Demand Analysis of Water Resources Based on Pulse Process of Complex System

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Abstract—In this paper, we examine the demand for fresh water of China in 2025 from the complex system modeling perspective and we develop an efficient, economical and practical water strategy to meet the demand for fresh water in 2025. Different from previous research, this study focus on studying several factors that can influence the demand for fresh water, and their interplay within the complex large-scale system. We construct the Directed Graph Model and the Impulse Process Model to study the complex system in a qualitatively way. After that, on the basis of qualitative study, we study the whole system quantitatively by using the Leontief Inverse Matrix. And draw an effective, feasible, and cost-efficient water strategy, namely, adjusting the relation between seawater desalination and the water protection.

Index Terms—complex large-scale system modeling, pulse process, demand analyze

I. INTRODUCTION

Fresh water is a very precious resource. Unfortunately, the amount of fresh water is not infinite. Overusing has already destroyed the balance of the water in the nature. As we all know, fresh water is the limiting constraint for development in much of the world nowadays, and China is no exception. According to a prediction, the water use will peak at 2030. The demand for fresh water will reach the limitation of the amount of the water available [1]. So it is easy to imagine that there may be some water stress in China in the future. It will be horrible. Thus, we need to do some study about the water condition, and develop an appropriate strategy to solve the potential problem.

In order to develop a strategy, we have to predict the water condition in 2025 first. Traditional prediction method is to use the population prediction [2-4]. Because after analyzing the factors that can influence the demand for water using the correlation analysis, we find that the most important factor is the population. There are several ways to predict the future population, such as the Malthusian Theory of Population [5-7] and the Logistics algorithm [8-9]. After predicting the population, we can use the correlation between the population and the demand for water to get the correlation equation. Finally, it is not difficult to predict the water condition in 2025.

However, this kind of method cannot get a pretty exact result for it only considers the population. We are supposed to include all the factors to get the result. While, as we all know, the relationship between things are so complex that we usually cannot get an accurate result while evaluate objects. We know that the demand for fresh water is influenced by many factors such as population, environment quality and so on. However, we cannot get the demand easily just by considering the relationship between water and the other factors. There is no denying that those factors are related. At this time, we must try to find out another method to solve this complicated problem. Huang Junli and his colleagues state in their paper Sustainable Utilization of Water Resources that possible influencing factors are water price, environment quality and utilization efficiency of water. However, the influencing factors are far more than these. We have to consider all the important factors together, and analyze them together. Based on this, we come up with the complex system model. It not only includes influential factors but also considers the mutual effect. We include fresh water demanded quantity, the production of sea water desalination, environment quality, industrial production value, agricultural production value and population these six factors in the complex system. Our complex large-scale system model consists of two parts: the directed graph model and the pulse process model. The directed graph has a comprehensive analysis of the relationship among elements, ensuring the integrity and veracity of the whole system. We build directed graph model to find the relationship of these factors and can get the adjacent matrix easily. Pulse process model can be built then according to the data. Then, we can work out the solution by using the difference equation. By now, we finish the complex system. However, it is necessary to ensure whether the system is stable or not so that we can know the strategy we should do. After stability analysis, we draw the water strategy.

We do an experiment analysis of the complex system model and make a comparison between our method and single factor model. Leontief Inverse Matrix is the way we use to calculate the quantitative relation between each two factors [10-12]. We substitute the real data into the model and get the quantitative result. It demonstrates that our analysis is a very useful method. Through
In this way, we can get the population in 2025, so it is easy to calculate the water condition.

We can find that both the amount of the total water consumption and the population increase annually, and their trends are in similarity in Table 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (million)</th>
<th>Total water use (billion cubic meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1284.53</td>
<td>549.70</td>
</tr>
<tr>
<td>2003</td>
<td>1292.27</td>
<td>532.00</td>
</tr>
<tr>
<td>2004</td>
<td>1299.88</td>
<td>554.80</td>
</tr>
<tr>
<td>2005</td>
<td>1307.56</td>
<td>563.30</td>
</tr>
<tr>
<td>2006</td>
<td>1314.48</td>
<td>579.50</td>
</tr>
<tr>
<td>2007</td>
<td>1321.29</td>
<td>581.90</td>
</tr>
<tr>
<td>2008</td>
<td>1328.02</td>
<td>591.00</td>
</tr>
<tr>
<td>2009</td>
<td>1334.74</td>
<td>596.52</td>
</tr>
<tr>
<td>2010</td>
<td>1340.91</td>
<td>602.20</td>
</tr>
<tr>
<td>2011</td>
<td>1347.35</td>
<td>610.72</td>
</tr>
</tbody>
</table>

Therefore, we can do the correlation analysis between population and total water consumption.

\[
r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2} \sqrt{\sum (y - \bar{y})^2}}
\]

According to the calculation, we will get that \( r = 0.9634 \) between these two items. So population has high correlation level with total water consumption. After constructing the linear regression of the data, the result is obvious.

However, this kind of method is not accurate, it only consider the most important factor. So, we come up with another model.

III. COMPLEX LARGE-SCALE SYSTEM MODELING

A. Model Description

We include all the influencing factors in a complex system, and model on the basis of the system [13-14]. We develop two steps to construct our model.

Construct the Directed Graph Model, and study the mutual influences of factors in the complex system with macro examination. Decide the qualitative and quantitative relationship among all the factors [15-17].

Construct the Impulse Process Model to predict the demand for water in 2025. Additionally, we will discuss the stability of the system impulse process, and hence develop relevant water strategy to modify the system [18].

B. Directed Graph Model

Fresh water requirement is affected by numerous factors; we choose six major factors to build our system [19-20]. The notation references are listed below.

\( v_1 \) fresh water demanded quantity
\( v_2 \) production of sea water desalination
\( v_3 \) environment quality
\( v_4 \) industrial production value
\( v_5 \) agricultural production value
\( v_6 \) population
First of all, we have to analyze and decide the relationship between all the six factors.

- $v_1 - v_2$: Positive effect.
- $v_1 - v_3$: Negative effect.
- $v_2 - v_3$: Positive effect.
- $v_3 - v_4$: Positive effect.
- $v_4 - v_5$: Positive effect.
- $v_5 - v_6$: Positive effect.
- $v_6 - v_2$: Positive effect.
- $v_6 - v_1$: Positive effect.

According to the relationship listed above, we can develop our directed graph $G = (V, E)$ where $V$ is the vertex set, refers to the system elements and $E$ is the arc set, refers to the relationship among system elements.

![Directed Graph](image)

The adjacent matrix $A$ of the directed graph is:

$$A = \begin{bmatrix}
0 & 1 & -1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 1 & 0
\end{bmatrix}$$

The meaning of characters in the matrix:

$$a_{ij} = \begin{cases}
1, & v_i v_j + \\
-1, & v_i v_j - \\
0, & v_i v_j \notin E
\end{cases}$$

C. Impulse Process Model

In order to predict the amount of the freshwater requirement, and develop an appropriate water strategy, we analyze the possible system change that caused by alternation of some element $v_i$ in the system.

$p_i(t)$ refers to the variation (impulse) of $v_i$ at time $t$

$$p_i(t+1) = v_i(t) + p_i(t+1), i = 1, 2, L, n, t = 0, 1, 2, L$$

$$p_i(t+1) = \sum_{i=0}^{n} w_{ij} p_i(t)$$

or

$$p_i(t+1) = \sum_{i=0}^{n} a_{ij} p_i(t)$$

$v(t) = (v_1(t), v_2(t), L, v_n(t)) p(t) = (p_1(t), p_2(t), L, p_n(t))$

So, we can construct homologous Pulse Process Model:

$$v(t + 1) = v(t) + p(t + 1)$$

$$p(t + 1) = p(t)A$$

$$p(t + 1) = p(t)W$$

Setting: $v(0) = p(0)$

According to the pulse process model, we can work out the solution easily by using the difference equation.

$$\bar{v}_i = \frac{a + I_0 + \Delta t}{1 - b}$$

Suppose in the original status, the consumption of fresh water increases dramatically, then predict the evolution of the system.

We assume that the demand for fresh water increase dramatically in the original status, that is, $P_1(0) = 1$

Then, the prediction process of the system to 2025 displays as Table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>$P_1$</th>
<th>$P_2$</th>
<th>$P_3$</th>
<th>$P_4$</th>
<th>$P_5$</th>
<th>$V_1$</th>
<th>$V_2$</th>
<th>$V_3$</th>
<th>$V_4$</th>
<th>$V_5$</th>
<th>$V_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>-1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2015</td>
<td>-1</td>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>1</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>-2</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2017</td>
<td>2</td>
<td>-1</td>
<td>-2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
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<tr>
<td>2018</td>
<td>1</td>
<td>-2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>2019</td>
<td>-3</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>-1</td>
<td>6</td>
<td>0</td>
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<td>8</td>
<td>8</td>
<td>2</td>
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<td>2020</td>
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<td>6</td>
<td>-4</td>
<td>-2</td>
<td>-2</td>
<td>-5</td>
<td>8</td>
<td>14</td>
<td>4</td>
<td>0</td>
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<tr>
<td>2021</td>
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<td>-6</td>
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<td>-7</td>
<td>1</td>
<td>-11</td>
<td>-5</td>
<td>-14</td>
<td>12</td>
<td>-3</td>
<td>1</td>
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<tr>
<td>2022</td>
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<td>-2</td>
<td>-11</td>
<td>1</td>
<td>6</td>
<td>-6</td>
<td>3</td>
<td>12</td>
<td>1</td>
<td>-2</td>
<td>7</td>
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<td>2023</td>
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<td>-6</td>
<td>14</td>
<td>6</td>
<td>15</td>
<td>12</td>
<td>1</td>
<td>-5</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>2024</td>
<td>-5</td>
<td>-6</td>
<td>15</td>
<td>15</td>
<td>-2</td>
<td>29</td>
<td>7</td>
<td>-5</td>
<td>10</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>2025</td>
<td>-21</td>
<td>15</td>
<td>29</td>
<td>-7</td>
<td>-11</td>
<td>8</td>
<td>-14</td>
<td>10</td>
<td>39</td>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

As we can see in the table, the status of $v_i$ in 2025 is -14, that is, the fresh water requirement in 2025 will shift -14 unit amounts comparing to 2011.
By pulse process prediction, we can obtain the total demand for fresh water in 2025, and according to the statistics, the total water resources stored in China will be adequate to meet the need. However, since the system has possibility of existing instability, and it is very likely that there will arise abnormal overflow issues when some element changes. This will break the balance in the whole water circulation system. So, it is necessary for us to do the stability judgment for the pulse process.

As for the pulse process, we can know that:

If for arbitrary \( t \), \( p(t) \) is bounded, then the pulse process’s pulse is stable.

If for arbitrary \( t \), \( p(t) \) is bounded, then the pulse process’s value is stable.

According to the pulse process model, it is obvious that if value is stable, then the pulse is stable.

So, due to

\[
p(t) = p(0)W
\]

We can know that systematic pulse process’s stability depends on the characteristic root of system’s digraph adjacent matrix. Mark nonzero characteristic root as \( \lambda \), then

\[
S_{\text{pulse is stable}} \Rightarrow |\lambda| \leq 1
\]

\[
S_{\text{pulse is stable}} \Leftrightarrow |\lambda| \leq 1 \text{ and all the } \lambda \text{ should be simple root}
\]

\[
S_{\text{value is stable}} \Rightarrow S_{\text{pulse stable}} \text{ and } \lambda \neq 1
\]

Our adjacent matrix

\[
A = \begin{bmatrix}
0 & 1 & -1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 \\
1 & 0 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 0
\end{bmatrix}
\]

So its characteristic polynomial is

\[
f(\lambda) = \lambda^6 + \lambda^5 + 4\lambda^2 + 4\lambda + 1
\]

So the system pulse process doesn’t have stability.

In order to avoid possible severe consequence that may be caused by the instability, we need to adjust our system. So we analyze the system’s directed graph, and study it’s return circuit.

Setting: \( a_i \) as the mark of those return circuit whose length is \( k , r \) as biggest integer that can make \( a_i \neq 0 \)

If \( S’ \) pulse has stability

\[
a_k = \pm 1, a_i = -a_{i-k} \quad (k = 1, 2, A, r - 1)
\]

In our model,

\[
a_1 = 0 \quad a_2 = 0 \quad a_3 = -1 \quad a_4 = 0 \quad a_5 = 2 \quad a_6 = 1
\]

So, \( r = 6 \)

We can obtain that:

\[
a_i = a_6 = 1 \\
a = a_6 = 1 \\
a \neq -a_5 \\
a_2 = -a_4 \\
a_3 \neq -a_3
\]

In order to make our system stable, we consider adjusting the relationship between \( v_2 \) and \( v_5 \).

There are mainly four ways to desalinate the sea water: distillation, electro dialysis process, reverse osmosis process and cooling method. Among them, the cooling method has the lowest cost, but can do certain harm to the environment. We can encourage the government to use the cooling method in order to seek for the biggest economic benefits, but it sacrifices the environment quality in some degree within the affordability of the nature. Then the relationship between \( v_2 \) and \( v_5 \) will change to:

\[
(+)v_2, \rightarrow (-)v_3
\]

After the adjustment, our adjacent matrix become to

\[
A = \begin{bmatrix}
0 & 1 & -1 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 \\
1 & 0 & 0 & 0 & 1 & 0 \\
1 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 & 0 & 0
\end{bmatrix}
\]

So it is characteristic polynomial is

\[
f(\lambda) = \lambda^6 + \lambda^5 + 4\lambda^2 + 4\lambda + 1
\]

The solution is:

\[
x_1 = 1.1907 + 1.1140i \\
x_2 = 1.1907 - 1.1140i \\
x_3 = -0.6253 + 0.9592i \\
x_4 = -0.6253 - 0.9592i \\
x_5 = -0.3843 \\
x_6 = -0.7464
\]

Once the system is adjusted to a stable pulse process, according to our prediction, before 2025, we should encourage the government to use the cooling method to develop the sea-water desalination production, even we have to sacrifice the environment quality in some degree within the affordability of the nature. This strategy can keep China’s water resources meet the demand in 2025, and make the biggest profit of it.

IV. EXPERIMENTS ANALYSIS

A. Quantitative Analysis

On the basis of original directed graph model, we introduce the weight of the relationship between the elements.

We collect all the relative statistics in the last decade in the table 4.
TABLE 4 REALISTIC DATA OF ELEMENTS IN THE COMPLEX SYSTEM

<table>
<thead>
<tr>
<th>Year</th>
<th>Use</th>
<th>Population</th>
<th>Agri.</th>
<th>Indus.</th>
<th>Environ</th>
<th>water</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>5497</td>
<td>128453</td>
<td>2739</td>
<td>0</td>
<td>9786</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>5320</td>
<td>129227</td>
<td>2969</td>
<td>0</td>
<td>10440</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>5584</td>
<td>129988</td>
<td>3624</td>
<td>0</td>
<td>10875</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>5633</td>
<td>130756</td>
<td>3945</td>
<td>0</td>
<td>11520</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>5720</td>
<td>131448</td>
<td>4081</td>
<td>0</td>
<td>12004</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>5819</td>
<td>132129</td>
<td>4889</td>
<td>0</td>
<td>13161</td>
<td>0</td>
</tr>
<tr>
<td>2008</td>
<td>5910</td>
<td>132802</td>
<td>5800</td>
<td>0</td>
<td>13616</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>5965</td>
<td>133475</td>
<td>6036</td>
<td>0</td>
<td>14291</td>
<td>0</td>
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<tr>
<td>2010</td>
<td>6022</td>
<td>134091</td>
<td>6932</td>
<td>0</td>
<td>14976</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>6107</td>
<td>134735</td>
<td>8130</td>
<td>0</td>
<td>15761</td>
<td>0</td>
</tr>
</tbody>
</table>

As for the calculation of every weight, we introduce the input-output analysis, use the calculation direct consume coefficient matrix, get the Leontief’s Counter Matrix.

\[ C = (C_j)_{n \times n} = (I - A)^{-1} \]

\[ A = \frac{X_i}{X_j} \quad (i, j = 1, 2, \ldots, n) \]

Eventually, the weights are:

\[ v_1 = +2.5 \]
\[ v_2 = -7.61 \]
\[ v_3 = +2.71 \]
\[ v_4 = +0.63 \]
\[ v_5 = +0.21 \]
\[ v_6 = +1.30 \]
\[ v_7 = +0.33 \]
\[ v_8 = +0.15 \]
\[ v_9 = +0.44 \]
\[ v_{10} = +0.37 \]

Therefore, we can draw the weighted directed graph

Acquire the adjacent matrix:

\[
W = \begin{bmatrix}
0 & 2.5 & -7.61 & 0 & 0 & 0 \\
0 & 0 & 2.71 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0.21 & 0 & 0 & 0 & 0 & 0.15 \\
1.30 & 0.33 & 0 & 0 & 0 & 0 \\
0.44 & 0 & 0 & 3.03 & 0.37 & 0
\end{bmatrix}
\]

According to the dependency between the factors that drew from the Leontief’s Counter Matrix, we can predict the system quantitatively. The prediction of the demand for fresh water displays in Table 5. If we assume the demand for fresh water increase dramatically, we can deduce the amount of the demand in 2025 as well.

TABLE 5 QUALITATIVE ANALYSIS PREDICTION CHART

<table>
<thead>
<tr>
<th>Year</th>
<th>( P_1 )</th>
<th>( P_2 )</th>
<th>( P_3 )</th>
<th>( P_4 )</th>
<th>( P_5 )</th>
<th>( V_1 )</th>
<th>( V_2 )</th>
<th>( V_3 )</th>
<th>( V_4 )</th>
<th>( V_5 )</th>
<th>( V_6 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0.2</td>
<td>1.3</td>
<td>0.4</td>
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<td>0.2</td>
<td>1.3</td>
</tr>
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<td>2013</td>
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<td>0.3</td>
<td>0.4</td>
<td>1.3</td>
<td>1.6</td>
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<td>0</td>
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<td>1.1</td>
<td>0.8</td>
<td>1</td>
<td>0.4</td>
<td>1.6</td>
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<td>-2.5</td>
<td>-0.9</td>
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<td>3.9</td>
<td>4.3</td>
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<td>-1.6</td>
<td>-1.3</td>
<td>-2.1</td>
</tr>
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<td>8.5</td>
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<td>-4.4</td>
<td>-4.1</td>
<td>0.6</td>
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<td>2.3</td>
<td>4.3</td>
<td>15</td>
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<td>21</td>
<td>-11</td>
<td>-1.8</td>
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<td>23</td>
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<tr>
<td>2020</td>
<td>3.4</td>
<td>6.1</td>
<td>9.6</td>
<td>3.0</td>
<td>1.3</td>
<td>20</td>
<td>-13</td>
<td>-5</td>
<td>7.7</td>
<td>7.9</td>
<td>24</td>
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<tr>
<td>2021</td>
<td>5.75</td>
<td>26</td>
<td>13</td>
<td>-7.0</td>
<td>-42</td>
<td>-5.4</td>
<td>-7.0</td>
<td>21</td>
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<td>0.9</td>
<td>-18</td>
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<tr>
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<td>-3.4</td>
<td>-18</td>
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<td>-62</td>
<td>-55</td>
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<td>-17</td>
<td>-84</td>
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<tr>
<td>2024</td>
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<td>-10</td>
<td>-79</td>
<td>19</td>
<td>142</td>
<td>-12</td>
<td>284</td>
<td>-59</td>
<td>-81</td>
<td>-15</td>
<td>28</td>
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<td>-10</td>
<td>-7.8</td>
<td>79</td>
<td>321</td>
<td>231</td>
<td>471</td>
<td>-15</td>
<td>-89</td>
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<td>349</td>
</tr>
</tbody>
</table>

As we can see in the table, the status of \( v_1 \) in 2025 is 470.83, that is, the fresh water requirement in 2025 will shift 470.83 unit amounts comparing to 2011, accordingly, 657.803 billion tons.

Characteristic polynomial

\[ f(x) = x^6 + 2.109x^3 + 3.270x^2 - 2.192x - 2.521 \]

Make the characteristic polynomial equals to 0, namely, \( f(x) = 0 \)

The solutions are

\[ x_1 = 0.8949 + 1.3453i \]
\[ x_2 = 0.8949 - 1.3453i \]
\[ x_3 = 0.8814 \]
\[ x_4 = -0.9866 + 0.7724i \]
\[ x_5 = -0.9866 - 0.7724i \]
\[ x_6 = -0.6980 \]
According to necessary and sufficient condition of realizing the stability of pulse process system: If pulse is stable \( || \frac{1}{f} \leq 1 \) and all the \( f \) should be simple root.

We can conclude that our Quantitative model is in a stable status. On the basis of our prediction of the demand for fresh water in 2025, our model can satisfy our need basically. But one thing that should be mentioned is that the statistics we use to do the stability analysis may contain some errors, so our system may not be absolutely stable. Nevertheless, according to the calculation results, we can conclude that our system is relatively stable. Namely, as long as the elements don’t change dramatically, our system will maintain its stability.

B. Model Testing and Evaluation

We use the linear fitting equation to work out the demand for water according to the population, and compare the result to the realistic data in the table 6. Because there is no adequate statistics, we use the data from 1998 to 2001.

<table>
<thead>
<tr>
<th>Year</th>
<th>Realistic data of total water</th>
<th>Predicted data of total water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>5435.00</td>
<td>4702.72</td>
</tr>
<tr>
<td>1999</td>
<td>5591.00</td>
<td>4820.72</td>
</tr>
<tr>
<td>2000</td>
<td>5498.00</td>
<td>4936.21</td>
</tr>
<tr>
<td>2001</td>
<td>5567.00</td>
<td>5408.85</td>
</tr>
</tbody>
</table>

Meanwhile, we test our complex system model as follows.

<table>
<thead>
<tr>
<th>Year</th>
<th>Realistic data of fresh water</th>
<th>Predicted data of fresh water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>5435.00</td>
<td>5435.72</td>
</tr>
<tr>
<td>1999</td>
<td>5591.00</td>
<td>5436.72</td>
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<tr>
<td>2000</td>
<td>5498.00</td>
<td>5436.21</td>
</tr>
<tr>
<td>2001</td>
<td>5567.00</td>
<td>5436.21</td>
</tr>
<tr>
<td>2002</td>
<td>5497.10</td>
<td>5430.00</td>
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<tr>
<td>2003</td>
<td>5320.25</td>
<td>5432.58</td>
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<tr>
<td>2004</td>
<td>5548.00</td>
<td>5439.43</td>
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<tr>
<td>2005</td>
<td>5633.21</td>
<td>5454.77</td>
</tr>
</tbody>
</table>

Finally, we set the demand for water in 1998 as the original value, make a comparison between these two models to find out the difference. The data displays in the Table 8.

<table>
<thead>
<tr>
<th>Year</th>
<th>Realistic data of total water</th>
<th>Predicted data of total water</th>
<th>Predicted data of fresh water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>5435.00</td>
<td>4702.72</td>
<td>5435.72</td>
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<tr>
<td>1999</td>
<td>5591.00</td>
<td>4820.72</td>
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<td>4936.21</td>
<td>5436.21</td>
</tr>
<tr>
<td>2001</td>
<td>5567.00</td>
<td>5408.85</td>
<td>5434.85</td>
</tr>
</tbody>
</table>

We calculate the deviation of the models respectively. And we find that the deviation of the complex system model is 87.5, and the single factor model is 645.625.

According to the result, under the normal condition, the fitting linear model which uses the population to predict the demand for water can reflect the relationship between the two factors well. However, because the demand for water can be influenced by many factors, Single Factor analysis may cause precision of the model stay in a low level. Among the numerous factors, any change of a single factor may cause a failure in the entire prediction. For instance, the severe flood in 1998 makes the precision of the prediction very low. Therefore, we think the complex large-scale system is really necessary.

In the complex system model, we fully consider several factors that can influence the water consumption, making our consideration more comprehensive. Also, we completely consider the relationship among all the factors, making our model more robust. Not only do we qualitatively analyze the model, we also calculate out the system status when the element changes by using quantitative analysis. We use the model to analyze the stability of the system and draw a strategy under the support of mathematic calculated result. The adjustment strategy in the system harmoniously changes the relationship between sea-water desalination and environment quality and their status in the whole system. The way to work out the strategy makes our strategy more credible and practical.

In summation, our model comprehensively considers several factors including population, economy, environment, physical, water desalination, protection and so on. Our system is a relatively complete and practical model. It will play a crucial role on water strategy and the prediction of water consumption in the future.

V. CONCLUSIONS

We include population, economy, physic, environment and water desalination into our complex system, and build models aiming at the system. After studying the system in a qualitatively way, we find out that the original system is in an unstable status. So we reach a conclusion: we need to develop a strategy, which is “encouraging the government to use the cooling method in the sea-water desalination production”. Thus, we can change the relation between sea-water desalination and environment from positive correlation to negative correlation. Accordingly, the complex system will change to a rather stable status. Then we deal with the realistic statistics. After that, on the basis of qualitative study, we study the whole system quantitatively by using the Leontief Inverse Matrix. The actual data will change under the effect of system pulse. We deduce the system pulse process, and derive the demand for water in 2025. Meanwhile, we prove the system is in a stable status under the quantitative analysis. In summation, in order to solve the potential water stress, we develop an efficient, economical and practical water strategy. The strategy is: The government should maintain the overall stability in most fields and encourage the cooling method in sea-water desalination production, and sacrifices the environment quality in some degree within the affordability of the nature in order to seek for the biggest economic benefit.
REFERENCES


