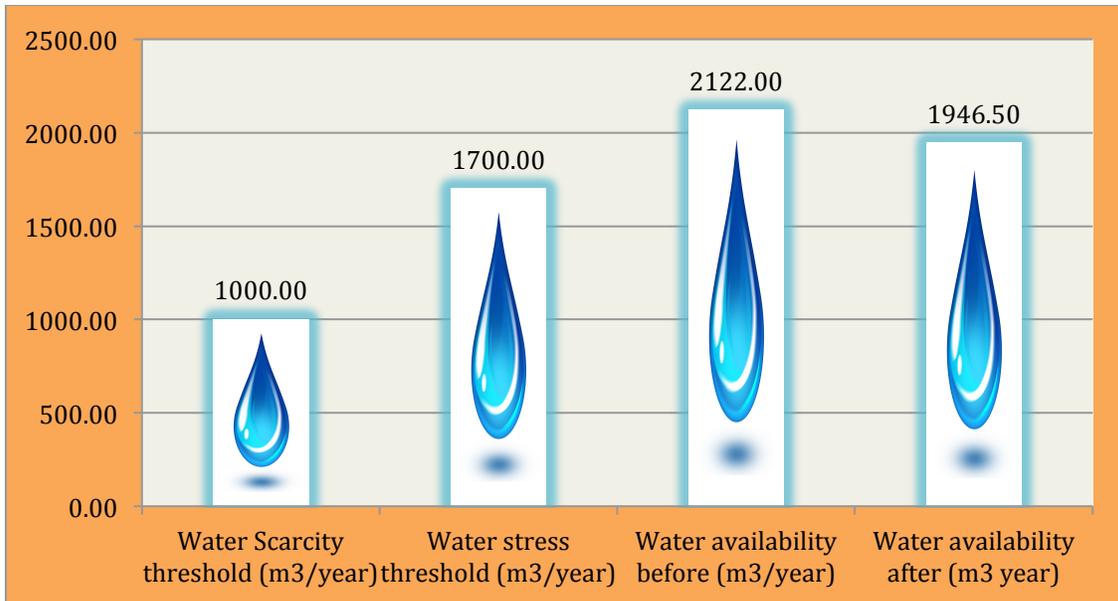
for 78% of total water consumption I compiled a graph that reflects the impact of water transfer on agricultural sector of Zhangye.

Figure 6: impact of water transfer on water availability in Zhangye's agricultural sector



From Figure 6 it can be seen that the additional water transfer/discharge to the Heihe River did impact water intake available to the agriculture, but it does not seem dramatic or significant enough to change the water use patterns of the local farmers. Hence, I conclude that the water saving policy among farmers was not as effective as the officials hoped. Knowing Zhangye's total water availability and its population in 2005 (1, 272, 000 (Li 2010) ) and 2010 (1, 200, 000 (China Statistical Yearbook 2012)), I compiled a graph that reflected the reduction of available water caused by the transfer project.

Figure 7: Impact of water transfer on the per capita water availability in Zhangye city



As it can be seen from the Figure 7, water transfer did decrease per capita water availability by 175.5 m<sup>3</sup> per capita/year, but it still remains 246.5 m<sup>3</sup> above water stress threshold, which suggests that this water transfer was a success. Since the pilot project decreased the gap of water shortage in Heihe River by almost 23% (Figure 5), while letting Zhangye city to keep its water availability above water stress level it qualifies for a **“B” Category -Partial solution.**

### Case 3 Ningxia Hui Autonomous Region (1987- ongoing. 2003-ongoing)

Figure 8. Ningxia and its water availability on the map of China



This transfer took place in the Ningxia Hui Autonomous Region in the northwest of China. This autonomous region is situated in a water scarce area. Ningxia is part of Huanghe water basin and it has 0.93 billion  $m^3$  of renewable water per year within the region (China's Ministry of Water Resource 2010). The population of the province is relatively small and reached 6,390,000 people (China Statistical Yearbook 2012). Given its population and the total renewable water available per year it is possible to conclude that the current average water availability in the province equals about  $145.5 m^3$  per person/year which is below the water scarcity ( $1000 m^3$ ) threshold. According to the official data water availability in the province is  $148 m^3$  (China's Ministry of Water Resource 2010). The  $2.5 m^3$  difference between my calculations and the official data can be explained by the fact that Chinese officials did not take into account the population growth of 106,000 people over the years. Ningxia water scarcity problem

had been worsening ever since 1951 as the area experienced increasing its severe droughts every 2 out of 3 years (Ningxia Commission of Development and Reform 2008). Striving to deal with poverty and almost absent industrial development caused by the lack of water, in 1987 The State Council approved a project of annual diversion of 4 billion m<sup>3</sup> from Yellow River for Ningxia (Jiang et al 2008). This amount has been allocated ever since and Figure 9 shows the actual amount of per capita availability in 2014.

Figure 9: Effect of water diversion on water availability in Ningxia (2014)

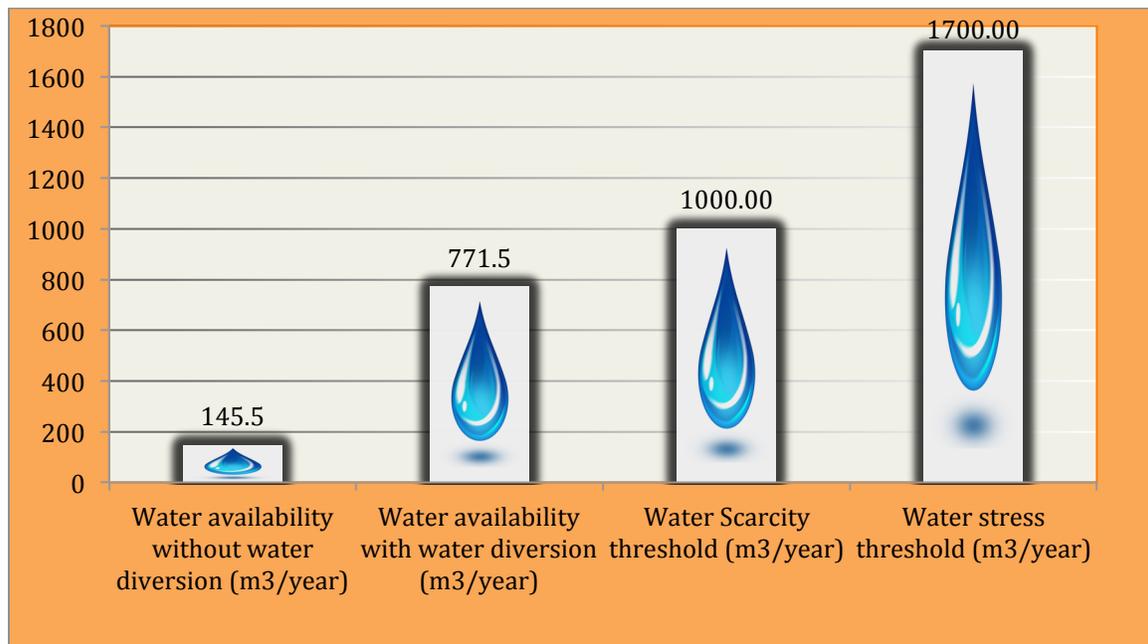
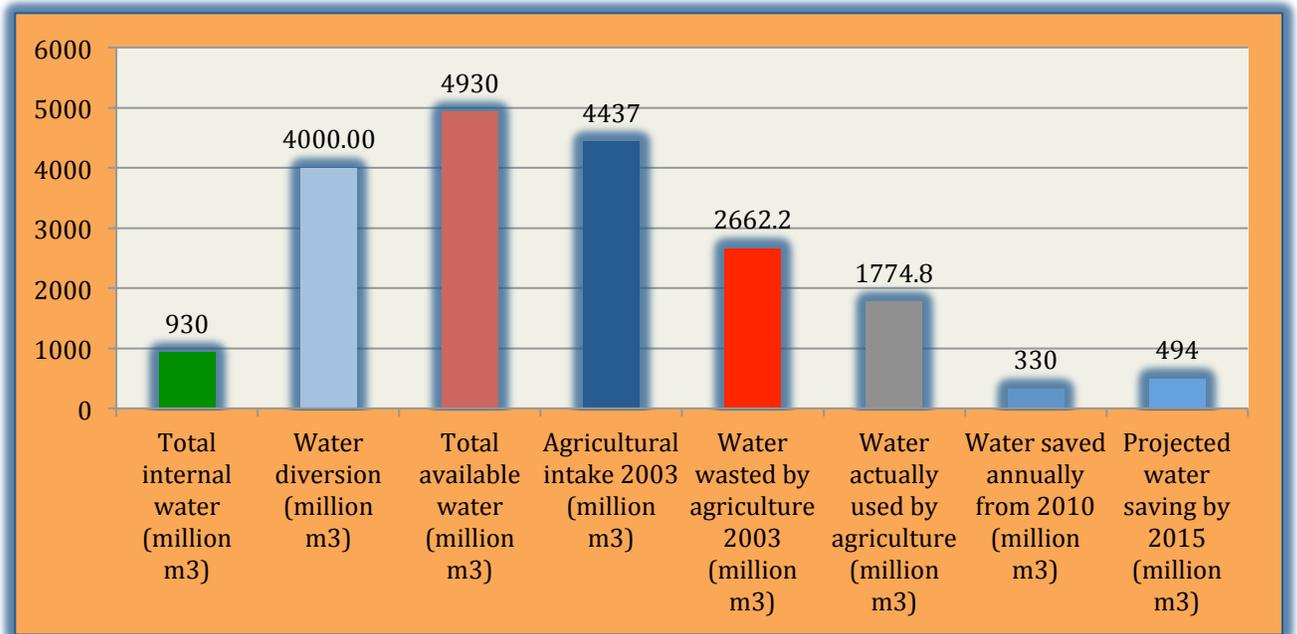


Figure 9 testifies that the water diversion project initiated in 1987 is sustainable and has given Ningxia’s current population an additional 626 m<sup>3</sup> of water/year per capita, which is 400% more than it would have without water allocation. Nonetheless, it is clear that despite an increase of total water resources, water availability is still below water scarcity threshold which impedes the development of the industries. Another reason of Ningxia’s slow development is its heavy reliance on agriculture which consumes 90% of

all available water (Svensson 2013). The agricultural sector's water efficiency in 2003 was only 40% which means that 60% of all water consumed by Agriculture was wasted (Speed 2009).

To encourage water saving and boost industrial growth and given that there was not another water source to increase overall water availability, in 2003 the Yellow River Water Resource Commission and water administration departments initiated water rights transfers (Bruns 2005). Following the plan, the industries invested in water saving technology for agricultural sector and in exchange they got all the saved water. In his analyzes of the Ningxia's pilot project Dianxiong says that "The new policy was feasible because only 18 percent of the main channels and 24.4 percent of lateral channels were paved with flagstones, so a large amount of water was seeping into the soil" (Dianxiong 2010). Since 2003 more than 16 projects to line irrigation channel took place, which were expected to save 330 million m<sup>3</sup> of water/year by 2010 and 494 m<sup>3</sup> by 2015 (Speed 2009). Therefore, the project is considered to be quite successful and worth continuing. According to the Ningxia's Commission of Development and Reform, the water right transfer brought a 50% vegetation increase on the steppe and a increase in 20% desert grasslands, which was followed by 29% increase in the number of sheep, that had more grazing area (Ningxia Commission of Development and Reform 2008). The number of people living in poverty decreased from 462,000 in 2000 to 435, 000 in 2006 thanks to the project (Dianxiong 2010). Below, in a Figure 10, I present a cumulative effect of the water diversion project initiated in 1987 and water right transfer project that began in 2003.

Figure 10: Cumulative impact of the water diversion project initiated in 1987 and water right transfer project of 2003.



From Figure 10 it can be seen that from the beginning of 2003 water right transfer project, water efficiency of agriculture increased by 7.45% (330 million m<sup>3</sup>/year) in 2010 and is expected to be increased by 11.13% (494 million m<sup>3</sup>/year) by 2015. This project is an example of how to increase water availability of a water scarce area by improving water efficiency in agricultural sector. This case is qualified for a **“C” Category – Mitigating Measure.**

#### Case 4: Inner Mongolia (1987-ongoing, 2003-2006)

Figure 11: Inner Mongolia and its per capita water availability.



Inner Mongolia Autonomous Region is located in the north of China. This region is situated in a water stressed area. Inner Mongolia is part of Huanghe water basin and it has 38.85 billion  $\text{m}^3$  of renewable water within the region water per year (China's Ministry of Water Resource 2010). The population of the province has reached 24,820,000 people in 2010 (China Statistical Yearbook 2012). Given its population and the total renewable water available per year it is possible to conclude that the current average water availability in the province equals about 1,565  $\text{m}^3$  per person/year, which is above the water scarcity (1000  $\text{m}^3$ ) threshold, but 135  $\text{m}^3$  below the water stress (1700  $\text{m}^3$ ) threshold. Inner Mongolia's water scarcity problem had been worsening ever since 1980's when China increased its demand for water intense coal extraction in the autonomous region. Striving to deal with poverty and boost coal extraction, in 1987 the State Council approved a project of annual diversion of 5.640 billion  $\text{m}^3$  from Yellow River for Inner Mongolia (Jiang et al 2008). In 2003, the amount of water diverted from the Yellow River was increased by 220 million  $\text{m}^3$  (Jiang et al 2008). This amount has

been allocated ever since 2003 and figure 12 shows the actual Inner Mongolia's per capita water availability in 2014.

Figure 12: Effect of water diversion from Yellow River on Inner Mongolia's water availability in 2014

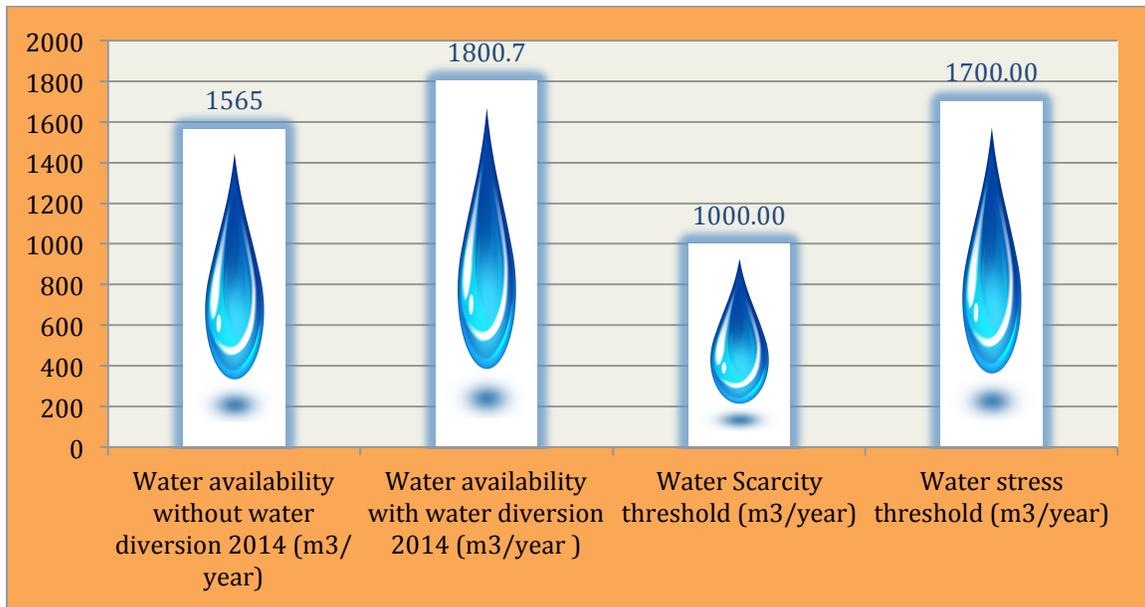
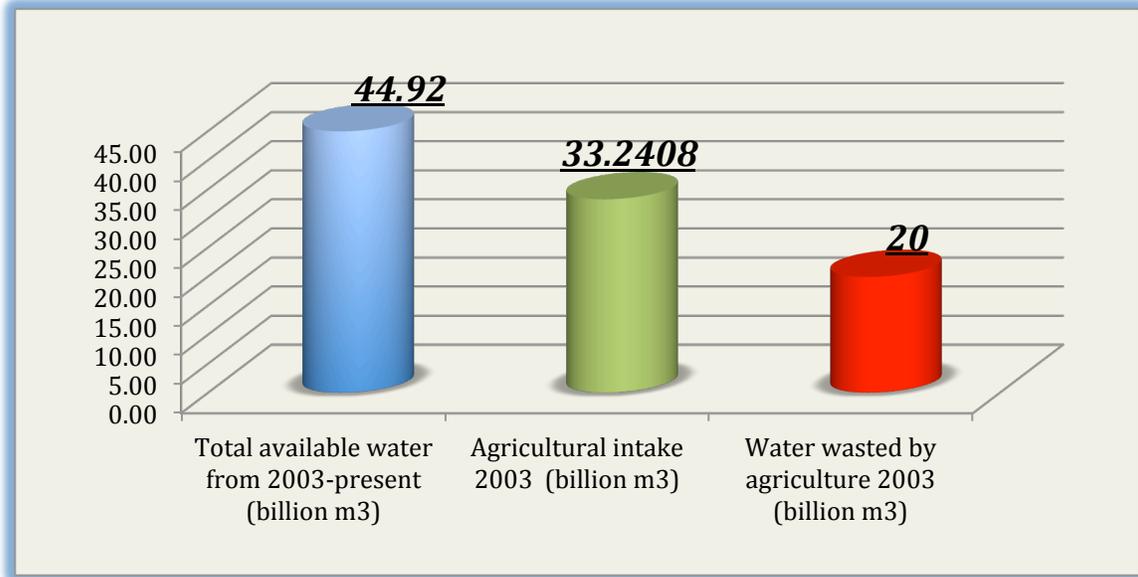


Figure 12 testifies that water the diversion project initiated in 1987 and increased by 220 millions  $m^3$  in 2003 is sustainable and is giving Inner Mongolia's current population an additional  $235,7 m^3$  of water/year per capita, which enables the region to be  $100.7 m^3$  above the water stress threshold. Nonetheless, given that the Chinese government pushes to increase coal extraction in the region, an initiative to increase its share allocated for the heavy industry at the cost of the agricultural sector took place in 2003. This initiative was proposed by the Yellow River Water Resource Commission and the water administration departments and allowed water rights transfers between the industries (Bruns 2005). According to the plan, heavy industries invested in water saving technology for the agricultural sector, and in exchange, they got all of saved water. Agriculture is responsible for 74% (Svensson 2013) of all water intake in Inner Mongolia, but its efficiency rate is 40% (Speed 2009), which means that 60% (or

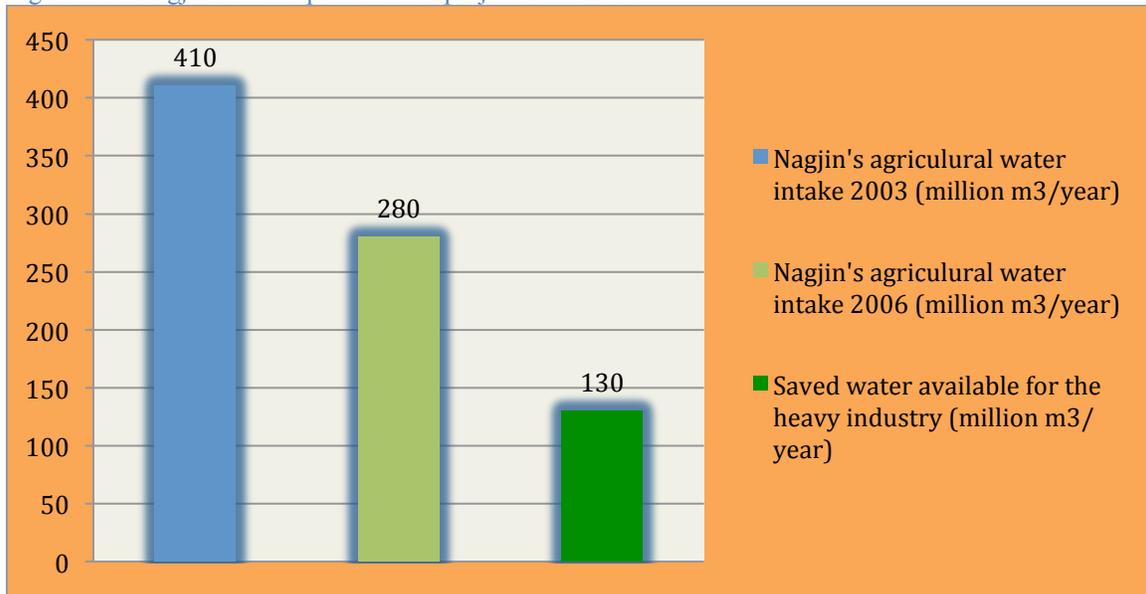
according to my calculations almost 20 billion m<sup>3</sup> ) are being wasted solely by agriculture (Figure 13).

Figure 13: Water loss in agriculture (2003)



Concerned by this staggering water loss and striving to increase water efficiency in the agricultural sector, in 2003 the Yellow River Conservancy Commission initiated two pilot projects in irrigation districts of Inner Mongolia (Tao et al 2007). One of them took place in April 2003 in Hangjin irrigation district. In 2006 it resulted in the reduction of water loss by 130 million m<sup>3</sup>/year (Speed 2009). The results were achieved because by September 2006 six canal lining subprojects that were financed by the industrial enterprises had been completed in Hangjin (Zheng et al 2012). The project helped the local farmers to alleviate their burden to pay for the water that had never reached their farms. Moreover, 130 million m<sup>3</sup> of water/year saved from leaking by canal lining became available to the water hungry industries. (Zheng et al 2012 ). Below is a graph that illustrates Hangjin's water preservation project effect on agricultural intake.

Figure 14: Hangjin's water preservation project 2003-2006



In conclusion I argue that the water diversion from the Yellow River initiated in 1987 and increased by 220 million m<sup>3</sup> in 2003, is a successful project. It has brought to the Inner Mongolia's current population an additional 235,7 m<sup>3</sup> per capita/year, helping an average water availability of the region to be 1800,7 m<sup>3</sup> which is 100,7 m<sup>3</sup> above the water stress threshold. I also argue that the pilot project in Hangjin irrigation district (2003-2006) is another testimony to how implementation of water rights transfer can increase water efficiency by 31.7%, making it 71.7 % efficient comparing to 40% average efficiency in the rest of Inner Mongolia. This projects qualifies for the **“A” Category – Complete Solution.**

**Case 5: Water transfers between Hebei and Beijing (1980s –ongoing, 2004 – ongoing, Water for the Olympic games transfer 2008)**

Figure 15 (on the left): Hebei, Beijing and their per capita water availability on the map of China.  
Figure 16: Map of Hebei and Beijing



( Source: <http://www.chinatouristmaps.com/provinces/hebei.html>)

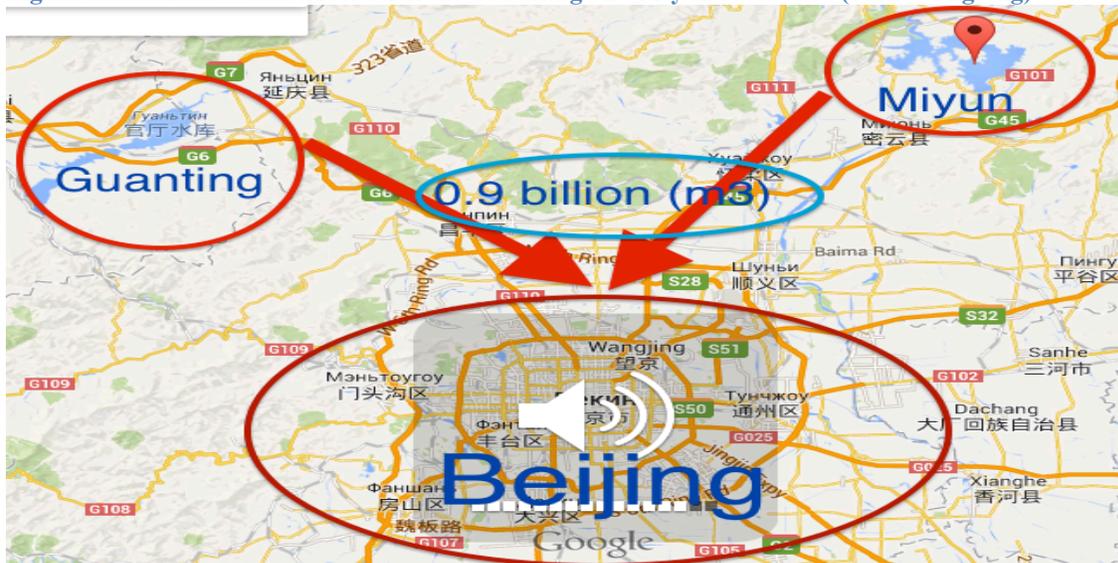
Hebei province and Chinese capital Beijing are situated in the northeast of the country. Due to their population both areas are experiencing an extreme level of water scarcity. Hebei and Beijing are part of the Haihe water basin with 13.89 billion  $m^3$  and 2.31 billion  $m^3$  of renewable water within the regions per year correspondently (China's Ministry of Water Resource 2010 ). The population of Hebei province is 72, 410, 000 while Beijing's population is 20,190,000 and continues to rapidly grow at the 1.45% (China Statistical Yearbook 2012). Given the population and the total renewable water within the regions it is possible to conclude that the current average water availability in the Hebei province equals about 192  $m^3$  of water per capita/year, while Beijing has only 114.4  $m^3$ . As the numbers show both, Hebei and Beijing have a dangerously low water availability which is 8 to 9 times below the water scarcity (1000 $m^3$ ) threshold. However it is important to note that the above water availability is calculated based on the internal renewable water sources within the region and does not take into account for annual

water transfer between Hebei and Beijing.

### **Water transfer 1 (Guanting and Miyun reservoirs – 1980s -ongoing)**

Striving to deal with rapidly growing population and given the exceptional cultural, political, economic and educational importance of Chinese capital, its water scarcity has been a paramount focus of the China's government. Starting from the 1980<sup>s</sup> Guanting and Miyun reservoirs have been obliged to provide Beijing with a total of 0.9 billion m<sup>3</sup> of water/year (Jiang et al 2008). Originally Guanting was built in the 1950s to supply Beijing with drinking water, but due to the heavy pollution, in the 1980s Beijing began withdrawing drinking water from the Miyun reservoir (Wang 1986). Miyun reservoir is located in the mountainous area northeast of Beijing and its water supply account for 80% of Beijing's drinking water (Zheng 2006). Therefore, starting from the 1980s some 213, 525, 000 m<sup>3</sup> of water (about 23.4 % of 0.9 billion m<sup>3</sup>) have been annually supplied from Miyun's reservoir to Beijing (Zheng 2006). In 2006 Miyun reservoir total capacity was 4.375 billion m<sup>3</sup> which is only 60% of what it had in 1999. The loss 40% water loss over 7 year period happened due to the continues droughts in northeast China (Yang 2006). Miyun reservoir cannot prevent the continues droughts, but the authorities do carefully protect it from pollution, ensuring clean water supply for Beijing for as long as it lasts. In figure 17 I have created a map providing details on the geography of the water from two aforementioned reservoirs.

Figure 17: Annual Water Transfer from Guanting and Miyun reservoirs (1980<sup>th</sup> -ongoing)



### Transfer 2: Chicheng water transfer (2004 -ongoing)

Despite this water transfer, Beijing continued experiencing water shortage problems exacerbated by the droughts. Starting from the 1999 almost uninterrupted droughts and water shortage have become dominant factor limiting economic and social development of Beijing (Wang et al 2011). Between 1988 and 2005 China's capital could obtain a 50% GDP growth, while closing down or moving water intense industries out of Beijing and reducing agricultural water share to 38.7%, resulting in 10% reduction in its water consumption (Wang et al 2011). On the other hand, between 2002 and 2005 Municipal and residents total water share had increased from 31.3% to 39.1%. Due to Beijing rapid population growth (2000 – 14 million, 2008- 16 million, 2011 – 20.2 million - China Statistical Yearbook 2012 ) in 2004 Hebei's county Chicheng started transferring 347 million m<sup>3</sup> of water/year to Beijing (Jiang 2004). The annual transfer has been executed ever since and Figure 18 illustrates the geography of this water transfer.

Figure 18: Annual Water Transfer from Checheng county (Hebei)



### Transfer 3. Emergency transfer for the Olympic games 2008

By 2008 the Beijing population reached 16 million people (China Statistical Yearbook 2012) and it was hosting the Summer Olympic games in Beijing which increased water demand. Envisioning water shortages Beijing signed an agreement with Hebei province according to which Chinese capital would receive additional 400 million  $m^3$  of water via a transfer (Yang 2006). The Hebei was not properly compensated for its previous water transfer due to the politically and culturally expected sacrifice for the capital (Jiang 2004). However, this time, Beijing invested 100 million Yuan in the agricultural sector of Hebei to improve province's water efficiency and ensure availability of an additional 400 million  $m^3$  for the Olympic games. Despite the additional transfers, China's capital is still short on water and the Beijing's Projected Water shortage of 1.2 billion  $m^3$  by 2010 (Jiang 2004) is now a reality. Below (figure 19) I compiled a graph, illustrating an impact of all three water transfers on Beijing and Hebei total water resources.

Figure 19: Effect of Water Transfers on Total amount of water in Beijing and Hebei

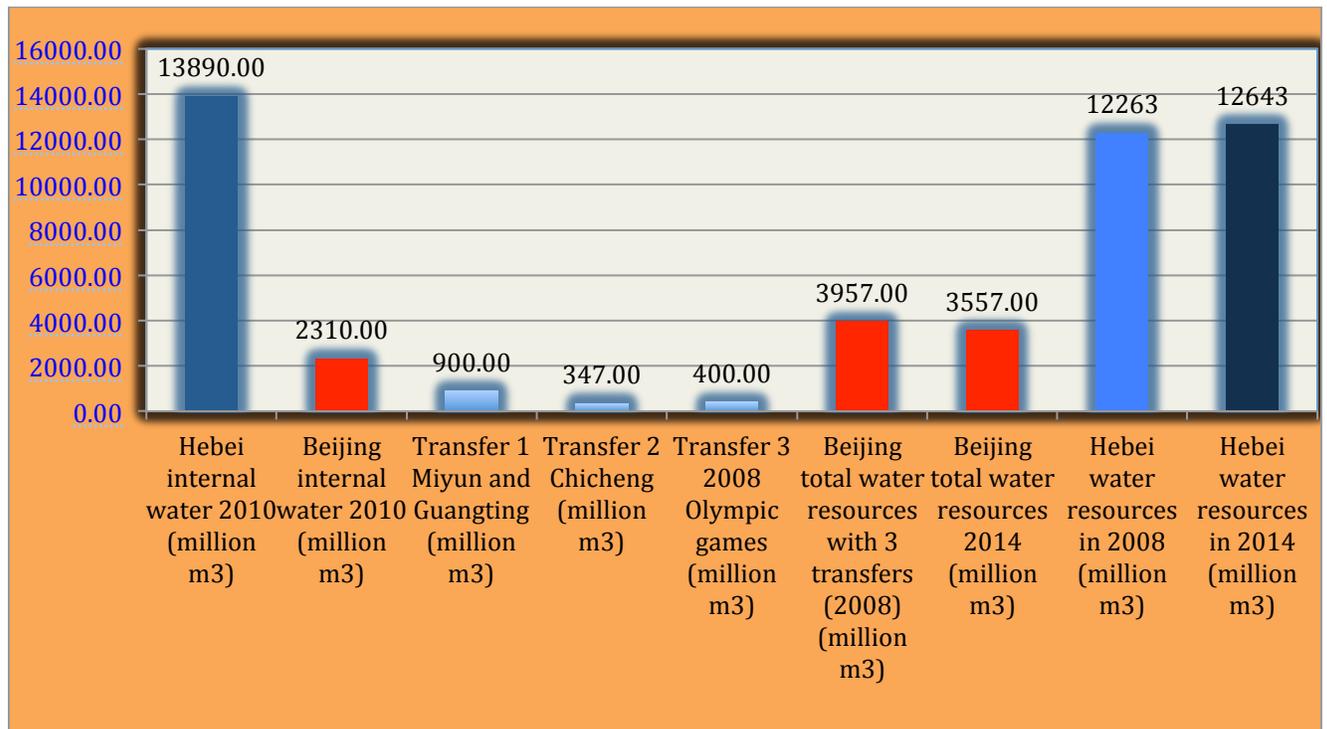


Figure 19 demonstrates that all three water transfers have not dramatically decreased the total water resources of Hebei, but did increase Beijing total water resources by 72.3 % in 2008 and by 54% in 2014. According to Beijing Water Authorities Beijing Water consumption has reached 3.6 billion m<sup>3</sup> which is 443 million m<sup>3</sup> more than indicated in Figure 19 total water resource availability. Most likely this amount is received by additional transfers from Hebei and by over extraction of Beijing ground water which leads to drying up of lakes and wetlands. It also leads to land corrosion and subsidence which is already damaging part of Beijing.

Knowing Beijing and Hebei population in 2008 and 2014 it is possible to calculate the impact of water transfers of per capita water availability for the citizens of both areas in these years. The results of these calculations are

presented in the figure 20.

Figure 20: Effect of Water transfers on per capita water availability in Beijing and Hebei

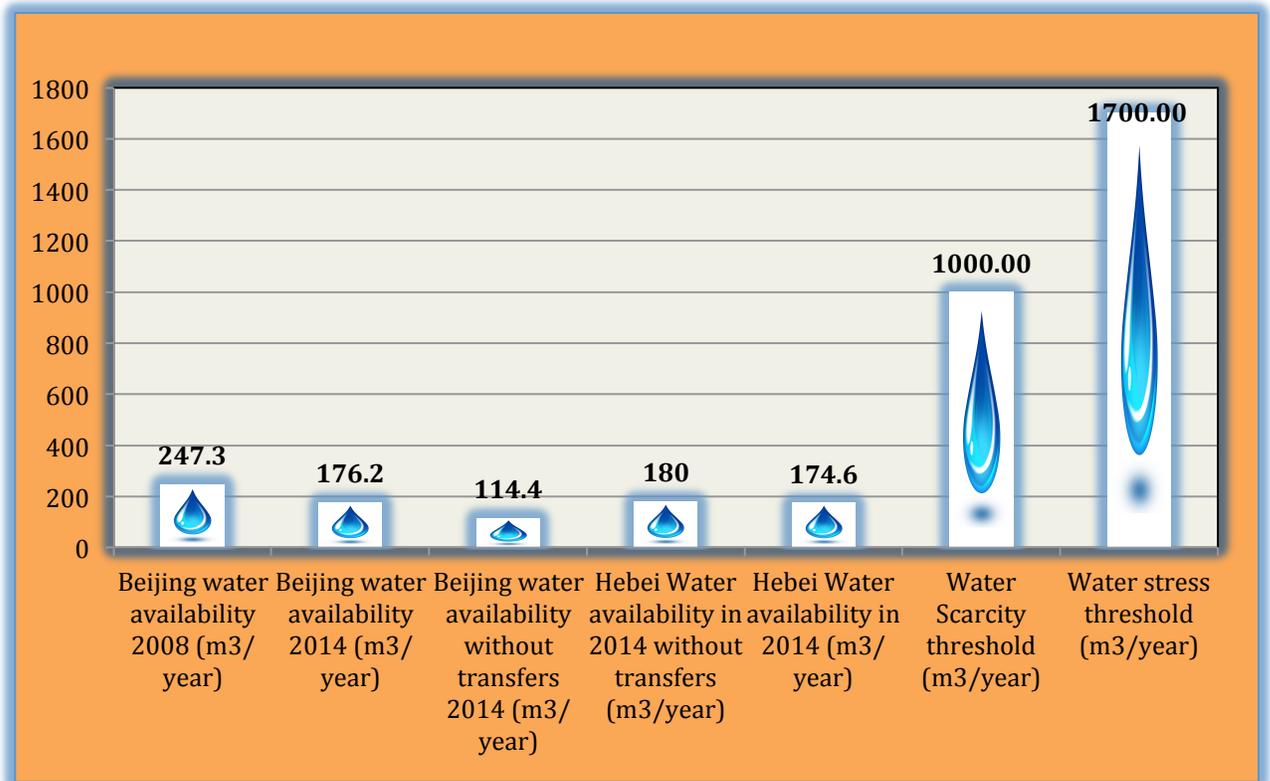


Figure 20 demonstrates that current water transfers add 61.8 m<sup>3</sup> of water per capita/year for Beijing population which does not solve the city's water scarcity problem as it is still 823.8 m<sup>3</sup> of water per capita/year below the threshold of absolute water scarcity. Nonetheless, according to my calculations that take into account Beijing current population and 213,525 millions of m<sup>3</sup> of water transferred from Miyun reservoir, Chinese capital gets 64 % of its drinking water from the Miyun reservoir. Given the ultimate importance of clean drinking water to human beings and the fact that the water transfers discussed in this case did increase an average per capita water availability for Beijing I conclude that these water transfers present an evidence of a successful (although not sufficient) way of

mitigating Beijing water scarcity. This case qualifies for the “**C**” **Category –Mitigating Measure.**

**Conclusion:**

In this chapter I analyzed five cases in which water transfer(s) took place. Every case was successful as it increased water availability of a target population/River. However, the rate of success varied and the cases spread among following categories

A) Complete Solution: **Case 4.**

B) Partial Solution: **Case 1, Case 2.**

C) Mitigating Measure: **Case 3, Case 5**

**Case 1:** Water Transfer between Yiwu and Dongyang in Jinhua river increased water efficiency in Dongyang and improved its economy through a flat 25 million dollars annually + 1.25 cents for the amount of water that was actually transferred. On the other hand, Yiwu increased its water availability by 79,5 m<sup>3</sup> which gives its citizens 1142.5 m<sup>3</sup> per person/year. The most important part is that this trade is sustainable and has a potential to grow by more than 300% (If Yiwu’s population is not going to increase dramatically) giving Yiwu’s citizens additional 262,5 m<sup>3</sup> of water per year making it 1325,5 m<sup>3</sup> per person per year. Therefore It qualifies for the ***B category.***

**Case 2:** Water transfer from Zhangye city, Gansu province to Heihe river was very different from the rest of the cases since water transfer was taken from the Zhangye city and sent to the Heije River. Given that this water transfer did not decrease water availability of its population to the water stress threshold (Figure 7) and mitigated water shortage in the Heihe River by almost 23 % (Figure 5) It qualifies for the ***B category.***

**Case 3:** The first water transfer in Ningxia Hui Autonomous Region in a form of water diversion project was initiated in 1987 proved to be sustainable since it continues to provide Ningxia's current population with additional  $626 \text{ m}^3$  of water/year per capita. (Figure 9). Water right transfer initiated in 2003 increased water efficiency of agriculture by 7.45% (330 million  $\text{m}^3$ /year of saved water) in 2010 and is expected to be increased by 11.13% (494 million  $\text{m}^3$ /year of saved water) by 2015 (Figure 10) . This project is an example, showing how to increase water availability of a water scarce area by improving water efficiency in agricultural sector, which is responsible for more than 75% of all water intake across China. Water diversion initiated in 1987 increases Ningxia average per capita water availability by 400% making it  $771.5 \text{ m}^3$ , which qualifies this case for the ***C category***.

**Case 4:** Water Transfers in Inner Mongolia started in 1987 with water diversion from the Yellow River. In 2003 the amount of diverted/transferred water was increased by 220 million  $\text{m}^3$ . It brings to the Inner Mongolia's current population an additional  $235,7 \text{ m}^3$  per capita/year, helping an average water availability of the region to be  $1800,8 \text{ m}^3$ , which is  $100,7 \text{ m}^3$  above water stress threshold (Figure 12). The pilot project in Hangjin irrigation district (2003-2006) is another testimony of how implementation of water rights transfer can increase water efficiency by 31.7%, making it 71.7 % efficient comparing to 40% average efficiency in the rest of Inner Mongolia (Figure 13 &14). Based on the aforementioned this case falls under the ***A category***.

**Case 5:** Current water transfers from Hebei to Beijing add  $61.8 \text{ m}^3$  of water per capita/year for Beijing population (Figure 20). It does not solve the city's water scarcity problem as it is still  $823.8 \text{ m}^3$  of water per capita/year below the threshold of absolute

water scarcity. However, the water transfers from the Miyun reservoir provide Chinese capital with at least 64 % of its drinking water, which brings extra significance to this water transfer. Based on the collected and analyzed data this case is qualified for the C *category*.

## **Chapter 5: Does transferring water present an efficient solution to water scarcity in Northeast China**

The analysis of the previous water cases revealed that water transfers can be an efficient way of dealing with water scarcity. In this chapter I am discussing the South - North Water Diversion Project (SNWDP) as it is China's major and most costly effort to solve its northeast water scarcity problem. Using the data from the cases analyzed in a previous chapter I am addressing five main critiques/concerns that scientists expressed studying the SNWDP. I am employing the 1000 m<sup>3</sup> threshold model I applied for five pilot water transfer projects in chapter four to determine for which category: *A. Complete solution, B. Partial solution C. Mitigating measure D. Failure: no positive effect* the SNWDP is qualified for.

### **Discussion on the SNWDP Pro's and Con's**

Figure 21 South –North Water Diversion Project under construction



Source: [http://www.circleofblue.org/waternews/2012/commentary/editorial-in-the-circle-fresh-](http://www.circleofblue.org/waternews/2012/commentary/editorial-in-the-circle-fresh-focus/along-the-eastern-line-of-chinas-south-north-water-transfer-project)

[focus/along-the-eastern-line-of-chinas-south-north-water-transfer-project](http://www.circleofblue.org/waternews/2012/commentary/editorial-in-the-circle-fresh-focus/along-the-eastern-line-of-chinas-south-north-water-transfer-project) Photo © Nadya Ivanova /

Circle of Blue

Throughout history China's northwest has experienced a severe water scarcity problem and in the 1950s Mao Zedong suggested a possibility of borrowing some water

from the more water rich south and transferring it to the water scarce northeast of the country. Decades later, in 2002, the South-North Water Diversion Project (SNWDP) started to be built. The SNWDP is an ambitious and very costly project that was estimated at 62 billion (by 2014, 79 billion dollars already have been spent) U.S. dollars and officials claimed will solve the water shortage problem for the cities of northeast China, which is the most rapidly developing region of China that contains 40% of its population (Zheng 2010). The SNWDP consists of three routes: the Eastern route, the Central route, and the Western route. The project has large coverage, crosses several Yangtze river basins and is characterized by great complexity and intricate diversity (Fuzhang et al 2004). The SNWDP is often labeled as an arrogant and utterly challenging engineering aspiration because when fully completed it would span 12 provinces and 3000 kilometers of canals and tunnels (Freeman, Carla 2011). According to the plan, 13 billion m<sup>3</sup> of water would be transferred through the Central line (was finished in December 2013), around 8 billion m<sup>3</sup> would be sent up north via Western route (in a planning stage), while the Eastern line, which is expected to be finished by the end of 2014, will have a capacity of transferring 14.8 billion m<sup>3</sup> (Keith et al 2013). Among the three routes the Western one is the most complicated as it has to be built through a very difficult mountainous terrain (Yardley, Jim 2007). The SNWDP is an unprecedented attempt to solve a problem by water transfer at this scale and, therefore, it seems to be controversial whether it is going to be effective in mitigating China's northeast water scarcity.

The SNWDP has several issues over which many scholars argue. Such a project is expensive to build and maintain, which inevitably increases water prices (Burgér

2012). However, some researchers suggest that in the preceding cases, driven by the increasing prices and enhanced governmental regulations, a number of industries are achieving a rate of 98 % reuse of consumed water, which means that water transfers project can be potentially efficient (Xie 2009). The construction is predicted to more than double water costs from 0.26 to 0.80 dollars per cubic meter, but there are high hopes that the effect on China's welfare would still be positive as long as a market for water would exist, facilitating the increased water quality and better infrastructure (Berrittella et al 2006). On the other hand, there is a big concern that price would be too high for the rural Chinese and, therefore, it would benefit only the cities which would exacerbate the inequalities of the country (Yang 2003). Some officials are so skeptical of the eastern route's ability to deliver drinkable water that they are looking at desalination as an alternative options, since it becomes cheaper as desalination technologies become more efficient and cheaper every year (Zhou 2004). The East route was finished by the end of 2013 and I believe that only after several years of operation it might be possible to know whether pricing is the crucial barrier in South –North Water Diversion Project success or failure.

The next predicament that the SNWDP comes across is constantly increasing water demand of the rapidly developing northeast China. Increase of the middle class, and the long time it takes to build the channels diminish the role of the water transfer as main solution. According to the former official Mr. Wang, Beijing's problem of water scarcity is exacerbated by the new western models of living where city planners envision the city with golf courses, swimming pools and other water intense facilities, while they should have decided on the size of the city according to the water availability (Wang et al 2005).

On the other hand water scholar He argues that if transferred fresh water is well managed, it could be an economically viable and environmentally sustainable way of mitigating north China's chronic water shortage problem (He et al 2010). It seems that the SNWDP might not be a solution of China's northeast water scarcity if the middle class demands for higher consumption are going to be ever increasing.

The population of China's northeast keeps growing at an outstanding pace which further diminishes the role of water transfer. Migration from the rural areas is one of the major reasons that leads to the growth of Beijing's population. The capital's population increases by a million every two year (Feng 2003), therefore population development scholar Hou Dongmin argues that Beijing cannot sustain a larger population and that instead of trying to bring more water in the city Chinese government should make serious efforts to limit population growth if not reduce it. Based on the existing literature it seems that even if the SNWDP is successful in bringing the planned quantities of safe drinkable water, it would not solve the problem of water scarcity unless accompanied with new city policies urging people to use water more responsibly.

Another major aspect that might diminish the efficiency of the SNWDP is water availability in the South. Southern officials are worried that three such vast water transfers to the north would hurt water supplies of the south. Therefore, there is a strong opposition toward building the third (West line) of the SNWDP (Gleick et al 2009). The major critique of the water transfer project in that regard is that the project authors used the outdated data from 1950s and early 1990s in their calculation of water availability in the South and since then the water flow in the south has significantly dropped, partly because of the more frequent droughts (Cai et al 2005). According to the studies

conducted in 2006 by Dr. Du, the diversion project would take up to third of the water flow from the Han river, which might put it in danger (Du et al 2006). This claim got even more support due to the recent drought in the South that was the biggest one in the last 50 years (He et al 2011). Considering the fact that droughts in the Chinese south are becoming more frequent, which at times have already caused some degree of water scarcity in several areas, the launching of the first line (East line) of the SNWDP at the beginning of this year would inevitably exacerbate the water problem in the south if such droughts are going to be a common place. However, Chinese officials claim that sufficient studies were conducted and the project is expected to mitigate northern water scarcity problem without putting in danger the south water security (Commission of the State Council 2005). Beijing's government admits that there are some potential risks, but they do not see a better solution of solving their severe water deficit predicament (Yang et al 2005). Nonetheless, there is also an opinion among scholars that the project is justified despite the hazard if only the appropriate watershed management initiative takes place in the Han River basin (Zhang et al 2009).

### **Analysis of five major critiques of the SNWDP**

The literature review and discussion on the SNWDP's Pro's and Con's revealed five major concerns regarding this water diversion project:

1. ***The price of transferred water is going to be too high***

The case study of water transfer between Yiwu and Dongyang in Jinghua river demonstrated that an increased price led to the increase in water quality and improvement in the water management system. Water Transfers in Ningxia Hui Autonomous Region and in Inner Mongolia indicated that due to the increased water

price and additional investment from the industries were brought it and farmers were alleviated from the necessity to pay for the water that was previously wasted without ever reaching the fields. The case of water transfer from Zhangye city Gansu province to Heihe river indicated some changes in the irrigation methods, that enabled some farmers to sell saved water to other sectors of the economy.

## 2. *Water Pollution*

Water transfer between Yiwu and Dongyang in Jinhua river demonstrated that an increased price can lead to the improvement in water quality and improvement in the water management system that ensures water safety.

## 3. *Environmental hazards*

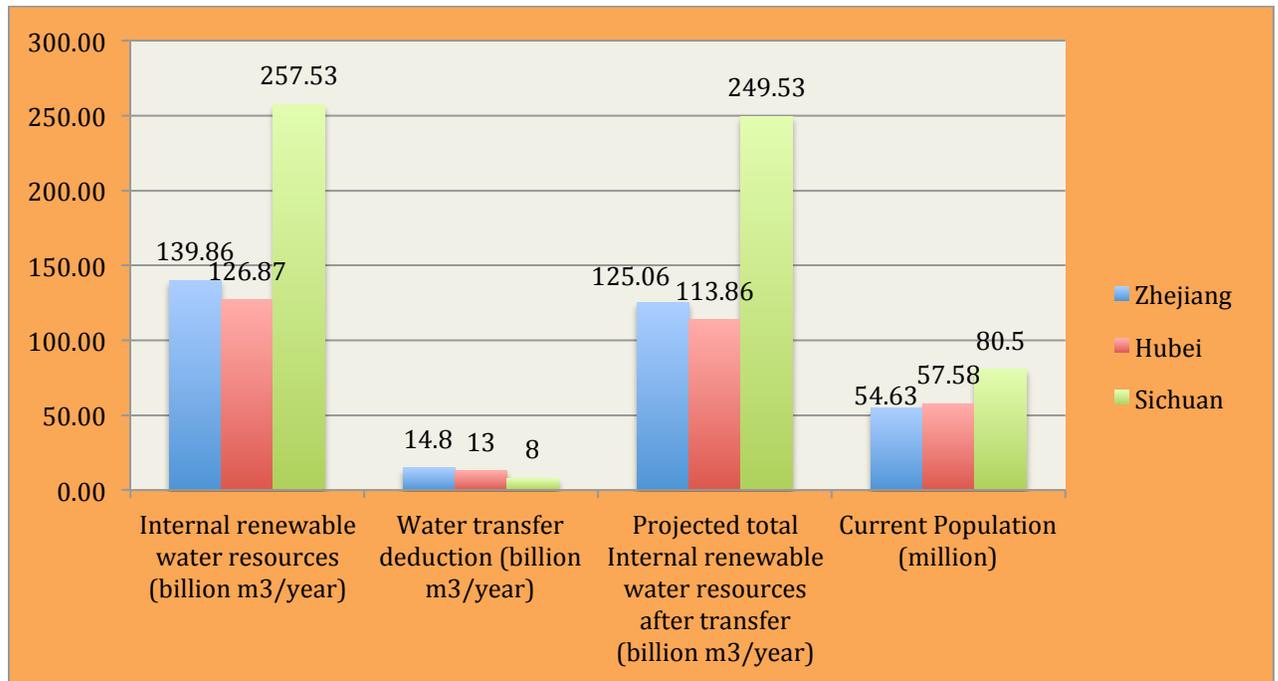
Although there are some risks to damage local ecosystems, ground water depletion of China's North should be taken into account. By 2005 the annual withdrawal of groundwater in the north exceeded renewable supply by 8.8 billion m<sup>3</sup> (China's Water Crises 2010). This leads to the drying up of lakes, wetlands, and increasing salinity of groundwater supplies. Therefore, given that by the end of this year SNWDP will bring 27.8 billion m<sup>3</sup> to China's northeast where the groundwater depletion is the most intense, I argue that not addressing ground water of the west presents a bigger environmental hazard than the SNWDP might potentially be.

## 4. *The SNWDP will put water availability in the South in danger*

It is known that the eastern route of the SNWDP is withdrawing water from Zhejiang province, while the central route is supplied with water resources of Hubei province and the western route is planned to take water from Sichuan province (Jaffe and Schneider,

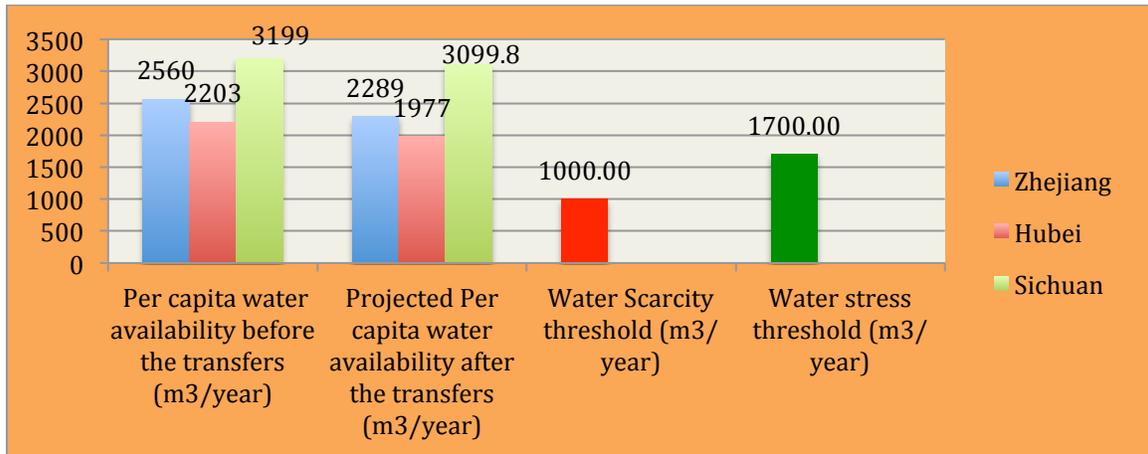
2011). After simple calculations I compiled a graph that illustrate the projected effect of the SNWDP on the water availability in three aforementioned provinces.

Figure 22. Projected effect of SNWDP on total water resources in Zhejiang, Hubei, Sichuan



From the Figure 22 we can see, that eastern route of the SNWDP will take 10.6% of Zhejiang, 10.3 % of Hubei and 3.1% of Sichuan annually renewable water, which makes the concern of big amounts of withdrawals from the South unreasonable. To further prove my argument, I compiled a graph that illustrates per capita water availability in three aforementioned provinces before and after water transfer.

Figure 23. Projected effect of SNWDP on per capita water availability in Zhejiang, Hubei and Sichuan



**5. Rapid population growth will swiftly diminish the SNWDP’s role as a main solution**

I found this critique to be the most insightful. While northern and southern provinces of China are slowly decreasing their population, millions of Chinese are migrating to the country’s northeast decreasing per capita water availability. Beijing’s population of 14 million (2000) has increased by 6.2 million in 11 years to 20.2 million (China Statistical Yearbook 2012).

Figure 24. Eastern and Western Route of SNWDP Supplying China’s Northeast

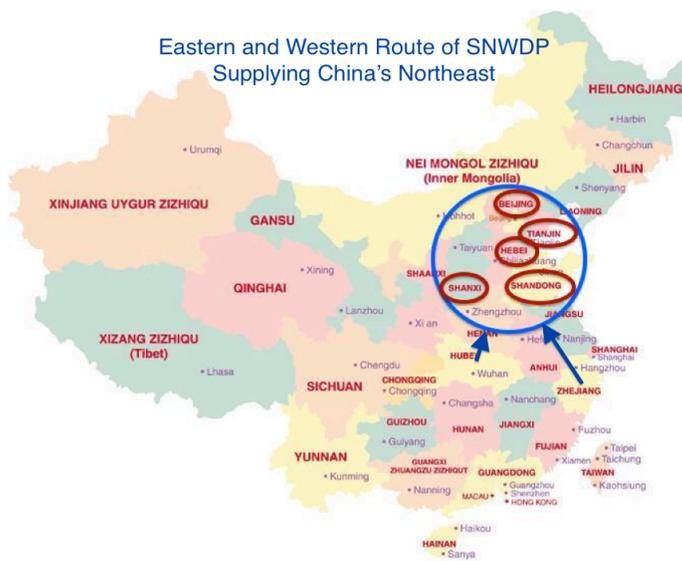


Figure 24 illustrates five most water scarce provinces of China's northeast. The SNWDP is meant to bring its water to these provinces helping them solve their scarcity problem. However, after conducting simple calculations I realized that the SNWDP is already too late to solve China's northeast water scarcity.

Figure 25: The amount of water needed to solve China's Northeast water scarcity

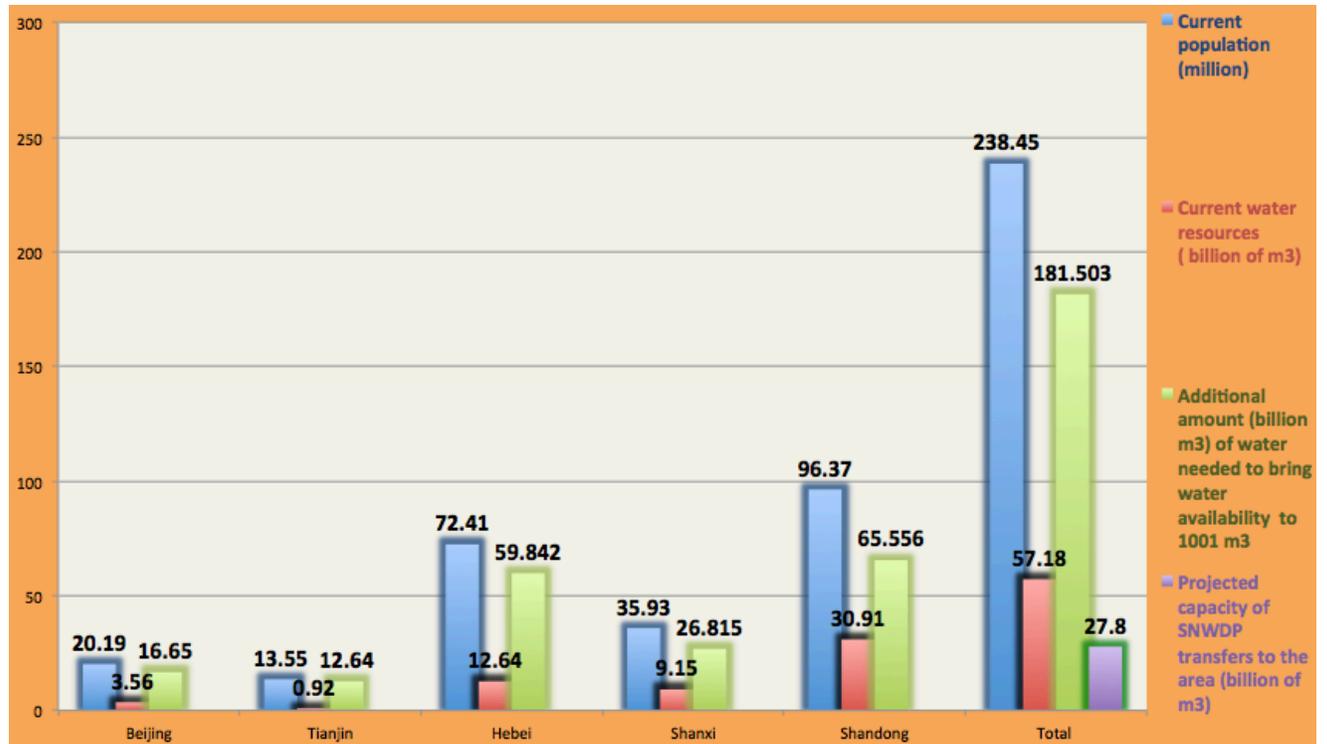


Figure 25 clearly demonstrates, that in order for five northeast provinces to solve their water scarcity problem ( to go above water scarcity threshold of 1000m<sup>3</sup>/water/year) their total population of 238.45 million people needs an additional 181.503 billion m<sup>3</sup>/water/year. The eastern and central routes of the SNWDP are projected to have a total capacity of 27.8 billion m<sup>3</sup>/water/year. This final graph (Figure 25) enables me to suggest 3 case scenario of SNWDP effect on water scarcity in northeast China.

### **Case scenario 1:**

If 27.8 billion of water transferred via eastern and central routes were to be evenly distributed among all five provinces, then the SNWDP would only mitigate China's northeast water scarcity by 15.32 % and this water transfer would be qualified under **"C" category: *Mitigating Measure***.

### **Case scenario 2:**

If most of the water from the SNWDP goes to the politically, economically and culturally important Beijing and Tianjin city, then it would be able to bring Beijing over water scarcity threshold, while increasing Tianjin city water availability in 13 times, making it come very close to the water scarcity threshold. In this case scenario, transfers to Beijing would get a **"B" category: *Partial Solution***, while Tianjin city would be qualified for **"C" category *Mitigating Measure***. Although, I have to emphasize, that given projected in this case scenario 13 time increase of Tianjin total water availability (currently it has less than 73 m<sup>3</sup>/water/year per capita ) the citizens and the administration of the city would perceived it as a complete solution.

### **Case scenario 3:**

If most of the water from the SNWDP goes to politically, economically, culturally and symbolically important Beijing, enabling it to solve its water scarcity problem then this water would be qualified for the **"B" category: *Partial Solution***. If the remaining 4 most water scarce provinces of China's northeast would evenly receive the rest of water from SNWDP, then they would be able to mitigate their water scarcity problem by 6.76%. This would qualify them for **"C" category: *Mitigating Measure***.

## **Conclusion:**

Striving to deal with the lack of unified analyses of small-scale water transfer projects in China I analyzed five cases in which water transfers took place. I looked at the various cases of small-scale water projects in China initiated after 2002 when water rights legislation was introduced. Each case was successful in increasing the water availability of a target population and/or river system. However, the rate of success varied and the cases spread over the following categories:

- A) Complete Solution: **Case 4.**
- B) Partial Solution: **Case 1, Case 2.**
- C) Mitigating Measure: **Case 3, Case 5**

Based on the aforementioned results I concluded that my hypothesis: *Water transfer is an efficient system in resolving water scarcity in the regions it is applied* had been justified. Nonetheless, striving to answer the main question of the research: *Does transferring water present an efficient solution to the water scarcity in China's northeast* I discussed the Pro's and Con's of the SNWDP expressed by academics and Chinese officials. Using the data from the cases analyzed in chapter four I addressed five main critiques/concerns revealed by the literature review:

- *The price of the transferred water is going to be too high*
- *Water pollution will compromise the project*
- *Environmental hazards of SNWDP are bigger than the benefits*
- *The SNWDP will put water availability in the South in danger*
- *Rapid population growth will swiftly diminish SNWDP's role as a main solution*

In the end, I am able to show that four out of five critiques are misleading. I find the fifth major concern of a rapid population growth to be the most insightful critique. I utilized the 1000 m<sup>3</sup> threshold model for five pilot water transfer projects and three case scenarios on the SNWDP effects on the water scarcity of the northeast China, and my thesis clearly demonstrates that SNWDP will not solve water scarcity problem in the northeast China. However, the SNWDP is symbolically important to Beijing politically, economically and culturally, in addition to mitigating water scarcity in the rest of water-poor provinces of China's northeast. Therefore I suggest that if the projected 27.8 billion (m<sup>3</sup>) of water, transferred via eastern and central routes, were to be evenly distributed among the five most water scarce northeastern provinces, then the SNWDP would only mitigate China's northeast water scarcity by 15.32 %.

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