



Advanced Water Management Through Hydrodynamic Modelling: A Study For The Aid Of The Water Resources In China

Li Na^{1*}, Aiman Al-Odaini²

^{1*}Research Scholar Lincoln University College Malaysia

² Lincoln University College Malaysia

Email: na@lincoln.edu.my

Citation: Li Na & Aiman Al-Odaini (2024), Advanced Water Management Through Hydrodynamic Modelling: A Study For The Aid Of The Water Resources In China *Educational Administration: Theory And Practice*, 30(4), 9503- 9508

Doi: [10.53555/kuey.v30i4.4414](https://doi.org/10.53555/kuey.v30i4.4414)

ARTICLE INFO

ABSTRACT

To forecast the medium-term development of the Nam Theun 2 Reservoir's water quality and to measure the impact of different scenarios, a 3D water quality model was used. Although the hypolimnion will be anoxic in some places of the Reservoir, 15-year models indicate that the oxygen content in the water column will continue to grow. Also, as time goes on, less and fewer reduced chemicals will be present. Using two situations in which either natural or human-induced forcings have been altered, the importance of hydrodynamics in the development of water quality is highlighted. When looking at models from different years with different hydrometeorological circumstances, it becomes clear that the length of major hydrometeorological events, such as rainfall, floods, and drops in air temperature, significantly affects the seasonal changes in water quality over the whole reservoir. Commissioning the power plant right after impoundment would have altered the physicochemical quality of the water discharged downstream, according to simulations. Lastly, the model has been used to measure the effects of a rise in the incoming flux of NO₃- and PO₄-3 after possible changes to the land use within the watershed. Both individually and in combination, the fluxes have been doubled.

KEYWORD: *Hydro Economic Model, Water Management, Hydrodynamic Modelling, Climate Effect.*

1. INTRODUCTION:

Researchers assert that the activities that people participate in and the growing populations that they are responsible for are generating a rising amount of strain to be placed on the natural resources and ecosystems. This pressure is being caused by the activities that people involve in. The strain that is being experienced is a result of natural resources and ecosystems. There is a growing demand for water, which is putting ecosystems all over the world in jeopardy. This is causing the water deficit to become even more severe. It is for this reason that the water shortage is becoming worse, which is one of the causes. In addition to being an alluvial plain, the North China Plain (NCP) has a total size of 320,000 square kilometres and is in the provinces of Hebei, Henan, Beijing, Tianjin, and Shandong. Additionally, it is referred to as the North China Plain. The National Capital Public Park (NCP) was established because of the Yellow, Huai, and Hai rivers. These rivers are responsible for the park's initial formation (McBride, 2019).

The results of a study that was conducted by experts indicate that over the course of the last several decades, the area has been seeing an increase in the number of instances in which there is a lack of water. This scenario has been brought about by a few circumstances, including the rapid urbanization of the area, the growth in population, and the unpredictability of the atmospheric conditions. Pisaniello, 2020 believes that the plain is a tremendously strong economic force since it is home to a population of more than 200 million people, a large industrial sector, and a considerable quantity of wheat and maize production. On top of that, the plain is remarkable in terms of the quantity of agricultural products that it can sustain. It is crucial for the home, agricultural, and industrial sectors to have access to clean water; nevertheless, those who utilize water are

having difficulties because water is becoming increasingly restricted. The availability of water that is free of pollution is an extremely important need for these types of businesses. The lack of available water puts a strain not just on the available water resources but also on the ecosystems that they support. Because of this, water management becomes more challenging since it compels decision-makers to assign a higher priority to the many applications of water that are present within a system. One of the reasons for this is that the scarcity of water that is readily accessible puts a pressure not only on the water resources but also on the ecosystems. The overexploitation of the groundwater aquifer, which has been combined with the excessive storage of surface water for agricultural purposes, has resulted in a decrease in the levels of groundwater. This reduction has happened as a negative consequence. A significant number of rivers have either dried up or been severely contaminated because of this, which, in conjunction with the excessive storage of surface water, has led to the aforementioned situation (**Marchis, 2020**).

2. BACKGROUND OF THE STUDY:

A document titled "2011 No. 1 Central Policy Document" was drafted by the Chinese government in order to offer a policy framework that is comparable to the European Water Framework Directive. Taking into consideration the rising worries around water, this article was written as a response to such issues. Although this policy statement is primarily concerned with objectives related to a wide range of water scarcity and water quality problems, it is of the utmost importance to emphasise the significance of an integrated approach in order to address the interconnected and complex issues that are associated with water resource management. This is because it is the only way to effectively address these issues. Water quality management, water allocation, and water efficiency are three of the many disciplines that are included in the aims. These are all disciplines that are often considered to be distinct from one another on account of their similarities and differences. Although it is possible to define the objectives on an individual basis, it is also possible that solutions that are focused on a particular sector might conflict with those that are supplied by other disciplines. This is something that is imaginable. A number of different elements, such as the discharge of pollutants and the flow of rivers, for instance, have the potential to influence the quality of the water that passes through rivers. It is not feasible to estimate the allowed volumes of pollutant effluents without first providing information on reservoir releases and water allocations, for example. This is because of the fact that because of this, it is not possible. The reason for this is because it is not at all feasible. An approach known as integrated water resources management (IWRM) is a method that, when implemented in this context, improves resource coordination while simultaneously safeguarding economic and ecological sustainability, as well as social equity (**Schmidt, 2019**).

3. PURPOSE OF THE RESEARCH:

This scenario is the consequence of the fact that the purpose of this doctorate research is to widen the use of hydro economic approaches to improve water quality, availability, and distribution. This is the reason why this is the situation that exists. There is a strategy that has been created that models water management as a joint optimisation problem. The goal of this approach is to reduce the cost of water distribution over the whole basin while still satisfying the demand from users. This is the reason why the approach is being used. The purpose of this method is to find a solution to an optimization issue so that it can accomplish its goal. The article describes a technique that "simplifies the water management difficulty into a case of a single-objective optimisation" as a potential solution to the tough problem of water management. This approach is given as a viable solution. One possible answer may be found in this article.

4. LITERATURE REVIEW:

The Chinese government, in response to the growing concerns over water, produced the "2011 No. 1 Central Policy Document," which is a policy framework that is equivalent to the European Water Framework Directive. This document was established in 2011. In the year 2011, this paper was made public. This study was conceived as a response to the growing concerns that have been expressed over water throughout the course of recent events. To address problems about the management of water resources that are both complex and interrelated, researchers are now doing research. The actions that they are doing are bringing attention to the fact that an integrated strategy is required in order to effectively address these challenges (**Geng, 2020**).

The policy statement in question, on the other hand, places a significant emphasis on objectives that fall under a variety of categories that are associated with water quality and water scarcity. These goals are described in the statement that comes after this one. There are a few other domains that are included in the goals. These domains include water quality management, water allocation, and water efficiency, all of which are often regarded to be independently different domains. One of these fields is water efficiency, which is one of the priorities. Even if it is feasible to define the goals on an individual basis, it is also possible that solutions that are centered on a particular sector might conflict with those that are offered by other areas of study. This is

something that is imaginable. The quality of the water that flows through rivers may be affected by a number of different factors, including the discharge of pollutants and the flow of rivers, for example. These factors have the potential to have an effect on environmental quality. Without initially giving information on reservoir releases and water allocations, for instance, it is not possible to provide an accurate estimate of the permitted amounts of polluting effluents. This is due to the fact that because of this, it is not feasible to fulfill the need. Because it is not even somewhat possible to do so, this is the explanation behind this. IWRM, which stands for integrated water resources management, is a method that, when seen in this context, is a strategy that enhances resource coordination while simultaneously ensuring economic and ecological sustainability, as well as social equality, if it is adopted (Balas, 2019).

5. RESEARCH QUESTION:

- "Can the hydroeconomic optimisation method" be implemented in what ways?

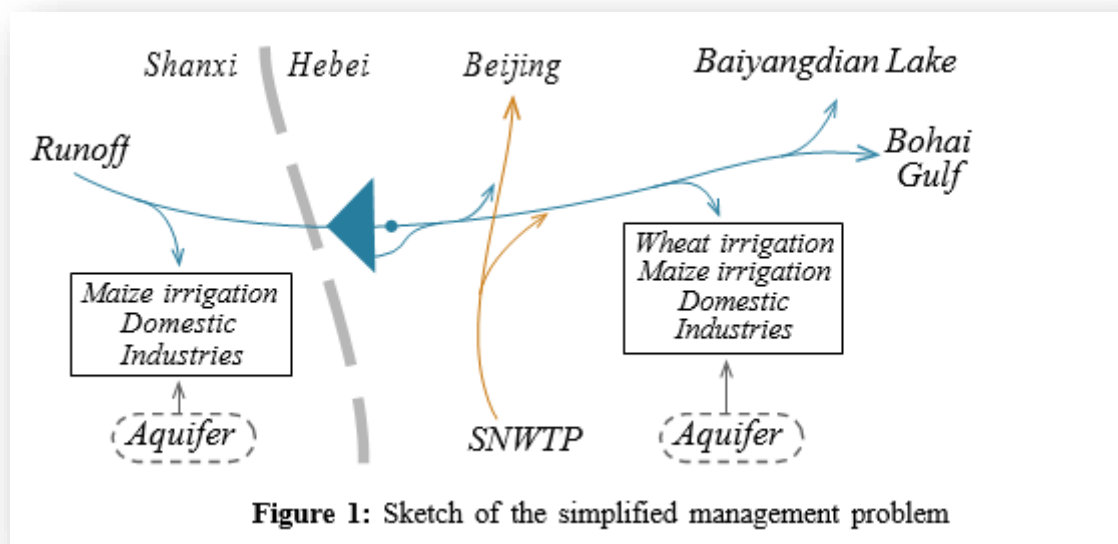
6. RESEARCH METHODOLOGY:

This PhD dissertation examines water resource management from a hydroeconomic optimization perspective. The overarching goal of this study is to find the most cost-effective solutions for managing water resources and preventing water shortages in the ZRB. An introduction to fundamental optimization methods and their use in the context of the ZRB problem will be covered in the lecture. The agenda for the session will cover this. The last phase, presenting potential uses of the data to aid decision-making, is undoubtedly crucial.

• Research design:

People with decision-making authority must settle on several allocations of resources in terms of their quantitative value. Part of the problem with management is this. The rainfall-runoff model is used to determine the available water amount. After then, this information is used as a random input for the optimization process. Two aspects that define them are the amount of water that consumers utilize and the expenses associated with water limitations. Curtailment costs are the marginal expenses associated with water shortages that result from not meeting a user's water demand. When all water restrictions are added together, the total cost of water shortage is calculated. When talking about water shortage, these two phrases are used interchangeably. You may calculate the total societal cost of water management by adding up all the charges associated with water scarcity and availability, the costs of water treatment, and the benefits of hydropower, among other things. You may do this simply tallying up all of the costs.

7. CONCEPTUAL FRAMEWORK:

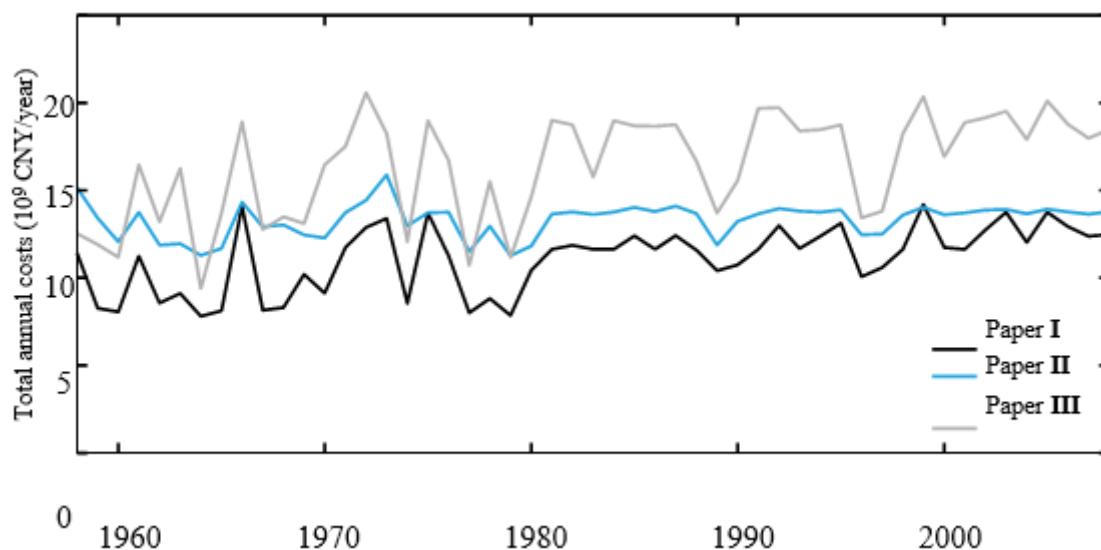


8. RESULT:

The average annual expenses of surface water shadows from all three studies. The lowest water values were seen in the Paper I simulation, as confirmed by the equilibrium water value tables. Similarities are also seen in the surface water values measured in the other two trials. The total costs of the Paper III simulation were much more than those of the other two trials, even if there were some similarities. The first six months of the year

have the largest total expenditures. This is due to the fact that yearly water use peaks between March and July, whereas the rainiest month is August.

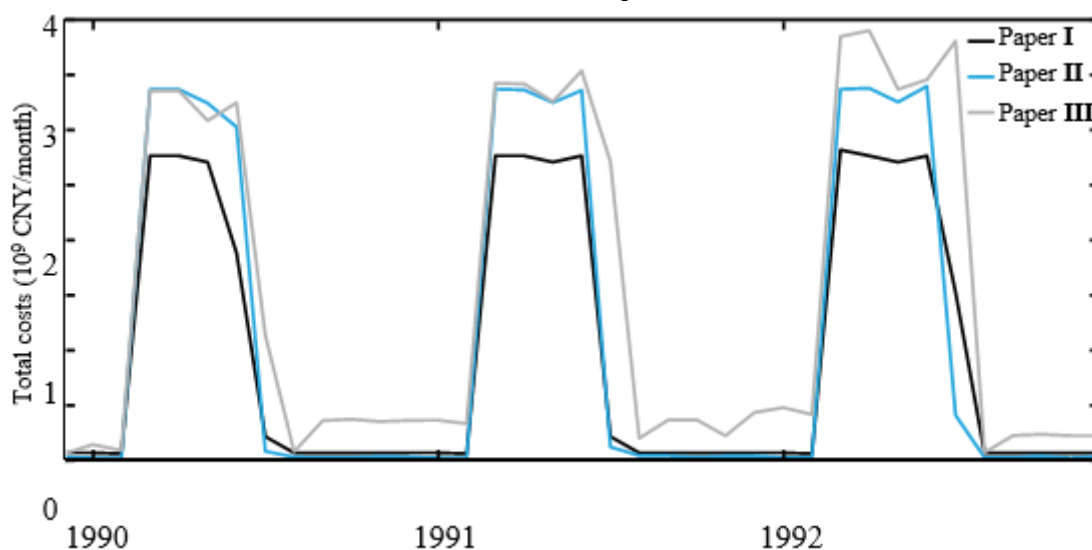
Figure 1: In "comparable" situations, the yearly sum for all three models.



When water is scarce, the already high cost of complying with water quality standards becomes intolerable. Reducing the river's BOD at an affordable cost was crucial to Paper III's conclusions in order to achieve the water quality requirement. A "substitute mitigating" approach that was suggested was the transfer of surface water for allocation.

By way of Node 2's customers, who will then use the water to dilute Node 1's BOD wastes. The projected costs during the dry season in late fall and winter in Paper III were much higher than in the two preceding studies. During the dry months, the findings showed that the model was forced to reduce BOD emissions, either by limiting water users more or by removing more BOD.

Figure 2: Income for each model month in 1990, 1991, and 1992. Per I: Requirements for minimum in-stream flow and monthly groundwater pumping; Part II: The first groundwater storage at 100 km³ (or 36% full), taking into account Thiem drawdown and the minimal in-stream flow needs; Water quality grade II, a set groundwater price of 2.5 CNY/m³, and a minimum in-stream flow requirement of 5% of natural runoff are all included in Paper III.



Using the three models, they examined several economic scenarios. A summary of these costs is provided, which helps to illuminate the likely monetary consequences of future water management in ZRB. The monetary rewards of the SNWTP were an endeavor of both articles. When comparing overall expenditures with and without the SNWTP, the amount of water given by the SNWTP from the Yangtze River to the ZRB and Beijing

had a marginal benefit of 4.7 CNY/m³, with a standard deviation of 0.2 CNY/m³. This figure is very sensitive to the quantity of water that the basin is allowed to access. The hydroeconomic model should ideally include all river basins that receive water from the SNWTP as boundary conditions. The true worth of the SNWTP could then be ascertained, and the distribution with the highest efficiency could be selected.

9. DISCUSSION:

The PhD project's primary objective was to develop methodologies; however, it also sought to construct a realistic dataset to substantiate the approach by collecting data concurrently. For this PhD dissertation to be completed within the allotted time, several assumptions and simplifications had to be made. Handling sensitive material, overcoming language obstacles, and navigating a complicated institutional structure all posed challenges to the thorough gathering and validation of data. An important part of the optimization models is the readily available natural water, which is computed using a basic rainfall-runoff model. Since runoff data reflects current management methods, it is challenging to verify the accuracy of the anticipated natural water availability. On the other hand, those in charge should know more about the water resources that are at their disposal. In addition, they calculated the potential expenses associated with treatment fees, BOD production, user water demand, and water limitations. Instead of user demand and curtailment cost, actual water demand functions would be used in a perfect world. Using the proposed framework, they may express the demand function as a step-wise function with different demands and curtailment costs. More granular "BOD" generation, a broader variety of crop types, users in rural and urban regions, and other forms of sectors are all potential additions to the optimization framework that might help it better represent users. For the runoff group, regarding watering needs. Again, limitations in both time and data prevented this advancement from happening (Raith, 2019).

To top it all off, the modeling framework introduces even another degree of doubt. Because of the SDP framework's dimensionality curse, the models don't work for problems like forced regional aggregation or managing several reservoirs. The authors of ZRB assumed this to be true without testing it using a multi-reservoir optimization technique like SDDP. Keeping the pumping cost constant is a good near-optimal strategy for plans with short time horizons. Ignoring the responses of the dynamic pumping costs to pumping will result in excessive monthly pumping rates. Bringing together the patterns from Paper II and Paper III is your best choice. To better represent the true cost of pumping the water, groundwater allocation over a longer time period may be more appropriate. When the groundwater level rises again, the integrated model suggests that pumping costs could go down over time. This link may be possible with lesser aquifers if, for example, equilibrium water levels can be reached after twenty years of regressive repetition. It took over 150 years to reverse the process and bring the water demand back down to a sustainable level since the ZRB aquifer couldn't keep up with demand. Because of this, merging the two models will become computationally challenging. Researchers examined uncertainty using Monte Carlo simulations in the first article. With no problem, the optimization model could handle a massive population. They calculated the impact of unknown input data on expected end costs using uncertainty analysis. As expected given the input uncertainty, the computed standard deviations fell between the 15% to 33% range. There ought to be a direct correlation between lowering the input uncertainty and lowering the output uncertainty. Articles 2 and 3 offer models that need much more computational resources. The computational demands of classical uncertainty analysis become apparent when working with big numerical models. A single model run requires an enormous amount of processing power—150,000 CPU hours—and the author has no idea how to lower this number. A different option was to grade the input data using a simple local sensitivity method that was based on terahertz-sensitive levels. Simplifying the issue can potentially speed up the execution of the calculations for each model. The limitations of this PhD program have not "fixed" the problem just yet (Cebe, 2020).

10. CONCLUSION:

The goal of this PhD dissertation was to use hydroeconomic theory in a new way to solve the complicated problems of managing surface water, groundwater, and water quality. Taking water management into account as a joint optimization issue, the proposed method aims to decrease the cost of water supply throughout the basin while simultaneously satisfying all water needs. Water management is a complex subject, but the approach simplifies it to a one-objective optimization problem.

A Chinese river basin's complicated water management problem was effectively addressed using the method. A sort of stochastic dynamic programming, the water value approach allowed the first system to formalize the management problem with relative simplicity. The produced water value tables were ideal for water management due to their aesthetically pleasing and practically useful design, which allowed for a quantitative understanding of the fundamental water issues. The effective optimization models allowed for a thorough investigation of the framework's uncertainty. According to the concept, customers would continue pumping groundwater until their demands were satisfied if rules were not in place to limit its use. Not only that, but the findings also showed that the middle route of the South-to-North Water Transfer Project would help with water deficit reduction via better resource management.

They were able to replicate the effect of groundwater pumping costs, which vary with pumping head, by including a dynamic aquifer in the second edition. The paper detailed the potential use of a hydroeconomic optimization method to replenish a depleted groundwater aquifer via the development of a pricing strategy. To "allow" for the non-convexity caused by the complicated objective function, a hybrid genetic algorithm-linear programming formulation was developed. This approach may be readily modified to include stable Thiem local drawdown cones. According to the water value approach, the equilibrium values of groundwater were unaffected by the types of water entering the region, the volume of water above ground, or the time of year. Past methods that have made use of this data have the ability to simplify linked surface and groundwater management. The study found that the dynamic groundwater aquifer prevented overexploitation even in years with low precipitation by acting as a buffer. Despite the water issue, customers' water costs remained low. While stochastic dynamic programming is computationally costly, it is sufficiently flexible to handle complex nonlinear objective functions.

In its third iteration, the water resource management model successfully dealt with complex water quality constraints. The second study laid the groundwork for the framework's architecture by proposing a very basic groundwater module with a set user fee. They used the biochemical oxygen demand to simulate the formation of pollutants and set up controls to aim for the minimum dissolved oxygen level downstream, as determined by the Streeter-Phelps equation. Even though the stochastic dynamic programming optimization problem had non-linear constraints and an objective function that was not linear, it was nonetheless computationally feasible. Users farther down the pipeline were given surface water to dilute, as seen in the data. No matter how stringent the water quality limitations were, the ecological discharges consistently exceeded the minimum level. Even if the total increase in prices is smaller than the shortfall costs, traditional water supply and demand assessments should still take water quality into account. The finest management approach underwent significant adjustments, proving this.

11. REFERENCE:

1. Cebe, K. & Balas, L. (2020). Water quality modelling in Kaş Bay. *Applied Mathematical Modelling*, 40(3), 1887-1913. DOI: 10.1016/j.apm.2015.09.037
2. Balas, L. (2019). Monitoring and modeling land-based marine pollution. *Regional Studies in Marine Science*, 24, 23-39. DOI: 10.1016/j.rsma.2018.06.010
3. Genç, A.N., Vural, N. & Balas, L. (2020). Modeling transport of microplastics in enclosed coastal waters: A case study in the Fethiye Inner Bay. *Marine Pollution Bulletin*, 150, 110747. <https://doi.org/10.1016/j.marpolbul.2019.110747>
4. Schmidt, P.J., Emelko, M.B., Thompson, M.E., 2019. Analytical recovery of protozoan enumeration methods: Have drinking water QMRA models corrected or created bias? *Water Research* 47(7), 2399-2408.
5. Marchis, M.D., Freni, G., Napoli, E., 2020. Modelling of E. coli distribution in coastal areas subjected to combined sewer overflows. *Water Science and Technology* 68(5), 1123-1136.
6. McBride, G.B., Stott, R., Miller, W., Bambic, D., Wuertz, S., 2019. Discharge-based QMRA for estimation of public health risks from exposure to stormwater-borne pathogens in recreational waters in the United States. *Water Research* 47(14), 5282-5297.
7. Raith, M.R., Kelty, C.A., Griffith, J.F., D.L., Jay, J.A., Wang, D., Boehm, A.B., Aw, T.G., Rose, J.B., Balleste, E., Meijer, W.G., Sivaganesan, M., Shanks, O.C., 2019. Comparison of PCR and quantitative real-time PCR methods for the characterization of ruminant and cattle fecal pollution sources. *Water Research*.