



Economy and Environment Program for Southeast Asia



Application of Trade-off Analysis Framework in the Ma Oya River Basin Development Project

Bhadranie Thoradeniya

May, 2010

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ACKNOWLEDGEMENTS

The financial and technical support provided by the Economy and Environment Program for Southeast Asia (EEPSEA) is greatly appreciated. Tribute is paid to the economists, experts, researchers, and the staff of EEPSEA for the support provided in numerous ways. Special mention is made of Dr. David Glover, Dr. Herminia A. Francisco, Prof. Theodore M. Horbulyk, Prof. Nancy Olewiler, and Dr. Arief Anshory Yusuf for their valuable suggestions and comments, and of Ms. Catherine Ndiaye and Ms. Ang Cheng Hiang for their excellent secretarial support.

This research was carried out as part of the requirements for the PhD degree of the author, and the continuous guidance and encouragement provided by the PhD research supervisors Prof. Malik Ranasinghe and Prof. N T S Wijesekara are gratefully acknowledged. The facilities provided by the 'Construction Management' division of the Department of Civil Engineering of University of Moratuwa, Sri Lanka are sincerely appreciated. Sincere thanks are due to Ms. Sanjeewanie Moragalla, Ms. Madara Weerasinghe and Mr. Chandika Jayawardena for their diligent help in the tedious processes of data collection and analysis.

My children, Prageeth and Dilini, deserve a hearty appreciation for assisting me in all possible ways from computer programming and data collection to relieving me from household duties so that I could devote my full attention to the project. Finally I affectionately remember the tolerance, encouragement, and support extended in every way by my husband Asoka.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	1
1.1 Preamble	1
1.2 Research Problem	2
1.3 Research Objectives	2
1.4 Scope of the Study	2
1.5 Dissemination of Results	3
1.6 Structure of the Report	3
2.0 BASIN ISSUES AND THE ‘EDUCATED TRADE-OFF’ FRAMEWORK	3
2.1 General	3
2.2 Issues of the Ma Oya River Basin	4
2.3 ‘Educated Trade-off’ Framework	4
3.0 STAKEHOLDERS AND RESOURCE USES	7
3.1 General	7
3.2 Stakeholder Involvement Approach and Data Collection	7
3.3 Data Analysis	8
3.4 Discussion	13
4.0 TECHNICAL REQUIREMENT OF RESOURCE USES	14
4.1 General	14
4.2 Critical Bounds of Technical Requirement of Direct Uses of the Project	14
5.0 ECONOMIC VALUE OF NATURAL RESOURCE USES	16
5.1 General	16

5.2 Economic Analysis for the Incremental Benefits and Costs of the Project	16
5.3 Discussion	18
6.0 SOCIAL AND ENVIRONMENTAL IMPACT VALUATIONS	19
6.1 General	19
6.2 Recreation Sector	20
6.3 Tourism Sector	21
6.4 Industry Sector	22
6.5 Dug-well Sector	24
6.6 Rainfed Agriculture Sector	25
6.7 Economic Analysis	27
7.0 COMBINED ECONOMIC AND ENVIRONMENTAL VALUE	27
7.1 General	27
7.2 Combined Economic Value	27
8.0 STAKEHOLDER EDUCATION AND FRAMEWORK VALIDATION	28
8.1 Stakeholder Workshops	28
8.2 Analysis	28
8.3 Discussion	31
9.0 CONCLUSION	32
REFERENCES	34
APPENDICES	35
Appendix 1: Flow chart for the stakeholder consultation	35
Appendix 2: Stakeholder groups and vulnerability	36
Appendix 3: Stakeholder contributions to river environment protection	37
Appendix 4: Factors used for stakeholder education	38

LIST OF TABLES

Table 1.	Gender-wise distribution of stakeholders among the DSDs	8
Table 2.	Numbers of respondents identified for each resource use sector at each DSD	9
Table 3.	Resource uses impacting other sectors as identified by the respondents	12
Table 4.	Issues in resource uses by stakeholders	12
Table 5.	Respondents' views of development/restoration of the river's environment	13
Table 6.	Number of days with possible flow variations	15
Table 7.	Expected annual income from water supply and power generation	17
Table 8.	Economic analysis with original project costs and benefits	18
Table 9.	Basic data for the zonal travel cost model	20
Table 10.	Water demand of industries along the river banks	23
Table 11.	Net present value of social and environmental benefits	27
Table 12.	Combined economic value for the cases 1, 3, and 4	28
Table 13.	Frequency and percentages of stakeholders from different user sectors	28
Table 14.	Summary of stakeholder responses between 'pre' and 'post' education	29

LIST OF FIGURES

Figure 1.	Percentage responses on threats to resource uses at present	10
Figure 2.	Percentage responses on expected threats to resource uses in the future	10
Figure 3.	Percentage responses on environmental impacts from own uses	11
Figure 4.	Percentage responses on environmental impacts from others' uses	11
Figure 5.	Sample cross-sections of the Ma Oya river	26
Figure 6.	Sample river cross section and the root zones of crops	26
Figure 7.	Technical and economic factors that influenced the stakeholders' decision-making	31
Figure 8.	Social and economic factors that influenced the stakeholders' decision-making	31

APPLICATION OF A TRADE-OFF ANALYSIS FRAMEWORK IN THE MA OYA RIVER BASIN DEVELOPMENT PROJECT

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EXECUTIVE SUMMARY

The general practice adopted in river development projects is to analyze the technical and economic feasibility of a proposal, given certain conditions. However, the social and environmental impacts are usually limited to the project area, mainly focusing on the people affected by the project. Past experiences have shown that this practice leads to stakeholder dissatisfaction, resulting to conflicts among stakeholders sharing the resource.

The stakeholders' lack of knowledge about the technical, economic, and environmental dimensions of their resource uses usually hampers their rational decision-making process, especially in situations where there are conflicts for scarce resources. To enhance the stakeholders' knowledge about the above dimensions of their resource use, this study applied the 'Educated Trade-off' framework for a proposed development project in the Ma Oya river basin in Sri Lanka.

1.0 INTRODUCTION

1.1 Preamble

Ma Oya is one of the most water-stressed rivers in the wet zone of Sri Lanka. One of the stakeholders in the use of river resources, the National Water Supply and Drainage Board, has proposed a project to mitigate the expected shortage in water supply and the sanitation problems caused by increasing demands for water. This project consisted of a balancing reservoir in the upper portion of the catchment (Yatimahana) and four low flow weirs. The reservoir would store the excess flows of the river during the rainy seasons and then release the controlled amounts of the required flows during the dry weather periods.

However, the implementation of the balancing reservoir may have adverse impacts on other sectors using the water. For example, the groundwater table of the river valley could remain low for a longer period because of the regulation of water flow, hence leading to production losses in the agriculture sector.

The general practice adopted in development projects is to analyze the technical and economic feasibility of a proposal. The social and environmental impacts are usually analyzed only in the project area and mainly focused on the people affected by the project. Inasmuch as the potential social and environmental impacts were not adequately considered in the proposed Yatimahana project, conflicts in decision making among stakeholders and possible opposition to the project were anticipated.

A five-step trade-off framework for educating stakeholders in rational decision-making, called the Educated Trade-off, had been developed by Thoradeniya (2009). The ETO framework is used either for resource management or for resource development scenarios. In resource management, the framework is expected to help in decision-making as to the priority of resource use, while in resource development, it is expected to help in decision-making on whether to accept or to reject the project.

This report discusses the application of the ETO framework to the proposed development work at the Ma Oya river basin of Sri Lanka.

1.2 Research Problem

Stakeholders are usually unaware of the technical, economic, and environmental dimensions of their resource use. Hence, faced with scarce resources, they often decide on how to prioritize the uses of these resources emotionally rather than rationally.

This research therefore focused on the need for a methodology to analyse and value the conflicting resource uses of stakeholders in situations with scarce resources when decision-making is most sensitive.

1.3 Research Objectives

This case study aimed to apply and validate the ETO framework on the Ma Oya river basin project at Yatimahana so as to enable stakeholders to make informed decisions about the project's development and other resource uses.

The more specific objectives of this study were to:

1. Identify the dominant stakeholders and impacts of the proposed development project;
2. Value the major social and environmental impacts of the Ma Oya river basin project to various stakeholders of the Ma Oya river and its valley;
3. Compare the net benefits of the current scenario and the proposed development project;
4. Use this knowledge to educate different stakeholders for decision-making; and
5. Validate the ETO framework as a tool for stakeholder education in decision-making.

1.4 Scope of the Study

With the proposed development of the Ma Oya river basin into a balancing reservoir, this study evaluated, in economic terms, the social and environmental impacts between the following two scenarios:

Without balancing reservoir: This is the baseline case (i.e., the continuation of the current situation). The impacts would be the result of the projected demand for water from the water supply and sanitation sector together with the demands for irrigation, industry, and other sectors.

It is understood that the baseline case is not static. The impacts of climatic change, population growth, development of the area, and other similar factors would

impact the current situation to change with time. Even though lack of data precludes quantitative analysis, the study tried to discuss this scenario qualitatively. Stakeholders at the grassroots were consulted to establish the deficiencies and conflicts over current resource uses.

With balancing reservoir: This scenario prioritizes the proposed schedule of the balancing reservoir's operation. As the reservoir is intended to store the buffer requirement of the water supply and sanitation sectors, the reservoir operation will result in prolonged periods of low flows. Such low flows will result in water deficiencies in other user sectors creating social and environmental costs.

Time frame: The proposed project is envisaged for a span of 20 years. A feasibility study was conducted in 2004 in anticipation of project implementation in 2008. As such, the project benefits and costs are valued for a 20-year period with monetary values based on the currency value of 2004.

1.5 Dissemination of Results

Ma Oya is one of the five river basins in Sri Lanka, which has formed an 'area-water partnership' called 'Maha Oya Mithuro' under the national and global water partnership programmes. Inasmuch as research findings would be very useful to the 'area-water partnership', preliminary findings would be disseminated through this partnership. The target audience are administrative officials of the government and line ministries with stakes in the river valley areas; environmental and other social organisations; and key stakeholders in the villages along the river banks.

The findings would also be conveyed to the National Water Supply and Drainage Board (NWSDB), the project proponent, through presentations and a report to its high officials. Further, results will be presented in national conferences, and technical papers will be submitted to national and international journals.

1.6 Structure of the Report

The next chapter presents the methodologies adopted under the different steps of the ETO framework. The third chapter presents the data collection and analysis of step one of the framework. The fourth, fifth, and sixth chapters present the technical requirements, economic value, and environmental (including social) valuation of the resource uses, respectively; these are the second, third, and fourth steps of the ETO framework. The seventh chapter, which estimated the combined economic value of a resource use, is the fifth step of the ETO framework. The eighth chapter presents the stakeholders' education and validation of the framework. The conclusion is presented in chapter 9.

2.0 BASIN ISSUES AND THE 'EDUCATED TRADE-OFF' FRAMEWORK

2.1 General

This chapter presents the uses and issues of the Ma Oya river basin, the five steps of the ETO framework, and various research methods adopted to achieve the objectives of these five steps.

2.2 Issues of the Ma Oya River Basin

Ma Oya is one of the most water-stressed rivers in the wet zone of Sri Lanka. Excessive sand mining has threatened the river's bathymetry as well as the downstream ecology. It is also beset with reduced water level, lower groundwater table in the associated catchment, and less dry weather flows.

Uncoordinated and uncontrolled use by multiple stakeholders was expected to diminish faster the river's valuable resources within next few decades. Hence, to mitigate expected shortages in the water supply and sanitation sectors because of increasing demands, the National Water Supply and Drainage Board has proposed a development project. This project consisted of a multi-purpose balancing reservoir at Yatimahana (in the upper portion of the catchment) and four low flow weirs. The reservoir would store excess river flows during rainy seasons and then release the required flows, under control, during the dry weather periods.

However, the implementation of the balancing reservoir may have adverse impacts on other sectors using water in the Ma Oya river valley. For example, because of regulated water flows, the groundwater table of the river valley could remain low for a longer period, leading to production losses in the agriculture sector. Because of increased concentrations of pollutants in the river, water quality would deteriorate. Hence, the growth of industries, which require water as a raw material for production or which disperse pollutants in a river, would be limited.

2.3 'Educated Trade-off' Framework

2.3.1 Step 1 - Identify the multiple stakeholders and the natural resource uses/ issues that need stakeholder participation for decision-making.

Stakeholders must be involved in decision-making for any social and environmental changes during the development and management of a river basin. In the development phase, decisions must be made to ensure that the new project/s would not adversely affect any of the stakeholders enjoying the benefits of the natural resources before the project's implementation. In the management phase, decisions are needed to prioritize resource allocation when a natural resource becomes scarce, such as low flows during the dry months.

As for the resource uses of a river or river valley, issues and stakeholders showed a significant variation spatially and temporally. The grassroots stakeholders (bottom level) directly experienced the impacts of any resource development project. Hence, consultations with this group would yield reliable information on the ground. However, no literature was found on the identification of stakeholders or on the impacts of their involvement in the river basin.

Therefore, a stakeholder involvement process was designed and carried out to collect data for a situation analysis (baseline situation) of the riverine villages through which multiple stakeholders and resource uses/issues could be identified. The stakeholder involvement level was low (i.e., 'consultation' as opposed to 'participation').

A six-step approach (See Box 1) was designed to obtain data from the grassroots stakeholders on their resource uses and the social and environmental impacts of such

resource uses on them and on others. Each step of the approach was designed to achieve a specific objective towards meeting the general objective of the study.

Box 1: Six-step approach for consulting stakeholder sample

Step 1 - Desktop study I

Step 2 - Reconnaissance survey and visit to Divisional Secretary (DS)

Step 3 - Desktop study II

Step 4 - Educate GN (Purpose and requirements) and communicate: letter and telephone

Step 5 – GN chooses the sample

Step 6 - Visit GN divisions and administer the questionnaire

In step 1, the appropriate administrative divisions were decided on using land survey maps. The desktop study was useful in making the decision on the actual study area (depending on the resource limitations) and on identifying the road network in order to prepare for the reconnaissance survey. The Divisional Secretariat (DS) division was identified as the administrative unit that could initiate the field studies (i.e., rapid assessment of resource uses).

The objective of step 2 (Reconnaissance survey and visit to DS) was threefold: first, to obtain data, such as maps showing the bottom level government administrative divisions (Grama Niladhari Divisions – GND), stream network etc. that were required for planning the stakeholder meetings; second, to create an awareness about the research and to inform the concerned bottom-level government officials (Grama Niladharis–GN) about the study; and third, to obtain necessary support for the study from government administration units.

Step 3 identified the bottom-level administrative divisions along both banks of the river using the data collected during the reconnaissance survey.

At step 4, the GN's of the selected GNDs were educated on the research's background, objectives, and expected results using letters followed up by telephone calls.

The GN's were entrusted to select the appropriate sample at step 5. Each GND was visited to administer the questionnaire survey under step 6.

2.3.2 Step 2 - Bound technical requirements of natural resource uses/issues.

In step 2 of the ETO framework, knowledge on engineering was used to estimate the critical bounds of the technical requirements for different resource uses. Issues dominated by water such as the requirements for irrigation, human consumption, and environmental would have the volume of required water as the technical measure with the **minimum volume to satisfy the requirements** as the critical bound. Other river basin uses such as sand mining, clay mining, and discharging of pollutants would have the volume of clay or sand extracted and volume of pollutant discharged as the technical

measure with the **maximum volume not to exceed assimilative capacity of the river basin** as the critical bound.

2.3.3 Step 3 - Estimate the economic value of the critical bound of the technical requirement of natural resource uses/ issues.

Step 3 required the estimation of the economic value of a resource use in a given scenario. The starting point of an economic analysis of a resource use is the financial analysis of that resource use. The financial analysis measures the receipts (benefits) and payments (costs) relevant to the investors or owners of the resource/project.

An economic analysis is similar to a financial analysis, except that it measures the benefits and costs from an economic point of view. Instead of relying solely on cash flow techniques as done for financial analysis, economic valuation requires the use of economic techniques of measurement. The merit of a resource use is then assessed in terms of its impact on the efficiency of the economy as a whole (Jenkins and Harberger, 1992).

The economic net present value (EcoNPV) of a resource use can be expressed as;

$$EcoNPV = \sum_{i=0}^n \frac{B_i - C_i}{(1+r)^i}$$

where B_i is the annual economic benefits from the use of resource at the i^{th} year, and C_i is the economic cost of the resource use at the i^{th} year. 'n' is the duration of the study period and 'r' is the discount rate.

2.3.4 Step 4 - Estimate the environmental value of the critical bound of the technical requirement of natural resource uses/ issues.

Implementation of a new project or prioritization of a resource allocation could cause imbalance in the existing system and create social and environmental impacts on other users. Valuations of such impacts as environmental and social costs (or benefits) were carried out in step 4. It must be noted that net environmental costs referred to here were those which were either 'not quantified' or 'underestimated' in the economic analysis as part of normal engineering practice.

All of the environmental benefits and costs of impacts valued in constant value terms became line items in the economic analysis. The net present value of the environmental costs (EnvioPV) can then be obtained as;

$$EnvioPV = \sum_{i=0}^n \frac{E_i}{(1+r)^i}$$

where E_i is the net environmental costs of the resource uses in the i^{th} year, 'n' is the duration of the study period, and 'r' is the discount rate.

As suggested by Ranasinghe (1994), the present value of environmental costs of the next best alternative (i.e., externalities of the alternative that is not adopted) is considered to be environmental benefits of the preferred alternative because of the avoided environmental costs. The present value of the *EnvioPV* is construed to be a cost as recommended by Pearce and Warford (1993), but in a number of cases, *EnvioPV* may

well be a benefit. Primary and secondary valuation methods are used to evaluate the environmental impacts.

2.3.5 Step 5 - Estimate the net value of the critical bound of the technical requirement of natural resource uses/issues by combining the economic and environmental values.

The net value of the critical bounds would be in terms of economic values. Again, for issues dominated by water such as requirements for irrigation, human consumption, and environmental needs, the economic value to satisfy the minimum water requirements would be the critical bound. For issues dominated by other river basin uses such as sand mining, clay mining, and discharging of pollution, the maximum economic value of damage to exceed assimilative capacity of the river basin (or the replacement value) would be the critical bound.

The combined value of the technical bound thus can be estimated as;

$$CombNPV = \sum_{i=0}^n \frac{B_i - C_i}{(1+r)^i} - \sum_{i=0}^n \frac{E_i}{(1+r)^i}$$

Knowing the combined economic value at the critical bound of the technical requirements would help stakeholders make decisions on which issues/uses to prioritize in a year that has less water. For example, in a river basin, minimum requirements for water supply would be top priority, followed by the minimum requirement for power generation and balance for irrigation in a dry year. The farmers can now be compensated for the loss of livelihood because the minimum requirements had not been met. In a good year when there is surplus water, irrigation could be given as much as it could absorb and even to recharge the aquifer (Seckler, 1996).

3.0 STAKEHOLDERS AND RESOURCE USES

3.1 General

This chapter describes the identification of multiple stakeholders and their natural resource uses as required in step 1 of the ETO framework.

3.2 Stakeholder Involvement Approach and Data Collection

The six-step approach described in Box 1, Section 2.4 was used for stakeholder involvement to achieve the objective of step 1 in the framework. The sample chosen by the GNs in the fifth step consisted of one to five persons from each GND representing all resource use sectors. The final sample of 427 stakeholders represented 145 GNDs under 16 District Secretariats Divisions (DSDs) on both banks of the river. The distribution of the stakeholder samples among the DSDs and according to gender is given in Table 1.

Table 1. Gender-wise distribution of stakeholders among the DSDs

DSD	Male	Female	Total	DSD	Male	Female	Total
Negombo	7	2	9	Dankotuwa	24	3	26
Katana	17	1	18	Pannala	38	4	42
Divulapitiya	57	7	64	Narammala	8	0	8
Meerigama	25	1	26	Alawwa	36	7	42
Warakapola	20	3	23	Polgahawela	17	2	19
Galigamuwa	4	1	5	Rambukkana	24	5	29
Kegalla	2	1	3	Mawanella	18	5	22
Wennappuwa	12	5	17	Aranayake	58	13	72
Total	144	21	165	Total	223	39	262

Note:

(1) Total distribution of the 427 sample: male – 362, female – 62

The development of the survey tool (a questionnaire) was based on the flow chart given in Appendix 1.

3.3 Data Analysis (Identification of resource uses, multiple stakeholders and their views)

3.3.1 Resource use sectors

The collected data were used to identify resource use sectors at each GND. Even minor uses that could be important for future decision-making were included, hence the resource uses identified by even a single respondent were considered. The resource use sectors identified in the 16 DSDs are given in Table 2.

Table 2. Number of respondents identified for each resource use sector at each DSD

DSD	Total	Resource Use Sectors														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Negombo	09	0	6	0	0	0	3	2	3	0	5	2	0	4	5	6
Katana	18	0	8	1	0	0	5	1	0	0	0	0	0	3	8	9
Divulapitiya	64	1	35	5	1	0	22	15	0	0	4	2	5	39	54	18
Meerigama	26	1	17	0	4	0	7	2	0	0	6	4	6	17	20	7
Warakapola	23	0	16	3	4	0	10	1	5	0	4	5	5	13	14	3
Galigamuwa	05	1	4	0	0	0	2	2	1	0	0	0	3	4	3	0
Kegalla	03	0	2	1	0	0	1	0	0	0	0	0	1	3	3	0
Wennappuwa	17	0	7	0	0	0	1	0	2	0	1	2	0	4	8	8
Dankotuwa	27	0	5	1	1	0	4	3	0	0	0	0	1	3	8	18
Pannala	42	0	17	3	2	0	17	14	1	1	8	2	6	26	35	5
Narammala	08	0	5	2	1	0	1	0	1	0	2	1	2	5	6	0
Alawwa	42	4	29	2	0	0	14	3	6	1	10	6	14	28	39	7
Polgahawela	19	0	12	1	0	0	6	4	1	0	1	2	1	16	18	2
Rambukkana	29	1	24	1	1	0	13	4	3	2	6	3	9	22	27	3
Mawanella	23	5	21	5	3	0	9	0	5	2	6	4	7	15	17	6
Aranayaka	72	10	61	8	1	1	21	2	10	0	5	3	14	42	33	20

Note: The resource use sectors denoted by 1 -15

- | | | |
|----------------------------|--------------------------|------------------------|
| 1. Drinking water (direct) | 2. Bathing /washing | 3. Water supply source |
| 4. Industrial use | 5. Hydropower generation | 6. Sand mining |
| 7. Clay mining | 8. Dumping garbage/waste | 9. Tourism industry |
| 10. Inland fishery | 11.Recreation | 12. Animal rearing |
| 13. Land owners/ farmers | 14. Dug-well users | 15. Environment sector |

3.3.2 Present situation of resource use sectors

Resource uses vary along a river. Hence, the user sectors which were already threatened by other use sectors or were in a conflict situation with other uses had to be identified at each GN division. The respondents were requested to indicate whether their resource uses have faced any conflict or whether they expected such a situation in the future. The percentages of responses received at each DS division are given in Figure 1 (for the present situation) and Figure 2 (for the future) on a three-point scale (Yes/ No/ No idea). On the average, 89% of the respondents accepted that their resource uses have faced conflict situations at present and 91% expected a similar situation in the future.

3.3.3 Stakeholders' views on reasons for conflicts/threats

Of the respondents who acknowledged present and future threats to their resource use, majority (94%) of the respondents were aware of the reasons for such threats. Based on the same three-point sale, 91% of the respondents accepted that they faced conflict/ threat because of the resource uses by other sectors.

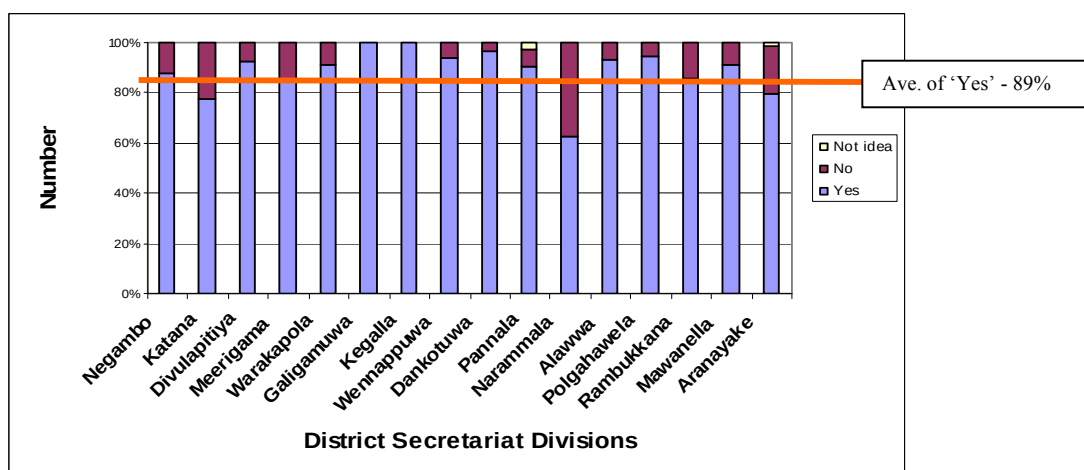


Figure 1. Percentage responses on threats to resource uses at present

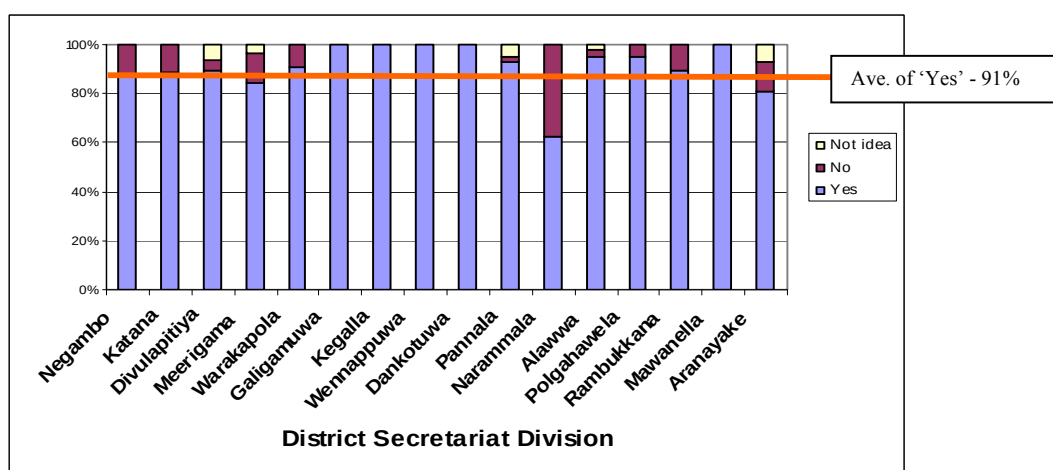


Figure 2. Percentage responses on expected threats to resource uses in the future

3.3.4 Social and environmental impacts

When asked whether there were any negative social/ environmental impacts from their own resource use and use by others, only 11% (on average) were aware or accepted that their uses resulted to negative social and environment impacts (Figure 3). Almost all (86%) attributed the negative social and environment impacts to the resource uses by others (Figure 4).

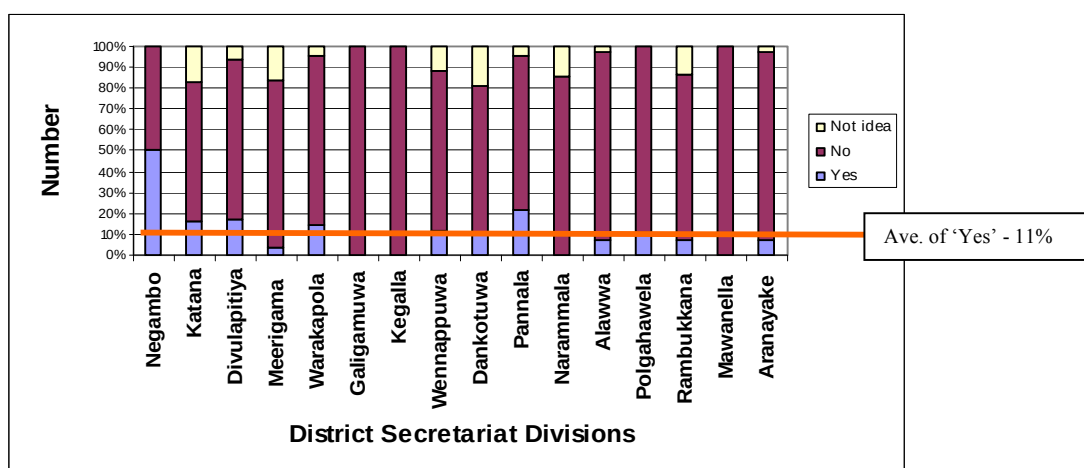


Figure 3. Percentage responses on environmental impacts from own uses

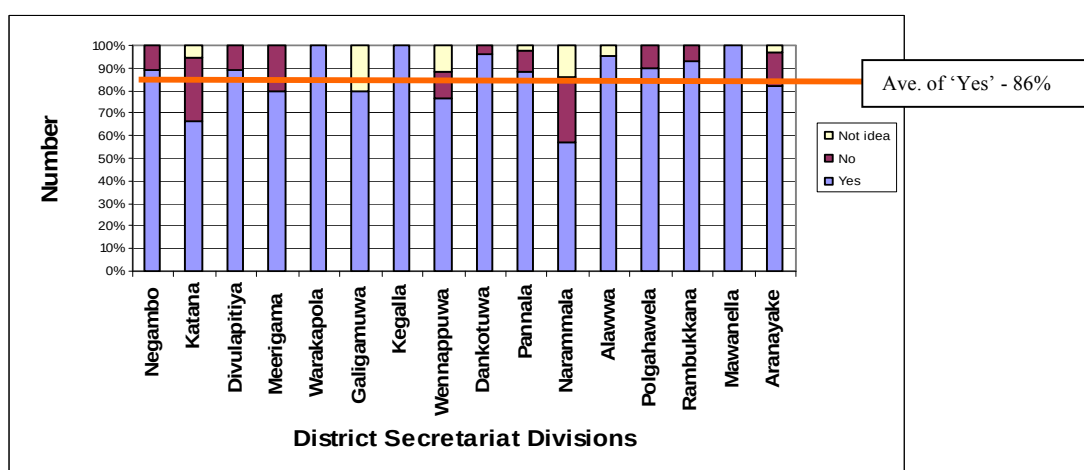


Figure 4. Percentage responses on environmental impacts from others' uses

The respondents identified the sectors whose resource use resulted to negative social and environmental impacts. These were the sand industry (259 respondents), the waste disposal sector (72 respondents), and the clay industry (51 respondents) (Table 3).

The stakeholders identified major issues pertaining to different resource use sectors (Table 4) and expressed their views on the reasons for the negative social and environmental impacts of such uses as well as possible remedial measures (Table 5). Moreover, they identified the stakeholders of riverine resource uses. Some of them were identified as vulnerable stakeholders (Appendix 2). Contributions made by the stakeholder sample towards the protection of the river and the environment are listed in Appendix 3.

Table 3. Resource uses impacting other sectors as identified by the respondents

DSD	Total	Resource Use Sectors														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Negambo	09	-	-	-	-	-	02	-	05	01	-	-	-	01	-	-
Katana	18	-	-	-	01	-	10	03	01	-	-	-	-	-	-	-
Divulapitiya	64	01	-	-	01	-	42	17	09	-	-	-	-	-	-	-
Meerigama	26	-	-	-	-	-	16	02	-	-	-	-	-	-	-	-
Warakapola	23	-	-	-	-	-	14	-	04	-	-	-	-	-	-	-
Galigamuwa	05	-	-	-	01	-	04	01	01	-	-	-	-	-	-	-
Kegalla	03	-	-	-	-	-	01	-	-	-	-	-	-	-	-	-
Wennappuwa	17	01	-	01	-	-	06	01	08	-	-	-	-	-	-	-
Dankotuwa	27	01	-	-	-	-	19	14	04	-	-	-	-	-	-	-
Pannala	42	-	-	-	01	-	25	12	04	-	-	-	-	-	-	-
Narammala	08	-	-	-	01	-	03	01	02	-	-	-	-	-	-	-
Alawwa	42	-	-	-	-	-	25	-	02	-	-	-	-	-	-	-
Polgahawela	19	01	-	-	-	-	14	-	-	01	-	-	-	-	-	-
Rambukkana	29	-	-	-	-	-	21	-	2	01	-	01	01	-	-	-
Mawanella	23	-	-	01	-	-	17	-	10	-	-	-	-	-	-	-
Aranayaka	72	01	01	04	-	03	40	-	20	-	01	-	05	-	-	-
Total	427	05	01	06	05	03	259	51	72	03	01	01	06	-	-	-

Note: The resource user sectors are denoted by 1 -15

- | | | |
|----------------------------|--------------------------|------------------------|
| 1. Drinking water (direct) | 2. Bathing /washing | 3. Water supply source |
| 4. Industrial use | 5. Hydropower generation | 6. Sand mining |
| 7. Clay mining | 8. Dumping garbage/waste | 9. Tourism industry |
| 10. Inland fishery | 11.Recreation | 12. Animal rearing |
| 13. Land owners/ farmers | 14. Dug-well users | 15. Environment sector |

Table 4. Issues in resource uses by stakeholders

User Sector	Main Issues	Frequency
Sand mining	Drowning risks because of slippery and deep river bottom, poor accessibility for bathing	224
	Erosion of banks, hence uprooting bamboo and other trees, resulting to the collapse of roads and railways on banks	244
	Dried up dug wells, reduced water levels, salty well water	241
	Loss of crop production	167
	Adverse environment impacts, rising temperature, air pollution, dryness etc.	16
	Distancing of families in the two river banks	10
Clay mining	Damages to village roads by transport of sand etc.	36
	Drug addiction/ theft by mining labourers	11
	Loss of habitable land	12
	Risk of diseases, poor health because of dust while transporting, non-filling of clay pits	61
Waste disposal	Fish kills	12
	Health hazards (bad smell etc.), stagnant pools	64
	Unsuitable water for drinking, bathing / washing	73

Table 5. Respondents' views on the development/restoration of the river's environment

Sector/Issues	View	Frequency
Washing/ Bathing	Construction/ rehabilitation of river access points	79
Waste disposal	Banning of waste dumping into the river	29
	Education of the people	13
Sand mining	Limiting depths of mining/ stopping of sand mining, need for proper management	143
	Effective and fair intervention of government officials	113
Land erosion bank slides	Construction of rock embankments; protection of banks	104
	Construction of bunds across the river	71
Environment	Long-term river protection, programming, education of people, specially of politicians	23
	Protection of natural swamps and depressions	24
	Re-introduction of river reservations	57

3.4 Discussion

'Bathing/washing' and 'sand mining' were the two direct uses of river resources indicated in all the DSD divisions (Table 2). In spatial distribution, hydropower was the least used sector. The two most prominent indirect uses were dug-wells for domestic water supply and groundwater for agriculture.

Majority (89%) of the respondents from all the DSD's agreed that their resource uses were threatened or in a conflict situation at the time of the study (Figure 1) and most of them (91%) did not expect the situation to be reversed in the near future. In fact, they thought that the situation would deteriorate under the assumption that there would be no change in the river system (Scenario 1) (Figure 2).

The following resource use sectors were identified as facing conflict situations with the number of GNDs indicated in the parentheses:

Dug-well users (111)	Land owners/ farmers (100)	Bathing /washing (87)
Environment sector (49)	Sand mining (24)	Water supply (14)
Clay mining (13)	Animal rearing (11)	Drinking water (direct)(06)
Inland fishery (04)	Recreation (03)	Dumping garbage / waste (2)

Almost all (94 %) of the respondents from each DSD said that they knew the reasons for these conflict/ threatening situations. Most of them (91%) attributed these conflicts to overexploitation by other users. Majority (86%) from each DSD likewise viewed the resource uses by other sectors as causing negative and social impacts, but interestingly, only 11% accepted that their own resource uses led to such negative impacts (Figure 3).

Identified as the sectors that often caused negative social and environmental impacts were the sand industry (61%), followed by the waste disposal sector (17 %), and the clay

industry (12 %) (Table 3). The negative effect of extensive mining for the sand industry was intensive during the dry weather low flow periods.

The above analysis of the present resource use sectors and stakeholders helped to identify the sectors that would be significantly impacted by the proposed reservoir. In normal situations (an average year), this river experiences 6-8 weeks of low flow condition (DHI, 1999). The proposed reservoir could result in longer low flow periods, depleting groundwater and increasing impacts on the indirect resource use sectors; i.e., dug-well (domestic water supply) and rainfed agriculture (agriculture depending on rain and high groundwater table for their crop water needs, without any irrigation facilities) sectors.

Other sectors that would be impacted by the proposed reservoir was the recreation sector because of the 'Bo-ella' waterfall's inundation; the industries; and the tourism sector because of the changes in water availability of the river at the 'Pinnawala Elephant Orphanage'.

These five impact sectors, which were not included in the project's extended economic analysis (Sweco Grøner, 2004), were considered in applying the ETO framework for the case study under step 4.

4.0 TECHNICAL REQUIREMENT OF RESOURCE USES

4.1 General

The major quantities which differentiated the two scenarios 'with' and 'without' reservoir project were the river water flow and the water level. A time-series of daily water flows for a 20-year period (from 2008 to 2027) at the proposed location of the reservoir was already established by the project proponents. A time-series of water flow for scenario 2 was therefore established by performing a reservoir operation.

The criteria considered for reservoir operation were the following:

- a) water supply requirement was given priority over power generation;
- b) the minimum required flow for power generation was 4 m³/s;
- c) the minimum operating level of the reservoir was 150 m above MSL;
- d) the inflow received beyond Full Supply Level (183 m above MSL) was immediately released;
- e) the established flows for upstream uses was deducted from the daily expected flow series; and
- f) daily evaporation losses of the reservoir was considered.

The basic equation for outflow calculation was as follows:

$$\text{Outflow} = \text{Daily flow} - \text{Upstream extraction} - \text{Reservoir capacity} + \text{Storage} - \text{Reservoir evaporation}$$

4.2 Critical Bounds of the Technical Requirement of Direct Uses in the Project

The main objective of scenario 2 was to meet the projected drinking water deficit. Designed as a multi-purposes reservoir, the project was expected also to generate

hydropower, supply water for three irrigation schemes, and provide forecasted demand deficits of the industrial sector. The river water flow for scenario 2 was modeled using the reservoir operation equation given in section 4.1. Accordingly, the number of days in a period of 20 years (7304 days) were analysed for the expected variation in water flow. The results are given in Table 6.

Table 6. Number of days with possible flow variations

Variation in flow (m ³ /s)	Days	Percentage	Variation in flow (m ³ /s)	Days	Percentage
> -2	903	12.1	4 – 5	8	0.5
-2 -1	1101	15.0	5 – 6	5	
-1 0	808	11.0	6 – 7	4	
0 - 0.125	3991	55.0	7 – 8	6	
0.125 – 1	341	4.6	8 – 9	1	
1 – 2	99	1.4	9 – 10	3	
2 – 3	14	0.2	10 – 11	3	
3 – 4	13	0.2	> 11	4	
			Total	7304	100.0

Project proponents have selected water supply, hydropower, industries and irrigation as the sectors with significant importance for this river system. Since this case study applies the ETO framework to the development of a new project against the management of an existing project, the critical bounds of the technical requirements for the water supply, hydropower, industries, irrigation and environment sectors were assumed to be those set by the project proponents (Sweco Grøner, 2004).

The survey carried out at the first step of the ETO framework application was used to verify the resource requirements given by the project report (Sweco Grøner, 2004) for the above user sectors. The sectors whose resource requirements were not included and/or not quantified in the project report are discussed below:

- **Ecological sector:** A previous study, Western Basins Sector Project TA 3030 –SRI (DHI, 1999), had estimated the requirement for preserving the ecology as 3 m³/s flow. The figure was considered over estimated by the project proponents because of the seawater barrier now in place at the estuary. However this study considered an environmental flow of 3 m³/s.
- **Pollution control/water quality:** A major use of the river is for waste disposal from cities, private dwellings, hospitals, and industries. There are both point and non-point waste disposal sources along the river. Surveys made on waste disposal showed that most of the wastewater treatment plants did not function properly, and the wastewater discharged into the river was not tested. However, the samples of water tested at water supply intakes occasionally satisfied the standards for drinking water with conventional treatments. During the lean period, the ‘with’ project scenario would improve the river flows until the reservoir storage would be released; thereafter, the ‘without’ project situation would prevail. As such there were no adverse impacts to this sector because of the proposed project.

- **Biodiversity:** Both river banks in the downstream reach of the proposed reservoir were either densely populated or used for rainfed agriculture. As such, the biodiversity sector was not significant in the segment being considered in this river.
- **Fishery production:** There was no inland fisheries industry at a commercial scale anywhere along the river.

5.0 ECONOMIC VALUE OF NATURAL RESOURCE USES

5.1 General

The case study considered two scenarios: a) ‘without balancing reservoir,’ i.e., the baseline case, and b) ‘with balancing reservoir,’ i.e., the proposed reservoir development project. The major change anticipated in the first scenario was the shortage of drinking water because of population growth; lowered groundwater table along the river as a result of continued sand mining; and climate change aggravating the situation. This demand for water was adequately estimated and considered as a benefit in the second scenario. This section presents the economic analysis carried out for the incremental costs and benefits between the two scenarios.

5.2 Economic Analysis for the Incremental Benefits and Costs of the Project

In the third step of the developed ETO framework, the economic values (benefits, costs, NPV, etc.) for the proposed project were estimated. These values were based on the financial benefits of the project because of increased water supply and the generation of power. Table 7 gives the expected annual income from increased water supply (technical measure) and power generation.

The annual income for water supply was based on the assumptions by the project proponents that 80% of the water was being sold for domestic purposes with a tariff of Rs. 2.90 per m³ and the balance of 20% was being sold for commercial purposes at a tariff of Rs. 42.00 per m³. Constant tariffs were applied throughout the project period, which was a key difference between the present analysis and the feasibility study. In the latter, annual tariff increases ranging from 10% to 20% have been used for both water supply and electricity sales. Financial values were converted to economic values using conversion factors suggested for Sri Lanka by Curry and Lucking (1992).

Apart from the incomes derived from the water supply and hydropower sectors, economic benefits were considered from a one-time increase of land value of Rs.120,000,000 and annual incomes of Rs. 100,000,000 from the irrigation sector and Rs. 130,000,000 from the industry sector keeping in line with the project proposal.

The income through increased land value was expected to benefit the landowners in the 12 areas which would be supplied with additional water. This project would not only increase the number of hours for water supply but also provide water to new connections. Provision of water, which is a basic need, was expected to bring in more people to these areas and create a higher demand for the land, thereby increasing land value (Sweco Grøner, 2004). However, this could be considered as double counting of benefits because the benefit

of additional water supplies (increased land value) was already considered. Therefore, an additional analysis was performed to study the impact from land value increases

Table 7. Expected annual income from water supply and power generation

Year	Water units (1000 m ³ /yr)	Total water sales (Rs. 1000)	Electricity qty –KWH		Total electricity sales (Rs. 1000)
			Lean*	Wet*	
2008	0	0	10,370	30,390	230,493
2009	377	4,041	3,020	17,510	114,277
2010	2,676	28,687	4,930	12,900	101,152
2011	3,935	42,183	3,940	22,440	146,890
2012	196	2,101	6,880	27,390	192,276
2013	4,040	43,309	3,790	14,710	103,859
2014	6,887	73,829	2,580	10,840	75,200
2015	2,126	22,791	5,180	21,520	149,655
2016	1,640	17,581	1,950	23,740	141,491
2017	1,682	18,031	3,690	22,400	145,104
2018	345	3,698	7,300	21,690	163,873
2019	0	0	9,150	31,370	228,180
2020	145	1,554	7,470	27,530	196,738
2021	49	525	4,270	29,450	187,128
2022	294	3,152	5,660	27,000	182,503
2023	1,252	13,421	4,680	10,870	88,531
2024	3,504	37,563	100	3,940	22,080
2025	2,048	21,955	4,160	13,270	98,338
2026	1,473	15,791	5,410	18,480	134,544
2027	1,434	15,372	3,350	10,960	80,682

Source: Sweco Grøner, 2004

Note: Lean – period of dry weather from February to April. and wet – Period from May to January

The irrigation benefits were accounted only from the three irrigation schemes, which were abandoned at the time of the study. However, their rehabilitation would incur considerable costs for irrigation infrastructure including major headwork constructions. Therefore, the conservative approach would be to neglect the benefits accruing from irrigation sector in the economic analysis.

The project construction cost Rs. 1,352,007,000 and Rs. 2,028,010,000 distributed during the first two years, respectively, with a one-time project rehabilitation cost of Rs. 33,000,000 considered in the 10th year. An annual fixed operation and maintenance cost of Rs. 9,400,000 was assumed for the 20-year period of project operation. Sweco Grøner (2004) stated that the residual values of assets have been considered, and these had an economic life beyond the analysis period, even though their values become almost negligible because of discounting practices.

Minimum Acceptable Rate of Return (MARR) considered acceptable for water supply projects was 10% (Table 8). This would reflect the opportunity cost of capital. The analyses of the original project benefits and costs given in Tables 8 yielded an EIRR of 8.28%. In this analysis, annual costs were considered at the beginning of a year, while the annual benefits were considered at the end of a year.

Table 8. Economic analysis with original project costs and benefits

i %	PV (cost)	PV (Benefit)	NPV	B/C	Remarks
10	3,279,971	2,867,344	-412,627	0.87	MARR
8.29	3,322,000	3,322,000	zero	1.00	EIRR

Note: All values in Rs. 1000

Three additional cases (case 2, 3, and 4) analysed for different scenarios yielded EIRR values of 7.95%, 4.95%, and 7.29%, respectively.

Case 2: Calculations performed to study the impact of the benefit by land value increase showed that the removal of these benefits reduced EIRR by 0.34% from 8.29% to 7.95%.

Case 3: The three irrigation projects considered for analysis have been abandoned for a long time. It is doubtful if these can be reactivated considering the socio-political situation in the area. Some of the lands cultivated under these irrigation systems have been reallocated for housing purposes. Farmers have abandoned these lift irrigation systems mainly because they could not afford the cost of electricity for water pumping. The river bed at these locations during the study was deeper by an average of about 5-6 meters. Therefore, even if the irrigation projects would be re-established, the benefits from harvest would be offset against the project costs of building irrigation headworks. Hence, the conservative approach was to neglect the benefits accruing from the irrigation sector, and the EIRR decreased to 4.95%.

Case 4: The project life of civil structures such as dams is usually 50 years. The cost incurred by such massive structures cannot usually be compensated during a relatively short period of 20 years. Therefore, case 3 was extended to a 40-year project life and analysed considering the refurbishing costs for electrical and mechanical components at 10-year intervals. The residual value of assets, which had an economic life beyond the analysis period (40 years), were neglected because of discounting practices. The EIRR was improved to 7.29% even without the irrigation benefits.

5.3 Discussion

In this analysis, constant tariffs were used for computations based on the values used for the starting year by the project feasibility report. This situation yielded an EIRR value of 8.29% and the NPV of the project at the MARR (10%) was a loss of Rs. 412.6 million.

In contrast, the project feasibility report used an annual increase in the tariff for both water supply and hydropower generation. The tariff based on the experiences of the past tariff increment pattern together with both the costs and benefits at the end of a year

resulted in a very high EIRR value of 15.2% (Sweco Grøner, 2004). This was an optimistic assumption whereas the present computations were based on more realistic assumptions.

Three additional cases were analyzed for the following reasons:

a) The land value increase considered in the project report double counted the benefits from increased water supply. Removal of the land value benefits lowered the EIRR by 0.34%, from 8.29% to 7.95%

b) All the three irrigation projects considered for revenue generation have been abandoned. Removal of irrigation benefits resulted in a very low EIRR of 4.95%.

c) The project life time was increased to 40 years as 20 years considered in the analysis (Sweco Grøner, 2004) was inadequate to realize the full benefits of a concrete structure like a reservoir dam, which has a lifespan over 50 years. This increased the EIRR value to 7.29%.

6.0 SOCIAL AND ENVIRONMENTAL IMPACT VALUATIONS

6.1 General

The fourth step of the ETO framework required the valuation of social and environmental impacts because of changes in resource uses. Such impacts expected for both scenarios depended on the changes of river 'water flow' and 'water levels' during the project's lifespan.

Under scenario 1, the changes of river water flow directly depended on the rainfall pattern; proposed upstream diversions both 'to' and 'from' the river; and catchment development work. Available literature did not show any concrete proposals for catchment development or river diversions to be implemented during the project life. There were no studies to predict rainfall changes either. Therefore, it was assumed that the water flow in the river would not be significantly impacted during the project period under scenario 1.

The river water levels were already being impacted from sand mining industry, and this had caused some social and environmental issues as discussed in chapter 3. Since the river had been mined to the bedrock during the last 15 years, further mining of annual sand deposits would not significantly change the water level. Therefore, no significant social and environmental impacts were assumed under scenario 1 (without project), as both 'water flow' and 'water level' could not be expected to undergo significant changes within the project life.

The major technical changes expected in river water flow and river water level under scenario 2 (with project) could be modeled by prolonged dry weather periods. The major impacts because of these changes for resource uses were identified during the data analysis of step 1 in the ETO framework. The direct resource use sectors that could be impacted were the recreation, tourism, and industries sectors, while the indirect resource use sectors included rainfed agriculture and dug-wells.

The indirect use sectors depended on groundwater levels whereas the direct users depended on river flow (discharge) or volume. The groundwater level in most of the river bank areas depended on the river water level. Significant changes expected with the

implementation of the reservoir were reduced flood (high water level) situations and prolonged periods of low water flows. These would result in low groundwater levels for longer periods. As a result, both indirect water use sectors, rainfed agriculture, and dug-wells could face scarce resource situations.

Major social and environmental impacts considered for the analysis were the following use sectors: recreation, tourism, industry use, dug-well, and rainfed agriculture.

6.2 Recreation Sector

A major recreation site of the local people is a waterfall (Bo-ella) located just upstream of the proposed dam. This waterfall is an open recreational site that is popular with the local population. Most visit the site on the independence day of Sri Lanka, 4th of February, as a tradition. The waterfall at the proposed dam site was expected to inundate with the filling of the reservoir, and the recreation site was expected to be lost.

To estimate the value of this recreational site, visitors were surveyed on 4 February 2009 to collect data required for the travel cost method (TCM).

The sample: The total sample consisted of 70 people who were visiting the site for recreation. Data such as their age, annual income, and mode of transport were collected. The gender ratio was 57 males to 13 females. Their annual income ranged from zero up to Rs 600,000. The visitors had used seven modes of transport; some of them had used more than one mode of transport. Majority (73%) used their own vehicles while 26% hired vehicles.

Three methods were tried to estimate the site's value: two variations of the travel cost models and a simple approximation.

a) Zonal travel cost model: Six zones were identified depending on the distance from the site. The number of visitors from each zone, the average travel cost per person, and the average number of visits per person are given in Table 9.

Table 9. Basic data for the zonal travel cost model

Zone	Distance (km)	Number of visitors	Average travel cost (TC) (Rs.)	Average number of visits per year
1	0 – 5	22	176	2.30
2	6 – 10	18	133	1.83
3	11 – 20	09	199	1.77
4	21 – 30	06	189	1.66
5	31 – 50	13	309	2.07
6	> 50	02	324	1.00

The above data does not yield an inverse demand curve for the trips to the site as visitation rate is only 1 – 2 across zones. Hence the data did not support the use of the zonal travel cost model for the valuation of this site.

b) Individual travel cost model: A statistical analysis was made to identify the factors influencing the number of visits. Seven factors were considered: a) gender, b) age, c) work category, d) distance traveled, e) monthly income, f) total travel cost, and g) other expenses incurred at the site. None of the above factors showed any significant influence on the number of trips made by the individuals.

Both methods (a and b) failed in application because of the special feature of this site - it was visited mainly by the local people during Sri Lanka's independence day as a tradition. About 44% of respondents had a single visit but the average was pulled up by two individuals who made 6 - 7 visits.

c) Simple approximation: As the site's special nature did not make it amenable to the standard function of the TCM for estimating its value, a simple approximation was made using the average value of total expenditure incurred by the visitors and the number of visitations per year.

i.e., The value of the site = average number of visits per annum x (total travel cost + total time value + and other expenses incurred at the site).

The total travel cost for the sample of 70 visitors varied from a minimum of Rs 0.00 to a maximum of Rs. 300.00, and the average total travel cost was Rs. 64.20. The other costs incurred during the visit varied from a minimum of Rs. 0.00 to a maximum of Rs. 3000.00 with an average of Rs. 161.70. The visitors spent an average of 7 hours at the site, valued between Rs. 0.00 and Rs. 3022.00 with an average of Rs. 279.40.

The average number of visits to the site was estimated by collecting data from a sample of 20 visitors. The estimates had a large variation – from a minimum of 950 to a maximum of 7420. The mean value of 2380 people was used for the final estimation.

$$\begin{aligned}\text{Therefore, the value of Bo-ella waterfall} &= \text{Rs. } 2380 \times (64.20 + 279.40 + 161.70) \\ &= \text{Rs. } 1.2 \text{ million per annum}\end{aligned}$$

The above value was a lower estimate of the waterfall as it did not provide for the existence value which accrues to citizens who do not visit the site as indicated by Zone A of Figure 5.

6.3 Tourism Sector

This river flows through a prominent tourism location in Sri Lanka called Pinnawala, where an elephant orphanage is found. Housed along the river banks, Pinnawala was initially conceived to provide shelter for baby elephants orphaned in the wild. The captive breeding programme by wildlife authorities resulted to more than 75 elephants at the orphanage, hence they could be naturally herded. This world-famous tourist attraction depends on the Ma Oya river for the water needed by the elephants to cool their body system. The herd uses the river two times a day. The surrounding area is likewise being developed for tourism.

Variation of river water flows resulted to two types of negative impacts. First, the very low flows could result to insufficient water for elephant bathing. Prolonged lack of water would lead to the need for another water supply or the orphanage would be closed.

This loss could be estimated using the ‘alternative project’ or the ‘travel cost method’ to assess the value of the orphanage.

Second, the high flows (floods) did not permit the elephants to use the river for bathing because the small elephants could be washed away. In this instance, the tourism industries along the route taken by the elephants from the orphanage to the river would be affected, but not the orphanage itself. Thus, the specific days when the elephants could not use the river because of floods would spell economic loss in the area.

The proposed project (scenario 2) did not create flows lower than that in scenario 1 during the dry periods. Therefore, there was no incremental loss in scenario 2 when the extreme low flow conditions were considered. In contrast, the proposed reservoir was beneficial to the tourism industry sector, and benefit was derived from the mitigation of floods by the proposed dam.

Twenty of the 22 business establishments were surveyed to determine how many businesses were affected by the floods, the number of days of floods, and the income loss. Results showed that the elephants could not use the river because of floods for an average of 18.5 days in a year, with a minimum of 5 days to a maximum of 35 days.

Data were collected in early 2009 at the height of terrorist activities in Sri Lanka. The average daily income declined considerably because of the reduced number of tourists visiting the country. The highest average daily income was Rs. 14,700 in 2002, which was considered as an indicative value of the individual income loss of a business establishment with the loss of the ‘security’.

The net income could be then arrived by deducting the ‘average operating cost’ from the daily income. Even though reliable data was not available for estimating the average operating cost, it was safe to assume from observations that this was less than 10% of the average income. It was also observed that the businessmen were hesitant to reveal their true incomes, but they gave much lower values, which were assumed to absorb the correction for operating cost.

The reservoir operation carried out under step 2 of the ETO framework (technical requirement) facilitated the estimation of the number of days in which the floods could be mitigated because of storage in the reservoir. This was estimated to be 8 days per year.

Therefore, the annual benefits expected per annum = Rs. $22 \times 14,700 \times 8$
= Rs. 2.59 million

6.4 Industry Sector

Industries located in river banks depended on two types of use from a river system: the extraction of raw water for manufacturing needs and the discharging of industrial wastes to the river system.

Raw water extraction: In the extraction of raw water, the quantity and quality of water were two important factors which contributed to cost. In discharging wastes, the important factor was the assimilative capacity of the river. In the dry weather situation (low river discharge), the waste disposal rate could exceed the assimilative capacity.

A survey covering 20 industries along the river banks showed that most of them belonged to the four industrial estates that have been established along river banks; others were individual enterprises (Table 10). Out of the four industrial estates, the 'Nurani Industrial Estate' was located about 1 km away from the river. The industries within Nurani Industrial Estate used the river only for waste disposal.

Table 10 . Water demand of industries along the river banks

Industrial Estate	Respondents	No. of industries	Demand up to 2025 (m ³ /day)	Project Allowance (m ³ /day)		
				2005	2025	Average
Thulhiriya	01*	05	8500	4500	18000	11250
Meerigama	01*	05	4500	2500	6000	4250
Makandura	12	15	Not known	6000	13000	9500
Nurani	03	04	-	-	-	-
Individual	03	About 10	Not known	-	-	-
Total	20					25000

Note: * At 'Thulhiriya' and 'Meerigama,' all the industries within the estate were supplied with water by one intake. Waste is also treated by one plant under one authority.

Eight industries used tube wells and six used dug-wells as their sources of water. One industry depended on an outside source (a tube well on a neighboring compound). Five respondents, including the two from 'Thulhiriya' and 'Meerigama,' directly drew water from the river. Seven respondents agreed that the river flow, water level, and water quality influenced their water intakes. Data were collected on the expansion of the industries requiring additional water supply or waste discharge facilities within the project life of the proposed reservoir (up to 2028). Six industries at Makandura and the 'Thulhiriya' and 'Meerigama' industrial parks have plans for expansion during this period. All such demands were well within the provisions proposed by the proposed reservoir project (Table 10).

The proposal for scenario 2 catered to the industrial demand (quantity) of the existing industrial estates throughout the full project life. Establishment of new industries outside the present industrial estates was a possibility, but the economic loss of such industries because of non-allocation of river waters could not be estimated with the available data.

Poor quality water (turbid water) cost extra expenditure in raw water treatment. The survey showed that the extra cost of treating turbid water under flood conditions was Rs. 6 per cubic meter. Since the reservoir was situated far upstream from the industrial estates, an estimate of 3-day flood mitigation per annum was assumed to estimate the benefits by the reservoir.

Therefore, the benefits expected for the industries were= Rs. 25000 x 6 x 3

= Rs. 0.45 million per annum

Waste water discharge: Prolonged periods of low water flows combined with reduced flood peaks impact the industries sector differently. The prolonged low water flows required careful treatment of waste water from the industries especially from the textile sector that released dyes with waste water. During the dry weather (low river discharge), the waste disposal rate could exceed the assimilative capacity of the river. The industries may

have to treat their effluent better or close production during these periods. The method of 'Response cost' could be used to estimate the impacts to this sector because of the proposed reservoir project.

However, the environmental authority has already raised the standards of permissible waste water releases to the open surface of water bodies, and this is already being implemented in the environmental clearance certificate of industries. As such, the proposed project (scenario 2) would not require the industries to enhance their treatment plant capacities and incur for them any additional costs.

6.5 Dug-well Sector

Prolonged low flows causing low groundwater table would result in longer periods of water shortages for the users of dug-wells for their daily domestic needs. Most of the dug-wells run completely dry or almost dry during the natural dry weather periods. This resulted to extra costs for fetching water and poor sanitation conditions. Again, the method of 'Cost of productivity loss' was proposed as the valuation technique.

A pilot study was carried out in 'Godigamuwa', which was situated in the lower left bank reach of the river. This location was selected as it was identified in the preliminary survey as an area where the dug-wells were highly impacted by droughts and ran dry fast.

A few techniques on 'Participatory Rural Approach' were used for initial data collection. In these techniques, the data were elicited by allowing a group of people from the location to engage in different activities. For example, the group created a chart for the crops grown in the area during different seasons. Questions were posed to the group to facilitate discussions. This was followed by a household survey to collect individual data from 146 sample households.

Out of the 146 households, 126 (86%) owned a dug-well and others used common dug-wells and the river for their domestic water requirements.

During the past 15 years, the river bed has deepened by about 10 to 12 meters because of sand mining. This has resulted in the drying up of dug-wells near the river. Thus, the dug-wells were excavated time and again. Many of the respondents (84%) were aware of the depth of their wells. The average depth of a well in the area surveyed was 11 meters whereas the normal depth of a dug well was usually between 4 to 6 meters. Some wells were around 20 meters deep, and some people used tube wells which reached up to 25 meters.

The flow at the proposed reservoir site varied from 0.0004 m³/s minimum to 137.6 m³/s maximum with an average value of 7.4 m³/s. According to the daily flow estimation of scenario 2, a total of 2,812 days during the 20-year period (i.e., 20 weeks annually) would have flows more than that under scenario 1. Literature have reported extreme dry flows in the river from 6 to 8 weeks, i.e. 15% (8/52) of the time per annum. This means that on the average, 'scenario 2' would have a higher flow for a period equal to more than twice the period of extreme dry flow in 'scenario 1'.

In addition, areas in the immediate upstream of the four low flow weirs would control groundwater level to a distance between 1 to 2 km depending on the weir height and the river slope. This would also maintain the water level in the dug-wells along these reaches. Hence, the impact on the dug-well sector could be marginally positive when

compared with scenario 1. Impacts of this sector, however, could not be further valued because of lack of data.

6.6 Rainfed Agriculture Sector

The prolonged low flows resulting to low groundwater table would reduce crop production. The environmental valuation technique used to value the impacts to this sector was the 'Cost of productivity losses' method. The household questionnaire survey for the dug-well sector was extended to collect the required data.

The major crop in the area was coconut, which was grown by 65% of the surveyed households. Banana was grown by 25% of the households. Other crops grown commercially were pineapple, paddy rice, pepper, betel, rubber, flowers, and yams (Manioc).

Coconut cultivators were a key group of stakeholders using river resources in the lower reach. Their major concern was the impact of the proposed balancing reservoir project on soil moisture retention in the river bank areas, which in turn, would impact coconut production.

Coconut fetch varying prices during the year because of changes in production capacity. The highest prices ranging from Rs. 20 to 50 per nut were fetched during December to February. The river water level was generally low during this period, and coconut production was also low. When the river water level was high in May and production was maximum, prices were at its lowest.

Research had shown that soil moisture availability had a positive correlation with coconut production. The cultivators were encouraged to practice mulching to maintain soil moisture within the root zone. The roots of a coconut plant are generally around 2.0 m deep. When the groundwater table is present around this depth, the required soil moisture within the root zone is maintained.

The river water levels were found to have a definite impact on the groundwater table of most of the Ma Oya lower reach areas, through the observation of water levels of the dug-wells along the river banks. Low water levels of the river corresponded with the low water levels of the dug-wells, and high water levels in the river corresponded with the high water levels of the dug-wells. Thus, the magnitude of the impact of the proposed reservoir on rainfed agriculture depended on the possible variation of groundwater table impacted by the river water levels, especially during the dry months.

A study was made based on the available data of river flow and water level. River cross-sections data in 2004 were available for 12 places within the 80 km reach from the river mouth. This was also the reach of the river in the lower plains and where rainfed agriculture was predominantly practiced. Sample cross-sections in Figure 7 show that the average depth of the river varied between 10 to 12 meters in this reach.

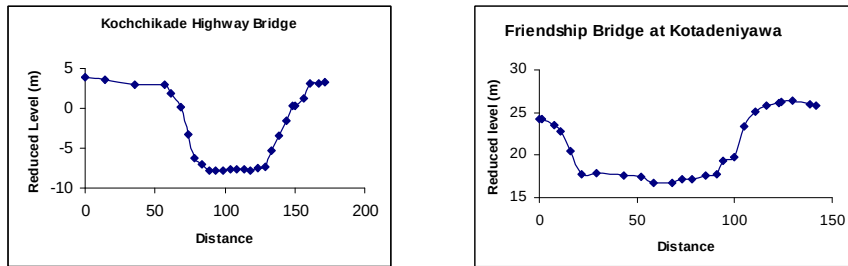


Figure 5. Sample cross-sections of the Ma Oya river

The computations for predicted changes in river flow (Table 6) showed that 88% of the time, the variations were less than 10 cumecs. During the dry season, the flows were actually expected to increase as a result of the flow regulations at the reservoir. However, observations on the relationships between river flow and water level measured at the gauging stations of Giriulla and Badalgama showed that for a flow variation of 10 cumecs, the water level variation was only a fraction of a meter.

The river bottom had been already lowered by about 10 to 12 meters rapidly during the past 10 to 15 years because of mechanized sand mining. The stakeholders claimed that the coconut cultivations in both river banks had been adversely affected by the rapid lowering of the river bottom level and by the corresponding low water levels.

Inasmuch as a coconut tree has a root depth of 2.0 meters, scenario 2 would not make a significant negative impact on coconut cultivation. This is because of the water level variations (in the magnitude of a fraction of a meter) during the low flow periods where the river water would be at much deeper levels. In fact, the regulated reservoir releases during the dry season could arrest the situation to some extent.

The other commercial crops had much less root depths, and similarly would not be negatively impacted by the proposed reservoir operations. Hence, the flow variation because of the reservoir will not impact rainfed agriculture of the river banks as expected. Figure 8 depicts a typical dry weather situation at a lower reach cross-section.

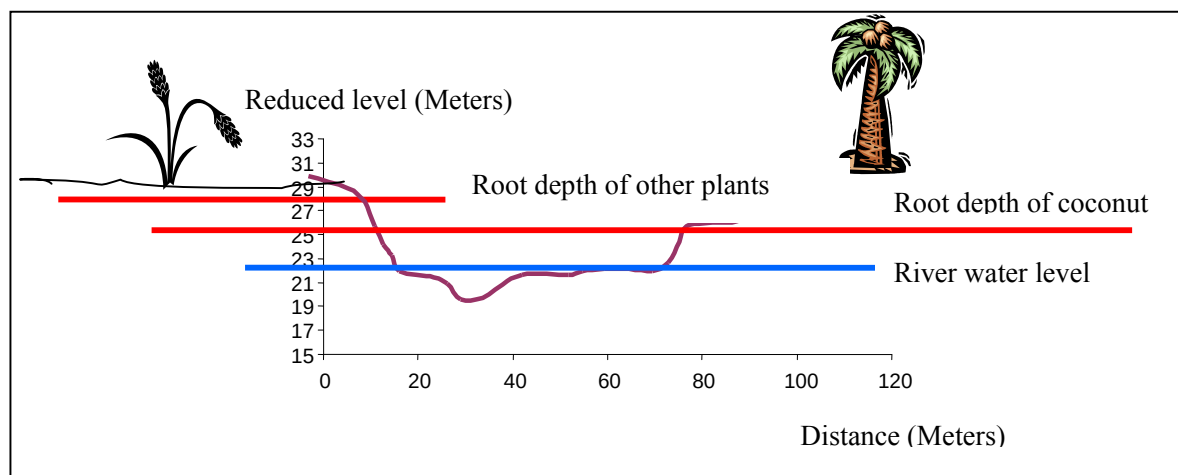


Figure 6. Sample river cross-section and the root zones of crops

6.7 Economic Analysis

$$\begin{aligned}\text{Total annual benefit from all sectors} &= \text{Rs. } 2.59 + \text{Rs. } 0.45 - \text{Rs. } 1.2 \text{ million} \\ &= \text{Rs. } 1.84 \text{ million}\end{aligned}$$

Net Present Value of the total social and environmental benefits *EnvioPV* for different discount rates are given in Table 11.

Table 11. Net present value of social and environmental benefits

	10% (20 yrs)	8.29% (20 yrs)	4.95% (20 yrs)	7.29% (40 yrs)
<i>EnvioPV</i> (Rs.)	12,946,246	17,695,097	23,027,993	23,727,467

An important sector that was not considered in this study were those who would benefit from the additional water supply for their incremental social and economic costs and benefits between scenario 1 and 2. Both the project feasibility report and this study considered only the financial value of water supply based on expected water prices per unit. However, this may considerably understate the value of scarce water to these communities, since without the reservoir project, their next best supply of water would be considerably more expensive to develop.

7.0 COMBINED ECONOMIC AND ENVIRONMENTAL VALUE

7.1 General

This chapter presents the fifth step of the ETO framework as applied to the case study. The combined economic value, which was the summation of the economic value of the project and the economic cost of the social and environmental impacts of the scenario 2, was estimated.

7.2 Combined Economic Value

The economic values of the project for the original case and three additional cases were estimated in Chapter 5. This is the procedure used in normal engineering practice to estimate the economic value of a project. This includes the social and environmental impacts in and around the site. For example, in this study, the replacement and resettlement costs of people for the reservoir construction were included in estimating the project economic value.

The ETO framework was developed to include the offsite social and environmental impacts, which have been usually ignored by normal engineering projects. Chapter 6 analyzes the impacts of the five threatened user sectors. Results show that the two sectors (tourism and industry) were benefiting from the project while the recreation sector was losing because of the inundation of a local recreation site. There was no appreciable incremental cost or benefit to the other two sectors.

As such, the combined economic value (*CombNPV*) for the incremental changes between scenario 1 and 2 for the cases 1, 3, and 4 are given in Table 12.

Table 12. Combined economic value for cases 1, 3 and 4

Case	EcoNPV (i=10%)	B/C*	EIRR*	EC (i=10%)	CombNPV	B/C**	EIRR**
1: Case 1	- 412,627	0.871	8.29	+ 12,946	- 399,681	0.875	8.34
2: Case 3	-1,116,227	0.651	4.95	+ 12,946	-1,103,281	0.665	5.02
3: Case 4	- 825,166	0.742	7.29	+ 14,871	- 810,295	0.747	7.34

Note: * Values estimated under normal engineering practice

** Values estimated under the application of 'Educated Trade-offs' framework

Case 2 is ignored because of its insignificant change between scenario 1 and 2

8.0 STAKEHOLDER EDUCATION AND FRAMEWORK VALIDATION

8.1 Stakeholder Workshops

Stakeholders were consulted to obtain their views on the proposed project; to educate them on technical, economic, and environmental (including social) spheres of the project; and to ascertain the impacts of what they learned. The sample included 218 stakeholders representing 10 different water uses. Eleven stakeholder workshops were conducted at the Divisional Secretariat offices situated along the river banks and one city center located in the river bank. The spatial distribution of workshops allowed the participation of stakeholders representing proposed project areas and the entire downstream reach of the river.

The two major tools used for stakeholder consultations were a set of presentations for introduction and education about the proposed development, and a set of questionnaires for 'pre' and 'post' education sessions.

8.2 Analysis

Table 13 shows the distribution of respondents among different use sectors.

Table 13. Frequency and percentages of stakeholders from different use sectors

Sector	Frequency	Percentage
Officials of NWSDB	13	5.96
Users of pipe borne water	9	4.13
Tourism sector	8	3.67
Recreation sector	22	10.09
Industrial sector	6	2.75
Dug well users	26	11.93
Paddy field owners / farmers	28	12.84
Coconut land owners	25	11.47
Environmental organisations	25	11.47
Government administrative mechanism	56	25.69
Total	218	100.00

8.2.1 Relationship between awareness and expectation of impacts

From 218 respondents, majority (67%) were unaware of the proposed reservoir project. Irrespective of awareness, majority (67%) also thought that they would get positive impacts from the project than their present situation, while less than half (44%) expected negative impacts.

Out of the 71 who were aware of the project prior to stakeholder workshops, almost two-thirds (70%) expected positive impacts, while only 49% expected negative impacts. This meant that 19% expected both positive and negative impacts from the project. Out of the 145 stakeholders who have heard about the project for the first time, 65% and 43% expected positive and negative impacts, respectively from the project. Chi-square analyses show that awareness of the project had no significant influence on the stakeholders' expectations, whether positive ($\chi^2_1 = 0.5197$) or negative ($\chi^2_1 = 0.8233$) at 95% level of significance.

Given below are the numbers of stakeholders with different impact expectations.

Reasons for expecting positive impacts;

- a) Good quality water supply and/or expansion of water supply 62 (43%)
- b) Extra benefits such as electricity for the area 34 (23%)

Reasons for expecting negative impacts:

- c) Reduced flow to downstream areas 30 (25%)
- d) Relocation 22 (19%)
- e) Negative impacts for dug-well users 16 (14%)

8.2.2 Willingness before and after stakeholder education

The level of willingness for the development project was measured using responses obtained on a scale of 11 points from +5 to -5 including zero: +5 indicated full willingness; 0 indicated indifference; and -5 indicated full opposition for the project. The summary of the responses received at 'pre' and 'post' stakeholder education sessions are compared in Table 14 where the 11 scale points are grouped into three categories: -5 to -1 as unwilling, 0 as neutral, and +1 to +5 as willing.

Table 14: Summary of stakeholder responses between 'pre' and 'post' education

Post \ Pre	Unwilling	Neutral	Willing	Total
Unwilling	16(42.1 %)	3(7.9 %)	20(50.0 %)	39
Neutral	1(7.1 %)	1(7.1 %)	12(85.7 %)	14
Willing	5(3.0 %)	1(0.6 %)	159(96.4%)	165
Total	22	5	191	218

The changes that have taken place in the three groups were as follows:

- Among the stakeholders who were 'unwilling' prior to education, 50% were convinced and were 'willing' for the project after the education session.
- Among the stakeholders who were 'neutral' prior to education, 86% were convinced and were 'willing' for the project after the education session.

- Among the stakeholders who were ‘willing’ prior to education, only 3% were negatively convinced and became either ‘unwilling’ or ‘neutral’ for the project after the education session.

Table 14 indicates that 81% of the stakeholders have not changed their position between the ‘pre’ and ‘post’ education sessions (i.e., only 40 showed clear change). However, since it was possible to indicate variation within a category (from +5 to +1 or -5 to -1), further analyses were made to capture all changes.

It was revealed that 78% (i.e., 169) accepted that their views regarding the project have changed because of the education session. Of the 169 persons, 104 have changed along the scale point, with 40 changes between groups and 64 changes within the group willing (+5 to +1) or unwilling (-5 to -1) for the project. Of the 65 whose responses showed no difference in the scale, 50 had marked extreme scale points at the ‘pre’ education session and could not have increased the scale point even if they wished to do so.

Hypothesis testing: To validate the ETO framework as a tool that could significantly impact the decision-making of stakeholders, hypothesis was tested using binomial distribution.

- H₀: Stakeholder involvement in decision-making on development projects in a river basin remains the same or becomes less with improved access to information through the ETO framework.
- H₁: Stakeholder involvement in decision-making on development projects in a river basin is rationally impacted with improved access to information through the ETO framework.

For the purpose of this study, the term ‘rationally impacted’ was defined as having the majority (more than 50%) of stakeholders being impacted.

“78% of the sample accepted that the education has changed their views about the project which led to the rejection of the null hypothesis at 95% significance level ($Z_{\text{Computed}} -9.87 > Z_{\text{Table}}, -1.05$). This allowed the validation of the ETO framework by accepting the alternative hypothesis.”

8.2.3 Influence of technical, economical, and environmental aspects

Further analysis was done to determine the factors that have influenced most the stakeholders’ change of views for decision-making. These factors were grouped into three: technical, economical, and environmental (including social) (Appendix 4). The stakeholders’ responses were assessed on a scale of 1 (no impact) to 5 (high impact).

Figure 9 shows that the most ‘influential’ technical factors were catchment data (T3), reservoir data (T4), and rainfall data (T2), while the least influential was the location of the river and cities (T1). The only economic factor used, the net benefit of the project (E1), had also impacted stakeholders considerably.

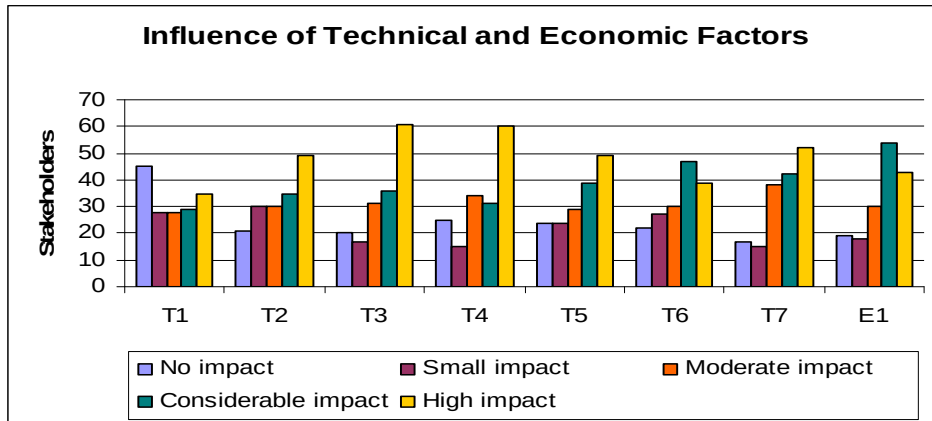


Figure 7. Technical and economic factors that influenced the stakeholders' decision-making

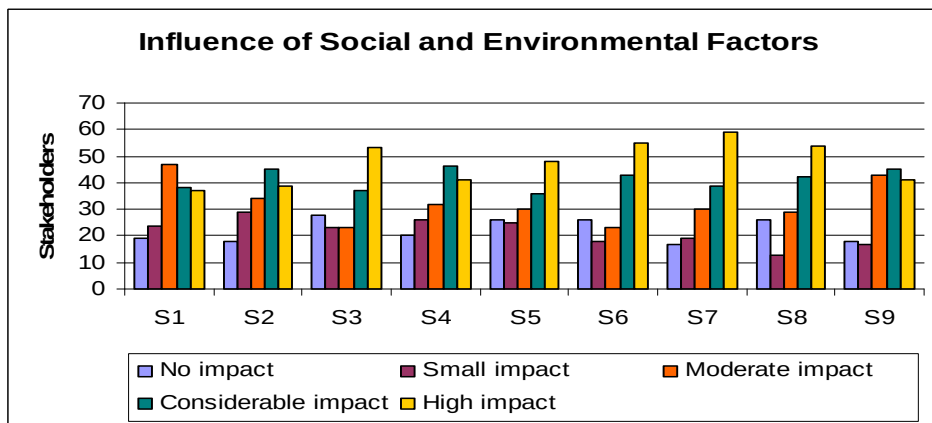


Figure 8. Social and economic factors that influenced the stakeholders' decision-making

Among the social and economical factors, understanding of the indirect positive impact of the low flow weirs on the dug-wells in the vicinity (S7) caused the major change among the stakeholders. This was followed by their understanding that the project did not negatively affect the downstream dug-wells and that there were no adverse effects on crops such as paddy rice and coconut (Figure 10).

8.3 Discussion

Stakeholder workshops were conducted to validate the broader hypothesis that the developed ETO framework was a useful tool in educating stakeholders for decision-making with regard to natural resource uses. This study hypothesized that the ETO framework was a useful tool for changing the perception of the majority (more than 50%) towards the proposed Yatimahana reservoir project.

This hypothesis was proven to be true at 95% significance level with $Z_{\text{Computed}} -9.87 > Z_{\text{Table}}, -1.05$. Thus, the null hypothesis was rejected. Majority (78%) of the stakeholders

agreed that their decision on the proposed project changed after the education session using the ETO framework.

Two of the three main reasons for disliking the project were associated with the fear of reduced flow to downstream areas, especially the dug-well sector and the agriculture sector without irrigation facilities. In the 'post' education session, the stakeholders' 'technical education,' especially on the rainfall and catchment data of the proposed reservoir, backed their confidence to change their views about the project.

9.0 CONCLUSIONS

This study aimed to apply the ETO framework to the Ma Oya river basin, hence enabling the stakeholders to make informed decisions regarding the proposed Yatimahana development project and other resource uses. The study also validated the ETO framework as a tool for stakeholders' education. The following conclusions were derived from the different steps of the framework.

The methodology used in the first step of applying the ETO framework facilitated the efficient identification of dominant stakeholders and the impacts of the development project, which were spatially distributed over 100 km.

The economic value of the technical requirement (the third step of the ETO framework) estimated the economic feasibility of scenario 2 with an estimated IRR of 8.29% for the base case with 20-year project life.

The fourth step of the ETO framework valued the social and environmental impacts in three sectors, which had not been considered in the project's feasibility study:

- recreation sector: inundation of a waterfall resulting in a loss of Rs.1.2 million per annum
- tourism sector: controlled water release at the proposed reservoir, hence increasing the tourism days in Pinnawala, a prominent site with an elephants' orphanage, and resulting to an estimated incremental income of Rs. 2.59 million per annum.
- industry sector : mitigation of floods resulted to Rs.0.45 million worth of savings per annum for water treatment.

Data analyses in the fourth step established that the 'dug-wells' and 'rainfed agriculture' sectors along the river banks areas were not impacted by the proposed development project.

It was observed that the value of water was considerably understated by considering only the financial benefits. Without the reservoir project, developing the next best supply of water would be considerably more expensive.

The incremental net benefit arrived at the economic evaluation under scenario 2, was found to marginally increase when the social and environment impacts were added at the fifth step of the ETO framework. Irrespective of the outcome, the application of the ETO framework educated the stakeholders in technical, economic, and environmental aspects to enhance the rationality of their decision-making. This was proven by the

acceptance of the alternative hypothesis, that the developed ETO framework was a useful tool in educating majority of the stakeholders (more than 50%) in making decisions about natural resource uses at 95% level of significance.

The following are recommended for future reference and further work.

- a) A major hindrance in involving stakeholders to decide about resource uses of the river basin was the lack of a cohesive platform to bring them together. This was inspite of the ongoing 'Area Water Partnership' project. Hence, a network of interested stakeholders in the GNDs along the river using the GN as the catalyst can be formed. This approach of using the GN as the catalyst was found to be effective in this study. Networking will facilitate the surfacing of all the stakeholders' concerns as well as the identification of emerging issues at an early stage so that remedial actions can be implemented.
- b) The benefits gained by avoiding social and environmental costs for the beneficiaries of the water supply schemes should be emphasized.
- c) The effective application of the second step of the ETO framework requires reliable technical data on water flow, water levels, and water quality. Data that met satisfactory standards were not available. Hence, immediate steps need to be taken to collect such data systematically.

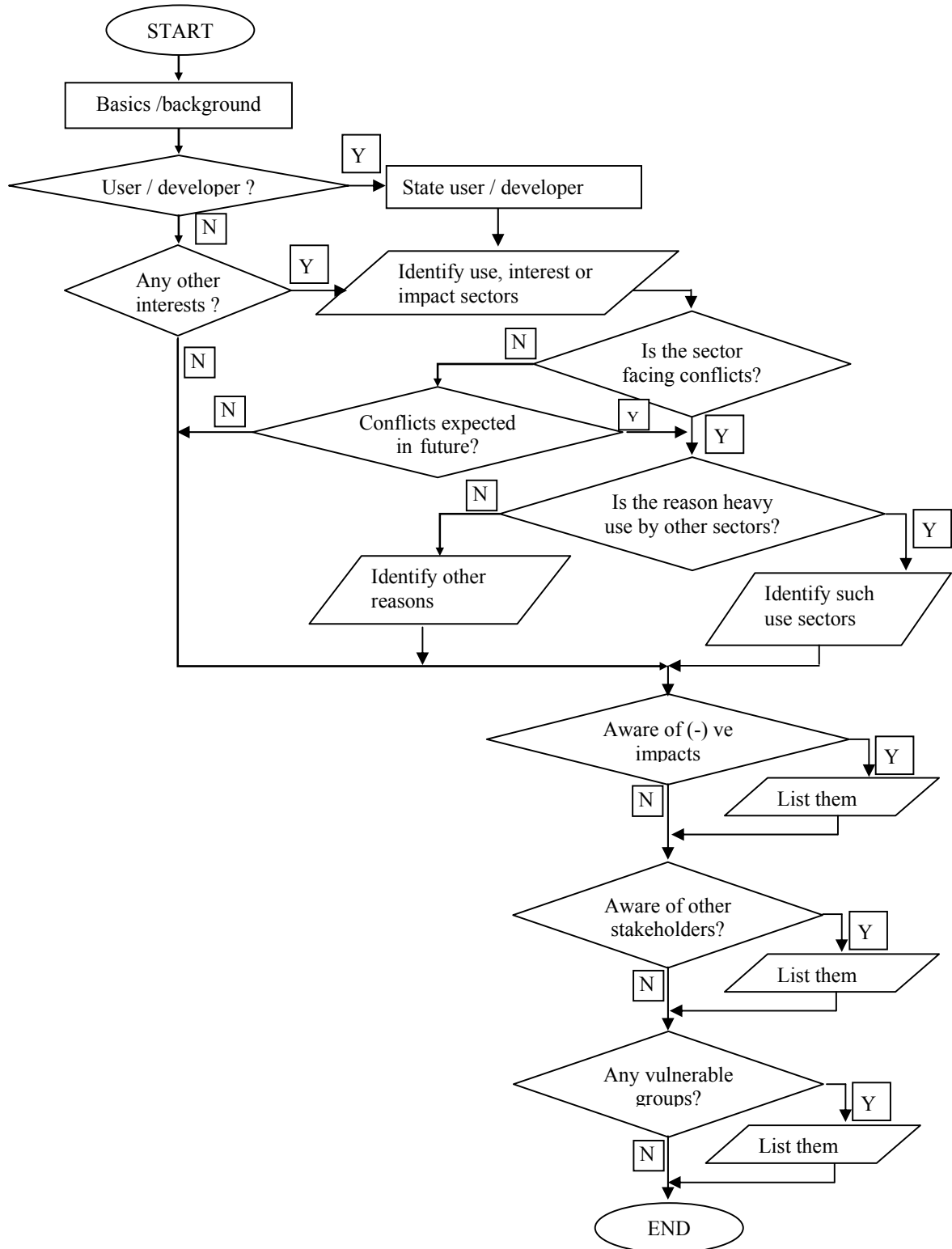
The above three recommendations should be included in policies for future river development work.

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APPENDICES

Appendix 1: Flow chart for the stakeholder consultation



Appendix 2: Stakeholder groups and vulnerability

No.	Stakeholders	Vulnerability
1	Sand miners	Threat of losing income for traditional miners Accidents in the sand industry
2	Land owners along river banks	Flood damages to houses on river bank Erosion of cultivated lands (coconut, paddy rice etc.) Erosion of other land (home gardens, reservations etc.)
3	People bathing, washing	Loss of life and injuries because of deep under water pits by sand mining Difficult access because of deep banks
4	People, shopkeepers discharging waste (including excreta)	
5	Fishermen	Obstruction from sand miners
6	People engaged in the tourist industry	
7	People in the area	Health problems from epidemics of malaria, dengue, diarrhea etc. and dust Instability of houses near clay pits Non-availability of sand for local people
8	Industrialists	Flood damages
9	People using dug-wells, tube wells	Drying up of dug-wells, tube wells
10	Environmentalists	
11	Local politicians / Pradeshiya Sabha	People – abandoned houses/ lands, damages to roads and bridges
12	People raising animals (pigs)	Danger in using the river for bathing of animals
13	Clay miners	Accidents in the clay industry
14	Slaughter house owners	
15	Boat yard owners	
16	Bamboo traders	Low flows
17	Timber industry – wood cutters	
18	Priests - Temples / Churches	
19	People – crossing the river	Danger from deep and slippery river bed
20	Farmers / Farmer organizations	Loss of production because of water shortages and lowering of groundwater level
21	People - recreation	
22	People - use piped water	Drinking water shortages
23	Village administrative officers (Grama Niladhari)	
24	People – direct drinking water	Poor water quality
25	Entrepreneurs – decoration stones	
26	Agriculture training center	
27	Owners – vehicle service station	
28	Railway department	Erosion of railway bridge foundations
29	National Water Supply and Drainage Board	Limitations to water intakes
30	Road users	Muddy roads, dust, erosion of bridge foundations

Appendix 3: Stakeholder contributions to river environment protection

- 1 Voiced out public issues through the village society
- 2 Planted trees on own land
- 3 Informed problems to DSD/ Grama Niladhari/ Government
- 4 Informed problems to the Central Environment Authority
- 5 Took legal action against illegal sand mining
- 6 Educated neighbors on consequences of dumping waste into the river
- 7 Informed the GN about negative issues from tourism
- 8 Stopped illegal sand mining on the shore
- 9 Contributed for making embankments with rock/sand bags/ coconut logs
- 10 Planted trees together with villagers
- 11 Educated political leadership
- 12 Lodged complaint with the police against clay and sand mining
- 13 Established an environment committee etc.
- 14 As a journalist, contributed about the environment damages to the media
- 15 Checked the conditions of permits in official level.
- 16 Leadership/ involvement in rehabilitation of irrigation works
- 17 Constructed a community hall sponsored by clay industrialists
- 18 Filled the clay pits as required (by the industrialists/ villagers)
- 19 Paid cost of watering the dusty roads
- 20 Contributed for the community's water supply scheme
- 21 Stopped construction of factories (that will cause environment pollution) with the Village Development Society and Death Donation Association etc.
- 22 Educated sand/ clay industrialists about the safety of the industries
- 23 Abided by the existing rules for sand mining
- 24 Initiated a project for inland fishery in clay pits
- 25 Influenced a sand miners association towards environment protection
- 26 Educated farmers not to use too much chemicals
- 27 Stopped sand/ gravel mining through protest campaigns
- 28 Proposed construction of embankment to safeguard the bridge
- 29 Proposed a weir through 'Farmer Associations'
- 30 Informed Geological Survey and Mining Bureau (GSMB) to look into the impacts of clay pits
- 33 Involved in fixing a fence along the river through Area Water Partnership
- 34 Supported data collection for the Yatimahana reservoir project
- 35 Constructed side walls to minimize the damages by driving vehicles into the river
- 36 Constructed drains to reduce erosion in river bank areas

Appendix 4. Factors used for stakeholder education

Technical factors

- T1 Location of the river with respect to districts and cities
- T2 Rainfall data
- T3 Catchment area for the river and the reservoir
- T4 Reservoir data; dam height, capacity and water spread area
- T5 Electricity generation data
- T6 Knowledge about the tributaries in the downstream
- T7 Future water demands at present intakes

Economical factors

- E1 Expected net economic benefit from the project

Environmental (including social) factors

- S1 Education of sectors that would have direct impacts from the project
- S2 Education of sectors that would have indirect impacts from the project
- S3 Understanding of the economic value of the 'Bo Ella' waterfall
- S4 Understanding of the extra income to the tourism sector at Pinnawala
- S5 Understanding of the profit that could be earned by the industrial sector as a result of the reduced number of days of turbidity
- S6 Understanding that there are no adverse impacts to the dug-well sectors in the downstream areas
- S7 Understanding that the low flow weirs are helpful in maintaining the water levels in the dug-wells of the vicinity
- S8 Understanding the reason for the absence of adverse impacts to the crops such as paddy and coconut by the project
- S9 Education of good and bad impacts to the riverine environment such as humidity and temperature

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