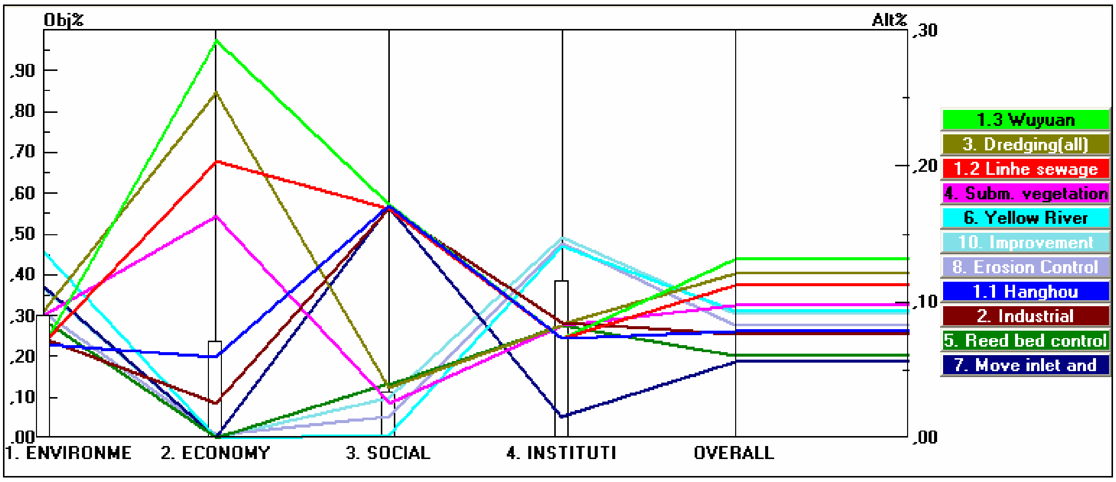
REPORT SNO 5397-2007

Ranking of Management and Control (MC) Measures

Lake Wuliangsuhai Restoration Project



Norwegian Institute for Water Research
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REPORT

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Abstract
The report discusses the data and assumptions behind a multi-criteria-analysis (MCA), which was carried out in the Lake Wuliangsuhai restoration project. A series of scenario analyses for alternative future lake water quality and for the different preferences of stakeholders for restoraton measures were conducted. The ranking of different measures using MCA has helped structure decision-making for a programme of restoration measures. It will provide a framework for evaluating new measures which may be proposed in a programme of measures for Lake Wuliangsuhai.

4 keywords, Norwegian	4 keywords, English
1. Multikriterie analyse	1. Multiple criteria analysis
2. Tiltaksanalyse	2. Programme of measures
3. Eutrofiering	3. Eutrophication
4.	4.

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Lake Wuliangsuhai Restoration Project

Ranking of Management and Control (MC) Measures

Preface

This report collates the results of a multiple criteria analysis of a programme of lake restoration measures for Lake Wuliangsuhai. The project was conducted in collaboration with IMESI(China) and supported by the Norwegian Foreign Ministry. F.Ruden and D.N. Barton were responsible for developing the analytical hierarchy framework implemented in Expert Choice software. D.N. Barton and E. Lindblom collated impact data for the different restoration measures to be analysed. F. Ruden conducted the stakeholder workshop (23-24 November, 2004) validating the analytical hierarchy model and elliciting stakeholder preference weightings for the different criteria. D. N. Barton conducted the analyses in Expert Choice.

Oslo, April 2007

David N. Barton

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Summary

As part of the Management and Control Plan for Lake Wuliangsuhai a workshop was held in Linhe 23-24 November, 2004, with the purpose of carrying out a multi-criteria analysis (MCA) and project ranking session with a group of stakeholder representatives. This report discusses the data and assumptions behind the MCA.

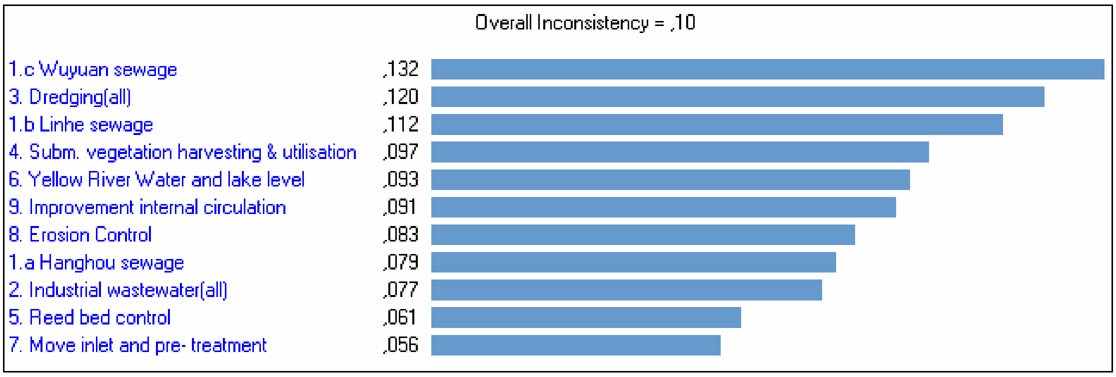
Relative to the third revision of the manuscript (July 2005), this fourth revision (August 2005) has revised costs of the measures MCM 7 - moving inlet and pre- treatment and MCM 8 – Erosion control, based on a revision by Chinese counterparts in the project after going through the third revised manuscript. An overview of all the cost revisions can be found in Appendix 5. Dredging (MCM 3), moving inlet and pre-treatment (MCM7) and erosion control (MCM 8) have had costs substantially revised over time. Revenues MCM 8 have also been revised in this latest version. Other effects of measures have remained as in the third version. Some figure titles have also been modified to clarify that rankings shown are based on the weighted rather than unweighted criteria.

As in previous drafts, we conducted a series of scenario analyses for alternative future scenarios for lake water quality ("turbid" and "clear"), as well as the differences in preferences for different criteria expressed by the stakeholders. We find that ranking of management and control measures (MCM) are not very sensitive to the choice of scenario or set of preferences.

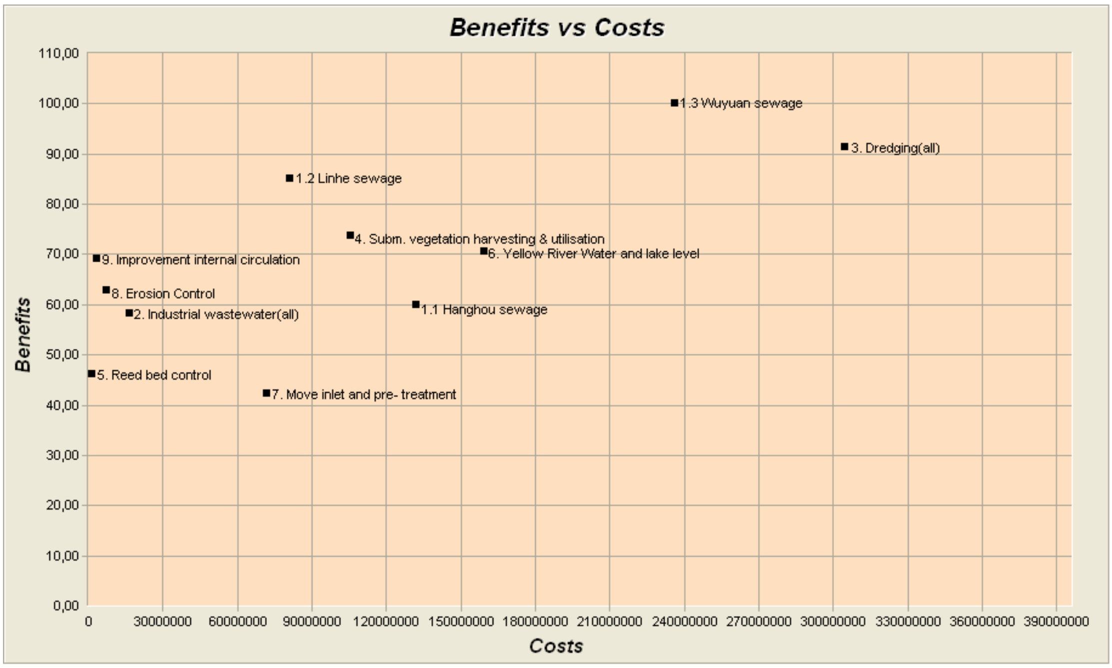
In a clear water scenario the ranking of MCM is presented in the table below, taking into account both the aggregate benefit calculated across 37 criteria, subcriteria and indicators, as well as cost of the measures. Based exclusively on environmental, social and institutional impacts ("benefits") the Wuyuan (MCM 1.3) ranks highest.

If cost of measures is also considered in the form of a cost/benefit ratio, the general conclusion is that the smallest, cheapest measures should be implemented first, starting with reed bed control (MCM 5). The ranking of measures with very different scales of implementation cost leads to this difference in implementation priorities. This is because environmental, social and institutional impacts ("benefits") are largely qualitative in the analysis and cannot capture the difference in the scale of the measures represented so clearly by 2 orders of magnitude difference in the costs of the cheapest and most expensive measures.

Management and control measures ranked by weighted benefits



Benefit/cost ranking of measures

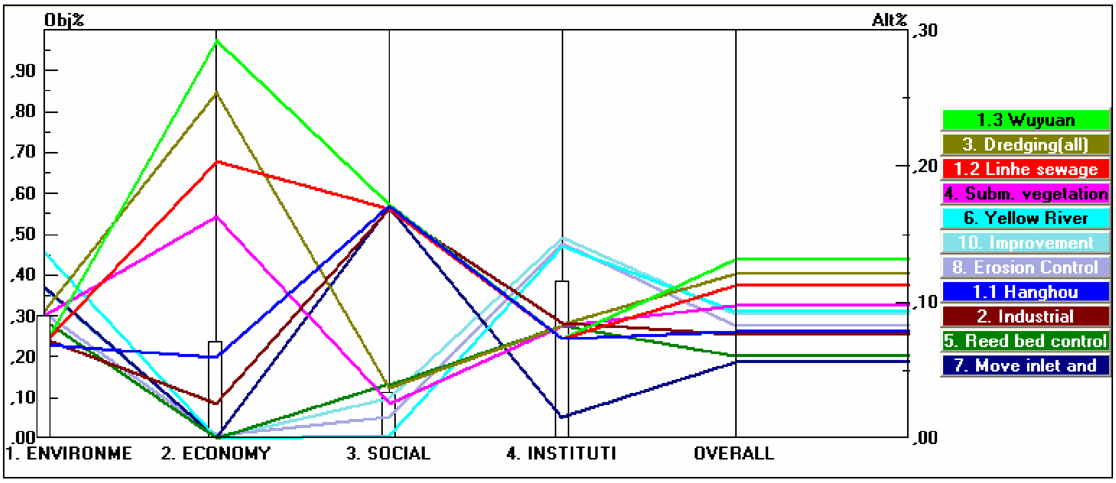


Cumulative costs and benefits of management and control measures

Ranking based on benefits only	Alternative	Individual benefits (normalised)	Individual costs (million Yuan)	Cost/ normalised benefits (million Yuan)	Ranking based on ratio costs/normalised benefits
1	1.3 Wuyuan sewage	1	236 029 934	236 029 934	10
2	3. Dredging(all)	0,914	304 757 590	333 432 812	11
3	1.2 Linhe sewage	0,852	81 376 045	95 511 790	5
4	4. Subm. vegetation harvesting & utilisation	0,738	105 776 571	143 328 687	6
5	6. Yellow River Water and lake level	0,705	159 330 406	226 000 576	9
6	10. Improvement internal circulation	0,691	3 598 918	5 208 275	2
7	8. Erosion Control	0,629	7 213 328	11 467 930	3
8	1.1 Hanghou sewage	0,599	132 093 951	220 524 125	8
9	2. Industrial wastewater(all)	0,582	16 425 647	28 222 761	4
10	5. Reed bed control	0,462	1 249 238	2 703 978	1
11	7. Move inlet and pre- treatment	0,423	71 797 479	169 733 993	7

The performance of each management and control measure (MCM) according to the four main criteria ENVIRONMENT, ECONOMY, SOCIAL and INSTITUTIONAL are presented in the following figure.

Performance of management and control measures by criteria



Limitations of the analysis include the fact that most of the environmental data used for ranking are based on qualitative expert opinion, rather than modeling. This was due to the fact that the decision to compare and rank measures using a multiple criteria approach was taken quite late in the project, after monitoring data and modeling tasks had been designed and carried out.

Further limitations include the limited experience Chinese counterparts had in adequate budgeting of management and control measures and scaling of the impacts. In several instances, costs of measures where adjusted significantly without corresponding adjustments in expected benefits (as measured by the different criteria and sub-criteria).

Cost and revenue of measures are based on the MC reports by the Chinese authors. The use of this data is not an endorsement of the valuation methods used in the MC reports as we had no way of checking the underlying data. For some measures revenue estimates play a large part in the high ranking of the measure, particularly: revenues from the sale of fertiliser from dredged mud (MCM 3) and from harvested submerged vegetation (MCM 4). In both cases, revenues are calculated based on existing fertiliser prices without consideration of how the market will evaluate these as substitutes for chemical fertiliser, nor are supply-side effects on local market prices considered. In the case of erosion control (MCM 8) significant increases in revenue have been assumed in agriculture and pasturing. In a large number of projects around the world the predicetd effectiveness of erosion control has been exaggeerated. In a detailed feasibility analysis these assumptions should be revised in detail.

Despite the limitations in the underlying data, the ranking exercise itself conducted at the Linhe workshop was considered a success. Stakeholders found the description of the impacts of each MCM understandable and the process of recording their preferences manageable.

Assuming further quality control of the data and analysis in this report by our Chinese counterparts, and periodic updating of preference weights for the different criteria, we are cautiously optimistic that the method illustrated in this report has helped structure decision-making and will provide continued guidance in evaluating additional measures which may be proposed in a programme of measures for Lake Wuliangushai.

1. Introduction to the ranking process

1.1 Objectives

During the 3rd Workshop held in Linhe 23-24 November, a multi-criteria analysis and project ranking session was carried out by a group of stakeholder representatives.

A main objective of the Linhe workshop has been to convey to stakeholders the latest revisions and developments regarding project finalisation, in particular the endeavours to bring salient results onto a common platform, and the strategy for analysing impacts and consequences of proposed action plans. In particular, the Linhe workshop addressed the stakeholder participants on the following issues:

1) Presentation of the latest revised set of criteria, to be used for judging the impacts of proposed action plans,
2) Presentation of the latest revision of the Compiled Data Matrix
3) Assigning weights (priorities) to all criteria by active stakeholder interaction and participation
4) Presentation of ranking and prioritisation results based on above issues

All the above issues were implemented successfully and with a considerable degree of interaction, including the tedious task of assigning pairwise weightings of all 37 indicators presently contained in the Compiled Data Matrix.

Reference is made to the Agenda, Minutes the list of Participating Stakeholders in the Appendices.

1.2 Why use a multiple-criteria decision support tool

The Lake Wuliangsuhai Lake Restoration Project is a complex programme, consisting initially of some 14 proposed management and control measures (MCP), the descriptions of which are contained in MCP reports, a number of additional reports, results from a number of sessions and workshops, etc.

The management and control measures are point and non-point measures located throughout a large river basin. Although the measures are all focused on reducing nutrient loading to the lake, they affect a number of different sectors, and have a number of side- or secondary effects. The process of multiple criteria analysis allowed stakeholders and consultants alike to uncover overlaps and synergies which brought the final number of Management and Control measures down to 10 (hereafter MC measures). Amongst the measures eliminated where those that were already underway or targeted for financing (e.g. agricultural irrigation efficiency).

The very nature of the multiple impacts calls for a decision-support tool to help prioritise between measures. Initially cost-effectiveness analysis was considered, as it was thought that the focus was on achieving nutrient loading reductions at minimum cost. However, it was quickly agreed that the decision-support tool would also have to handle other effects than those the measures were principally designed for. Extended benefit-cost analysis was rejected because there was insufficient time-series data to employ process-based models that could link i.a. nutrient emissions, run-off, irrigation water use, vegetation modifications in the lake to eutrophication impacts within the lake. Essentially, the multiple criteria approach replaces model based judgements of upstream-downstream linkages with expert judgement through the application of weighting of criteria. This is discussed further in following sections.

In order to tie many of the loose strings of this complex programme together, a common platform was needed. Moreover, a tool was required for extracting information, analysing impacts and for decision support.

Lastly, there was a need to bring all information onto a common platform, for the sake of comparison and processing of information. This resulted in the Compiled Data Matrix, which is presented in Appendix and which is a condensate of information from the 10 MC measures that were ranked. For other MC measures considered, but not ranked please see other chapters of the MCP report.

The solution to the above problems could have been reached by several approaches. The choice of multi-criteria processing in the form of *Analytical Hierarchical Processing* offers a relatively simple and practical solution to the above problems, and a software package 'Expert Choice'® was procured for this purpose, as manual processing would have been unrealistic.

By using this Decision Support System during the final stage of project finalisation, a number of pieces fall into place:

- Providing a common structure for reporting, including standard formats for important parameters and results from the 10 sub-projects (MC measures)

- Incorporating stakeholder and enabling a degree of consensus or differing stakeholder perspectives on important issues.

- Providing a relative measure for environmental impacts from respective MC measures and thus provides a tool for implementation strategies

- Inclusion of stakeholder interaction in the weighting process

In other words, the multi-criteria process can help formulate an implementation strategy which is both consistent and which is documented. By comparing each projects (10) against the same set of criteria (37) the multi-criteria process breaks down an otherwise complex task into smaller and manageable bits.

1.3 Certain limitations of the multi-criteria approach

The multi-criteria approach (MCA) is a powerful means of ranking activities. In the case of the MC measure of this project, a list representing the most cost-effective implementation strategy is an important contribution from a multi-criteria process. In the MCA context effect is understood as the weighted aggregate effect across a number of different sub-criteria that characterise each alternative. However, while the decision process may indicate the most efficient *sequence* of events leading to sustainable lake, there are no simple means of ascertaining when this particular point has been reached. Furthermore, the Lake Processes Report indicates the difficulties in modelling sustainable nutrient loading in shallow lakes given significant threshold effects and dual stable-states.

In other words, the multi-criteria process can show the way, indicate a cost-effective strategy, and provide a means of comparing impacts, but cannot indicate *when* to stop, i.e. when sustainable conditions for the Lake have been reached. An expert opinion will be required in this context, reflecting the various stakeholder perspectives.

The MCA tool is flexible with regards to qualitative and quantitative data availability. However, it is obvious that this priority setting exercise would have benefited from a much earlier definition of measures, with monitoring geared towards generating data to populate the data matrix for the different management and control measures.

1.4 Terminology

The below presentations make use of the following terminology:

- MC *measures* (MCM). These are the alternatives to be ranked. Detailed descriptions of these measures are given in the Management and Control Plan (MCP) Report.

- The *benefit* is a relative value calculated for each MC 'measure' described in the MCP report. The scale of the 'benefit' is arbitrary (i.e. not benefits in the monetary sense), but the values are relative and therefore comparable.

- The *cost* is obtained from the Data Matrix (Appendix), which in turn is based on reports from the individual MCP's.

- The *priority* is the importance of individual indicators, or aggregated indicators at higher levels (=criteria).

- The *impact ranking* is the order in which the MC measures / projects are listed according to their impact, irrespective of their costs.

- The *cost-efficiency ranking* is based on the project's impact and cost. In other words, the projects are ranked in terms of both (low) cost and (high) benefit.

- The *objective* is the anticipated result of an indicator cluster, and depends on the level. For example, the overall objective may be 'Towards *A Sustainable Lake'* whereas a lower level objective may be '*Environment*', etc.

- The *Stakeholder Perspective* is provided by a set of weightings which reflects the viewpoints of a particular stakeholder group. At the Linhe session two slightly different stakeholder groups emerged, as described below.

- Preference *Inconsistency* is used to measure to what extent stakeholders preferences for criteria/sub-criteria at the same level of the hierarchy are so-called transitive. Transitive preferences imply that if A > B > C, then A > C (> means 'preferred to'). Transitive preferences is one of the axioms that lie behind the utility maximisation algorithms of the Analytical Hierarchy Process implemented in Expert Choice.

1.5 Indicators

A considerable volume of knowledge and information has been incorporated into the MCP reports and then into the MCA. These reports deal with different topics, are characterised by different data formats, and exhibit a varying degree of detail. In addition, the sheer volume of information is considerable. To extract a single conclusion out of all this, in an objective and participative fashion, is a formidable challenge.

In order to condense relevant and comparable information from all the 10 MC measures compared, a data matrix has been established (see Appendix). The 37 parameters contained in this Compiled Data Matrix have been designated *indicators*. The analytical hierarchical processing approach adopted as part of this report is based on these indicators.

An indicator is a small packet of information; the format can be a single figure or a yes/no, designed to provide information of a related but much larger context.

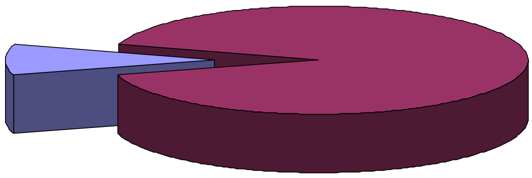


Figure 1: Indicator

The above illustration shows the principle of an indicator (blue) representing a larger context (purple). The advantages of using indicators are significant and include small volumes of information, ease of comparison, etc.

Indicators are organised in a certain *hierarchy*, and are termed *indicators*, *sub-criteria* and *criteria*, respectively, as one climbs up in the hierarchy. Such a hierarchy is useful in order to provide interim results for stakeholder groups at various levels. (Hence the name *Analytical Hierarchical Process*).

For example, an economist may want to highlight economic implications, a fish farmer may want information on the lake habitat, a politician may want an overall view, etc.

1.6 Main principles of hierarchical analytical processing

The Analytical Hierarchical Processing (AHP) is characterised by following principles:

1) An indicator is defined as the result of a certain field value and the corresponding weight of the respective indicator
2) A hierarchical structure is used for processing indicators upwards
3) Weighting of individual indicators is done by pairwise comparisons
4) The data remain unaffected by changes in weightings, etc.

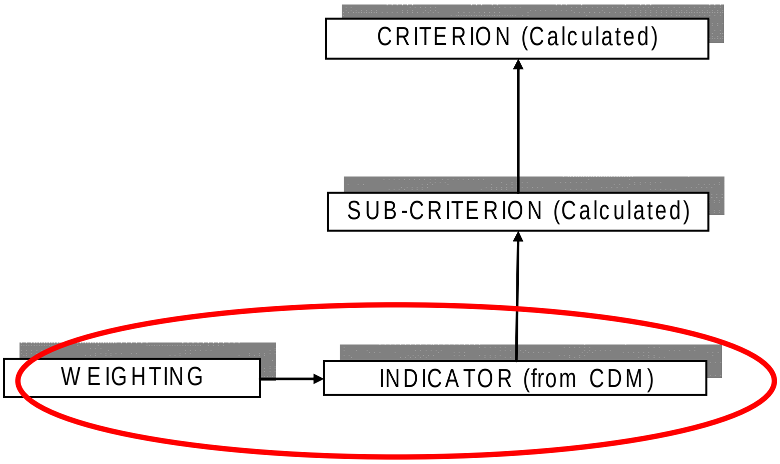


Figure 2: Analytical hierarchy

The processing of information is essentially combining indicator field values and their assigned priorities (red circle). The field values are listed in the Compiled Data Matrix (Appendix).

The result is then combined with other indicators in line with the hierarchical structure presented in Figure 1.7.2 below.

The three levels (indicator, sub-criterion and criterion) as outlined in the hierarchal map below offer opportunities for analysing model results at various levels. For example, a regional politician may want a total analysis while a limnologist may be more concerned with the impacts on a lower (lake) level, etc.

The most aggregate level of the structure is comprised of the 4 well known criteria used by the UN for classification of factors leading to sustainability :

1) ENVIRONMENT
2) ECONOMY
3) SOCIAL
4) INSTITUTIONAL

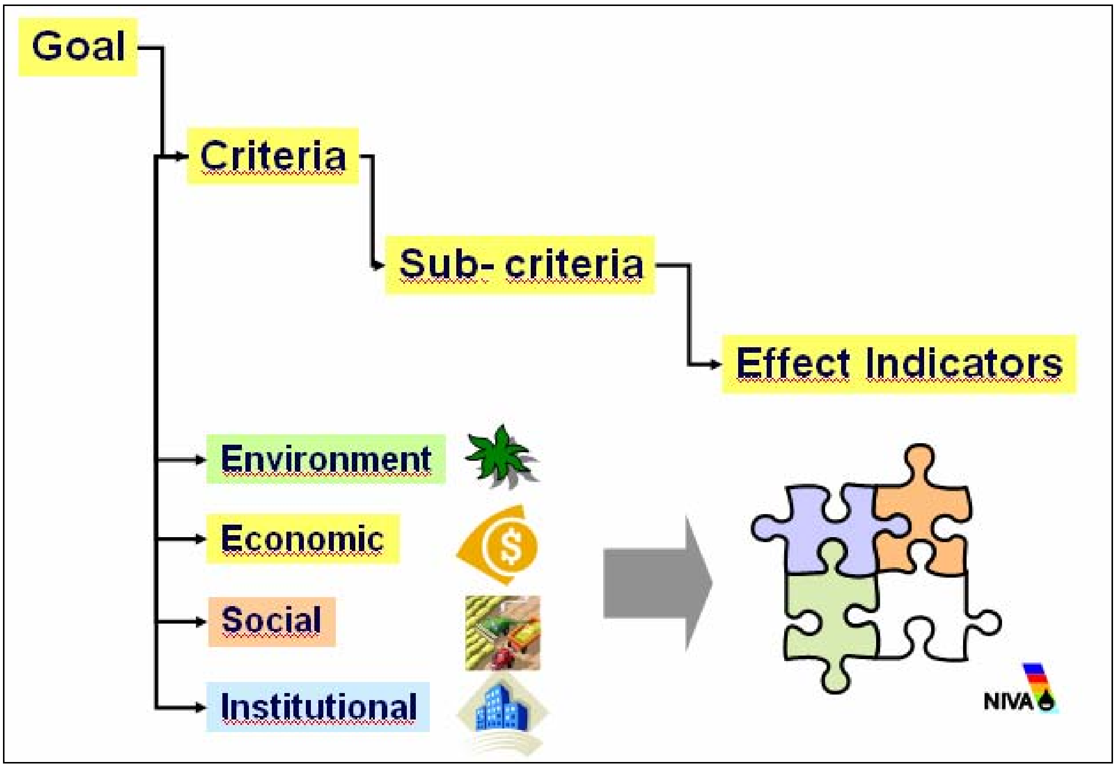


Figure 3: Four criteria

The sub-criteria are shown in found in **Error! Reference source not found.**. This indicator hierarchy is the backbone of the AHP. For measuring units and ranges, see the Compiled Data Matrix (Appendix).

1.7 Weighting algorithms

Expert Choice software offers a Distributive and an Ideal Mode to weighting alternatives. The Distributive mode distributes the weight of each criteria/subcriteria to the alternatives in direct proportion to the alternative priorities under each criterion. When using the distributive synthesis mode, the addition or removal of an alternative results in a re-adjustment of the priorities of the other alternatives such that their ratios and ranks can change. The distributive mode should be used when measuring under conditions of scarcity – for example when forecasting outcomes whose probabilities must add to 1, or when allocating a budget to a number of different alternatives. When using the ideal synthesis mode, the addition or removal of alternatives (that are not best on any criteria /sub-criteria) will NOT impact the relative priorities (ratios or ranks) of other alternatives. The ideal mode should be used when selecting one alternative from many and when the priorities of the alternatives not selected are not of interest. In the following analysis we will use a <u>Distributive mode</u> given that we are interested in the ranking under a cost / budget constraint, and not merely to find the best alternative

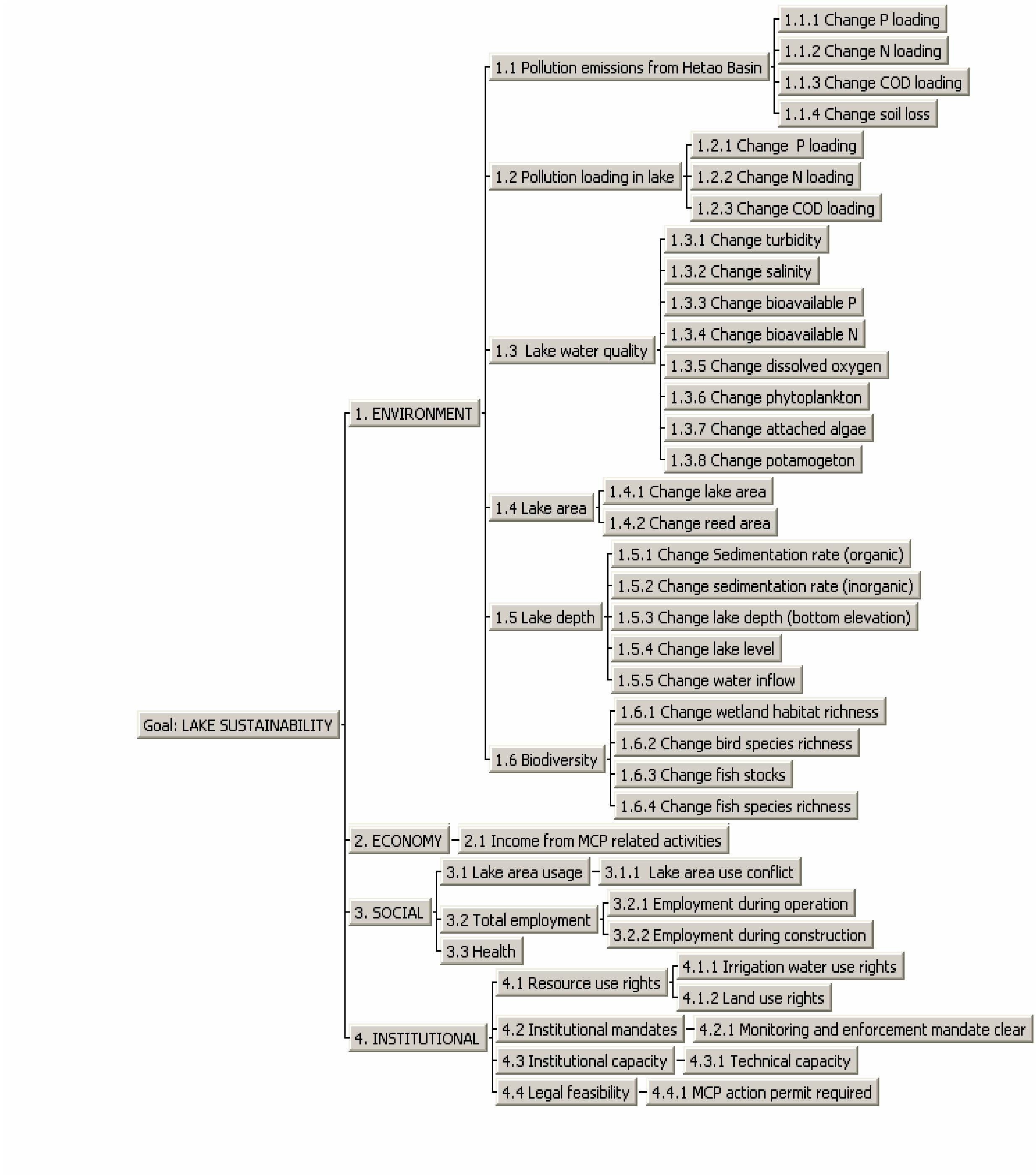


Figure 4: Complete list of sub-criteria

2. Brief description of measures

Municipal (MCM 1.1-1.3) and industrial (MCM 2) waste water treatment plants are identified by red circles in the Hetao drainage basin. The three municipal waste water treatment plants proposed are treated separately mainly due to their large investment costs. Further downstream there is a proposal (MCM 7) to move the outlet of the main drainage canal, passing run-off through natural pre-treatment in the wetland in the northern end of Lake Wuliangsuhai (red circle near lake). MCM 8 is a proposal to undertake erosion control in 15 km^2 of the mountains to the south-east of the lake (brown circle). MCM 6 is a proposal to transfer/import water directly from Yellow River to maintain the water level given decreasing return-flows from irrigated agriculture; the remainder would be released during the dry season back to the Yellow River (blue circle/arrows). A set of measures are proposed for Lake Wuliangsuhai itself(green circles). MCM 3 is a proposal to carry out dredging in several areas to improve fish spawning and transportation, using dredged materials to create islands of interest to birds. MCM 4 proposes to harvest aquatic pondweed (Potamogeton sp.) and utilize it for animal feed. MCM 5 is a proposal to control the spread of reed through harvesting. MCM 9 is a proposal to improve the internal circulation of the lake through a series of levies to redirect currents.

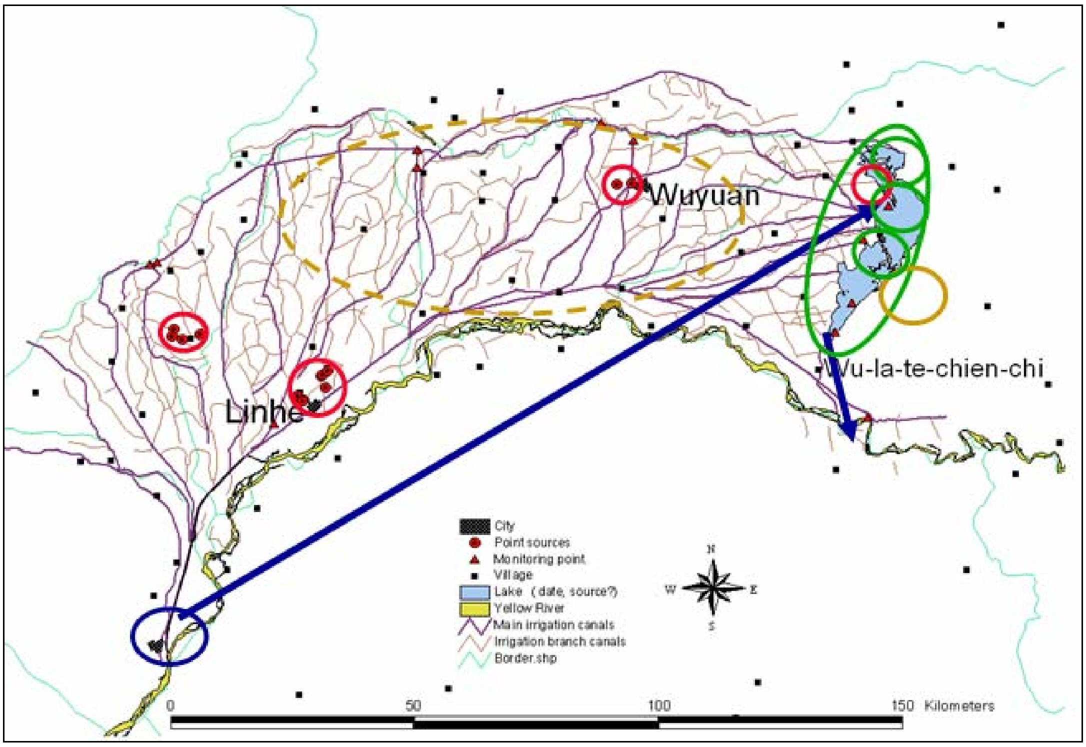


Figure 5: Multiple measures with multiple impacts in the Hetao Basin and Lake Wuliangsuhai

Other measures which were not included in the ranking exercise include agricultural irrigation efficiency measures (brown dashed circle). Compared to original proposals for MCM 3 and MCM 5, the use of dredged mud as fertilizer is not included due to lacking data on technical and commercial feasibility.

3. Stakeholder perspectives and weighting

3.1 Criteria level priorities (Stakeholder Group #1)

The process of weighting will imprint a firm Stakeholder Perspective onto the model outputs. Whereas most of the weighting sessions at Linhe ended with a general consensus, a notable disagreement arose over the relative importance of 1.1 *Pollution emissions from Hetao Basin* vs. *1.3 Lake Water Quality*. There was also initial disagreement on the relative importance 1. ENVIRONMENT versus 2. ECONOMY. Although the whole group of stakeholders reached agreement after some discussion we have chosen to keep this difference relative to Group #1 in the analysis in order to illustrate a possible "minority view" (group #1). Consequently the Workshop ended up with 2 slightly different stakeholder perspectives. The following table reflects those of Stakeholder Group #1, represented by Mr. Li Yawei of IMESI.

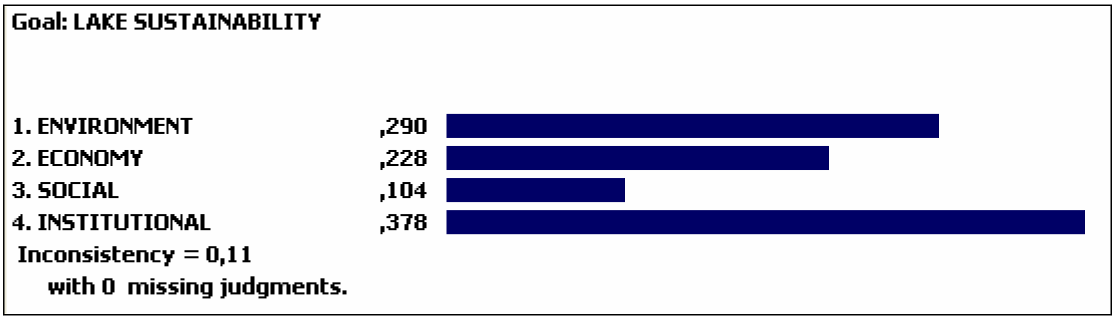


Figure 6: Criteria preferences group #1

Regarding the sustainability of the Lake, the stakeholder perspective as reflected by stakeholder group assigns #1 *INSTITUTIONAL* as the most important criterion, whereas *SOCIAL* is seen as the least important.

3.2 Criteria level priorities (Stakeholder Group #2)

The alternative view, as expressed by Mr. Liu Aijing (fish farm) is presented here denominated as Group #2.

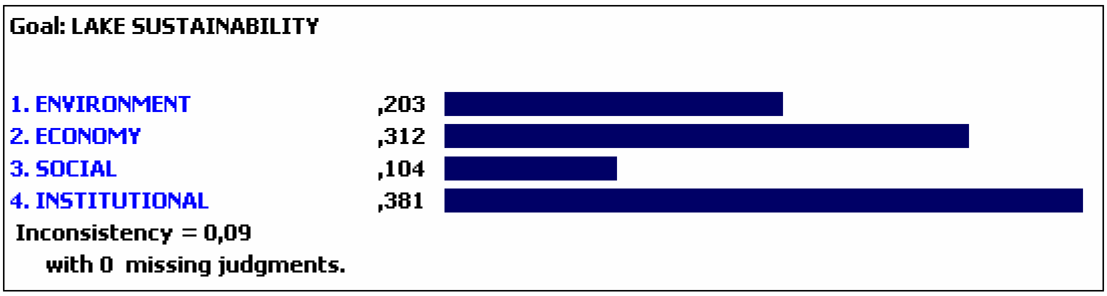


Figure 7: Criteria preferences group #2

3.3 Sub-criteria priorities of stakeholder groups

Moving downwards in the hierarchy we now present the sub-criteria weightings. This only differs for the criteria ENVIRONMENT. For ECONOMY, SOCIAL and INSTITUTIONAL we only present one set of weights that were valid for both groups.
Note that Criterion 2: ECONOMY has only one parameter (cost); consequently no pairwise comparison is possible. The parameter is therefore not included in the following discussion.

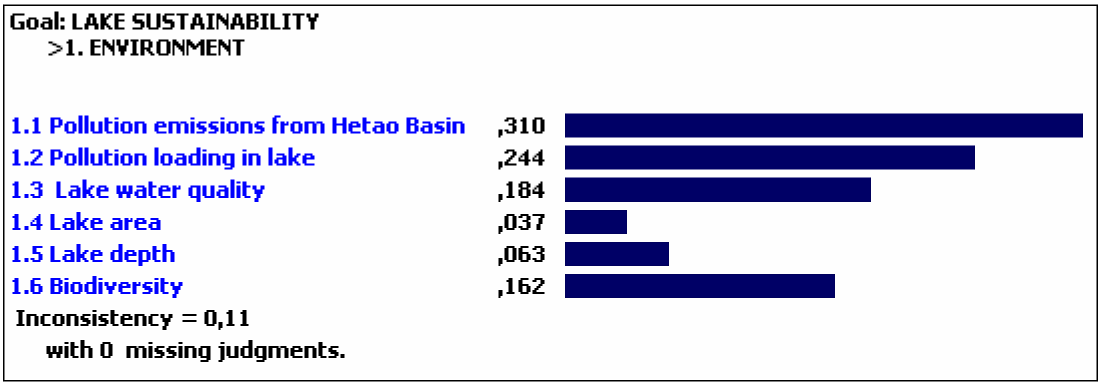


Figure 8: ENVIRONMENT sub-criteria preferences group #1

Regarding the sub-criteria under ENVIRONMENT towards the sustainability of the Lake, the stakeholder perspective from Group #1 assigns *Pollution emissions from Hetao Basin* as the most important criterion, and *Lake (open) area* as the least important.

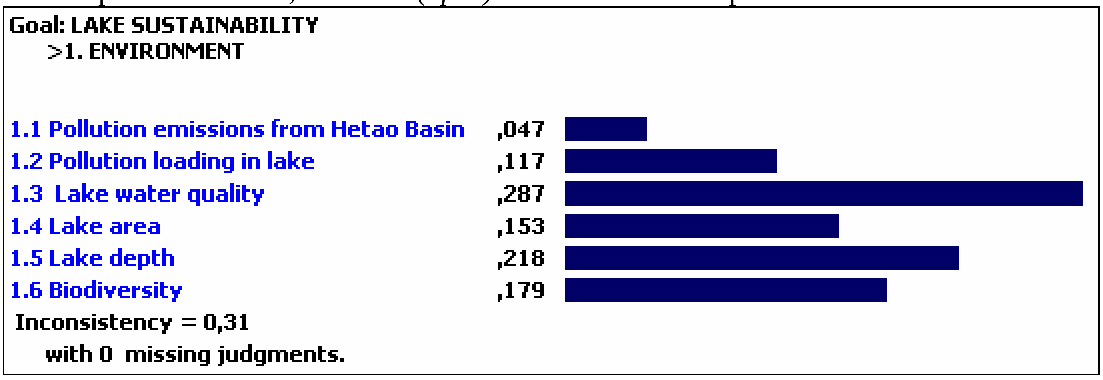


Figure 9: ENVIRONMENT sub-criteria preferences group #2

Regarding the sub-criteria under ENVIRONMENT towards the sustainability of the Lake, the stakeholder perspective from Group #2 assigns *Lake water quality* as the most important criterion, and *Pollution emission from Hetao Basin* as the least important. It is interesting to note that the level of inconsistency in relative preferences is considerably higher for group #2 than group #1 for these sub-criteria, owing to the fact that group #2 prefers 1.3 Lake water quality to 1.2 Pollution Loading in lake.

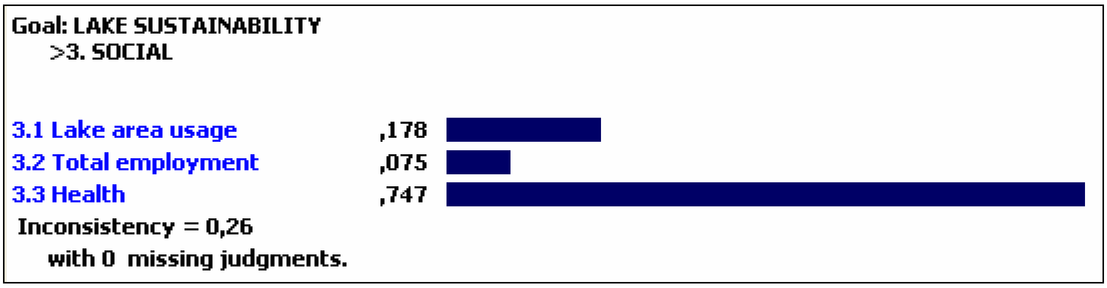


Figure 10: SOCIAL sub-criteria preferences groups #1 and #2

Within the criterion: SOCIAL the stakeholder perspective both groups assign *Health* as the most important criterion, and *3.2 Total employment* as the least important.

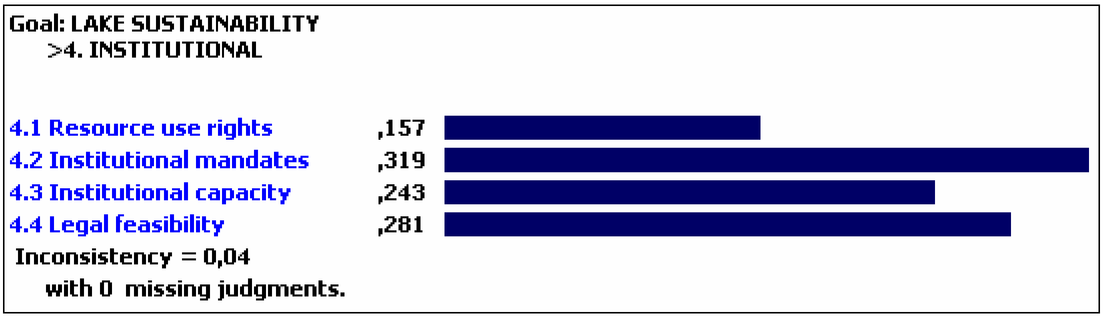


Figure 11: INSTITUTIONAL sub-criteria preferences groups #1 and #2

Within the criterion: INSTITUTIONAL the stakeholder perspective both groups assign *4.3 Institutional mandates* as the most important criterion, and *4.1 Resource use rights* as the least important.

Given all the criteria and their relative weightings in the hierarchy shown in Figure 4, Appendix 6 shows the relative weight/priority of each individual criteria in the ranking of the alternatives.

4. Presentation of ranking results

To recapitulate, the *setting of priority* (also called weighting) is a structural affair; being an independent part of the process, and independent of the field data stored in the Compiled Data Matrix. The *priorities* chosen by the stakeholders can therefore be changed at any time without corrupting or influencing the original data.

The *ranking* of an MCP is the combined effects of a prioritised model and a data set from originating from the MCP's. Consequently, both *values* and *priority* will influence the *ranking score* of a particular MCP.

In order to compare the 'benefits' between the various alternatives (MCM's) an arbitrary but relative 'benefit' value is calculated for each MCM, which are then ranked according to benefit, cost, or both. Variations of these perspectives are presented in the following.

While the multi-criteria approach can indicate what relative 'benefit' will be the result of a particular investment, the method can not indicate at what level the goal will be achieved. In other words, the method can not signal what 'benefit' level will result in the fulfilment of the project goal, i.e. a sustainable conditions for the Lake Wuliangsuhai.

However, the analytical approach offers several advantages. An essentially two-dimensional problem has effectively been narrowed down to a curve. A population of initiatives (MCM's) has been judged against a set of well-defined criteria. What remains is to determine the crucial point on a curve, i.e. when conditions for a sustainable lake (or any of the sub-criteria) have been met. A set of consistent expert opinions will be required in this context.

The multi-criteria hierarchical approach was only adopted for the project during the summer of 2004.   During the course of organising available data for the MCA it became clear that the other project components such as the monitoring and design of measures would have benefited from an earlier decision on the decision-criteria to be used in selecting measures.

It will also be stressed that the analyses and presentations in the following are not cast in stone; rather, the approach is indeed dynamic and should be subject to further refinements and revisions as per developing stakeholder opinions.

Scenario analysis

Scenario analysis differs from sensitivity analysis in that a set of assumptions are analysed simultaneously, be they group preferences, or different assumed states of the lake (clear water, turbid). In sensitivity analysis, individual criteria weights are adjusted one, or a few a time, using a single assumed set of preferences and within a single state of the lake.

Considerable effort was spent during the project in discussing the dangers of algal blooms and a so-called “turbid” state of the lake, due especially to excessive pondweed harvesting (MCM 4). Concensus was reached on the scope of harvesting that could be permissible, but some disagreement still remains on whether the Lake may eventually switch from its present macrophyte dominated “clear” water state to a algal bloom dominated “turbid” state. The effect on several of the measures on lake water quality depended on the assumption of whether the lake was in a “clear” or “turbid” state. For this reason we have evaluated the ranking of MCMs in both scenarios. The data matrices for the “CLEAR” and “TURBID” states may be found in Appendix.

We also tested whether using the different weighting preferences of group #1 or #2 affected ranking results.

Figures 6-1 and 6-2 (appendix 6) demonstrate that ranking of measures is insensitive to which group of stakeholders preferences is used (group #1 or #2) and insensitive to whether a “clear water” or “turbid water” scenario is used. These conclusions were based on a prior evaluation of MCM 1-8 in the March draft of the report. We do not expect this conclusion to change with the addition of MCM 9 in a later version.

This may also be due to the fact that the Project had generated no quantitative data that could be used to further distinguish the impacts of MCM alternatives. The differences between clear water and turbid scenarios were based on expert judgment of whether eutrophication effects would “increase, not change or decrease”.

Given the lack of sensitivity of the ranking to the scenarios and stakeholder groups we based the following comparison of benefits and costs on the “clear” water scenario and the preferences expressed by group #1.

Figure 12: Overall ranking results (benefits) (clear water scenarios, group #1 preferences)

shows the overall ranking results in the clear water scenario and for group #1 preferences, based on environmental, social and institutional impacts only (hereafter called “benefits”). Figure 13: Benefit/cost ranking of measures

shows relative performance of all the alternatives based on benefits and costs. Figure 14: Cumulative costs and benefits when the order of implementation is based solely on the benefits rank of the measure shows cumulative costs and benefits if measures were to be implemented incrementally based on the ranking of benefits.

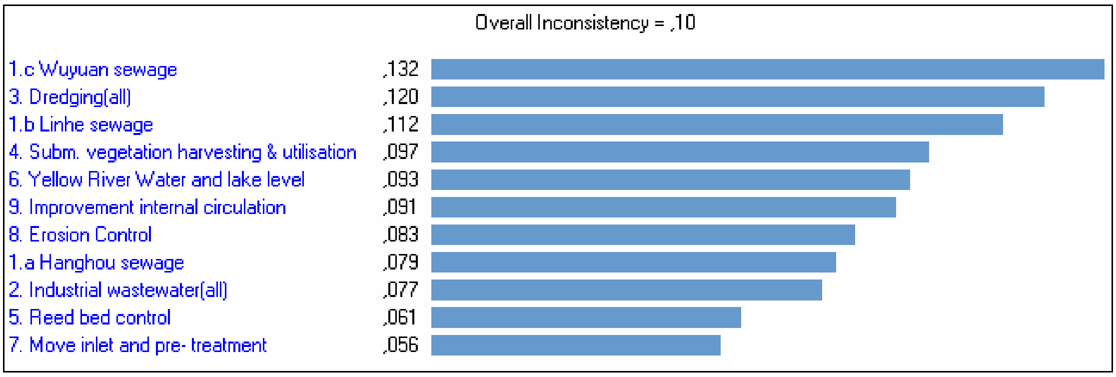


Figure 12: Overall ranking results (benefits) (clear water scenarios, group #1 preferences)

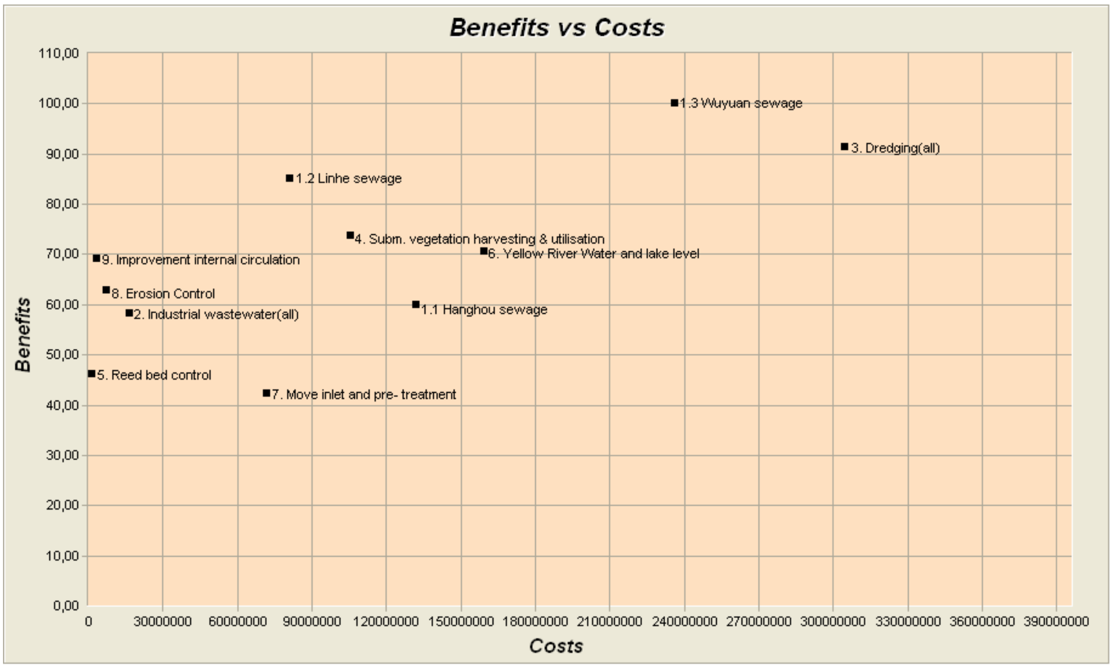


Figure 13: Benefit/cost ranking of measures

The above figure suggests that a ranking of measures is possible based on either benefits alone or their cost/benefits ratio, whereby measures are implemented in order of increasing cost/benefits ratio (the measure with the largest weighted benefits has a normalised score of 100%).

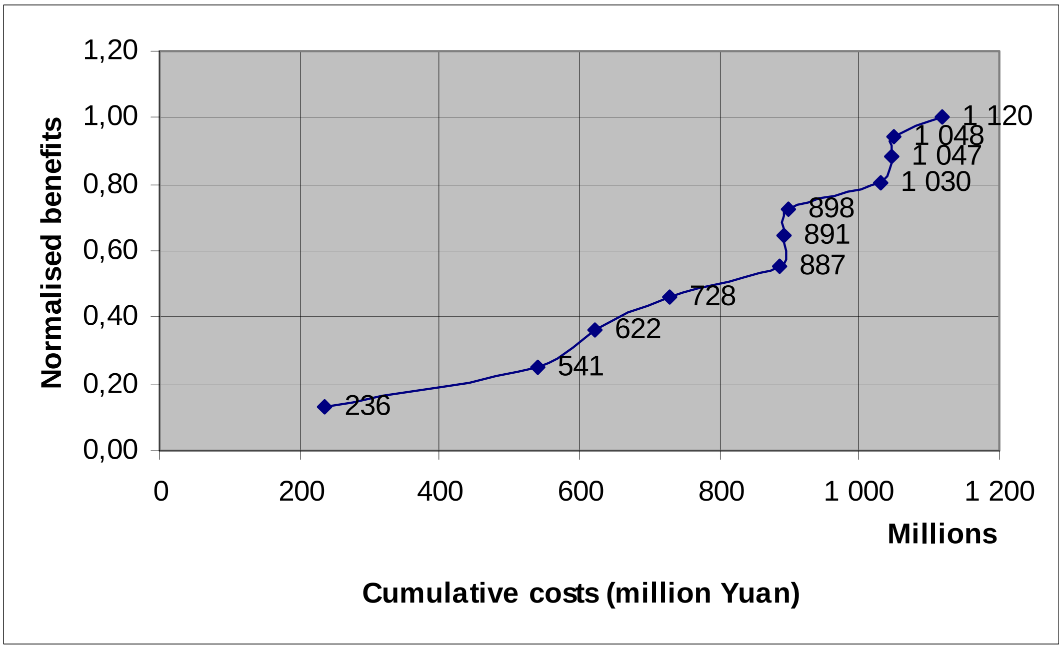
Ranking based on benefits only	Alternative	Individual benefits (normalised)	Individual costs (million Yuan)	Cost/ normalised benefits (million Yuan)	Ranking based on ratio costs/normalised benefits
1	1.3 Wuyuan sewage	1	236 029 934	236 029 934	10
2	3. Dredging(all)	0,914	304 757 590	333 432 812	11
3	1.2 Linhe sewage	0,852	81 376 045	95 511 790	5
4	4. Subm. vegetation harvesting & utilisation	0,738	105 776 571	143 328 687	6
5	6. Yellow River Water and lake level	0,705	159 330 406	226 000 576	9
6	10. Improvement internal circulation	0,691	3 598 918	5 208 275	2
7	8. Erosion Control	0,629	7 213 328	11 467 930	3
8	1.1 Hanghou sewage	0,599	132 093 951	220 524 125	8
9	2. Industrial wastewater(all)	0,582	16 425 647	28 222 761	4
10	5. Reed bed control	0,462	1 249 238	2 703 978	1
11	7. Move inlet and pre- treatment	0,423	71 797 479	169 733 993	7

Table 1: Cumulative costs and benefits of management and control measures (unweighted)**Error! Reference source not found.** illustrates in the first column the ranking of measures if implementation is based only on environmental, social and institutional criteria (benefits). The last column illustrates the ranking if the cost/normalised benefits ratio is used. The latter illustrates the limitation of the MCA analysis when the cost of measures varies across a large scale, while the qualitative characterisation of impacts does not capture the same variation in scale[1]. Consequently, the ranking based on cost/benefit ratio more or less implies implementing the cheapest measures first (because relatively little information is provided on the scale of benefits). Investments towards establishing sustainable conditions of the Lake Wuliangsuhai should follow this sequence if the budget for implementation is restricted or only gradually made available.

NB! In a later revision of the report – including two very cheap measures (reed bed control alone, and improvement of internal circulation) has made the problem of ranking measures of different scale more obvious[2].

If the order of implementation of measures is based solely on their benefits, Figure 14: Cumulative costs and benefits when the order of implementation is based solely on the benefits rank of the measure shows cumulative costs and benefits of incremental implementation. The multiple criteria analysis does not answer the questions of how many of the measures are needed to reach the goal of sustainable development of the lake. In other words, we cannot say at what level of normalised cumulative benefits (Y-axis) the lake attains sustainability.

This depends amongst other things on water management decisions in the greater Yellow River which are not included in the ranking exercise. See the separate report on Economic Analysis of Water Allocation (this Project) for a discussion.



[1] The April 2005 version of the report provided only information on the ranking based on the cost/benefit ratio.

[2] A way to deal with this scale problem is to include implementation costs in the analysis as any other criteria, weighting its relative importance. This issue was not foreseen in the November workshop when measures had similar scale. For this reason we do not have any information on the relative importance of costs versus other criteria from the stakeholders.

Figure 14: Cumulative costs and benefits when the order of implementation is based solely on the benefits rank of the measure

Note to Figure 14:

Ranking based on benefits only	Alternative	Individual normalised benefits	Cumulative costs (present value)
1	1.3 Wuyuan sewage	0,13	236 029 934
2	3. Dredging(all)	0,25	540 787 524
3	1.2 Linhe sewage	0,36	622 163 569
4	4. Subm. vegetation harvesting & utilisation	0,46	727 940 140
5	6. Yellow River Water and lake level	0,55	887 270 546
6	10. Improvement internal circulation	0,65	890 869 464
7	8. Erosion Control	0,73	898 082 792
8	1.1 Hanghou sewage	0,81	1 030 176 743
9	2. Industrial wastewater(all)	0,88	1 046 602 390
10	5. Reed bed control	0,94	1 047 851 628
11	7. Move inlet and pre- treatment	1,00	1 119 649 107

5. Sensitivity analysis

We have seen that the ranking of management and control measures is insensitive to which stakeholder groups preferences are used, as well as to uncertainties regarding the effects of measures under a “clear water “ and a “turbid water “ scenario. In this section we test the stability of the ranking to some more extreme assumptions where only environmental, social and institutional criteria are given importance in that order. This hypothetical analysis illustrates the importance of a balanced integrated study, supported by a multiple criteria decision-making framework that allows for the evaluation of multiple impacts. Once again the sensitivity analyses in the following figures are based on the “clear water “ scenario with preferences of group #1.

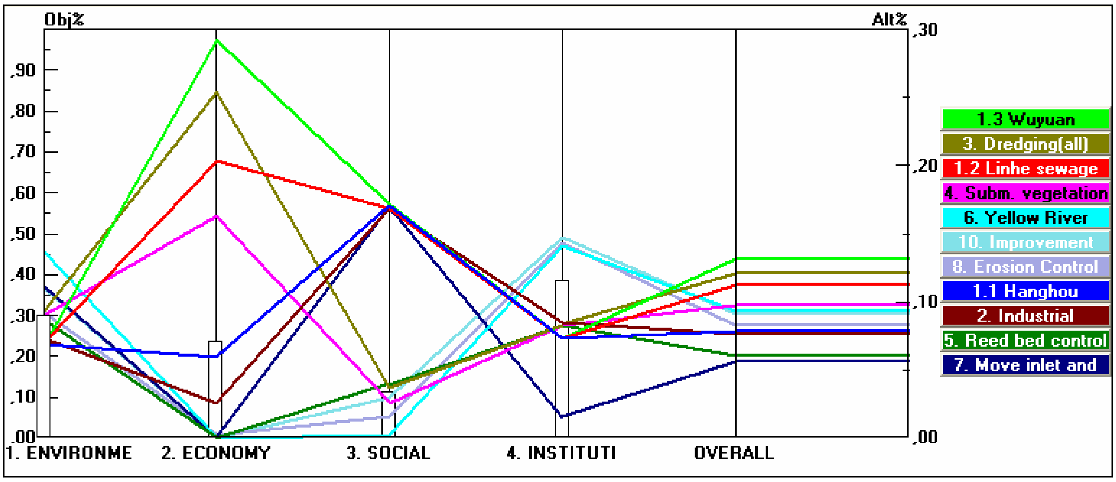


Figure 15: Ranking of alternatives -original stakeholder group #1 criteria weighting

The original weighting of criteria by stakeholder group #1 and the resulting weighting is reflected in Figure 15: Ranking of alternatives -original stakeholder group #1 criteria weighting

. Ranking is sensitive to this weighting (versus no preference in Figure 16: Ranking of alternatives – no preference/equal weighting

), with the exception of 1.3 Wuyuan urban sewage measure which is always preferred.

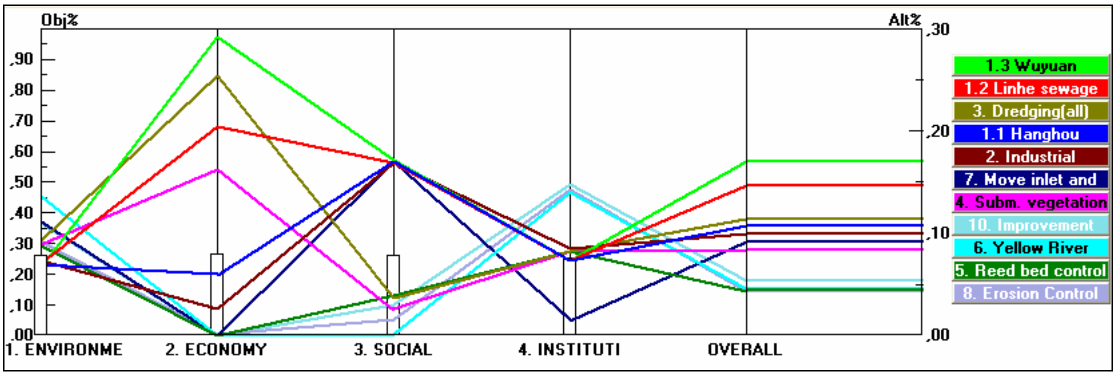


Figure 16: Ranking of alternatives – no preference/equal weighting

Figures 17-20 show the sensitivity of ranking to absolute priority/weighting being given to each criteria in turn. The analysis simply shows the importance of a balanced impact analysis which includes social, income generation(economy) and institutional criteria, in addition to the original environmental focus of the project.

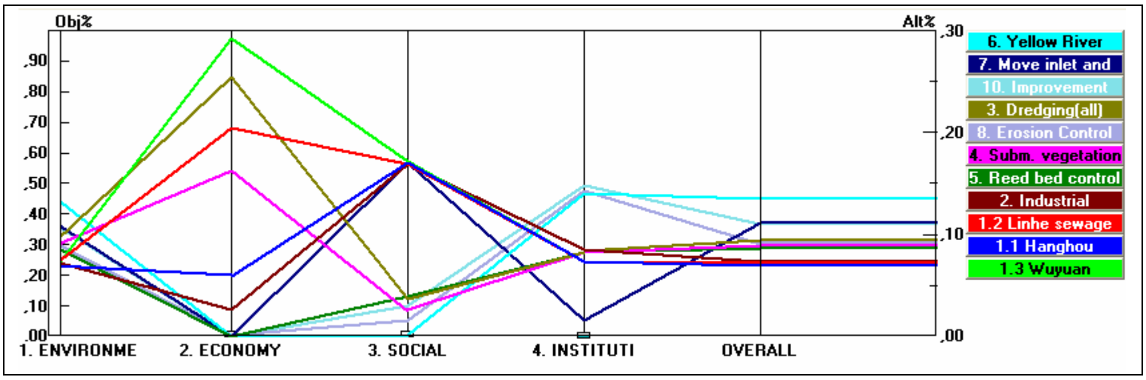


Figure 17: Ranking of alternatives – absolute priority to environmental feasibility

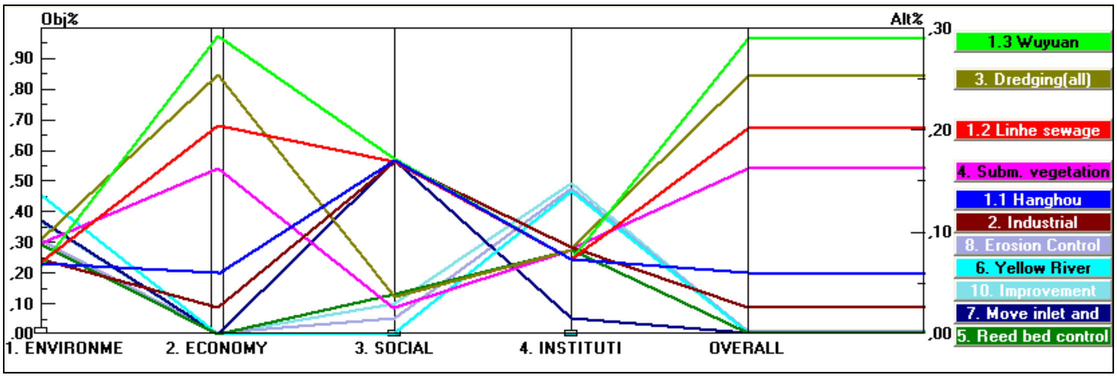


Figure 18: Ranking of alternatives – absolute priority to income generation (economy)

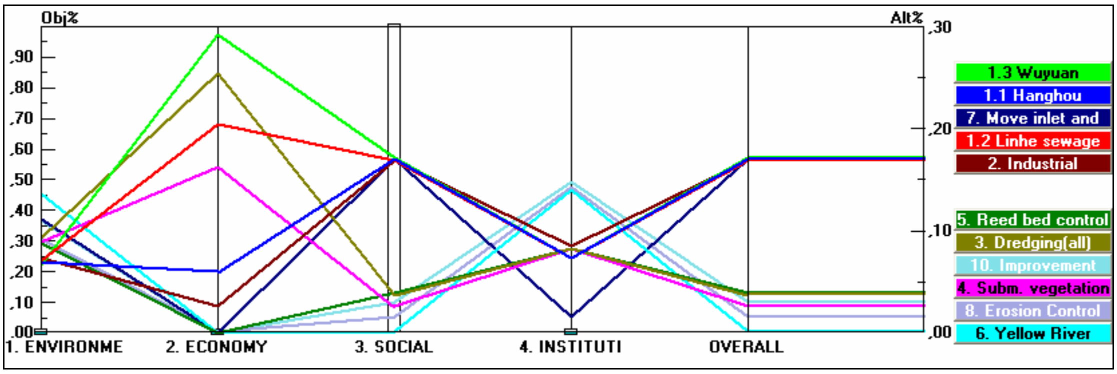


Figure 19: Ranking of alternatives – absolute priority to social feasibility

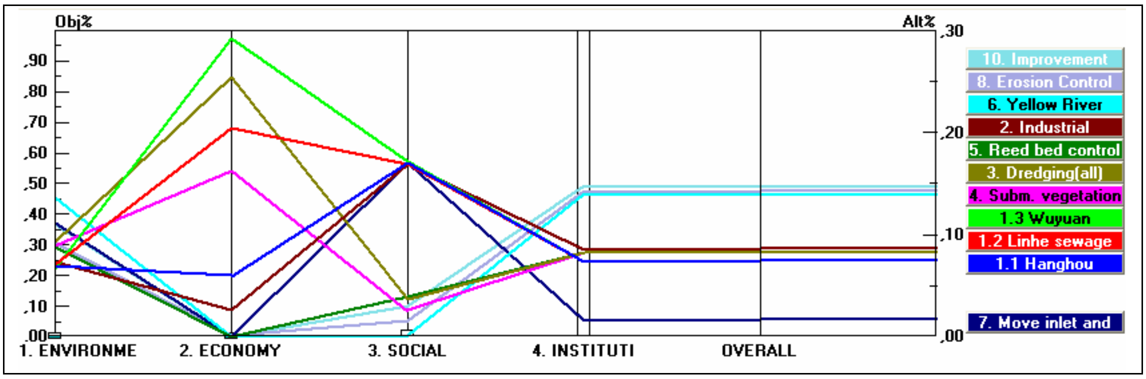


Figure 20: Performance of alternatives – absolute priority to institutional feasibility

6. Limitations and caveats

In this section we summarise the principal limitations of the analysis and caveats in interpretating the results of the MCA ranking.

- For a number of reasons the project did not employ quantitative models to predict environmental impact of the respective measures. Project experts characterised impacts qualitatively in terms of positive/negative/no impact in most cases, given professional reluctance to provide e.g. ordinal scores (1,2,3 etc.) for the respective impacts. This results in the multiple criteria analysis having greater difficulty in ranking measures based on environmental impact. The cost of measures is therefore instrumental in defining a unique ranking of measures.

- When costs were revised/rescaled for whatever reason, environmental impacts have not necessarily been rescaled accordingly. This was particularly true of the erosion MCM which had significantly lower revised costs, but no change in impact supplied from the author in charge of the measure MCP.

- A multiple criteria analysis with qualitative impacts does not do a good job of taking the scale of measures into account. In general, small measures with low costs (and possibly relatively limited impact) will be favoured by the methodology because environmental impact has no scale dimension (-/0/+).

Expectations versus modelled ranking results

Observations were made by the Chinese project manager regarding deviations between ranking results that were expected, versus what the MCA suggested. These are issues that might be pursued if new data on MC measures is to be generated.

The project manager would have expected the following outcome of the ranking: (1) Introduce water from Yellow River, (2) Move inlet and pre-treatment area, while these were in fact ranked as measures 4 and 11 respectively, with Wuyan and Linhe municipal treatment as 1 and 2. As stated above this is probably due to limitations inherent inusing qualitative impact indicators and quantitative evaluation of costs. This underlines the importance of the sensitivity analysis in the previous section.

7. Appendices

Appendix 1: Data matrix – Clear water scenario

	Costs	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.1 Delta P emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.2 Delta N emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.3 Delta COD emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.4 Delta soil loss	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.1 Delta P loading	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.2 Delta N loading	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.3 Delta COD loading	1. ENVIRONMENT|1.3 Lake water quality|1.3.1 Delta turbidity	1. ENVIRONMENT|1.3 Lake water quality|1.3.2 Delta salinity	1. ENVIRONMENT|1.3 Lake water quality|1.3.3 Delta bioavailable P	1. ENVIRONMENT|1.3 Lake water quality|1.3.4 Delta bioavailable N	1. ENVIRONMENT|1.3 Lake water quality|1.3.5 Delta dissolved oxygen	1. ENVIRONMENT|1.3 Lake water quality|1.3.6 Delta phytoplankton	1. ENVIRONMENT|1.3 Lake water quality|1.3.7 Delta attached algae	1. ENVIRONMENT|1.3 Lake water quality|1.3.8 Delta Potamogeton
UNITS	Yuan	tonnes tot-P/year	tonnes tot-N/year	tonnes COD/year	tonnes/year	tonnes tot-P/year	tonnes tot-N/year	tonnes COD/year	Secchi depth (m)	Conductivity (mS/M)	phosphate mg / l	nitrate mg / l	DO mg/l	Chlorophyl A mg/l	Chlorophyl A mg/l	wet weight / m2
	1	2	3	4	6				7	8	9	10	11	12	13	14
CRITERION		1. ENVIRONMENT														
SUB CRITERION		1.1 Pollution emissions from Hetao				1.2 Pollution loading in lake			1.3 Lake water quality							
INDICATOR	Cost	1.1.1	1.1.2	1.1.3	1.1.4	1.2.1	1.2.2	1.2.3	1.3.1	1.3.2	1.3.3	1.3.4	1.3.5	1.3.6	1.3.7	1.3.8
1.a Hanghou sewage	132 093 951	-19	-50	-838	none	0	0	none	none	none	decr	minor decr	minor decr	decr	decr	minor decr
1.b Linhe sewage	81 376 045	-33	-96	-2349	none	0	0	none	none	none	decr	minor decr	minor decr	decr	decr	minor decr
1.c Wuyuan sewage	236 029 934	-6	-9	-734	none	0	0	none	none	none	decr	minor decr	minor decr	decr	decr	minor decr
2. Industrial wastewater(all)	16 425 648	-5	-464	-7639	none	0	0	none	none	none	decr	decr	decr	decr	decr	minor decr
3. Dredging(all)	304 757 590	-140	-650	0	none	0	0	none	none	none	none	none	none	incr	decr	decr
4. Subm. vegetation harvesting & utilisation	105 776 572	-61	-530	0	none	-61	-530	none	none	none	none	none	none	minor incr	decr	decr
5. Reed bed control	1 249 239	0	0	0	none	0	0	none	none	none	incr	incr	none	none	none	none
6. Yellow River Water and lake level	159 330 406	0	0	0	none	0	0	none	incr	none	decr	decr	incr	decr	decr	none
7. Move inlet and pre- treatment	71 797 400	-64	-1100	0	none	-38	-500	decr	decr	none	decr	decr	incr	decr	decr	decr
8. Erosion Control	7 213 320	0	0	0	decr	0	0	none	decr	none	none	none	none	none	none	none
9. Improvement internal circulation	3 598 910	0	0	0	none	0	0	none	incr	decr	decr	decr	incr	minor decr	minor decr	none

	1. ENVIRONMENT|1.4 Lake area|1.4.1 Delta open water area	1. ENVIRONMENT|1.4 Lake area|1.4.2 Delta reed area	1. ENVIRONMENT|1.5 Lake depth|1.5.1 Delta sedimentation rate (organic)	1. ENVIRONMENT|1.5Lake depth|1.5.2 Delta sedimentation rate (inorganic)	1. ENVIRONMENT|1.5 Lake depth|1.5.3 Delta lake depth (bottom elevation)	1. ENVIRONMENT|1.5 Lake depth|1.5.4 Delta lake level	1. ENVIRONMENT|1.5 Lake depth|1.5.5 Delta water inflow	1. ENVIRONMENT|1.6 Biodiversity|1.6.1 Del	1. ENVIRONMENT|1.6 Biodiversity|1.6.2 Del	1. ENVIRONMENT|1.6 Biodiversity|1.6.3 Delta fish stocks	1. ENVIRONMENT|1.6 Biodiversity|1.6.4 Delta fish species richness	2. ECONOMY|2.2 Gross annual income from MCP related activities	3. SOCIAL|3.1 Lake area usage|3.1.1 Lake area use conflict|(L: 1,000)	3. SOCIAL|3.2 Employment|3.2.1 Total employment from operational phase	3. SOCIAL|3.2 Employment|3.2.2 Total employment from construction phase	3. SOCIAL|3.3 Health	4. INSTITUTIONAL|4.1 Resource use rights|4.1.1 Irrigation water use rights	4. INSTITUTIONAL|4.1 Resource use rights|4.1.2 Land use rights	4. INSTITUTIONAL|4.2 Institutional mandates|4.2.1 Monitoring and enforcing mandate clear	4. INSTITUTIONAL|4.4 Legal feasibility|4.4.1 Institutional capacity|	4. INSTITUTIONAL|4.5 Legal feasibility|4.5.1 MCP action permit required|
UNITS	km2	km2 Phragmites	mm/year	mm/year	m depth	meters over sea level	m3/year	# different wet landcove	# bird species observed	tonnes catch per unit effort	# fish species observed	Present value (Yuan)	Increase / decrease	Number of employees	Number of emplyees /year	Infant mortality rate	conflict/no change	conflict/minor conflict/no change	yes/no	1-5 (5 is best)	yes/no
	15	16	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	36	37	38
CRITERION	1. ENVIRONMENT											2.EC	3. SOCIAL				4. INSTITUTIONAL				
SUB CRITERION	1.4 Lake area		1.5 Lake depth					1.6 Biodiversity				2.1	3.1	3.2 Empl.		3.3 H	4.1 Res.		4.2	4.3	4.4
INDICATOR	1.4.1	1.4.2	1.5.1	1.5.2	1.5.3	1.5.4	1.5.5	1.6.1	1.6.2	1.6.3	1.6.4	2.2.1	3.1.1	3.2.1	3.2.2	3.3.1	4.1.1	4.1.2	4.2.1	4.3.1	4.4.1
1.a Hanghou sewage	NA	NA	decr	none	0,00	0,00	-4230000	NA	NA	NA	NA	52 597 129	NA	30	1900	incr	none	none	yes	2	no
1.b Linhe sewage	NA	NA	decr	none	0,00	0,00	-9380000	NA	NA	NA	NA	180 616 557	NA	30	650	incr	none	none	yes	2	no
1.c Wuyuan sewage	NA	NA	decr	none	0,00	0,00	-16940000	NA	NA	NA	NA	258 943 877	NA	30	2800	incr	none	none	yes	2	no
2. Industrial wastewater(all)	NA	NA	minor decr	none	0,00	0,00	-1500000	NA	NA	NA	NA	22 554 515	NA	30	260	incr	none	none	yes	3	no
3. Dredging(all)	incr	none	none	none	0,22	0,00	0	incr	incr	incr	incr	225 545 151	none	60	0	none	NA	NA	NA	NA	NA
4. Subm. vegetation harvesting & utilisation	incr	none	none	none	0,00	0,00	0	incr	incr	incr	incr	144 348 897	incr	201	0	none	NA	NA	NA	NA	NA
5. Reed bed control	none	minor decr	none	none	0,00	0,00	0	none	minor incr	none	none	0	none	79	0	none	NA	NA	NA	NA	NA
6. Yellow River Water and lake level	minor incr	incr	incr	incr	0,80	0,80	253000000	minor incr	none	incr	none	0	incr	0	1250	none	none	conflict	yes	3	yes
7. Move inlet and pre- treatment	none	none	none	decr	0,05	0,00	0	none	incr	none	none	0	minor incr	30	1250	incr	none	minor conflict	no	1	no
8. Erosion Control	incr	decr	none	decr	0,00	0,00		incr	incr	none	none	1 454 760	minor incr	5	130	none	incr	NA	no	3	yes
9. Improvement internal circulation	none	none	none	none	0,00	0,00	0	minor incr	none	minor incr	minor incr	0	none	0	40	none	none	none	yes	3	yes

Note: this matrix was revised 29.8.05.

Appendix 2: Data matrix – Turbid water scenario

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		Costs	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.1 Delta P emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.2 Delta N emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.3 Delta COD emissions	1. ENVIRONMENT|1.1 Pollution emissions from Hetao|1.1.4 Delta soil loss	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.1 Delta P loading	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.2 Delta N loading	1. ENVIRONMENT|1.2 Pollution loading in lake|1.2.3 Delta COD loading	1. ENVIRONMENT|1.3 Lake water quality|1.3.1 Delta turbidity	1. ENVIRONMENT|1.3 Lake water quality|1.3.2 Delta salinity	1. ENVIRONMENT|1.3 Lake water quality|1.3.3 Delta bioavailable P	1. ENVIRONMENT|1.3 Lake water quality|1.3.4 Delta bioavailable N	1. ENVIRONMENT|1.3 Lake water quality|1.3.5 Delta dissolved oxygen	1. ENVIRONMENT|1.3 Lake water quality|1.3.6 Delta phytoplankton	1. ENVIRONMENT|1.3 Lake water quality|1.3.7 Delta attached algae	1. ENVIRONMENT|1.3 Lake water quality|1.3.8 Delta Potamogeton
2	UNITS	Yuan	tonnes tot-P/year	tonnes tot-N/year	tonnes COD/year	tonnes/year	tonnes tot-P/year	tonnes tot-N/year	tonnes COD/year	Secchi depth (m)	Conductivity (ms/M)	phosphate mg / l	nitrate mg / l	DO mg/l	Chlorophyl A mg/l	Chlorophyl A mg/l	wet weight / m2
3		1	2	3	4	6				7	8	9	10	11	12	13	14
4	CRITERION		1. ENVIRONMENT														
5	SUB CRITERION		1.1 Pollution emissions from Hetao				1.2 Pollution loading in lake			1.3 Lake water quality							
6	INDICATOR	Cost	1.1.1	1.1.2	1.1.3	1.1.4	1.2.1	1.2.2	1.2.3	1.3.1	1.3.2	1.3.3	1.3.4	1.3.5	1.3.6	1.3.7	1.3.8
7	1.1 Hanghou sewage	143 283 666	-4	-27	-570	none	0	0	0	none	none	decr	minor decr	minor decr	decr	decr	minor decr
8	1.2 Linhe sewage	48 930 600	-22	-90	-2190	none	0	0	0	none	none	decr	minor decr	minor decr	decr	decr	minor decr
9	1.3 Wuyuan sewage	208 204 934	3	-14	-216	none	0	0	0	none	none	decr	minor decr	minor decr	decr	decr	minor decr
10	2. Industrial wastewater(all)	19 671 000	-2	-460	-7200	none	0	0	0	none	none	decr	decr	decr	decr	decr	minor decr
11	3. Dredging(all)	309 930 000	0	0	0	none	0	0	0	none	none	none	none	incr	incr	decr	decr
12	4. Subm. vegetation harvesting & utilisation	101 238 651	0	0	0	none	-61	-530	0	decr	none	incr	incr	none	incr	decr	decr
13	5. Reed bed control & mud utilisation	72 875 934	0	0	0	none	0	0	0	decr	none	incr	incr	none	incr	minor decr	none
14	6. Yellow River Water and lake level	37 000 000	0	0	0	decr	0	0	0	incr	none	decr	decr	incr	decr	decr	none
15	7. Move inlet and pre- treatment	28 400 000	0	0	0	none	-38	-500	decr	decr	none	decr	decr	incr	decr	decr	decr
16	8. Erosion Control	3 974 500	0	0	0	decr	0	0	0	decr	none	none	none	none	none	none	none

	A	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
1		1. ENVIRONMENT|1.4 Lake area|1.4.1 Delta open water area	1. ENVIRONMENT|1.4 Lake area|1.4.2 Delta reed area	1. ENVIRONMENT|1.5 Lake depth|1.5.1 Delta sedimentation rate (organic)	1. ENVIRONMENT|1.5Lake depth|1.5.2 Delta sedimentation rate (inorganic)	1. ENVIRONMENT|1.5 Lake depth|1.5.3 Delta lake depth (bottom elevation)	1. ENVIRONMENT|1.5 Lake depth|1.5.4 Delta lake level	1. ENVIRONMENT|1.5 Lake depth|1.5.5 Delta water inflow	1. ENVIRONMENT|1.6 Biodiversity|	1. ENVIRONMENT|1.6 Biodiversity|	1. ENVIRONMENT|1.6 Biodiversity|1.6.3 Delta fish stocks	1. ENVIRONMENT|1.6 Biodiversity|1.6.4 Delta fish species richness	2. ECONOMY|2.2 Gross annual income from MCP related activities	3. SOCIAL|3.1 Lake area usage|3.1.1 Lake area use conflict|(L: 1,000)	3. SOCIAL|3.2 Employment|3.2.1 Total employment from operational phase	3. SOCIAL|3.2 Employment|3.2.2 Total employment from construction phase	3. SOCIAL|3.3 Health	4. INSTITUTIONAL|4.1 Resource use rights|4.1.1 Irrigation water use rights	4. INSTITUTIONAL|4.1 Resource use rights|4.1.2 Land use rights	4. INSTITUTIONAL|4.2 Institutional mandates|4.2.1 Monitoring and enforcing mandate clear	4. INSTITUTIONAL|4.4 Legal feasibility|4.4.1 Institutional capacity|	4. INSTITUTIONAL|4.5 Legal feasibility|4.5.1 MCP action permit required|
2	UNITS	km2	km2 Phragmites	mm/year	mm/year	m depth	meters over sea level	m3/year	# different wet landcover	# bird species observed	tonnes catch per unit effort	# fish species observed	Present value (Yuan)	Increase / decrease	Number of employees	Number of emplyees /year	Infant mortality rate	conflict/no change	conflict/minor conflict/no change	yes/no	1-5 (5 is best)	yes/no
3		15	16	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	36	37	38
4	CRITERION												2.EC	3. SOCIAL				4. INSTITUTIONAL				
5	SUB CRITERION	1.4 Lake area		1.5 Lake depth					1.6 Biodiversity				2.1	3,1	3.2 Empl.		3.3 H	4.1 Res.		4.2	4.3	4.4
6	INDICATOR	1.4.1	1.4.2	1.5.1	1.5.2	1.5.3	1.5.4	1.5.5	1.6.1	1.6.2	1.6.3	1.6.4	2.2.1	3.1.1	3.2.1	3.2.2	3.3.1	4.1.1	4.1.2	4.2.1	4.3.1	4.4.1
7	1.1 Hanghou sewage	NA	NA	decr	none	0,00	0,00	-4230000	NA	NA	NA	NA	5830000	NA	30	1900	incr	none	none	yes	2	no
8	1.2 Linhe sewage	NA	NA	decr	none	0,00	0,00	-9380000	NA	NA	NA	NA	20020000	NA	30	650	incr	none	none	yes	2	no
9	1.3 Wuyuan sewage	NA	NA	decr	none	0,00	0,00	-16940000	NA	NA	NA	NA	28702000	NA	30	2800	incr	none	none	yes	2	no
10	2. Industrial wastewater(all)	NA	NA	minor decr	none	0,00	0,00	-1500000	NA	NA	NA	NA	2500000	NA	30	260	incr	none	none	yes	3	no
11	3. Dredging(all)	incr	none	none	none	0,22	0,00	0	incr	incr	incr	none	NA	none	incr	0	none	NA	NA	NA	NA	NA
12	4. Subm. vegetation harvesting & utilisation	incr	none	none	none	0,00	0,00	0	incr	incr	incr	incr	15000000	incr	201	0	none	NA	NA	NA	NA	NA
13	5. Reed bed control & mud utilisation	minor incr	dec	none	none	0,00	0,00	0	incr	minor incr	none	none	25000000	incr	79	0	none	NA	NA	NA	NA	NA
14	6. Yellow River Water and lake level	minor incr	incr	incr	incr	0,80	0,80	253000000	minor incr	none	incr	none	0	incr	0	1250	none	none	conflict	yes	3	yes
15	7. Move inlet and pre- treatment	none	none	none	decr		0,00	0	none	incr	none	none	0	minor incr	30	1250	incr	none	minor conflict	no	1	no
16	8. Erosion Control	incr	decr	none	decr	0,00	0,00		incr	incr	none	none	0	minor incr	5	130	none	incr	NA	no	3	yes

Note: values in red indicate the differences between the “turbid” and “clear” water. This matrix was last revised for the March 27 version of the report. The turbid water scenario was not used in the present (April version of the report).

Appendix 3: Agenda and minutes from workshop

The following agenda was presented to the participants at the Linhe workshop 23-24 November 2004. Note that the final *Session 4* was effectively implemented under the auspices of IMESI and consequently beyond the mandate of the priority setting and ranking session:

AGENDA

Lake Wuliangsuhai Restoration Project
3rd Workshop, 23-24 November, 2004

Consolidation of Management and Control Plans
through Multi-criteria Decision Support

Linhe, Inner Mongolia

IMESI - IVL - NIVA

23 Nov.	DAY 1, session 1 (before lunch break)
	Brief review of concepts, including Objectives Indicators Priority Weight Criteria, and levels of criteria The data matrix
	DAY 1, session 2 (after lunch break)
	Setting of priorities: Participants will establish priorities (weights) of (as many as possible) of important criteria.
24. Nov.	DAY 2, session 3 (before lunch break)
	Model outputs Scenarios Discussion Recommended revisions for the data matrix

Minutes from workshop on weighting and ranking sessions I-IV, 23-24 November 2004

Notes taken by Erik Lindblom, IVL

Session 1 – Introduction
8.45: **Mr Ruden** opened the meeting and welcomed the participants.
9.05: **Mr Li Yawei** introduced the project and this workshop to new participants.
9.20: The session continued with a justification of the choice of method, given by **Mr Ruden**. In order to rationally prioritise the suggested measures, especially if considering a variety of different aspects ranging from environmental and economical effects to social and institutional, a method or model is needed. The model used within this project relies on the concept of indicators, which was introduced in some detail. The indicators are used to succinctly describe the larger context. By wisely choosing the indicators even a number of comprehensive feasibility reports can be condensed into a limited data matrix, used by the method.
The model is schematically divided into three steps:
Summarise available information in a limited number of relevant indicators. For each suggested measure values are assigned to all measures, either continuous (e.g. load in tonnes per year) or discrete (increase/decrease).
Weight the indicators according to their importance for actual effect.
Calculate the score for each action based on the actual value of the indicator and the indicator's weight. Sum the score of all indicators to get the measures total benefit value.
A more detailed demonstration of weighting followed.

10.15 – 10.25: Break
Mr Lindblom presented the set of measures included in the current model. It differed somewhat from the original list of fifteen measures due to how the measures are interrelated (some measures are combined into one option) or lack of data. The participants commented on the suggested set:
It is not satisfying that the entire measure 3 (Agriculture) is excluded. At least some of its effects need to be included in some way. Possibly it can be described as a condition for the rest of the measures.
Internal circulation should be grouped with Reed bed control instead.
Raising water level should be combined Introduce water from Yellow River.

11.00: Since the introduction proceeded faster than planned for, the weighting of the first indicator set, "Pollution emissions from Hetao", was begun, led by **Mr Ruden**. Initially **Mr Shang's** opinion was very influential. **Ms Li Xiaoxia** assisted with translations and explanations. **Mr Li** and **Ms Liu** took active part. The discussion was quite intense, as different participants expressed their opinions and the method became clearer. After the first set of weights was given, more people were involved in the discussion. New questions were raised on specific details. Especially puzzling in the beginning was how to regard the indicators generally, ignoring the actual values given for different measures.

The remaining indicator sets belonging to the criteria group "Environment" were weighted before lunch. **Mr Li** took the lead in the exercise, which sometimes reminded of an auction were specific weights were raised or lowered by the group, with **Mr Li** as the auctioneer. All proceeded surprisingly fast and efficient. At this stage also **Mr Liu** and **Mr BaMeng EPB** and **Mr Fish Farm** were actively involved.

12.00 – 15.00: Lunch

Session 2 – Weighting

Due to the efficient morning session, we were well ahead of plan. Only half an hour remained until all sub-criterions were weighted. This accomplishment was a result of the group's astonishingly quick adaptation of the method and the active and enthusiastic role played by **Mr Li**.

We continued with weighting of the higher levels of criteria-groupings. As we proceeded upwards in the hierarchy (in total three levels), the focus shifted from specific technical details, via administrational viewpoints to more of policymaking. A few more participants took part in the discussion at this level.

A first difficulty was encountered when comparing water quality and pollution emissions. Two opinions were firmly expressed, weighting them as 3:1 or 1:2 respectively. These different expert opinions required different sets of weights. Secondly, the institutional criterions were a bit confusing. The meanings had to be explained and exemplified a number of times.

There was a short controversy when comparing Environment and Economy. **Mr Liu** however concluded "I'd rather be a beggar in Norway than an official in China". Soon there was a common agreement on how to weight Environment over Economy.

16.45: All weights were assigned, still well ahead of schedule. When going through the results, examining the indicator groups one by one and also noting the inconsistency values, a few sets were revised. This required a recollection of which indicators actually are included in each group, which was good for the general understanding and as a quality control of outcome of the day's work.

Session 3 – Results
8.30: Unfortunately we experienced an unwelcome program crash. Instead of preparing the day's presentation we had to restore as much of yesterday's work as possible. Most of the data was available as back-up, but a few details were lost. The first part of the morning's session was thus used as a recollection of the previous day, where the last lost details were entered. This was quickly finished.

After this the session could continue according to plan. The result was given, both on the lower levels (score per indicator for a certain measure, or score assigned the measures for a certain indicator) and the total score for all measures. The different measures were both presented in two ways:
Total benefit, as graphs where the totals were easily comparable.
Cost – benefit, where each measure is placed in grid with cost on the X-axis and benefit on the Y-axis.

10.00 – 10.15: Break
After the break the result of a slightly changed set of weights was presented. However, the result could not be discriminated from the original one, so it required no further comments.

There was a sense of disappointment, or anticlimax in the room. Apparently the participants did not fully appreciate the accomplishment. Instead they wanted to move forward, to discuss how the abstract scale of benefit should be interpreted and who should decide which level of benefit (i.e. which of the proposed measures should be implemented) is necessary for the lake's survival. This was however not part of the workshop, or in the mandate given to **Mr Ruden** and **Mr Lindblom**.

The ranked list of MCP's indicated what order to start the implementation process, how to proceed, but not when to stop. The task of presenting a ranked list & corresponding price tags was given to the Messrs. Ruden & Lindblom, to be presented during Session 4, below.

What were discussed were the necessary future steps to finish this process. The meeting agreed on the following:

Quality assure the data matrix
Evaluate different scenarios
Analysis of uncertainty/sensitivity

Session 4 – Implementation
The last session of the meeting was focusing on co-ordination of the implementation. This session was therefore visited by a number of local officials from relevant departments. It was held strictly in Chinese.

Mr Li introduced the project and the different engineering measures. He also presented the ranked list of projects prepared during the lunch break, providing the summary list of ranked projects, their relative benefits and corresponding (accumulated) costs.

Appendix 4: Participating stakeholders

Workshop participants: Representatives from implementing agencies

name	working units	principalship	telephone
He peixiong	Bayannaoer city aquatic product station	engineer	8213413 ,13847868877
Lanfeng	Bayannaoer city aquatic product station	stationmaster, engineer	8213413, 13327088155
An shuwen	Wulateqianqi purcasing bureau	accountant	3213821, 13500682500
Xu xiangdong	Wulateqianqi environment protection bureau	engineer	3213614, 13500682501
Li yongming	Bayannaoer city development reform committee	section officer	0478-8224714
Qu yurong	agriculture assart bureau	section officer,engineer	0478-8230971,13947899328
Zhang shiwang	Wulateqianqi development reform bureau	vice-director general	0478-3212382,13500682617
Jia ji e	Bayannaoer city purcasing bureau	section officer accountant	0478-8234720,13947816622
Duan jianguo	Wulateqianqi management bureau	engineer	0478-3214178,13947802686
Liu bingzhong	Bayannaoer construct committee	section officer,engineer	0478-8212795,13009589625
Li aimin	Wuliansuhai fish farm	vice-factory director	
Ye junfeng	Ba meng environmental monitoring station	stationmaster	
Guo yuhua	Ba meng environmental monitoring station	vice-stationmaster	
Liu aijin			
Shang shiyou	Inner mongoliya agriculture university	professor	
Liu huizhong	Hetao irragation bureau	director general	
Lu quanzhong	INner mongoliya environment technology bureau	head-engineer	
Liu dongmei	INner mongoliya environment technology bureau		
Li xiaoxia	INner mongoliya environment technology bureau		
Li yawei	INner mongoliya environment protection bureau	director general	
Han mei ying	Inner mongoliya university: Student		
Zhang qiang	Wulateqianqi construct bureau	vice-officer,assistant enginee	0478-3269328

Appendix 5: Cost tables for Management and Control Measures

MCP	Present value of costs (12.05)	corrections 20.1.05	corrections 7.4.05	revised 13.7.05	revised 29.8.05
1. Urban sewage treatment (all)	400 419 200			449 499 930	449 499 930
1.1 Hanghou municipal treatment plant	143 283 666			132 093 951	132 093 951
1.2 Linhe municipal treatment plant	48 930 600			81 376 045	81 376 045
1.3 Wuyuan municipal treatment plant	208 204 934			236 029 934	236 029 934
2. Industrial wastewater (all)	16 035 334	19 671 000		16 425 648	16 425 648
3. Dredging (all)	309 930 000		61 433 794	304 757 590	304 757 590
4. Harvesting submerged vegetation & utilisation	101 238 651		125 113 916	105 776 572	105 776 572
5. Reed bed control	72 875 934		1 365 655	1 249 239	1 249 239
6. Introduce Water from Yellow river and water level	56 706 018	37 000 000		65 980 821	159 330 406
7. Moving Inlet point & pre treatment	27 351 101	28 400 000		368 669 499	71 797 480
8. Erosion Control	73 469 367	3 974 500	10 661 104	454 398 465	7 213 328
9. Improvement internal circulation			3 660 000	3 598 918	3 598 918

Note: from “cost export to EC” worksheet in <MCA Linhe - working file -29.8.05.xls> . Values in last column were used as input in the MCA ranking.

The last column of the table indicates cost revisions made by the NIVA/IVL team that were made to MC measures after the Chinse authors had completed their drafts. The cost sheets for individual MCs refer to the original data provided by the Chinese authors. In some cases Chinese MC authors were not able to supply costs at the level of detail that would ideally be required as inpu to the rakning exercise.

A weakness of the MCA ranking – after these cost revisions - is that MC authors did not revise the impacts for those MC measures where costs were revised This is partly due to the fact that the impact matrix is largely qualitative (given the lack of quantitaive modelling of environmental impacts in the project). Future revision of the ranking exercise should emphasise more information on the environmental impacts of measures, using either quantitative impacts based on models, or ordinal impact scales based on expert opinion.

Assumptions in analysis of management and control measure costs

The following page show:

1. investment costs
2. operating cost
3. revenues
4. present value and annuities of total costs calculated based on 1-3 using a discount rate of 12% and an analysis horizon of 30 years.

All cost data reproduced here can be found in the following Excel file on the project catalogue: <MCA Linhe - working file -29.8.05.xls>.

MCP		Investment(I)	O&M	Investment life, years	Present value (O&M)	Present residual value of investment year 30 (R)	Total present value(I+O&M +R)	Income/year	Present value of income
1a	Hanghou WWTP	90 930 000	4 630 000	25	41 770 962	607 011	132 093 951	5 830 000	52 597 129
1b	Linhe WWTP*	37 310 000	4 912 000	25	44 315 111	249 066	81 376 045	20 020 000	180 616 557
1c	Wuyan WWTP	181 850 000	6 140 000	25	55 393 889	1 213 955	236 029 934	28 702 000	258 943 877
1	Sum domestic WWTP	310 090 000	15 682 000	25			449 499 930		
2a	Hongchang	5 417 000	336 000	25					
2b	Renze	1 500 000	80 000	25					
2c	Weixin	3 225 000	288 000	25					
2d	Haojiang paper	closed							
2	Sum industrial WWTP	10 142 000	704 000	25	6 351 351	67 704	16 425 648	2 500 000	22 554 515
3	Dredging	309 930 000	0	20	0	5 172 410	304 757 590	25 000 000	225 545 151
4	Harvesting submerged vegetation	54 980 000	6 037 240	10	54 466 808	3 670 237	105 776 572	16 000 000	144 348 897
5	Reed bed control	200 000	120 000	5	1 082 617	33 378	1 249 239	0	0
6	Introduce yellow river water	40 970 000	13 180 000	50	118 907 404	546 997	159 330 406	0	0
7	Moving of inlet and wetalnd construction	57 912 920	1 539 000	30	13 884 560	0	71 797 480	0	0
8	Erosion control	3 974 500	359 000	30	3 238 828	0	7 213 328	1 454 760	13 124 563
9	Farmland pollution control	ommited - estimate >3 billion RMB							
10	Improvement of water circulation	3 660 000	0	20	0	61 082	3 598 918	0	0

Note: figures in red (revision 29.8.05)

Appendix 6: Covering objective priorities

The following table shows an overview of the relative contribution of each criteria to the ranking of the alternatives (so-called "covering objective priorities"), given the weighting of criteria assumed in the base case analysis.

Model Name: MCP -LINHE WORKSHOP CLEAR water group 1 (Li)- 14

Covering Objective Priorities

1.1.1 Change P loading	,042
1.1.2 Change N loading	,015
1.1.3 Change COD loading	,029
1.1.4 Change soil loss	,004
1.2.1 Change P loading	,037
1.2.2 Change N loading	,010
1.2.3 Change COD loading	,024
1.3.1 Change turbidity	,004
1.3.2 Change salinity	,002
1.3.3 Change bioavailable P	,015
1.3.4 Change bioavailable N	,005
1.3.5 Change dissolved oxygen	,014
1.3.6 Change phytoplankton	,008
1.3.7 Change attached algae	,002
1.3.8 Change potamogeton	,005
1.4.1 Change lake area	,005
1.4.2 Change reed area	,005
1.5.1 Change Sedimentation rate (organic)	,002
1.5.2 Change sedimentation rate (inorganic)	,001
1.5.3 Change lake depth (bottom elevation)	,006
1.5.4 Change lake level	,003
1.5.5 Change water inflow	,007
1.6.1 Change wetland habitat richness	,023
1.6.2 Change bird species richness	,005
1.6.3 Change fish stocks	,007
1.6.4 Change fish species richness	,012
2.1 Income from MCP related activities	,228
3.1.1 Lake area use conflict	,019
3.2.1 Employment during operation	,007
3.2.2 Employment during construction	,001
3.3 Health	,078
4.1.1 Irrigation water use rights	,040
4.1.2 Land use rights	,020
4.2.1 Monitoring and enforcement mandate cle...	,121
4.3.1 Technical capacity	,092
4.4.1 MCP action permit required	,106

David N. Barton