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ANALYSIS

# Ecosystem service value assessment for constructed wetlands: A case study in Hangzhou, China

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ABSTRACT

Based on a comprehensive analysis of various classifications of natural resource values, we summarized an ecological economic value system of constructed wetland (CW) ecosystems for treating eutrophic water. Using the CW located at the Hangzhou Botanical Garden as an example, the contingent valuation method (CVM) and shadow project approach (SPA) were applied to estimate the economic values of CW system ecosystem services. The CVM estimated a value of 800,000 yuan (yuan: Chinese Currency, 7.6 yuan = 1 USD as of August, 2007) as the total economic value of the CW in a twenty year period. Meanwhile, the SPA calculated a value of 23.04 million yuan as the total economic value of the CW in a twenty year period. It is determined that compared to the CVM, the SPA provides a more approximate value of the true monetary value of the Hangzhou Botanical Garden CW. This study could fill the gap of knowledge and provide a benchmark when evaluating constructed ecosystem services and help policy makers to promote the development of constructed wetlands in China.



## 1. Introduction

Ecosystem services represent the benefits that people obtain directly or indirectly from ecosystems (Costanza et al., 1997; MA, 2003). Assessing the economic values of ecosystem services play various and important roles in linking human activity and natural systems. As a specific interdisciplinary field of practice, the remarkable work of Daily (1997) and Costanza et al. (1997) has made a breakthrough in ecosystem services valuation. To date, most recent studies (Alberini et al., 2005; He et al., 2005; Spash et al., in press; Hougner et al., 2006; Brander et al., 2007; Costanza et al., 2007; Sattout et al., 2007), however, still focus their attention on estimating the value of natural ecosystem services; only few (Bolund and Hunhammar, 1999; Tian and Cai, 2004; Shen et al., 2005) attempt to estimate the value of constructed (or artificial) ecosystem services. From our points of view, constructed ecosystem services are similar to natural ecosystem services in essence, however, differ in the following main aspects: 1) enhancement of certain services and decline of most other services in constructed ecosystems comparing to natural ecosystems (Foley et al., 2005). Like human-dominated ecosystems services and unlike natural ecosystems services, certain constructed ecosystems services are usually designed intentionally; 2) higher direct use values (e.g., food production, recreation) than indirect use values are usually estimated

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through constructed ecosystem services in comparison with natural ecosystem services. For instance, constructed greenhouse usually provides a remarkable direct use value (mainly food production), while a tiny indirect use value; 3) the assessment scale of constructed ecosystem services is explicit than natural ecosystem services, since boundaries of the constructed ecosystem are usually more distinct than the natural ecosystem.

The constructed wetland (CW), a typical constructed ecosystem, was initially developed approximately forty years ago in Europe and North America to exploit and improve the biodegradation ability of plants (Shutes, 2001). Possessing the advantages of low construction and operating costs as well as its ability to be used on its own or in combination with other systems, CW is especially suitable for small communities in developing countries where potential health benefits from pathogen removal are considerable (Cooper et al., 1996; Shutes, 2001).

In China, the first CW study for wastewater treatment was launched as early as the period of the "7th Five-Year Plan" (1986–1990) (Li and Zheng, 1993). The first reed bed wetland appeared in 1987 and the first full-scale CW emerged in 1990 (Ding and Shen, 2006). Since 1999, China has been making a great progress in the area of CW application, reaching a peak with 127 research reports in 2004 (Gao, 2006). The problem, however, that urban wastewater treatment rates operate at only 46% as of 2004 must now be addressed (white paper on China Environment Protection, 1996–2005). Most small towns in China today still release daily wastewater, with excessive amounts of eutrophic materials containing nitrogen and phosphorus, directly into water systems without treatment (Jin et al., 2005). This is one of the major causes of water pollution, especially eutrophication pollution, in China.

When it comes to the economic valuation of constructed ecosystems in China, few studies have been conducted up to this point. Tian and Cai (2004) evaluated ecosystem services of constructed landscapes in Beijing; however, their study merely referred to natural ecosystem data from Costanza et al. (1997) with some revision. Another attempt was conducted by Shen et al. (2005) to assess ecosystem services of a CW system in Shenyang. Unfortunately, their sample capacity was limited since they only applied seventy-nine survey results. What is worse, several obvious calculation fallacies were present when calculating discount value, which rendered their results highly suspect. From both ecological and socioeconomic perspective, it is therefore necessary and meaningful to establish more CWs in China and apply further and more thorough studies towards them.

In this paper, a successful case study applying a CW in China is presented. Hangzhou Botanical Garden pumped groundwater to refill an ornamental fishpond from the 1960s to 2000. This approach was not only costly (total actual cost was approximately 520,000 yuan $yr^{-1}$ from 1991 to 2000), but seriously damaged the groundwater environment. A CW wastewater treatment system was established specially to solve the problem. The wastewater from the ornamental fishpond can now be reused and the groundwater resource is now protected. Furthermore, the water quality of Jade Spring located within the ornamental fishpond and the ornamental quality of the fishpond itself is improved now.

The objectives of this study are 1) to summarize an ecological economic value system of the CW ecosystem for treating eutrophic water; and 2) to estimate ecosystem services of the CW in Hangzhou Botanical Garden using economic valuation methods. Two main methods are selected from the direct and indirect aspects in order to achieve our purposes, respectively. The first one is the widely used and argued contingent valuation method (CVM) (Loomis and Walsh, 1997; Ahlheim, 1998; Bateman et al., 1999; Adjaye, 2000; Carson et al., 2001; Venkatachalam, 2004); The second one is the shadow project approach (SPA), an altered replacement cost (RC) approach which is widely applied to assess the value of an ecosystem service by how much it costs to replace or restore it after it has been damaged (Gosselink et al., 1974; Garrod and Willis, 1999; Spash, 2000; Hougner et al., 2006).

## 2. Basic theory and methods

### 2.1. *Ecological economic value system of CW ecosystem services*

The CW ecosystems provide many essential goods and services which contribute to human welfare, such as outflow water, gas regulation, groundwater recharge, habitat for diverse species, scientific and educational values (Fig. 1). Since the terms "value", "valuation" and "value system" have a range of meanings in different disciplines (Farber et al., 2002), no uniform definition for value system of ecosystem services is available. Based on a comprehensive analysis of various classifications of natural resource values (Arrow et al., 1993;

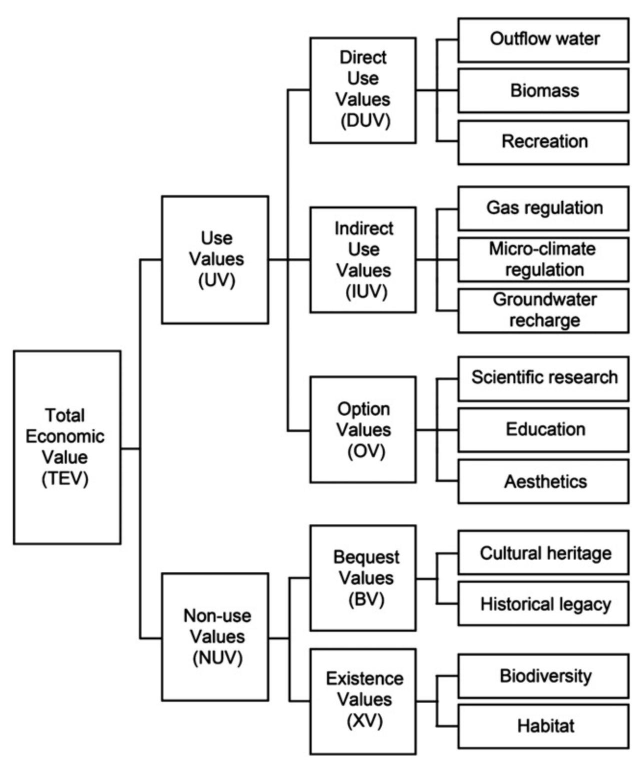


**Fig. 1 – Ecological economic value system for the constructed wetland ecosystem treating eutrophic water.**

Costanza et al., 1997; Turner et al., 2000; Barbier, 2000; Farber et al., 2002; Boyd and Banzhaf, 2007), we adopted the term “ecological economic value system” for the CW ecosystem treating eutrophic water (Fig. 1).

## 2.2. Contingent valuation method

### 2.2.1. Basic theory

The contingent valuation method (CVM) is a simple, flexible and widely used non-market valuation method especially used in areas of environmental cost–benefit analysis and environmental impact assessment (Cummings et al., 1986; Mitchell and Carson, 1989; Venkatachalam, 2004). It can be applied to estimate non-use values, non-market use values or both when applying environmental resources. Moreover, it is recognized as the only method that can be used to estimate the non-use values of environmental goods and services (Loomis and Walsh, 1997; Ahlheim, 1998; Bateman et al., 1999; Adjaye, 2000). Carson et al. (1995) provide a bibliography of over 2000 contingent valuation papers and studies from over forty countries. Although CVM is the most frequently used non-market valuation technique for environmental goods, it still has its constraints and limitations. There are various sources of possible bias in the interview techniques (Mitchell and Carson, 1989; Fishbein and Azjen, 1975; Brookshire et al., 1976; NOAA, 1994; Carson et al., 2001). There is also controversy over whether respondents would actually pay the amounts as they promised in the interviews (Mitchell and Carson, 1989; Ahlheim, 1998; Bateman et al., 1999; Carson et al., 2001; Venkatachalam, 2004). Debate persists over the reliability of CVM and the overall suitability of passive use values in economic policy analysis (Ahlheim, 1998; Carson et al., 2001; Venkatachalam, 2004). Carson et al. (2001) provide a concise overview of the most commonly alleged problems of CVM and conclude that many of them can be resolved by careful study design and implementation. Therefore, although CVM has its limitations mentioned above, it is still an effective way to estimate environmental goods and services if carefully designed and implemented.

### 2.2.2. Calculation method

According to the value system summarized above, the total economic value (TEV) of a CW system is equivalent to the sum of its use values (UV) and non-use values (NUV). UV is equivalent to the sum of the direct use values (DUV), indirect use values (IUV) and option values (OV); NUV is equivalent to the sum of the existence values (XV) and the bequest values (BV). The calculation formulas are shown as follows:

$$\mathrm{TEV} = \mathrm{UV} + \mathrm{NUV} = (\mathrm{DUV} + \mathrm{IUV} + \mathrm{OV}) + (\mathrm{XV} + \mathrm{BV}) \tag{1}$$

$$\mathrm{DUV} = \sum_{i=1}^{n} (365 * P_{2i} * S_i + L_i); \tag{2}$$

$$\mathrm{OV} = \sum_{i=1}^{n} P_{li} * A * \alpha; \tag{3}$$

$$\mathrm{XV} = \sum_{i=1}^{n} P_{li} * A * \beta; \tag{4}$$

$$\mathrm{BV} = \sum_{i=1}^{n} P_{li} * A * \gamma; \tag{5}$$

where IUV is used only for qualitative analysis in this study; $P_{1i}$ (hundred yuan m$^{-2}$ yr$^{-1}$) is the public's willingness to pay (WTP) for the CW (excluding its outflow water) in the year i; $P_{2i}$ (yuan ton$^{-1}$) is the WTP for the outflow water in the year $i$; $L_i$ is the value of biomass of the CW in the year $i$ (since CW biomass here are more like a kind of green garbage and are not sold to the market, the value of $L_i$ can be neglected.); $S_i$ is the actual treatment burden of the CW, that is, 160 ton day$^{-1}$; $\alpha$, $\beta$, and $\gamma$ stand for the proportions of motivation for future optional use, constant existence and heritage, respectively; $A$ is the total area of the CW (600 m$^2$); and $n$ is the service life of the CW (set to twenty years in the present case).

### 2.2.3. Survey

*2.2.3.1. Market hypothesis.* At present, China is implementing a strategy of sustainable development while procuring an environment-friendly harmonious society. The environmental awareness of the public is growing continually. CW ecosystems offer a substantial ability for wastewater treatment, provide no secondary pollution and allow for outflow water to be reused for irrigation, industrial cooling, washing cars, etc. Due to serious damage to global water stocks and the increase in scarcity of water resources, the public acknowledge their WTP for the CW (including the outflow water). Furthermore, since many cities in China have started to charge for wastewater drainage, WTP will grow stronger over time.

*2.2.3.2. Questionnaire design.* As seen in the most recent environmental surveys (Casey et al., 2006; Sattout et al., 2007), open-ended payment questions have been employed and cast in a referendum format to elicit information concerning WTP. A pretest interview was carried out among college students and staff engaged in environmental protection activities. Respondents were then randomly selected among visitors to the ornamental fishpond in the Hangzhou Botanical Garden and interviewed face-to-face after being educated about CW systems in general.

The CVM survey questionnaire (Table 1) used for this study contains five sections. The questionnaire starts with standard initial greetings and warm-up questions, followed by Section 1, which inquires about the respondent's attitude towards the water quality of the ornamental fishpond followed by a general introduction to CW systems. The purpose of the survey is then explained to the respondents in this section. In Section 2, respondents are questioned as to their individual information, such as gender, age, education and income. Section 3 seeks opinions concerning the propositional approach of water supply of the ornamental fishpond. Section 4 presents the valuation scenario. First, the significant social and ecological effect after the construction of CW system is explained, after which the respondents are asked to provide their WTP for the CW (excluding its outflow water) and their motivations behind their WTP response. Optional motivations include motivation questions concerning the future optional use of the CW, for its constant existence and for heritage purposes. Second, Section 4

**Table 1 – Main questions within the constructed wetland economic values questionnaire located in the Hangzhou Botanical Garden**

| Questions | Answers |
|---|---|
| If you visit Hangzhou Botanical Garden, will you view the ornamental fishpond? | ☐Yes<br>Frequency: ☐Seldom ☐Sometimes<br>☐Often ☐Frequently<br>☐No |
| If the water in the ornamental fishpond is polluted, which approach do you think will be the best way to maintain the fishpond? | ☐Pump the groundwater<br>☐Supply with the resident living water<br>☐Reuse the outflow water of the constructed wetland<br>☐Other methods |
| After building the constructed wetland, not only the wastewater of the fishpond is resolved, but the Jade spring is also made to reemerge after drying up for many years. In addition, it also has abundant biodiversity, aesthetic qualities, scientific as well as many other values. From this information, what is your willingness to pay for the constructed wetland (excluding its outflow water) in Hangzhou Botanical Garden (hundred yuan $m^{-2}$ $yr^{-1}$)? | <0.4, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, >1.0<br>Motivation for paying (multi-choice available)<br>☐For future optional use<br>☐For constant existence<br>☐As heritage for offspring |
| Most indexes of the outflow water met the national standard of first-grade surface water, and can be used for irrigation, industrial cooling, washing cars, etc. The price of residential water in Hangzhou is 1.65 yuan $ton^{-1}$, and the groundwater fee is 1.85 yuan $ton^{-1}$. From this information, what is your willingness to pay for the outflow water of the constructed wetland in Hangzhou Botanical Garden (yuan $ton^{-1}$)? | <0.1, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0 >2.0 |
| Other recommendations and suggestions | |

then introduces to respondents the quality and the available usage of the CW outflow water. Using the price of residential water and the fee for groundwater as a comparison, respondents are asked to provide their WTP for outflow water. Section 5 probes the attitude of the respondents towards and suggestions for the CW. The data acquired in this section is collected for accessorial analysis, for instance, to see whether any uncatalogued factors impact WTP.

### 2.3. *Shadow project approach*

The shadow project approach is a way of replacing primary ecosystem functions after the environment has been degraded (Huan, 2001). For example, if we continue to use the previous technology to maintain the ecological landscape of the ornamental fishpond and keep it in good condition, the sum of the annual water cost, the annual electrical cost and the annual management cost are collectively called the shadow price. Meanwhile, with lower economic input and lower consumption of resources, the CW provides for the same good conditions to the ornamental fishpond as did the previous technology. Therefore, the shadow price can be used to estimate the ecosystem service value of the CW. However, the SPA (or RC) does not account for any values attributable to non-use benefits (Hougner et al., 2006). Thus, in this study, the non-use values were excluded when using the SPA to calculate the TEV.

$$\begin{aligned} TEV &= \sum_{i=1}^{n}(TSC_i - AC_i) = \sum_{i=1}^{n}(SC_{wi} + SC_{ei} + SC_{mi} - AC_i) \\ &= \sum_{i=1}^{n}(SP_{wi} \times SA_{wi} + SP_{ei} \times SA_{ei} + SC_{mi} - AC_i) \end{aligned} \quad (6)$$

where $TSC_i$ is the total shadow cost of the ornamental fishpond in the year i; $AC_i$ is the actual cost of the ornamental fishpond after constructing the CW in the year i; $SC_{wi}$ is the shadow cost of water in the year i; $SC_{ei}$ is the shadow cost of electricity in the year i; $SC_{mi}$ is the shadow cost of management in the year i; $SP_{wi}$ is the shadow price of water in the year i; $SP_{ei}$ is the shadow price of electricity in the year i; $SA_{wi}$ is the shadow amount of water in the year i; $SA_{ei}$ is the shadow amount of electricity in the year i; and $n$ is the service life of the CW (set to twenty years in the present case).

Theoretically, the price of water is divided into three components in this study: 1) water resource price, 2) project price, and 3) environmental price (Feng et al., 2001; Wang et al., 2005). The water resource price is the price set by the country that reflects its command and ownership of resources as the main governmental body, which includes compensation of water resource consumption, compensation of effects to aquatic ecological environments and costs to strengthen the protection of scarce water resources as well as to improve water conservation and to improve water desalination technology development, etc. The project price is the price of production by means of concrete or abstract materialized labour to alter water resources into water products, after which the product enters the market as a commodity that includes costs, expenses, profits and taxes. The environmental price is the price of water pollution control and water environmental protection, which is caused by wastewater discharge. In this study, the wastewater charge levied by the government is used as the environmental price. According to data from Shanghai, which is about 150 km away from Hangzhou and is also located in the Yangtze River delta area, 0.57 yuan $ton^{-1}$ is set as the water resource price (Wang et al., 2005).

### 2.4. *CW system description in Hangzhou Botanical Garden*

The CW is located within the Hangzhou Botanical Garden (120°10′E, 30°15′N; Fig. 2; Online Fig. 1). It was built during the

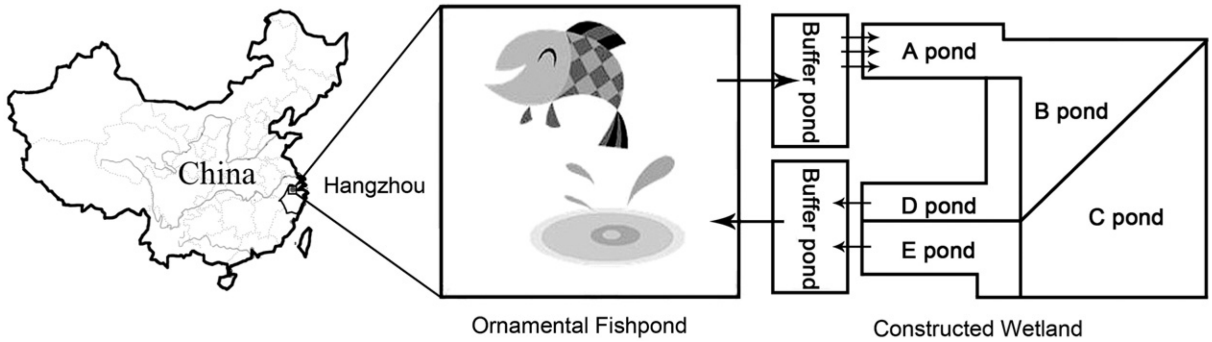


**Fig. 2 – Constructed wetland in Hangzhou Botanical Garden.**

period from May to August, 2001, and covers 600 $m^2$, including three upper and two lower pools. It is surrounded by a concrete wall and set with a concrete base and filled with a 70 cm sand substrate layer. The system was designed as a compound vertical flow CW, with a treatment capacity of 480 ton $day^{-1}$. The actual treatment burthen load is approximately 160 ton $day^{-1}$. According to Chinese Environmental Quality Standards for Surface Water (GB3838-2002, Table 2) by SEPA (2002), most outflow water indexes, such as total phosphorus (TP), chemical oxygen demand ($COD_{Mn}$) and five day biochemistry oxygen demand ($BOD_5$), met the standard of first-grade surface water (Table 2).

### 2.5. *Response rate and statistical analysis*

A high response rate was achieved since interviews were carried out face-to-face. All three hundred questionnaires sent out were retrieved. Four, however, were incomplete and, therefore, there were 296 usable questionnaires in total. Percentage distributions of WTP are showed in Tables 3 and 4. Personal factors in this study include sex, age, education, income. The data was tested according to personal factors distribution (e.g. the sex ratio (male/female) of the survey data is 1.08, and of the entire Hangzhou city is 1.04. Relative error is approximately 3.9%.) and found to be statistically representative of the whole population in Hangzhou city. Pearson correlation analysis was conducted between personal factors and WTP. All statistical analysis in this study was executed using Microsoft Office Excel and SPSS Base 13.0 software for Windows (SPSS, 2004).

**Table 2 – Outflow water quality of the CW (constructed wetland) in Hangzhou Botanical Garden from 2002 to 2004 (unit: mg $L^{-1}$ )**

| | $NH_3$–N | TN | TP | pH | $COD_{Mn}$ | $BOD_5$ |
|---|---|---|---|---|---|---|
| Grade I* | 0.15 | 0.2 | 0.02 | 6–9 | 2 | 3 |
| Grade II* | 0.5 | 0.5 | 0.1 | 6–9 | 4 | 3 |
| Grade III* | 1.0 | 1.0 | 0.2 | 6–9 | 6 | 4 |
| Grade IV* | 1.5 | 1.5 | 0.3 | 6–9 | 10 | 6 |
| Grade V* | 2.0 | 2.0 | 0.4 | 6–9 | 15 | 10 |
| CW# | 0.11± 0.08 | 1.27± 0.24 | 0.015± 0.031 | 7.11± 0.20 | 1.25± 0.45 | 0.93± 0.77 |

Notes:
*The threshold of Chinese Environmental Quality Standards for Surface Water (GB3838-2002). Grade I is the level for water of the best quality.
#The mean value and standard deviation of the outflow water of the CW in Hangzhou Botanical Garden from 2002 to 2004.

## 3. Results

### 3.1. *WTP, correlation analysis and linear regression equation*

All respondents in the survey were willing to pay for the CW (including the outflow water). Statistical results show that the mean WTP for the $P_1$ is 0.6 hundred yuan $m^{-2}$ $yr^{-1}$; the median and standard deviation of $P_1$ is 0.62±0.32 hundred yuan $m^{-2}$ $yr^{-1}$ (Table 5). Motivation for paying for $P_1$ was divided as: 42.7% ($\alpha$) for future optional use, 38.6% ($\beta$) for constant existence, and 18.7% ($\gamma$) for heritage purposes (Table 5). The mean WTP for the outflow water ($P_2$) is 1.2 yuan $ton^{-1}$; the median and standard deviation of $P_2$ is 1.21±0.66 yuan $ton^{-1}$ (Table 5). Since the WTP discrepancy is large, using the mean value will cause a higher degree of error (McFadden, 1994; Green et al., 1998); therefore, according to the general rule, the

**Table 3 – $P_1$ percentage distributions of willingness to pay (WTP)**

| Sequence | $P_1$ (hundred yuan $m^{-2}$ $yr^{-1}$) | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|---|
| 1 | <0.4 | 67 | 22.6 | 22.6 |
| 2 | 0.4 | 24 | 8.1 | 30.7 |
| 3 | 0.5 | 56 | 18.9 | 49.6 |
| 4 | 0.6 | 29 | 9.8 | 59.4 |
| 5 | 0.7 | 21 | 7.1 | 66.5 |
| 6 | 0.8 | 23 | 7.8 | 74.3 |
| 7 | 0.9 | 5 | 1.7 | 76.0 |
| 8 | 1.0 | 41 | 13.9 | 89.9 |
| 9 | >1.0 | 30 | 10.1 | 100.0 |
| | Total | 296 | 100.0 | |

Note:
$P_1$ (hundred yuan $m^{-2}$ $yr^{-1}$) is the WTP of the public for the constructed wetland (excluding its outflow water).

**Table 4 – $P_2$ percentage distributions of willingness to pay (WTP)**

| Sequence | $P_2$ (yuan ton$^{-1}$) | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|---|
| 1 | <0.1 | 18 | 6.1 | 6.1 |
| 2 | 0.1 | 7 | 2.4 | 8.4 |
| 3 | 0.2 | 5 | 1.7 | 10.1 |
| 4 | 0.3 | 4 | 1.4 | 11.5 |
| 5 | 0.4 | 8 | 2.7 | 14.2 |
| 6 | 0.5 | 19 | 6.4 | 20.6 |
| 7 | 0.6 | 21 | 7.1 | 27.7 |
| 8 | 0.7 | 5 | 1.7 | 29.4 |
| 9 | 0.8 | 9 | 3.0 | 32.4 |
| 10 | 0.9 | 2 | 0.7 | 33.1 |
| 11 | 1.0 | 45 | 15.2 | 48.3 |
| 12 | 1.1 | 3 | 1.0 | 49.3 |
| 12 | 1.2 | 10 | 3.4 | 52.7 |
| 14 | 1.3 | 1 | 0.3 | 53.0 |
| 15 | 1.4 | 3 | 1.0 | 54.0 |
| 16 | 1.5 | 20 | 6.8 | 60.8 |
| 17 | 1.6 | 18 | 6.1 | 66.9 |
| 18 | 1.7 | 19 | 6.4 | 73.3 |
| 19 | 1.8 | 18 | 6.1 | 79.4 |
| 20 | 1.9 | 8 | 2.7 | 82.1 |
| 21 | 2.0 | 30 | 10.1 | 92.2 |
| 22 | >2.0 | 23 | 7.8 | 100.0 |
| | Total | 296 | 100.0 | |

Note:
$P_2$ (yuan ton$^{-1}$) is the WTP of the outflow water.

median value is used as the average WTP value (Hanemann, 1984; McFadden, 1994; Bateman et al., 1995; Green et al., 1998; Alberini et al., 2005) to calculate the economic value. Representation is 99%.

Pearson correlation analysis shows that males granted a higher WTP than females; younger people granted a higher WTP than elder people; richer people granted a higher WTP than poorer people; and the better educated granted a higher WTP than the lower educated (Table 6). There is no significant correlation between $P_1$ and personal factors; however, sex and income have significant correlations with $P_2$ (Table 6).

Based upon correlation analysis using linear regression for respondents expressing a WTP, the collective impact of the independent variables on the dependent variable WTP was tested. Since the sex ratio normally should be approximately 1:1, we excluded it in the regression model. Analysis showed that income was able to explain 95.2% of the variability in $P_2$. Based on these results, we have obtained the following explanatory regression equation:

$$P_2 = 6*10^{-6}I + 1.029 \quad R^2 = 0.95 \tag{7}$$

where $P_2$ is the WTP of the outflow water; $I$ is the yearly income per individual.

**Table 5 – Willingness to pay (WTP) and motivation for paying**

| WTP | N | Median | S.D. | α | β | γ |
|---|---|---|---|---|---|---|
| $P_1$ | 296 | 0.62 | 0.32 | 42.7% | 38.6% | 18.7% |
| $P_2$ | 296 | 1.21 | 0.66 | | | |

Notes:
$P_1$ (hundred yuan m$^{-2}$ yr$^{-1}$) is the WTP of the public for constructed wetland (excluding its outflow water).
$P_2$ (yuan ton$^{-1}$) is the WTP of the outflow water.
α, β, and γ stand for the proportions of motivation for future optional use, constant existence and heritage purposes, respectively.

**Table 6 – Pearson correlation analysis of the effects of personal factors on $P_1$ and $P_2$**

| Items | Sex | Education | Age | Income | $P_1$ | $P_2$ |
|---|---|---|---|---|---|---|
| Sex | 1 | | | | | |
| Education | 0.037 ns | 1 | | | | |
| Age | 0.179 ns | −0.224** | 1 | | | |
| Income | 0.083 ns | 0.168** | 0.062 ns | 1 | | |
| $P_1$ | 0.110 ns | 0.031 ns | −0.040 ns | −0.016 ns | 1 | |
| $P_2$ | 0.151** | −0.001 ns | −0.067 ns | 0.119* | 0.586** | 1 |

Notes:
*$p$<0.05, **$p$<0.01, ns: no significant.
$P_1$ (hundred yuan m$^{-2}$ yr$^{-1}$) is the WTP of the public for constructed wetland (excluding its outflow water).
$P_2$ (yuan ton$^{-1}$) is the WTP of the outflow water.

### 3.2. *Estimated economic value of CW by CVM*

According to the above results and analysis, it can be calculated that DUV=1.40 million yuan; OV=307,000 yuan; XV=278,000 yuan; and BV=135,000 yuan. IUV is only used for qualitative analysis in this study by CVM.

The discount rate of environmental values has always been the focus of controversy. Most environmentalists, however, oppose this, some advocating a zero discount rate while others believe that a minus discount rate should always be set (Zeng, 2003). All of the viewpoints related to this question have their own reasoning. In order to provide a reasonable evaluation of the economic value of the CW, 5% (Liu, 2003) was chosen as the discount rate for this study. The service life of the CW is twenty years. Table 7 shows the discount values of the CW.

### 3.3. *Estimated economic value of CW by SPA*

According to the price of groundwater and electricity, the total economic value of the CW is more than 610,000 yuan for the year 2001 and over 1.2 million yuan for the year 2005 (Table 8). Economic value analysis of the CW ecosystem in the Hangzhou

**Table 7 – Discount values of different values of the constructed wetland**

| Classification of value | Value (thousand yuan) |
|---|---|
| Direct use values (DUV) | 528 |
| Indirect use values (IUV) | Only for qualitative analysis in this study |
| Option values (OV) | 116 |
| Existence values (XV) | 105 |
| Bequest values (BV) | 51 |
| Total economic value (TEV) | 800 |

**Table 8 – Results of shadow project approach**

| Year | $SC_{wi}$ (thousand yuan) | $SC_{ei}$ (thousand yuan) | $SC_{mi}$ thousand yuan) | $TSC_i$ (thousand yuan) | $AC_i$ (thousand yuan) | $TEV_i$ (thousand yuan) |
|---|---|---|---|---|---|---|
| 2001 | 602 | 22 | 21 | 646 | 35 | 611 |
| 2002 | 840 | 22 | 21 | 884 | 16 | 867 |
| 2003 | 840 | 22 | 21 | 884 | 10 | 874 |
| 2004 | 942 | 22 | 21 | 986 | 10 | 976 |
| 2005–2020 | 1197 | 24 | 21 | 1242 | 10 | 1232 |

$SC_{wi}$: the shadow cost of water in the year i; $SC_{ei}$: the shadow cost of electricity in the year i; $SC_{mi}$: the shadow cost of management in the year i; $TSC_i$: the total shadow cost of the ornamental fishpond in the year i; $AC_i$: the actual cost of ornamental fishpond after building the CW in the year i; $TEV_i$: the total economic value of the CW in the year i.
Notes:
1. Both the project water cost and the environmental cost are set according to the cost of commercial use water in Hangzhou, China.
2. When calculating the shadow cost of water and electricity, the inflation rate is assumed to equal the discount rate. Therefore, the discount value of the SPA is not calculated and the current cost is only used to estimate the future cost of water and electricity. Obviously, the result is a conservative estimation.

Botanical Garden showed that the construction cost was recovered after one year. Based on development experience and the current status of water prices throughout developed countries (for example, 5 to 10 Euros ton$^{-1}$ in Germany that is equivalent to 50 to 100 yuan ton$^{-1}$), as well as taking into account the water resource shortage problem in China, it is estimated that water prices in China will continue to rise sharply. Therefore, the CW can create an economic value of more than 23.04 million yuan within a twenty year period.

## 4. Cost-benefit analysis

At the policy making level, it is necessary to assess whether establishing a CW in Hangzhou Botanical Garden is a reasonable venture in the long run. The value of CW benefits can be compared to the maintenance costs of the ornamental fishpond and the value of the land for alternative usage. The monetary benefits of the CW are represented mainly by the reduction of maintenance costs for the ornamental fishpond. The results of this study have shown that the establishment of the CW will obviously reduce maintenance costs of the ornamental fishpond. According to the shadow project approach, the monetary benefits of the CW (over 23.04 million yuan in twenty years) are, in fact, remarkable.

The total cost of the CW should include both the construction and maintenance costs of the CW as well as the opportunity cost of the land itself. The construction cost is 280,000 yuan and the opportunity cost of the land is approximately 20,000 yuan yr$^{-1}$. Although the maintenance cost of the ornamental fishpond was 35,000 yuan in 2001 and 16,000 yuan in 2002, the CW itself almost does not have maintenance cost. Thus, the total cost of the CW is approximately 680,000 yuan in twenty years. Meanwhile, estimated benefits should also include social, cultural and recreational benefits. For instance, primary and middle schools in Hangzhou organize students to visit the CW each year. Therefore, the CW also plays an important role in local education and recreation. Thus, the benefit/cost ratios of the CW are over 1.2 and 33.9 by CVM and SPA, respectively. It is therefore worthwhile to establish the CW ecosystem for treating eutrophic water in the Hangzhou Botanical Garden.

## 5. Discussion

The total economic value within a twenty year period of the 600 m$^2$ CW located in the Hangzhou Botanical Garden was estimated to be 800,000 yuan by CVM and 23.04 million yuan by SPA. That is, an average economic value of 66.67 yuan m$^{-2}$ yr$^{-1}$ by CVM and 1920 yuan m$^{-2}$ yr$^{-1}$ by SPA. In comparison, He et al. (2005) calculated a price of 1.06 yuan m$^{-2}$ yr$^{-1}$ for a natural wetland, 1.31 yuan m$^{-2}$ yr$^{-1}$ for farmland and 1.88 yuan m$^{-2}$ for forest area as the average economic value of terrestrial ecosystem services in China. Tian and Cai (2004) calculated a price of 0.92 yuan m$^{-2}$ yr$^{-1}$ for an artificial pool and 12.20 yuan m$^{-2}$ yr$^{-1}$ for a CW in Beijing. As already mentioned in the cost-benefit analysis section, these comparisons again reflect that the Hangzhou Botanical Garden CW has significant monetary benefits.

The CVM reflects the WTP of the public for environmental goods and services to some extent. However, errors of estimation may present in various aspects. Firstly, due to constraints and limitations of CVM itself, there are various sources of potential bias in terms of interview techniques as well as controversy over whether people would actually pay the price stated in the interviews. These inherent flaws can lead to errors, such as 1) information bias and errors, in which the respondents could not get an actual description from the provided assumptions, making them likely to provide a WTP deviating from their actual willingness (Fishbein and Azjen, 1975; NOAA, 1994); 2) strategic errors, in which respondents were aware that their answers could affect their own interests and they subsequently often deliberately raised or lowered their WTP due to this concern (Brookshire et al., 1976). For example, during the interview, a young woman asked whether the value of $P_2$ will increase the price of residential water. Correlation analysis (Table 5) provides evidence that no significant correlation between $P_1$ and personal factors, while sex and income have significant correlations with $P_2$. One reason for this result is that respondents may believe that $P_1$ had no relationship to their benefits, while $P_2$ may in fact affect their benefits. On the other hand, most research results (Hanemann et al., 1991; Sugden, 1999; Horowitz and McConnell, 2003) support the view that income affects WTP, called the "income effect". Mitchell and Carson (1989) believe that the lack of a positive income effect is commonly interpreted as an indication that respondents did not seriously consider their budget constraints when providing hypothetical choices. In addition, results from Alberini et al. (2005) also supports the view that WTP increases with usage, knowledge of goods and services, the environmental attitude of the respondent, income, and education, but decreases with the increase in age of the respondent. In sum, criticisms mainly arise from two standpoints, namely, the validity and the reliability of the results, and the effects of various biases and errors (Venkatachalam, 2004). Carson et al. (2001) and Venkatachalam (2004) have already provided detailed reviews and discussions, as well as advice and guidelines, for conducting contingent valuation surveys.

Secondly, during the practical treatment process, it was found that a treatment burden of 160 ton day$^{-1}$ is adequate to maintain the water quality in the ornamental fishpond. Therefore, when calculating the economic value of the CW, the actual treatment burden was used.

Thirdly, due to the lack of ample data and efficient methods, the value of the CW from the standpoints of groundwater recharge, regulating the micro-climate and nutrient retention, etc, could not be estimated. Therefore, a qualitative analysis was performed, but the indirect use value of the CW was not assessed. For instance, the CW contributes to the restoration of Jade Spring (Online Fig. 1). One year after the establishment of the CW, attributing to the groundwater recharge, the Jade Spring, a spring with over 1400 years of history and one of the three most famous springs in the West Lake region, was renewed and began to reestablish itself after many years' silence. The indirect use value of groundwater recharge by the CW is inestimable, and the CVM does not include this when performing quantitative calculations. This is another reason why the TEV offered by the CVM is significantly lower.

Fourthly, in terms of the TEV of ecosystem services, there is a widely discussion on the challenge of aggregating economic value (Farber et al., 2002). The aggregation of isolated individual values does not necessarily represent a socially-relevant unit — a community, a state, a nation or the entire planet (Farber et al., 2002). The TEV of an ecosystem (e.g. wetland) is not simply the sum of relevant disaggregated values (Lambert, 2003). Whether to aggregate or disaggregate the values across a political or economic jurisdiction may lead to an over or under estimation (Lambert, 2003; Bateman et al., 2006). The CVM technique (Farber et al., 2002; Bateman et al., 2006) and the scale of estimation (Konarska et al., 2002; Lambert, 2003) are very important in economic valuation exercises. In this study, we added various disaggregated values into the TEV. This may also lead to some estimation errors.

The most important reason, however, is that it is precisely because the public is not currently required to pay for services provided by ecosystems that they do not pay enough attention to the value of ecosystem services. This is why the WTP from the survey is far below its actual value (Ahlheim, 1998; Lambert, 2003). Spash et al. (in press) have pointed out that former studies that attempted to validate the CVM by matching intended or stated WTP with actual payments have largely failed to question what motivates respondents to answer. This study, however, analyzed personal factors that could affect the motivation in the answers of the respondents and investigated their motivations for paying for the CW. Furthermore, according to the special purpose of establishing CW in Hangzhou Botanical Garden to treat eutrophic water and based on the pretest interview result, in order to acquire an appropriate total economic value, we separated the WTP for outflow water of the CW from the total WTP for the CW ecosystem. Ahlheim (1998) argued that contingent valuation surveys should focus on the assessment of the shadow price of an environmental good rather than the respective WTP. The only way to solve this problem, Ahlheim stated, is to enable the public to pay for the services they enjoy from ecosystems. As for CW systems, the most direct and effective way is to raise the price of water.

As for SPA, we actually did a conservative estimation. The non-use value, an infinitesimal part of the CW in this study, was excluded and a conservative calculation was made for the shadow price of water and electricity. An annual consumption of more than 90,000 tons of groundwater, over 20,000 kWh of electricity and an annual management cost of more than 20,000 yuan–whose shadow cost adds up to more than 880,000 yuan–is a significant amount of money. As a result of these costs, the garden authority is reluctant to foot the bill, thus, the maintenance cost is bound to transfer to the public. Certainly, the public cannot accept these huge costs. Thus, before the introduction of CW technology, the authority of the Botanical Garden only had to reduce the use of groundwater, electricity and the management costs to temporarily weaken the conflict in this dilemma. Taking these factors into consideration, it is obvious that the result of the SPA remains a conservative value within this study.

In addition, as mentioned above, Ahlheim (1998) suggested using a shadow price to replace WTP. Another reason to do so is the fact that the valuation of public goods by their shadow prices is compatible with the Hicks–Kaldor criterion. From the point of view of this study, SPA provides a more approximate value of the true monetary value of CW ecosystem services compared to CVM. However, neither CVM nor SPA can reflect the ecological value, a value that is widely recognized as a more adequate and reasonable value of ecosystem services (Mitchell and Carson, 1989; Farber et al., 2002; Norton and Noonan, 2007). Winkler (2006a,b) has stated that existing methods used in the valuation of ecosystem services emphasizes either the economic system or the ecosystem. Moreover, Winkler (2006a,b) provided the conceptual foundations for a new method of valuation for ecosystem services that deals simultaneously with the ecosystem, the economic system and society within a balanced approach. Boyd and Banzhaf (2007) argued the need for standardized environmental accounting units and proposed a definition, rooted in economic principles, of final ecosystem service units. Norton and Noonan (2007) analyzed the dilemma between ecologists and economists and then proposed a pluralistic and iterative approach for the valuation of anthropogenic ecological change. Although these new approaches are merely primary frameworks and are only possible in principle at the current time, they provide a new perspective, remarkably different from the former monistic valuation methods, for evaluating ecological and economic impacts of anthropogenic change and environmental goods, as well as for ecosystem services.

## 6. Conclusion

The Hangzhou Botanical Garden case study clearly shows that the advantages of low cost, easy to maintain, high purification effects and significant environmental benefits make CW systems a suitable wastewater treatment technology for ornamental ground and surface water in China. It could provide a broad development prospect in the future.

This study also shows that constructed ecosystem services contribute substantially to human welfare as natural ecosystem services do. Other types of value (religious, social, cultural, global, intrinsic and aesthetic, etc.) are also important, but the economic value tends to be the most important value for most countries, especially in developing countries, like China, when policy makers must make difficult choices concerning the allocation of scarce government resources. However, as Lambert (2003) said, “the economic and financial valuation is not a panacea.” It is only a starting point, especially when referring to the gap of constructed ecosystem services valuation, to offer consultation for government policy makers and to make the public aware of the values that ecosystem services provide. Further attention and more studies are necessary and urgently needed.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolecon.2008.02.008.

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