Journal of Environmental Management 90 (2009) 699–709

Journal of Environmental Management

www.elsevier.com/locate/jenvman

An environmental sustainability based budget allocation system for regional water quality management

Jehng-Jung Kao*, Tze-Chin Pan, Chin-Min Lin

Institute of Environmental Engineering, National Chiao Tung University, Hsinchu, Taiwan 30039, ROC

Received 28 April 2006; received in revised form 14 December 2007; accepted 4 January 2008
Available online 21 February 2008

Abstract

A budget allocation system for regional water quality management to achieve environmental sustainability was developed in this study to assist a local authority with making appropriate budget allocations for improving Regional Water Environmental Sustainability (RWES) in an efficient manner. The system consists of visions and goals, RWES indicators, and an analysis of budget allocation versus RWES. Visions and goals define task priorities for improving water environmental sustainability. Indicators are used to measure the progress of related tasks toward RWES goals. These indicators are classified by the Driving Force-State-Response (DSR) framework to facilitate the analysis of relationships among indicators. Linkages between budget allocation and indicators are also analyzed, and the result is used to assess whether the available budget is allocated properly to raise the RWES. The applicability of the system is demonstrated by a case study involving a local environmental protection authority.

Keywords: Environmental sustainability; Budget allocation; Accounting; Driving Force-State-Response (DSR); Indicator; Regional water quality management

1. Introduction

Improving the environmental sustainability of bodies of water has become an important policy goal for local water management authorities in Taiwan. To achieve this goal, various issues must be carefully evaluated. These issues include regional visions and goals, proper measures of Regional Water Environmental Sustainability (RWES), appropriate allocation of the budget, and assessing the efficiency of budget allocation to enhance RWES. The interaction among these issues is complex. Many officers, experts, local groups, residents, and other stakeholders are expected to be involved in making an appropriate plan to effectively promote RWES. A systematic tool capable of being used for such a complex group analysis task is therefore desirable. Furthermore, the traditional budget system and water environment sustainability indicators for a local region are usually two separate systems; therefore, budgetary allocation is frequently not considered appropriate for the improvement of RWES. Hence, it is necessary to develop a system that integrates both. A Web-based budget allocation system for improving water environment sustainability has been thus developed in order to facilitate this group analysis. The proposed Web-based system is intended to help a regional water quality management authority to make a budget plan that will effectively improve RWES.

Visions should be defined for pursuing regional sustainability (ICLEI, 1996). In the system that is developed in this study, visions serve as the driving force for evaluating the progress of improving RWES. The progress of improving sustainability can be evaluated by a set of appropriate environmental sustainability indicators with reasonable target values (Walmsley, 2002). Many organizations and nations throughout the world have established various indicator systems (e.g., OECD, 2003; Esty et al., 2005; ANZECC, 2000). However, these

Abbreviations: RWES, regional water environmental sustainability; DSR, driving force-state-response; KI, key indicator; BOD, biochemical oxygen demand; NT$, new Taiwan dollar.

* Corresponding author. Tel.: +886 3 573 1869; fax: +886 3 573 1759.
E-mail address: jjkao@mail.nctu.edu.tw (J.-J. Kao).

0301-4797/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2008.01.003

indicator systems were mostly developed for a whole country and are not entirely suitable for a region. Sustainability issues for a region are different from those for a nation. Therefore, many regional authorities or organizations have established their own indicators according to regional or community characteristics to measure regional improvement (Best et al., 1998; Bay Area Alliance and NCCC, 2003; Melhus et al., 2003). In addition, different regions require different sets of indicators according to regional specific characteristics.

Developing a set of indicators specifically for evaluating RWES is thus essential. Previous studies have developed several RWES indicator sets. For instance, the United Nations (UN/WWAP, 2003) selected a set of indicators for water resource management. The USEPA (2002) developed several watershed indicators to examine the vulnerability of water resources. Hellströn et al. (2000) proposed a series of criteria and indicators for assessing an urban water management plan in Sweden. Lundin and Morrison (2002) applied a life-cycle assessment approach to develop indicators for urban water systems. However, none of these indicator sets consider causal relations among indicators, and they are not readily used to assess the effectiveness of a budget allocation plan. Therefore, in addition to developing a suitable set of indicators for evaluating RWES, the selection of appropriate indicators for evaluating the effectiveness of budget allocation for improving RWES is also explored.

To represent the relationship among indicators, the UN Commission on Sustainable Development (UNCSD, 2001) proposed the Driving Force-State-Response (DSR) framework to classify the indicators. The DSR is a causality-based framework (Spangenberg et al., 2002). It is adopted for developing the proposed system to analyze the action–response relationship among indicators, and to reflect the environmental status, environmental impact, and the performance of associated actions or plans.

To reduce externalities and to promote efficient environmental management systems, various green or environmental accounting systems have been proposed to link financial accounting systems with environmental performance for various sectors, including federal, national, or local governments, as well as companies and institutes. For instance, the System of Integrated Environmental and Economic Accounting (UN, 2003) is a satellite system of the System of National Accounts. The former system supplements the latter by converting energy and environmental related measures into monetary units for subsequently adjusting the national GDP. Although the environmental protection expenditure in every category is identified, the system does not link the expenditure to related environmental protection performance for evaluating the efficiency of the expenditure.

The Environmental–Economic Accounting proposed by the Federal Statistical Office of Germany (2004) focuses on measuring eco-efficiency at the national level based on productivity indicators. However, the eco-efficiency indicator, although reflecting the relation between GDP and input factors (e.g. natural resources and pollutants), does not explain the influence of budget allocation on environmental improvement, and the efficiency of the budget allocation for increasing regional sustainability cannot be evaluated with it.

Full Cost Accounting (USEPA, 1998) considers the cost incurred in the past, present, and future, and is applied for analyzing the actual cost of an environmental management strategy. This system, although applicable for a regional government, does not consider the state of the environmental changes or any of the various environmental sustainability measures.

Environmental Management Accounting (Jasch, 2001; USEPA, 1995; Deegan, 2003) analyzes the environmental conservation costs and benefits of supporting business management decisions. However, external costs such as the impact of wastewater on a river are usually not accounted for.

Environmental Financial Accounting (Adams et al., 2000; USEPA, 1995) focuses on reporting the environmental cost and liability for investors, lenders, and other external audiences. Environmental Cost Accounting (USEPA, 1995; Graff et al., 1998) adds the environmental cost information into the traditional cost accounting system and analyzes how the environmental costs are allocated to products or processes. Both systems are primarily designed for a private company and are not applicable for a regional government to adjust its budget allocation for increasing regional environmental sustainability.

According to the 'polluter pays' principle, the European System for the Collection of Economic Data on the Environment identifies the cost of environmental protection and determines the amount of the transfers (Eurostat, 2002). For evaluating the effectiveness of protection efforts, this system briefly describes a set of Response indicators, under the DSR framework, to link protection expenditures. However, no report is available for describing the detailed implementation of the Response indicators.

In this study, similar to the concept proposed by the system described by Eurostat (2002) for linking Response indicators with protection expenditures, a set of RWES indicators are integrated into an existing financial budget allocation system for analyzing the (a) applicability of budget allocation for improving RWES and (b) consistency of the allocation in meeting various RWES visions and goals. The proposed system should facilitate the decision and evaluation processes for an effective budget allocation to achieve short- and long-term environmental sustainability visions and goals. The system is implemented on a typical web browser and is accessible on the Internet from anywhere at any time. Such a web solution substantially facilitates the analyses by people in different offices or places.

The budget allocation procedure using the proposed system involves the following steps. First, the users choose the sets of tasks (or alternatives) and determine the budgets based on their specified visions, goals and associated indicators. Next, the system displays the tasks along with their environmental outcomes and associated expenditures. Then the system allows users to change their chosen tasks, aggregates the new budgets, displays the new outcomes and sums up the total cost of all the tasks. Finally, the system keeps the allocated budgets within limits.

This paper provides a conceptual framework and a demonstrative system to assist managers in the allocation of available budgets in order to improve RWES. In the following sections, the conceptual framework of the system is explained. Next, the study area and RWES visions, goals, and indicators are described. Then, the Key Indicators (KIs) used for linking RWES indicators and the budget allocation system are described in detail. Finally, the budget allocation analysis for a case study at hand is demonstrated to illustrate the applicability of the proposed system.

2. The conceptual framework and structure of the system

The conceptual framework of the proposed RWES-based budget allocation system is illustrated in Fig. 1. Visions and goals describe the water that local residents expect to have available. RWES indicators are used to measure whether a regional water environment is being improved toward sustainability or not. To enhance RWES, the local government is responsible for properly allocating the available budget to the appropriate action plans. Allocation of the budget should carefully consider the achievement of the indicators in each year.

An indicator system and a budgetary system are generally two separate systems. In order to evaluate the efficiency of a budget allocation for improving RWES, relationships should be established between budget items and indicators. However, these relationships will be too complex if all indicators are selected. Furthermore, some indicators are strongly correlated to other indicators. When there are several indicators that are strongly correlated to each other they probably link to the same budget item and may cause unnecessary duplication and complexity for analyzing their relationships. Therefore, only a sub-set of indicators are selected as KIs and these are allowed to link directly to a budget item.

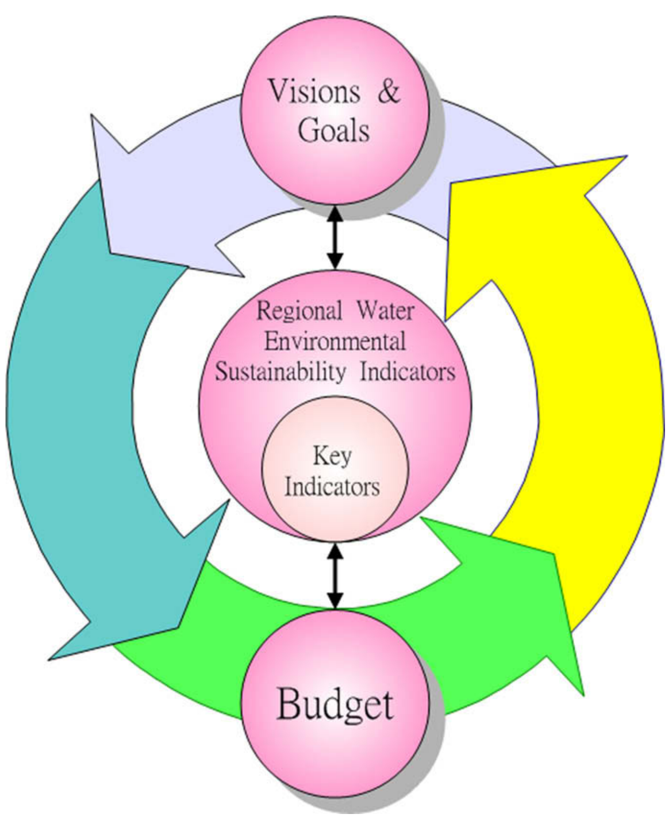


Fig. 1. The framework of the RWES-based budget allocation system.

The structure of the proposed system shown in Fig. 2 consists of five major sub-systems: visions/goals setting, RWES indicator management, analysis for the relationship between RWES indicators and budget allocation items, budget allocation analysis, and an integrated interface, respectively. Three major databases were developed for storing and managing visions and goals, RWES indicators and budget allocation items, respectively. The original system was developed in Chinese, and a demonstrative English version was made available on the Internet, http://RwesBa.ev.nctu.edu.tw. An integrated Web-based interface, as shown in Fig. 3, was developed for the system. Budget allocation can be adjusted using this interface according to achievements on various indicators. The sub-systems, databases, and the interface are detailed in the following sections.

3. Study area

The study area is Hsinchu City in Taiwan, Republic of China. The area of the city is about 103 sq km with three major rivers passing through it. The water quality of the rivers is as follows, Touchien River is lightly polluted, and Keya and Yenkang Rivers are medium-polluted according to a river pollution index (ROC EPA, 2004). There are about 390,000 people living in the city at present, and they collectively generate wastewater at a rate of about 72,000 m^3/day (HCCEPB, 2002). A new sewage collection system is currently under construction, and 96% of the citizens are served by tap water (HCCEPB, 2002). In addition, there is a high-tech industrial district, Hsinchu Science Park, located within the city limits discharging a significant amount of wastewater, at a rate of about 86,000 m^3/day (Hsinchu Science Park Administration, 2005). According to the environmental protection plan prepared by the Bureau of Environmental Protection in Hsinchu City (HCCEPB, 2002), the visions for the water environment are to (1) provide clean water; (2) protect aquatic habitat; and (3) sustain a quality living environment. The Bureau of Environmental Protection is responsible for the first vision, and plays an important role in the other two visions. However, it is not the primary city agency responsible for visions (2) and (3). For demonstration purposes, we made up several goals, as shown in Fig. 3.

The layout of the original budget allocation plan of the Bureau of Environmental Protection for water quality management made it difficult for a manager or a citizen to comprehend the effectiveness of the intended financial investment for improving RWES. An appropriate system to analyze the relationship between the budget allocation and indicators is therefore desired and is explored in this study.

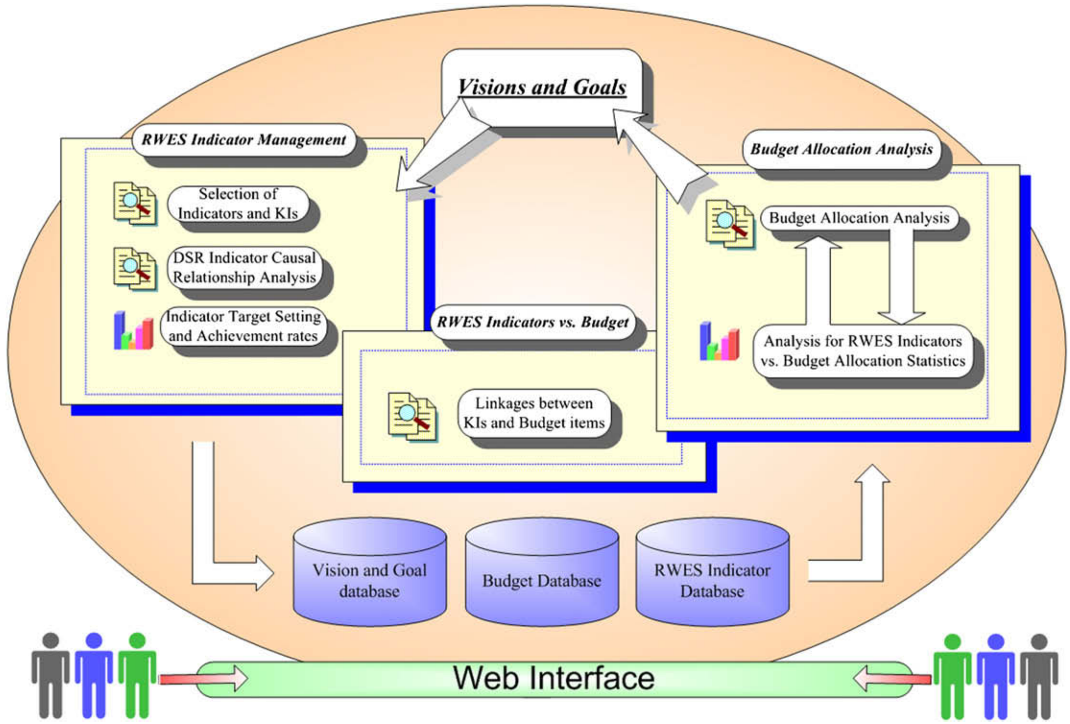


Fig. 2. The structure of the environmental sustainability based budget allocation system for regional water quality management.

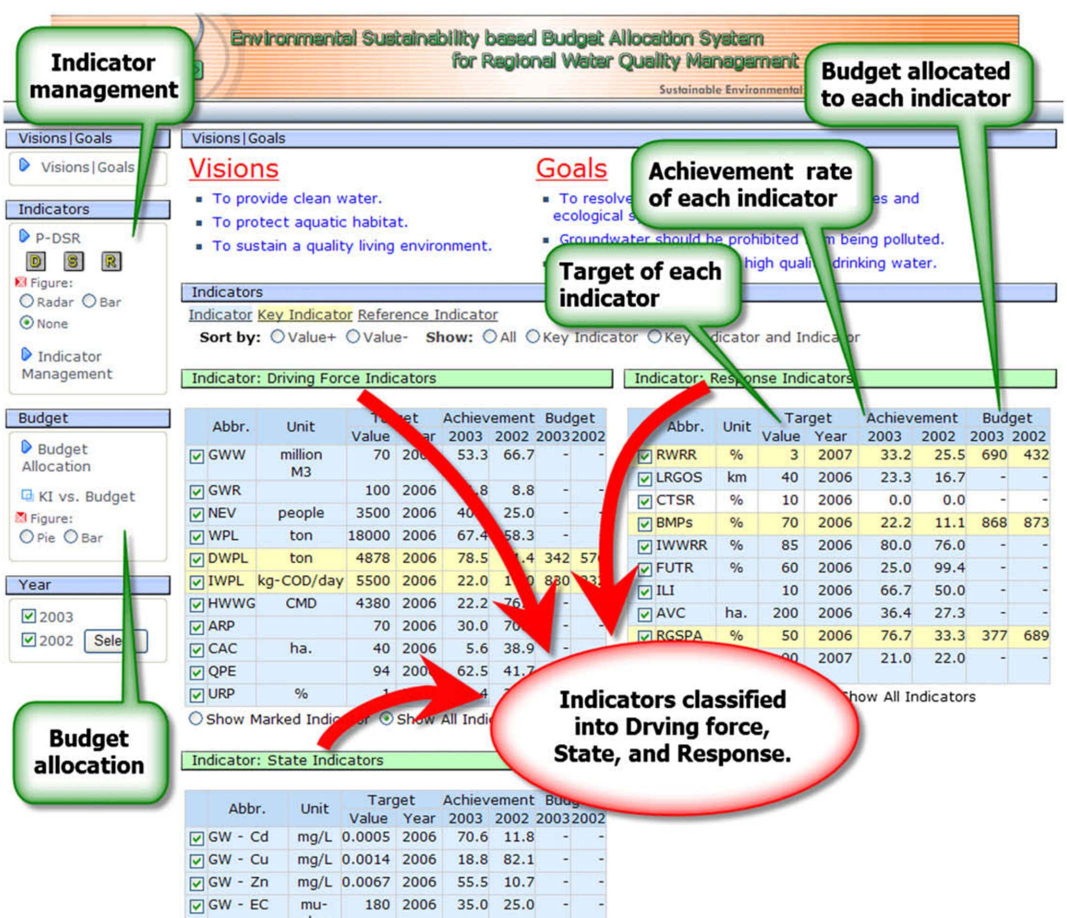


Fig. 3. A typical Web-based interface of the system.

4. RWES indicators

After visions and goals are established, the appropriate RWES indicators should be developed to measure the progress of achieving these visions and goals. Various indicators for regional levels (Melhus et al., 2003; Oregon Progress Board, 2003; USEPA, 2002), national levels (ROC CEPD, 2002; ANZECC, 2000; Diakoulaki et al., 2003), and international levels (UNCSD, 2001; Esty et al., 2005; WHO, 2004) were collected in this study for developing Hsinchu City RWES indicators. A region generally has specific environmental characteristics and thus requires a careful selection of an appropriate set of indicators. Criteria from various sources are adopted to select indicators, e.g., the definition of an indicator should be clear, understandable, and related to stakeholder care (ICLEI, 1996; Best et al., 1998; Bossel, 1999). The indicators must also be able to guide the policy and support the decision making and must include the function of early warning to prevent a problem from occurring (ICLEI, 1996).

The interface shown in Fig. 4 is used for setting up, selecting, and managing the selected indicators. The regional authority can select appropriate indicators based on local, spatial, and temporal characteristics of the region. Each indicator can be assigned a base value and a target value for respective years. These values are used to evaluate the progress for improving RWES. Selected indicators can be linked to appropriate goals, and then the achievement of each goal can be evaluated according to a selected set of indicators.

In order to improve RWES, the target of each indicator can be based on the principles described below.

(1) The following three factors should be considered in order to set a reasonable target.
   (i) *Regional characteristics*. For example, in Hsinchu a significant number of industrial plants discharge a large amount of wastewater into a receiving water body. Although the level of pollutants in individual sources of discharged wastewater can meet current water quality standards, the amount of the wastewater is too large and creates a significant threat to the receiving body. Therefore, a total mass-based target, instead of a concentration-based target, should be set, especially to deal with heavy metal pollution.
   (ii) *Feasibility*. For example, although increasing the ratio accessible waterfront is desirable, in order to prevent floods it is currently not possible to convert all RC-based riverbanks into green or nature banks. Instead, upstream watershed protection and recovery should be improved first and then human activities should be restricted to reduce runoff and erosion. Once the upstream runoff and land erosion have been effectively reduced, the reinforced concrete based banks can be gradually transformed into accessible waterfronts.
   (iii) *Cost-effectiveness assessment*. Allocating a large amount of funds to improve a specific indicator may not be cost effective. Instead, the funds should be used to improve other essential indicators. For example, although health risk assessment is important for water-borne diseases, the investigation and sampling cost is quite high and the collected data are still

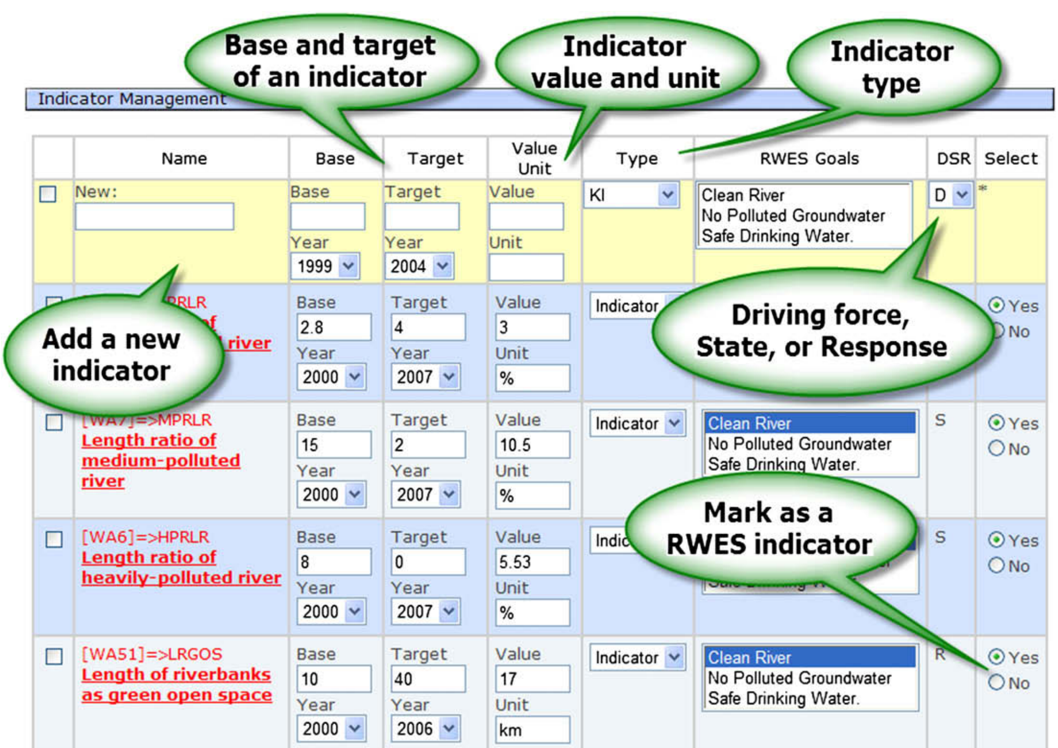


Fig. 4. RWES indicator management interface.

not reliable enough to make a proper decision. Instead, these funds may be better allocated to monitor the quality of water at residential water intakes.

(2) The expectations of local residents should be considered. For example, they expect safe drinking water, so the target for the quality of the drinking water should be set high.
(3) Specified targets should reflect RWES visions and goals. For example, unpolluted groundwater is one major goal, so the target set for the ratio of groundwater samples complying with the required standards should be high.

As shown in Fig. 4, a desired value can be assigned to each indicator for a target year, and the budget allocated for each indicator is computed by summing up individual amounts allocated to related tasks. To express the progress of RWES improvement, the achievement rate of each indicator is calculated according to the following equation:

$$A = \left(\frac{B-P}{B-T}\right)100\% \qquad (1)$$

where A is the achievement rate of an indicator; B is the indicator value in the base year; P is the indicator value of this year; T is the indicator value in the target year. The achievement rate indicates the progress of improvement of an indicator toward a desired target value.

In this study, the DSR framework (UNCSD, 2001) was adopted to represent the causal relationships among indicators for three major water bodies: rivers, groundwater and drinking water. This framework consists of three types of indicators: Driving Force, State, and Response. Driving Forces (D) represent human activities that impact on the environment or State (S) either positively or negatively, and thus the society must Respond (R) to reduce any negative impact or to enhance any positive effect for improving the State of the regional water environment. For example, industrial development has rapidly increased in Hsinchu City in recent years. The industrial water pollution loading can be regarded as a Driving Force indicator that can significantly reduce the quality of the water body (a State indicator) of the receiving water body. An effective strategy such as pollution source reduction should be adopted to reduce the industrial water pollution loading. And the number of dischargers adopting pollution source reduction programs can be used as a Response indicator to assess the progress in the implementation of the strategy. Various indicators have been selected and divided into DSR categories by an indicator management interface, as shown in Fig. 4.

All the RWES indicators selected for Hsinchu City are listed in Fig. 5. Because the three bodies of water influence each other, some indicators are connected to more than one body of water. Indicators connected to all bodies of water are categorized as common indicators. Some of the main water quality problems are caused by domestic and industrial wastewater discharges. The water pollution loading, therefore, is regarded as a major Driving Force common indicator.

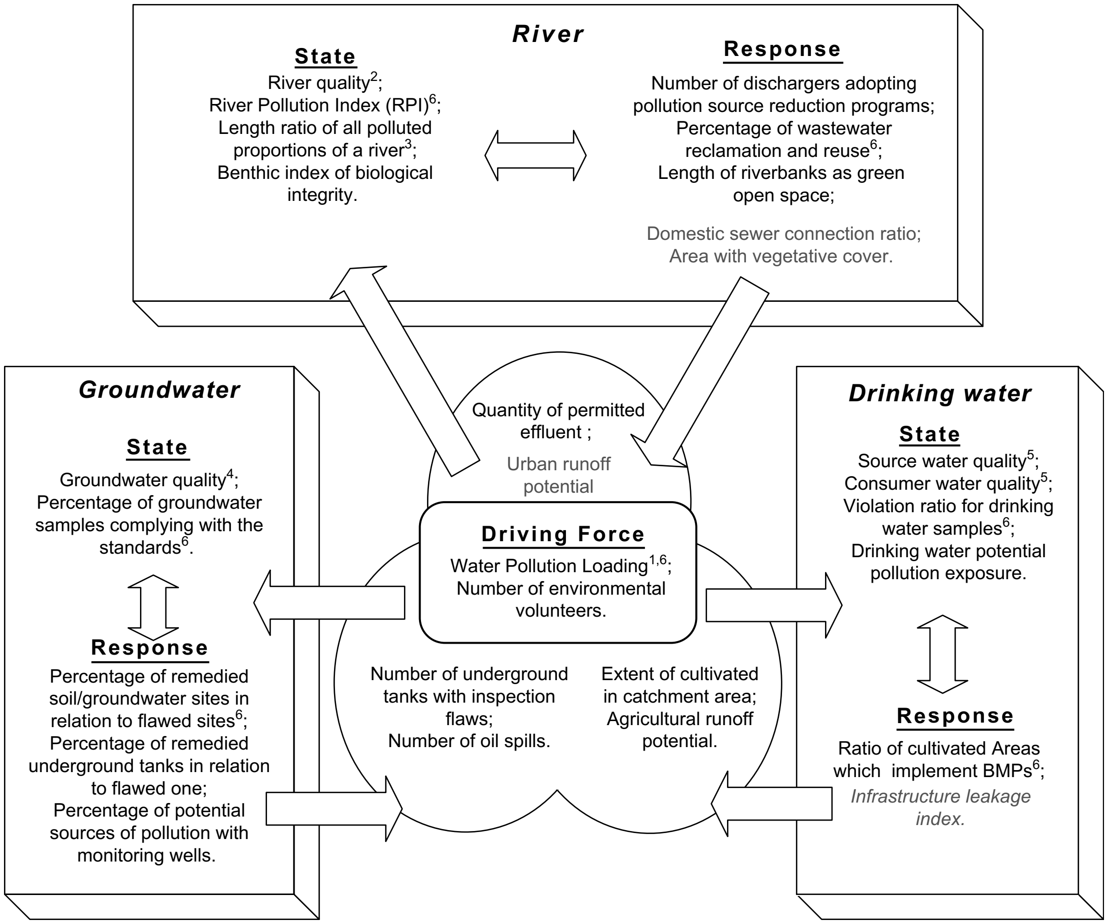
For rivers, water pollution loading, quantity of permitted effluent and urban runoff potential are the major Driving Force indicators and impact on the State indicators, such as river quality and the length ratio of all polluted portions of a river. Because of rapid velocity on steep slopes, re-aeration is generally effective for rivers in Taiwan. It is believed that the removal of Biochemical Oxygen Demand (BOD) loading can simultaneously improve dissolved oxygen; thus, BOD instead of dissolved oxygen is chosen as the major RWES indicator to represent the state of the river. To reduce the river pollution loading, source reduction and wastewater reclamation and reuse are two effective strategies. Therefore, the number of dischargers adopting pollution source reduction programs and the percentage of wastewater reclamation and reuse are regarded as Response indicators.

For groundwater bodies, leakage from aged tanks and oil spills are the major causes of pollution. The number of underground tanks with inspection flaws and the number of oil spills are thus regarded as Driving Force indicators that can affect the State indicators, including groundwater quality and the percentage of groundwater samples complying with the standards. The major strategy to reduce the impact of groundwater pollution is to address the problems of soil and groundwater pollution sites and flawed underground tanks. Monitoring wells should be installed close to potential pollution sources in order to detect groundwater pollution during the early leakage stage to prevent the spread of pollution. To measure the effort being made by an authority, three Response indicators need to be measured: the percentage of remedied soil/groundwater sites in relation to the flawed sites; and the percentage of remedied underground tanks in relation to flawed ones; the percentage of potential sources of pollution with monitoring wells.

With respect to the drinking water body, the major Driving Force indicators are the water pollution loading, the extent of cultivation in the catchment area, and the agricultural runoff potential. These indicators affect the State indicators of source and consumer water quality and the violation ratio for drinking water samples. Furthermore, since one of the intake points of the drinking water is located downstream of a high-tech industrial district, the heavy metal concentration in the river is an essential indicator in the protection of drinking water resources. The Response indicators for this intake are similar to those for the river body. The other major source of drinking water is from an off-stream reservoir located upstream of a local river. Proper management of the upstream watershed of the reservoir for controlling non-point source pollution is the critical strategy for reducing pollution loading. The ratio of cultivated areas which implement Best Management Practices (e.g. USEPA, 2007; Kao and Chen, 2003) is recommended as the Response indicator.

5. Key indicators (KIs)

The DSR framework, although it can describe the causal relations among indicators, does not reflect the planning effort for improving RWES. A proper plan is essential to promote RWES. Therefore, this framework is extended to evaluate the budget allocated for planning efforts. Furthermore, general



[1] includes total, municipal, industrial, and husbandry wastewater.

[2] includes heavy metal, EC, BOD, NH_3-N, SS, and pH.

[3] includes heavily-polluted, medium-polluted, lightly-polluted, not-polluted reaches.

[4] includes heavy metal, EC, pH, and TOC.

[5] includes heavy metal, E. coli, fluoride, total THMs, total hardness, and pH.

[6] Key Indicators (KIs).

Fig. 5. RWES indicators in the DSR framework.

overhead expenses are incurred for daily operations that are not directly related to any specific indicator. A special budget allocation sub-system is therefore developed in this study to separate basic overhead and planning expenditures. Water quality management tasks are greatly affected by the budget allocation. The budget should be properly allocated in accordance with visions and goals. The budget allocation sub-system is used to support the analysis and decision of an appropriate budget plan to effectively enhance RWES.

To evaluate the effectiveness of the available budget in improving RWES, functions for assessing the relationship between indicators and budget items should be made available. However, it is impractical to link all indicators with budget items because some indicators are directly or indirectly related to more than one budget item, and some indicators are related to each other. Linking all indicators to all budget items is too complicated and will make it difficult to evaluate the effectiveness of each allocated budget item. This is especially true during the initial stage of applying the system. For example, the river pollution index consists of BOD, dissolved oxygen, suspended solids, and ammonia nitrogen. If both the index and BOD were linked to a budget item, then the budget allocated for reducing the BOD would be accounted twice, and this duplication would complicate the computation and the evaluation of the associated budget item. A set of KIs are therefore selected from the entire set of indicators. Only KIs can be linked to budget items. KIs are selected based on five major rules.

1. KIs should not be duplicated, such as the example of the river pollution index and BOD described above.

2. KIs should reflect regional environmental sustainability or strategies for achieving visions and goals. For example, although the indicator of quantity of permitted effluent provides information about the point sources being managed, it does not reflect the real improvement required to achieve regional environmental sustainability.
3. KI data must be easy to collect and calculate. For example, the health risk caused by polluted drinking water, although important, is difficult to evaluate at present in Taiwan due to the limited data available.
4. KIs should be directly linked to specific budget items. Some indicators can be improved only when other related indicators are improved first. However, linking budget items to such indicators cannot directly measure the effectiveness of the effort made by a regional authority. For example, although the benthic index (Kerans and Karr, 1994) of biological integrity provides a direct measure of a river's ecological health, to improve this index it is necessary to ameliorate water quality, provide green river banks, and reduce the effect of storm water. Most investments for improving this index are indirect, and thus they are not appropriate to serve as a KI.
5. Indicators that are strongly affected by external or background factors should not be used as KIs because they are not easy for regional authorities to improve. For example, due to the natural geologic characteristics in the upstream catchment of the Touchien River in Taiwan, the indicator for downstream suspended solid (SS) concentration is often affected by significant rainfalls upstream. However, the natural geologic characteristics are hard to alter and, thus, the SS indicator cannot be used to measure the effectiveness of investment.

From the many requirements and duties of a regional water quality authority, this study has selected eight KIs, as shown in Fig. 5. Because the environmental authority in Hsinchu City is currently not responsible for the sewage system, the indicators which relate to that have not been selected, although sewer-related indicators are critical for promoting RWES.

For the sake of convenience in further analyses, each budget unit is the equivalent of New Taiwan Dollar (NT$) 1000 and linked to one KI only. A budget item with an amount more than one unit can be linked to multiple KIs, and a table for the monetary amount or percentage of the budget allocated to each KI is provided. The total investment of the budget for each KI can thus be computed for further analyses.

6. Budget allocation analysis

The budget information was provided by the accounting office of the HCCEPB. A Web-based program was developed to display the table in its original order and form, as illustrated in Fig. 6. The budget items are classified into four levels. The budget items in a higher level include several sub-items in a lower level. The budget of each item can be allocated and linked to related KIs. If an item in a higher level has been allocated, none of its sub-items are allowed to be allocated again so as to avoid duplication.

After clicking the mouse on a budget item, a pop-up window with an allocation table, as illustrated in Fig. 6, will be shown. The manager can link the budget item to appropriate KIs by entering the appropriate percentages or dollar amounts of its budget into the table. In general, each budget item may be linked to a single KI only. However, some budget items may be associated with more than one KI. For example, the budget of a project for field investigation for possible pollution sources of river and groundwater bodies is associated to two KIs: water quality violation rates of both river and groundwater. The manager can allocate proper portions of the budget, in indivisible units of NT$1000, to each associated KI. The amount to be allocated to each related KI listed in the left-hand column of the table should be determined based on the performance of the associated indicators, the task to be implemented, the financial support provided by the budget item, and the RWES improvement expected to be made after the implementation of the task.

After the allocation of all the budget items, as shown in Fig. 7, a pie chart generated by the system shows the percentage of the entire budget allocated to each KI, and a bar chart shows the achievement rate of each KI. By comparing budget allocation and achievement rates of the indicators, the manager can evaluate and decide how to adjust the budget allocation. The proposed procedure for evaluating the budget allocation is as follows.

Step 1. Check the achievement rate against the desired target of each indicator and evaluate the performance with respect to the improvement of regional environmental sustainability in previous or next year(s). The manager should review carefully all achievement rates and determine which indicators should be improved first.

Step 2. Assess the values of indicators which have changed from previous years and review the changing trend to see whether the (1) desired improvement of the indicator is feasible; (2) planned tasks are good enough to achieve specified indicator targets in time; and (3) actions to be implemented are appropriate to raise regional environmental sustainability.

Step 3. Evaluate the effectiveness of past investments in the improvement of regional environmental sustainability in order to determine possible adjustments to budget allocation in the coming year. The four principles listed below can assist the manager to determine any adjustments to budget allocation.

1. Ensure that high priority KIs and KIs with low achievement rates should be allocated with a sufficient amount from the budget.
2. Any KI with poor performance or small improvement, but with significant investment in the previous years, should be examined in terms of efficiency or suitability for the implementation of related tasks.
3. The budget items which relate to a KI that has exceeded its desired target or is expected not to

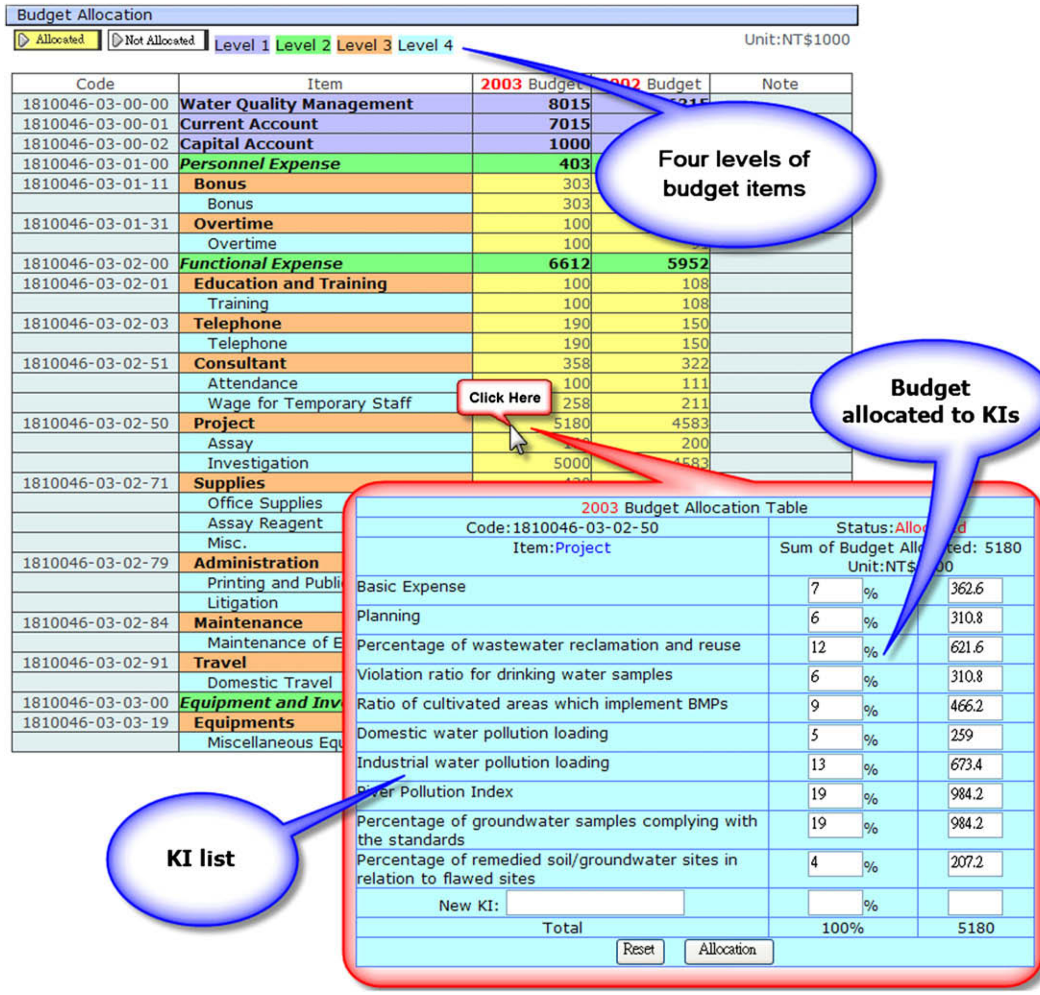


Fig. 6. Budget allocation table.

improve significantly in the coming year should be reviewed to see if it is possible to reduce the budget allocated to it.

4. If the time is close to the target year and the achievement rate of an indicator is still far away from its desired target, effective actions should be taken to improve the indicator and try to achieve the target in time.

The achievement rate for the industrial water pollution loading indicator is computed based on the achieved reduction of the pollution loading. For example, the amounts of pollution loading in 1999, 2002, and 2003 were 9000 kg-COD/day, 8405 kg-COD/day and 8230 kg-COD/day, respectively, and the target loading in the target year of 2006 was set at 5500 kg-COD/day. Therefore, as shown in Fig. 7, the achievement rate for this indicator increased from 17% in 2002 to 22% in 2003, and it revealed that the indicator for the rate of industrial wastewater reclamation and reuse in 2003 did not perform well. Water pollution loading is mainly attributed to industrial wastewater, and this KI is thus a high priority indicator. Furthermore, in Hsinchu City, a limited water supply is a critical problem because the amount of industrial water uses is quite large and more than that for domestic water uses. Industrial wastewater reclamation and reuse, therefore, is an essential task which should be enforced to reduce the amount of discharged industrial wastewater. Due to the low achievement rate for this KI, appropriate plans and actions should be implemented in order to achieve the desired target. Some possible actions might include: a cessation in the issue of permits to discharge; a review of the number of existing permits; the requirement that all dischargers adopt pollution source reduction programs; a program to recycle grey water; assistance to improve wastewater treatment and reclamation facilities. However, in order for such actions to be possible, the budget for industrial wastewater pollution loading needs to be increased.

To facilitate budget allocation analysis for the improvement of RWES, the developed system integrates the interfaces for managing visions and goals, indicators, budget allocations, and the relationship between indicators and budget allocations. As shown in Fig. 3, the users can start by setting their visions and goals, as well as by establishing a set of RWES indicators, including the desired target year and target value of each indicator, as illustrated in Fig. 4. Then, the system can display the achievement rate of each indicator, as illustrated in Fig. 3, in order to evaluate their individual performance with respect

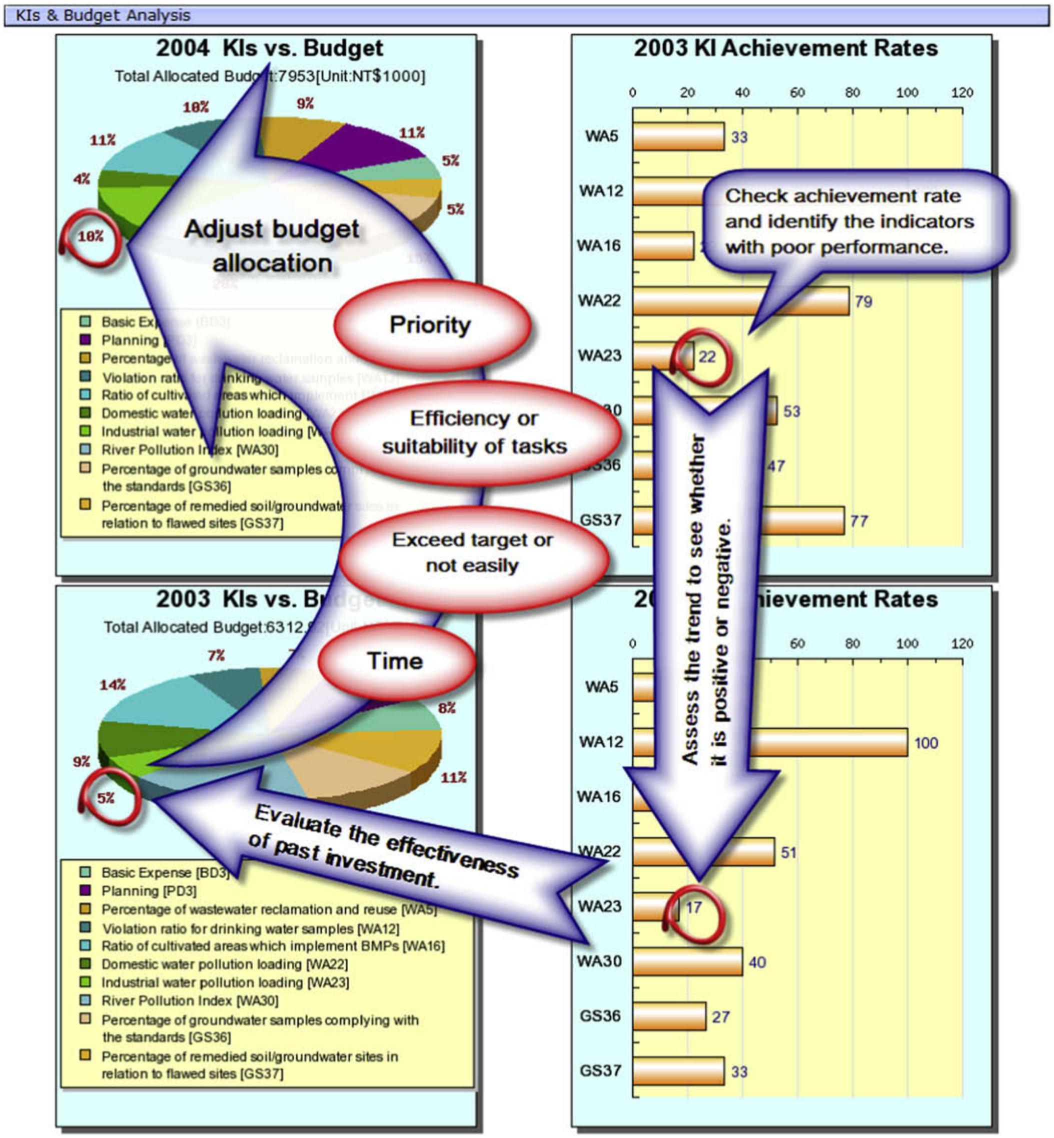


Fig. 7. KIs and budget analysis.

to RWES improvement. A budget allocation and indicator management interface, as shown in Fig. 6, are provided for linking budget items to indicators. Finally, an iterative budget allocation procedure, as shown in Fig. 7, can be implemented to select a set of tasks within the budget limit which are expected to achieve the desired target of each indicator.

7. Conclusions

This study has developed an environmental sustainability based budget allocation system for regional water quality management authorities. Most indicator systems are generally independent of any system of budget allocation and the proposed system makes it possible to integrate both. In order to reduce the complexity involved in linking RWES indicators to budget items, a set of KIs has been proposed. KIs make it possible to establish direct linkages to budget items and to reflect any improvement in RWES. With the proposed system, the progress of RWES can be evaluated by analyzing trends in indicator values, and their efficiency can be evaluated through a comparison of KI values and budget-associated tasks. By examining indicator achievement rates and the allocated budget, a manager can make any necessary adjustments to the budget items in order to improve related indicators.

The proposed system provides several sub-systems for setting visions and goals, managing RWES indicators, linking indicators to related budget items, and for analyzing the effectiveness of budget allocations in the improvement of RWES. The process of linking all expenditure items to their appropriate indicators is a job both complex and tedious. The proposed system provides an integrated and user-friendly tool for completing this job methodically. Moreover, this system is Web-based and can be accessed at any time from anywhere on the Internet. Based on its application in this case study, it is evident that the proposed system can provide critical information, which is generally not provided by conventional budgetary accounting systems, for the assessment of the suitability of a budget allocation plan for the improvement of RWES. However, a limitation of the developed system should also be noted here. More specifically, the system currently does not cover all aspects of regional water management because some indicators, although strongly related to the public vision of water quality, are not incorporated into the indicator framework since they are currently not under the jurisdiction of the agency related to this study. Finally, although it would increase the complexity of the system and require more exploration, it is recommended that the proposed system be expanded to other related agencies in order to develop a system that is comprehensive.

Acknowledgments

We would like to thank Ms. Yue-Siang Chen, the former accounting director of the Bureau of Environmental Protection of Hsinchu City, for providing the budget data. However, it must be noted that all the data and information presented in this paper are used solely to demonstrate the applicability of the developed system and should not be regarded as official documents from Hsinchu City, Taiwan, ROC. We also would like to thank National Science Council of the Republic of China for providing partial financial support for this work under Grant No. NSC 95-2221-E-009-114. We appreciate very much for the valuable comments provided by three anonymous reviewers. Without them, our manuscript cannot be significantly improved.

References

Adams, R., Coulson, A., Mueller, K., Sturm, A., Vartel, C., 2000. Accounting and Financial Reporting for Environmental Costs and Liabilities: Workshop Manual. Association of Chartered Certified Accountants, London.

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Core Environmental Indicators for Reporting on the State of the Environment. ANZECC, Canberra.

Bay Area Alliance for Sustainable Communities and Northern California Council for Community (Bay Area Alliance and NCCC), 2003. Bay Area Indicators: Measuring Progress Toward Sustainability. Bay Area Alliance and NCCC. Available from: http://www.bayareaalliance.org/ (accessed 30.03.06.).

Best, A., Dusen, H.V., Colin, R., 1998. Sustainable Seattle – Indicators of Sustainable Community. Sustainable Seattle, Seattle.

Bossel, H., 1999. Indicators for Sustainable Development: Theory, Method, Applications. International Institute for Sustainable Development, Winnipeg, Canada.

Deegan, C., 2003. Environmental Management Accounting: an Introduction and Case Studies for Australia. Environment Australia, in collaboration with EPA Victoria, and the Institute of Chartered Accountants in Australia. Available from: http://www.deh.gov.au/settlements/industry/finance/publications/project.html (accessed 08.04.06.).

Diakoulaki, D., Glykoyanni, A., Deliyannis, A., 2003. Environmental Signals. Greece National Center for the Environment and Sustainable Development, Kifissia, Greece.

Esty, D.C., Levy, M.A., Tanja, S., de Sherbinin, A., 2005. 2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship. Yale Center for Environmental Law & Policy, New Haven, Connecticut.

Eurostat, 2002. SERIEE European System for the Collection of Economic Information on the Environment – 1994 Version. Office for Official Publications of the European Communities, Luxembourg.

Federal Statistical Office of Germany, 2004. Environmental Productivity, Use of Area, Water, Waste 2003. Federal Statistical Office of Germany, Wiesbaden, Germany.

Graff, R.G., Reiskin, E.D., White, A.L., Bidwell, K., 1998. Snapshots of Environmental Cost Accounting. Tellus Institute, Boston.

Hsinchu City Environmental Protection Bureau (HCCEPB), 2002. Environmental Protection Plan. Environmental Protection Bureau, Hsinchu, Taiwan, Republic of China (in Chinese).

Hsinchu Science Park Administration, 2005. Major Events of Wastewater Treatment Plant. Hsinchu Science Park Administration (in Chinese). Available from: http://59.124.43.251/SPAWEB/wastewater/page7-2-10.jsp (accessed 27.12.05.).

Hellströn, D., Jeppsson, U., Kärrman, E., 2000. A framework for systems analysis of sustainable urban water management. Environmental Impact Assessment Review 20, 311–321.

International Council for Local Environmental Initiatives (ICLEI), 1996. The Local Agenda 21 Planning Guide: an Introduction to Sustainable Development Planning. ICLEI, Toronto.

Jasch, C., 2001. Environmental Management Accounting – Procedures and Principles. United Nations Division for Sustainable Development, New York.

Kao, J.J., Chen, W.J., 2003. A multiobjective model for non-point source pollution control for an off-stream reservoir catchment. Water Science and Technology 48 (10), 177–183.

Kerans, B.L., Karr, J.R., 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee valley. Ecological Applications 4 (4), 768–785.

Lundin, M., Morrison, G.M., 2002. A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems. Urban Water 4, 145–152.

Melhus, P., Dorrance, L.B., Clark, D.L., Condon, E., Hazen, C., Johnson, R., Jones, M.S., Mitchell, P., Paton, B., Quevedo, E., Roberts, B., 2003. Silicon Valley Environmental Index. Silicon Valley Environmental Partnership. Available from: http://www.svep.org/ (accessed 10.04.05.).

Organisation for Economic Co-operation and Development (OECD), 2003. Environmental Indicators Development, Measurement and Use. OECD Environment Directorate Environmental Performance and Information Division, Paris.

Oregon Progress Board, 2003. Is Oregon making progress? The 2003 benchmark performance report. Report to the Oregon Legislative Assembly. Oregon Progress Board, Salem, Oregon.

ROC EPA, 2004. Yearbook of Environmental Protection Statistics. Environmental Protection Adminstration, Taipei, Taiwan, Republic of China.

ROC Council for Economic Planning and Development (ROC CEPD), 2002. Sustainable Development Indicators for Taiwan. ROC CEPD. Available from: http://www.cepd.gov.tw/sustainable-development/eng/main.htm (accessed 15.08.04.).

Spangenberg, J.H., Pfahl, S., Deller, K., 2002. Towards indicators for institutional sustainability: lessons from an analysis of Agenda 21. Ecological indicators 2, 61–77.

United Nations (UN), 2003. Integrated Environmental and Economic Accounting. UN, New York.

United Nations Commission on Sustainable Development (UNCSD), 2001. Indicators of Sustainable Development: Guidelines and Methodologies. UN, New York.

United Nations/World Water Assessment Programme (UN/WWAP), 2003. 1st UN World Water Development Report: Water for People, Water for Life. United Nations Educational, Scientific and Cultural Organization and Berghahn Books, Paris, New York and Oxford.

U.S. Environmental Protection Agency (USEPA), 1995. An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts. USEPA, Washington D.C.

U.S. Environmental Protection Agency (USEPA), 1998. Full Cost Accounting in Action: Case Studies of Six Solid Waste Management Agencies. USEPA, Washington D.C.

U.S. Environmental Protection Agency (USEPA), 2002. Index of Watershed Indicators: an Overview. USEPA, Washington D.C.

U.S. Environmental Protection Agency (USEPA), 2007. Agricultural Management Practices for Water Quality Protection. USEPA. Available from: http://www.epa.gov/watertrain/agmodule/ (accessed 25.01.07.).

Walmsley, J.J., 2002. Framework for measuring sustainable development in catchment system. Environmental Management 29, 195–206.

World Health Organization (WHO), 2004. Development of Environment and Health Indicators for European Union Countries: Results of a Pilot Study. WHO European Centre for Environment and Health, Bonn.