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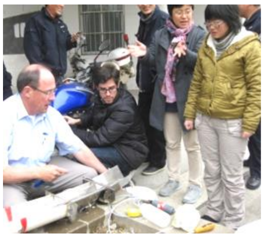
POLICY DIRECTIONS AND GUIDANCE FOR NUTRIENT POLLUTION MODELLING AND MANAGEMENT IN THE LAKE TAI BASIN



Prepared by

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ACEDP Lake Tai Water Pollution Treatment Project

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Introduction – Nutrient Pollution Management in the Lake Tai Basin

Lake Tai – an important but degraded natural resource

The Lake Tai (or Taihu) is the third largest freshwater lake in China with a surface area of 2,338 square kilometres (Km^2) and average depth of two (2) metres. The Lake's basin (36,895 km^2) spans across three (3) provinces (Anhui, Jiangsu and Zhejiang) and the Shanghai Administrative Region. Ninety percent of the lake's surface lies in Jiangsu Province with a small slice in Zhejiang along the south western boundary (Figure 1). The Basin is an important resource in one of the most densely populated and economically significant regions of the country.

Figure 1: Map of Lake Tai

Water quality and algal blooms in Lake Tai have been recognised as a serious national issue for the P.R. China, particularly following the severe Cyanobacterial algae outbreak in 2007. Agricultural outputs play a large role in water quality, due to the industry's immense size and dependence on artificial fertilisers.

Addressing the issue: The Lake Tai Master Plan and Non-Point Source Pollution

A comprehensive restoration program has been approved by the State Council. The National Development and Reform Commission (NDRC) has taken the lead role in coordinating the development and implementation of a Master Plan for Comprehensive Management of Water Environment in the Lake Tai Basin hereafter referred to as the 'Lake Tai Master Plan' (NDRC 2008). One focus area of this plan is the control of non point-source pollution (NPSP).

Eco-ditch trialling at Xingeng Demonstration Farm, October 2011

NSPSP generated from agricultural landscapes is given priority. Nutrient control standards encompassing fertilizer use guidelines; application of pesticides; livestock and aquaculture pollutant discharges; and farmland irrigation water quality have been introduced. Green farming agricultural projects have also been trialled involving initiatives in reducing chemical fertilizers, increasing organic fertilizers, replacing pesticides, precision application of fertilizers and pesticides, and ecological agro-ditch construction to prevent nitrogen and phosphorous losses.

According to the Master Plan (2008) nutrient management and precision application of fertilizer is expected to cut nitrogen fertilizer use by 30 percent; cut phosphorous fertilizer use by 20 percent; and; replace 40 percent chemical fertilizer with organic fertilizer.

Monitoring systems for agricultural NPSP have also been identified as a priority, with systems being set up at the county level to provide information on control and treatment. In addition, stronger law enforcement for monitoring has been identified as a means to address poor monitoring data. At the catchment scale the Lake Tai Basin Authority (TBA) in partnership with Hohai University has developed a Distributed Waste Load Model (DWLM). To support further development of the DWLM, TBA collects water quality and quantity data for all the key functional zones in the basin. There is currently limited modelling of nutrient processes at the farm-scale.

China Partnerships: Supporting Integrated River Basin Management

The Lake Tai Water Pollution Treatment Project (hereafter referred to as "the ACEDP Lake Tai Project", funded through the Australian China Environment Development Partnership (ACEDP) has been supporting current efforts to manage nutrient pollution in the Lake. The objective of the ACEDP Lake Tai Project is to increase awareness of Integrated River Basin Management (IRBM) approaches including institutional governance, science based management, and technical measures for pollution and algal control.

> ***While significant resources have been mobilized to control diffuse nutrient pollution, there is limited understanding of nutrient processes and the impact and effectiveness of management interventions***
>
> ***(Lake Tai Water Pollution Treatment Project, 2011)***

During the Lake Science and Non-point Source Pollution Management Workshop held in Suzhou in July 2010 NPS pollution was identified as a major but still poorly understood source of pollution for the Lake. Chinese officials raised concerns that while significant resources have been mobilized to control diffuse nutrient pollution, there is limited understanding of nutrient processes and the impact and effectiveness of management interventions.

Subsequent activities including the NPS Pollution and Science-based Management Study Tour to Australia, September 2010; and NPS Nutrient Pollution Assessment & Management Training Workshop held in Suzhou, November 2010 provided an introduction to nutrient modelling approaches and decision support systems used in Australia to inform policy and management decisions including:

- eWater's Source Integrated Modelling System (previously called E2 and Source Catchments) and examples of its use across Australia;
- Melbourne Water's use of an E2 model to inform the development of Better Bays and Waterways: A water quality improvement plan for the Melbourne Region; and
- The Department of Primary Industries (Victoria) use of Bayesian Networks to model nutrient processes at the farm scale.

Chinese partners expressed interest in the potential application of these approaches in Lake Tai. A project extension activity was subsequently conduced between July 2011 and January 2012 involving AUS Cluster members, eWater, Department of Primary Industries (Victoria), Melbourne Water and Earth Systems; and Chinese partners Taihu Basin Authority (TBA), Nanjing Institute of Geography and Limnology (NIGLAS), Suzhou Agriculture Technical College, Suzhou Environment Institute and Suzhou Agricultural Bureau, Environment Protection and Water Bureaus. The extension involved the development of two demonstration models – a Source Catchment model for the Dongshan Peninsula and a Bayesian Network for Xingeng Village Farm.

Policy directions: Modelling as a tool to inform Strengthened Nutrient Control Policy and Management in the Lake Tai

This document is directed at a broad range of stakeholders involved in the management of Lake Tai including policy decision makers, managers, technicians and researchers. It is intended primarily as a 'policy directions' document – outlining how modelling can be used to inform the development and implementation of nutrient pollution control policy and management interventions across the Lake Tai Basin.

Section 1 – draws on experiences from eWater and Melbourne Water to outline the purpose of nutrient process modelling and provide guidance on 'Best Practice Modelling'.

Sections 2 to 5 provide a summary of the two demonstration activities conducted in Suzhou and outline a series of policy directions and recommendations based on the results and findings.

The final section outlines the proposed establishment of a Water and Wastewater Centre for Excellence in Suzhou. The Centre would be a hub for Sino-Australia initiatives in the Basin and would establish a catchment-wide nutrient pollution control component with the following functions:

- To become a centre for nutrient modelling;
- To become a centre for monitoring system refinement;
- To become a resource centre for knowledge generation and sharing; and
- To become a centre for nutrient modelling and management education and training.

1. Nutrient Modelling to Inform Management

Why Model?

Nutrient modelling is one of a number of strategies that can assist in the management of Lake Tai. In addition to the commonly understood role of predicting and forecasting, nutrient modelling and the process of developing, calibrating and refining these tools can be useful in the following ways:

1. Explanation – understanding catchment processes.

Modelling can assist in explaining current catchment processes – for example: hydrological; and land / water management practices. They can also help in determining pollution sources. They can illuminate core dynamics and uncertainties between pollutant phases, and reveal seemingly straightforward scenarios to be complex (and vice versa).

2. Identification – identifying the issues and knowledge gaps.

Models can help identify key issues contributing to the problem (e.g. a particular land management practice that is contributing to significant nutrient pollution). Importantly, models can reveal any knowledge gaps and identify new questions which need further consideration.

3. Prioritisation – identifying hot spots and priority areas for rehabilitation.

Models can identify 'hot spots' and areas for priority rehabilitation. They enable testing of various scenarios for different land management practices and management interventions. These can be coupled with cost benefit analyses of different nutrient management practices to inform investment prioritisation.

4. Participation– encouraging coordination and stakeholder involvement.

The modelling process can be an important way of bringing policy-decision makers, managers and scientists together, from a variety of agencies and institutions. Some approaches can also promote a high level of community involvement (e.g. sourcing information and advice from farmers). The involvement of a range of stakeholders helps promote shared understanding of the problem and priorities; and ultimately a more coordinated management response.

5. Guidance – informing policy and regulation.

Models are primarily Decision Support Systems (DSSs) and can be used to:

- Improve predictability, allowing effective water quality monitoring systems to be designed and water quality targets to be set;
- Guide data collection and focus on specific areas for further research to improve the reliability of the model outputs; and
- Inform longer-term policy and regulatory mechanisms for improved nutrient management.

Best Practice Modelling

Best Practice Modelling can be defined as 'a series of quality assurance principles and actions to ensure that model development, implementation and application are the best achievable, commensurate with the intended purpose' (eWater, 2010).

The understanding of 'best' can vary with the circumstances of the project, subject to data availability, time, budget and other resource constraints. Knowledge and technology in the modelling field is also constantly evolving. These constraints may be better managed by the strategic Best Practice Modelling approach, which assists in identifying priorities for addressing modelling and data limitations.

eWater has developed comprehensive guidelines for best practice water management modelling that address how to best setup and utilise the model to achieve sound and useful results. These guidelines outline a common modelling framework and quality assurance process covering project administration; problem definition, options modelling; and preferred option identification (see Figure 2). Emphasis is placed on consideration and documentation of all these elements commensurate with the scope of the modelling project.

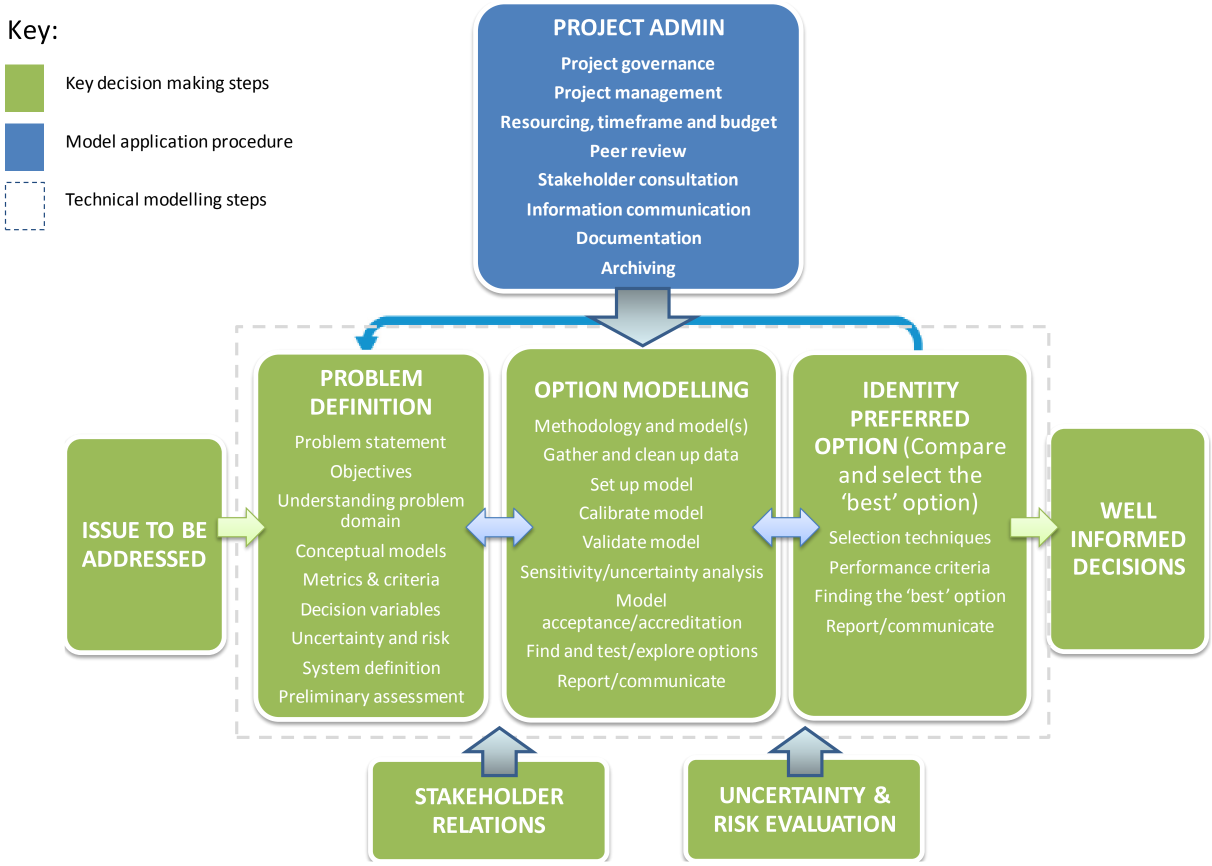


Figure 2: Decision Framework for Model Application (source: eWater 2011)

Melbourne Water's experience in developing a broad-based nutrient generation model to inform the development of the *Better Bays and Waterway – a Water Quality Improvement Plan for the Melbourne Region* is documented in a paper titled 'An Evaluation of PortsE2'. This paper provides practical insights to assist Lake Tai Catchment modellers and policy-makers in understanding the strengths and limitations of modelling and how models can be best used to inform policy, investments and management decisions for the control of non-point source (and point source) nutrient pollution at the catchment scale.

Melbourne Water identifies the following as being critical to building a successful model:

- Ensure all stakeholders who have an interest / stake in the model inputs or outputs are consulted and involved in the model development and analysis;
- Ensure clear documentation of decisions during model development and analysis phase to ensure transfer of knowledge;
- Be clear on the objectives of the model - a single model cannot provide all managers and decision makers with the tools necessary to make informed decisions;
- Ensure adequate time is allowed for assessing results and refining (or if needed, rebuilding) the model, before management decisions are made;
- Ensure catchment delineation and land-use types, including their spatial representation, reflect objectives of the model and will deliver the desired outputs;
- Allow for future needs of the model and the ability to incorporate new data and scenarios;
- Pay particular attention to calibration of the model – and ensure good communication between the modeller/s and those using the outputs of the model;
- Understand the types of results required at the beginning of the process and set up a methodology / process for extracting results in the desired format;
- If developing targets for pollutant load reduction is an objective of the model then be very clear on the form of these targets and the methodology before the model is developed;
- Land-use change scenarios can be a very powerful use of the model but ensure the methodology is established before the model is developed;
- Modelling management interventions such as Best Management Practices (BMPs) - e.g. Water Sensitive Urban Design (WSUD) or rural land Best Management Practices - can be very useful however careful consideration of the modelling approach and uncertainties is required; and
- Incorporate costs, and cost effectiveness to modelled management actions, along with other factors that will influence decisions.

eWater's Guidelines for Water Modelling and the lessons from Melbourne Water's development and application of the PortsE2 model were considered during the Source IMS and Bayesian Network demonstrations conducted in Suzhou Municipality, China. Like in Australia, movement toward the conduct of best practice modelling projects in China will require continued awareness of the role of modelling in nutrient management and the strengthened capacity and coordination between the range of policy-decision makers, practitioners and scientists involved in this process.

2. Source Integrated Management System (IMS) Demonstration for Dongshan Peninsula

Introduction

The Australian eWater Source Integrated Modelling System (Source IMS - previously called E2 and Source Catchments) is a water quality and quantity modelling framework that supports decision making and a whole-of-catchment modelling approach.

Source IMS was applied to the Dongshan Peninsula in Suzhou to demonstrate how this particular model could be used to investigate strategies to improve nutrient management.

Source IMS is an effective and mature model that is widely applicable. It has an open framework for hydrological model development, with an easy to use interface. It is not difficult to build the model, and can calibrate multiple parameters with high efficiency.

(Mr. ZHANG, Hongju, TBA, Ex1 Policy Workshop, January 2012)

Source IMS

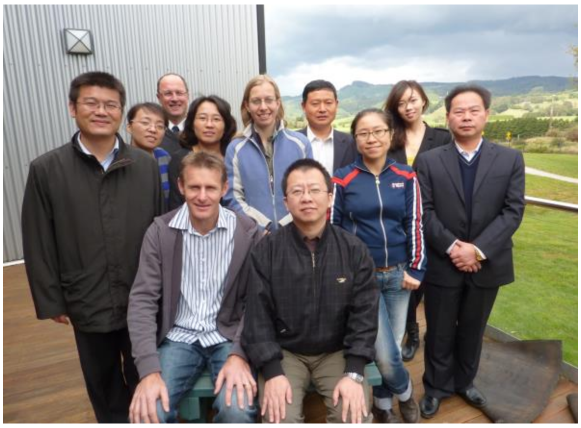
Source IMS is highly flexible. It can be applied at a range of spatial and temporal scales and integrates an array of models, data and knowledge that can be used to simulate how climate and catchment variables (rainfall, evaporation, land-use, vegetation) affect runoff, sediment and contaminants.

Source IMS is based on the following building blocks:

Sub-catchments: The sub-catchment is the basic spatial unit, which is then divided into hydrological response units (or functional units) based on a common response or behaviour such as land-use. Within each functional unit, three models can be assigned: a rainfall-runoff model, a constituent generation model and a filter model.

Nodes: Nodes represent sub-catchment outlets, stream confluences or other places of interest such as stream gauges or dam walls. Nodes are connected by links, forming a representation of the stream network.

Links: Links represent the river reaches. Within each link, a selection of models can be applied to: a) route or delay the movement of water along the link; and b) modify the contaminant loads due to processes occurring within the links, such as decay of a particular constituent over time.



Source IMS Working Group, Gippsland, September, 2011

Dongshan Peninsula

The Dongshan Peninsula is located in the south eastern corner of Lake Tai (N 31°05', E 120°24') (Figure 3).

The catchment area of interest covers 7,737 Ha with steep hilly terrain to the north of the Peninsula and flat lowland areas to the south.

Figure 3: Location of the Dongshan Peninsula

The dominant land-use is aquaculture ponds (predominantly used for crab farming) covering approximately 43% of the area, followed by upland fruit trees (29%) (Table 1). The majority of the lowland area is occupied by aquaculture, while the upland areas comprise a mix of fruit trees, low density urban and forested land. Dongshan Peninsula has a population of 53,000, of which around 44,000 people are in rural or low density urban areas.

Table 1: Non-point source (diffuse) Land-use categories and their associate areas

Land-use	Area (Ha)	Area (%)
Aquaculture	3307	42.8
Upland Fruit Trees	2234	28.9
Low Density Urban	555	7.2
Vegetables	483	6.2
High Density Urban	363	4.7
Water	247	3.2
Industrial	205	2.6
Upland Forest	183	2.4
Lowland Fruit Trees	159	2.1
Total	7,736	100

Runoff to Lake Tai is from both rainfall runoff and controlled drainage from the aquaculture ponds. Runoff enters the Lake via a combination of streams and constructed canals with a total of 13 exit points. Gates are located at each exit point and many of the canals are interconnected. When Lake levels increase to 3.45m or greater, all gates are closed to prevent flooding of the low lying areas and runoff is then pumped to the Lake via pump stations located at four of the 13 exit points to the Lake (Figure 4).

Model Development Process

A Source IMS Working Group was established comprising of Australian experts from eWater Cooperative Research Centre (eWater) and Earth Systems; and Chinese officials and scientists from Suzhou Municipality, the Taihu Basin Authority (TBA) and the Nanjing Institute of Geography and Limnology (NIGLAS).

A series of workshops and training activities were conducted both in China and Australia to build capacity for the development and use of the Source IMS framework. A substantial amount of training material was translated into Chinese. Two site visits were then undertaken to assist in developing and modifying the base model for the Dongshan Peninsula and to develop scenarios based on proposed nutrient management strategies. Over 40 Chinese and English papers were sourced and reviewed in the collation of model input parameters. Local water managers and farmers from within the Peninsula were also consulted to obtain flow and water quality data and advice on agricultural practices, for example, current practices and operations of aquaculture ponds.

Development of the Base Model

Land-use: Sub-catchments were divided into multiple Functional Units (FUs) or land-use categories. Nine diffuse source land-use categories – agriculture, vegetables, lowland fruit trees, forestry, industrial, high density urban, low density urban, proposed wetland and water (Figure 4) and one point source of nutrient pollution (sewage treatment plant, STP) were included in the model.

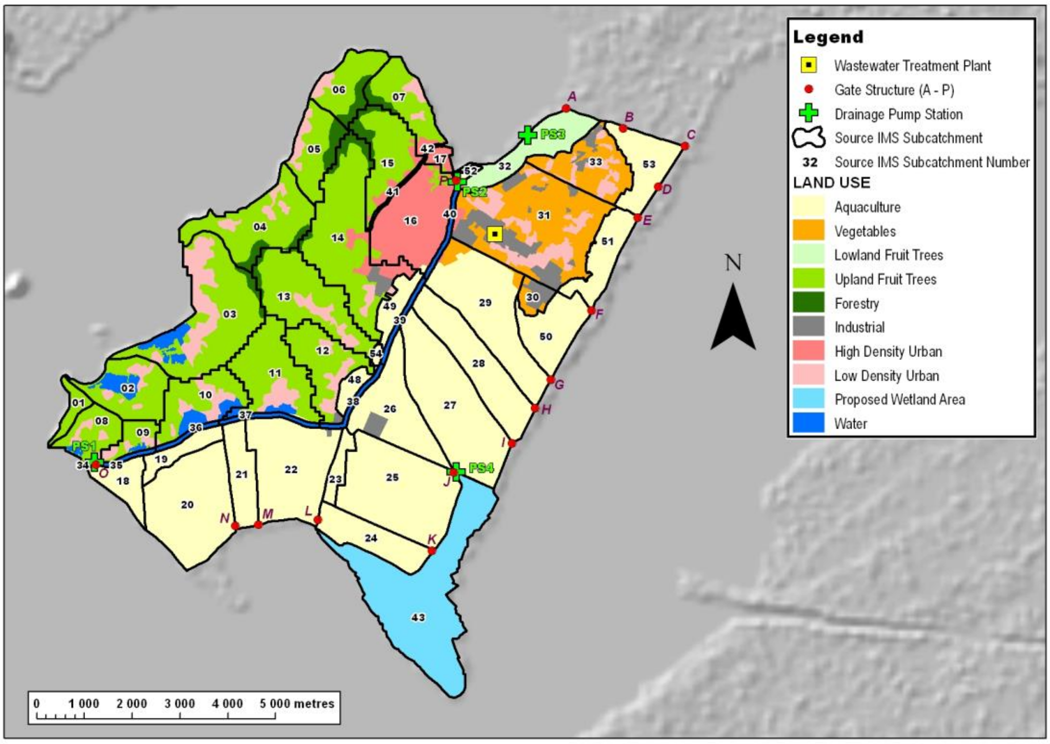


Figure 4: Land-use map of the Dongshan Peninsula

Sub-Catchment and Drainage Network Configuration: The base sub-catchment map was constructed to include 50 sub-catchments (see Figure 5). Due to the complex network of interconnected streams and canals, outputs into Lake Tai were aggregated to five reporting nodes. Outputs at Node 1 represented the aggregated rainfall runoff and pollutant load from the upland areas (Figure 5) to the north of the Peninsula. Nodes 3 and 4 represented runoff from all aquaculture ponds and Nodes 2 and 5 all remaining runoff to the Lake from streams and canals.

- *Model Run period* - The model was run at a daily time step over a 10 year period (2001 – 2010). This period included both wet and dry years, and was deemed a sufficient time period to demonstrate model application for the current land use.

- *Rainfall Runoff Modelling* **-** Source IMS uses conceptual rainfall runoff models as opposed to physically based rainfall runoff models to generate daily runoff estimates. Conceptual models rely on measured data for calibration. The SIMHYD model was selected as the rainfall runoff model. Due to a lack of measured daily runoff data for the Peninsula manual calibration was undertaken to ensure the proportion of runoff generated for each land-use corresponded with literature values for the region. The three most sensitive SIMHYD model input parameters were then adjusted to reflect the attributes of the given land-use type.

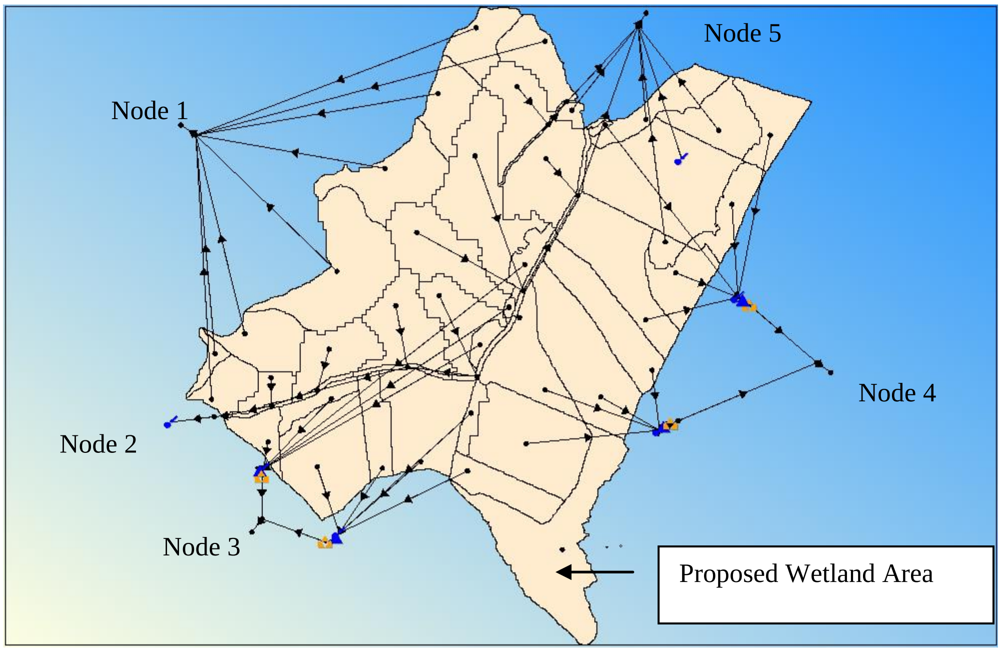


Figure 5: Sub-catchment and node link network configuration for base model.

- *Stream and canal runoff and pumping processes* - Runoff enters the Lake via a combination of streams and constructed canals with many of the canals interconnected. When Lake Levels increased gates were used to prevent backflow and water was pumped out. A time series file of Lake Level was provided for the modelling period as the basis for determining when runoff was pumped to the lake.

- *Nitrogen and Phosphorous Generation Data* - Initially an Event Mean Concentration (EMC)/ Dry Weather Concentration (DWC) approach was chosen however due to lack of storm event and dry weather data, a single mean concentration value was used for both EMC/DWC input parameters. Nutrient generation input parameters applied to the model represented the long term average annual nutrient generation rates for each land-use. Nutrient decay and/or filtering processes were not incorporated into the model given the short travel times for runoff from the point of generation to lake entry.

- *Aquaculture pond operations* – aquaculture ponds with total area of 3000 hectares are a major source of both runoff and nutrients on the Dongshan Peninsula. For modelling purposes these ponds were aggregated for each sub-catchment, forming 19 sub-catchments, which were further aggregated into four larger ponds. These ponds were built into the model as four storages with a total volume equal to all of the individual ponds. Table 2 depicts management criteria that were reflected in the model. Given the majority of outflow from the ponds entering the Lake occurs during December when ponds are drained, a fixed TN and TP concentration was applied to the ponds to reflect the concentration of the ponds in December. Nutrient accumulation and/or denitrification processes, and nutrient inputs via rainfall were not incorporated into the model.

Table 2: Aquaculture pond water levels

Period	Pond Water Level
December—February	Drained
March—June	0.8-1.0m
July—November	1.2-1.8m

Development of Model Scenarios

A key objective of the project was to demonstrate how the model could be applied to assess different management options to reduce nutrient export to the Lake. The scenarios were selected based on local and Lake Tai Basin policies or projects proposed in regional plans. Many projects have already been implemented in Dongshan as part of Lake Tai Master Plan, national and local remediation plans such as: riparian buffer construction, Dongshan STP closure and connection to Wuzhong district to improve centralized wastewater treatment, complete connection of industrial sewage all over the catchment, complete upgrade of 80% septic tanks in low density urban area, large scale demonstration farm construction in the region for vegetable, tee and fruit trees with improved nutrient management, and large scale aquaculture pond improved waterway management. According to our on-site investigation, all these management practices have been implemented to different extents. The modelling will assist local government in prioritising future investment in monitoring and investment. Numerous scenarios were considered by the Working Group with three selected for detailed investigation.

Details of the three scenarios put forward by the Source IMS Working Group are outlined in Table 3 below.

Table 3: Scenario Descriptions and Assumptions

Scenario	Description	Scenario assumption
1. Improved Point Source Management	Upgrading the septic system: 20% of low density urban areas upgraded to domestic waste units	EMC value for 80% for low density areas applied to 100% of low density areas.
	Connection of the Dongshan STP into the urban pipe network: decommissioning the wastewater treatment plant.	No WWTP output
2. Improved Diffuse Source Management	Reduced fertilizer inputs to vegetables and upland fruit trees: precision application of fertilizer, modifying the timing of application, alternating dry and wet farming.	20% reduction in TN and 10% reduction in TP generation rates for dry and wet farming practices
	Upgrading of aquaculture ponds: improved/modern management practices adopted in all aquaculture ponds.	Modern crab farming operations reduce pond TN and TP by 25%
3. Construction of Large Wetland	Construction of 7km^2 wetland for filtering of aquaculture ponds	Nominal depth of 0.7 m; removal rate of 50% with a detention time of 5 days

Working Group members discuss the development of the Dongshan Demonstration Model with eWater specialist, David Waters.

Results and Discussion

Model Parameter Calibration

Source IMS utilises several rainfall runoff models to simulate hydrological elements of a catchment, and integrates several constituent generation models to calculate non-point source pollution loads for different land use types. For rainfall runoff modelling, average values of runoff coefficients were collated from local literature to enable manual calibration of the model. Due to a lack of measured runoff data for the Peninsula it was not possible to fully calibrate the model, rather, the minimum and maximum TN and TP generation rates were used to demonstrate the potential variability and possible uncertainty in modelled results.

Modelled TN and TP concentrations show good agreement with local data collected from streams within the Peninsula and data reported from other rivers entering Lake Tai (see Table 4).

Table 4: Runoff from various land-uses - Comparison between literature and model results

Land-use	Runoff (%)	
	Literature*	Model
Upland Forest	35	37
High Density Urban	66	64
Industrial	61	60
Low Density Urban	50	48
Lowland Fruit Trees	30	30
Upland Fruit Trees	40	40
Vegetables	23	25

*Based on literature review conducted by NIGLAS

Base Model Results

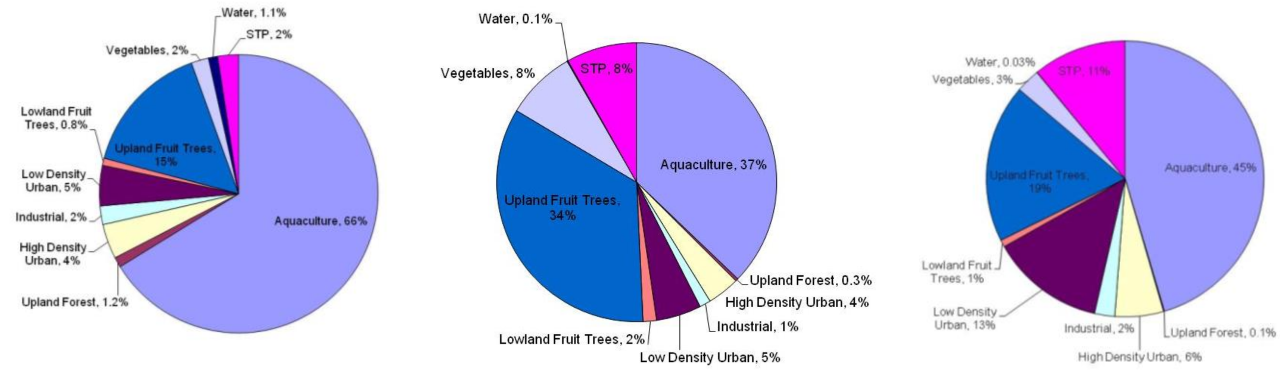
The base model showed good agreement to measured local water quality data from Dongshan and data reported in the Lake Tai Master Plan for other Rivers within the Basin. Figure 6 provides a summary of the modelled estimates of the proportion of runoff, Total Nitrogen (TN) and Total Phosphorous (TP) exported to the Lake for each land-use. Figure 7 provides a summary of the average annual contribution on a per unit area basis.

The following provides a summary of the key findings:

- Average annual runoff for the Peninsula is 61,500 ML/yr (around 62 GL/year) ranging from 44,800 ML/yr – 84,780 ML/yr (45-85 GL/year) over the 10 year model run period. Average annual modelled TN is 270 t/yr ranging from 190 – 380 t/yr. Average annual modelled TP load is 22 t/yr ranging from 16 – 30 t/yr.
- Aquaculture contributes around two-thirds (66%) of the average annual runoff with the second largest contribution from upland fruit trees (around 15%). Given the ponds are

drained in December it stands to reason that two-thirds (66%) of all runoff to the Lake occurs in December each year.

- Despite having a smaller area, the high runoff proportion and high TN generation rates of the upland fruit trees indicates they are contributing a similar proportion of TN to the aquaculture ponds (around 30-40% for both aquaculture and upland fruit trees).
- The majority of TP load contribution is from the aquaculture ponds due to the low TP generation rates from cropping and urban areas.
- Stream and canal runoff and pumping processes - 65% of the average annual runoff over the modelled period occurred as natural runoff whilst the remainder is pumped to the lake when gates are closed. The gates were closed and pumping occurred 10% of days.



a) b) c)

Figure 6: Base model – Nutrient Process Results

Figure 6a): Average annual runoff entering Lake Tai from Dongshan Peninsula.

Figure 6b): Average annual modelled TN load as a proportion of the total load entering Lake Tai from Dongshan Peninsula.

Figure 6c): Average annual modelled TP load as a proportion of the total load entering Lake Tai from Dongshan Peninsula.

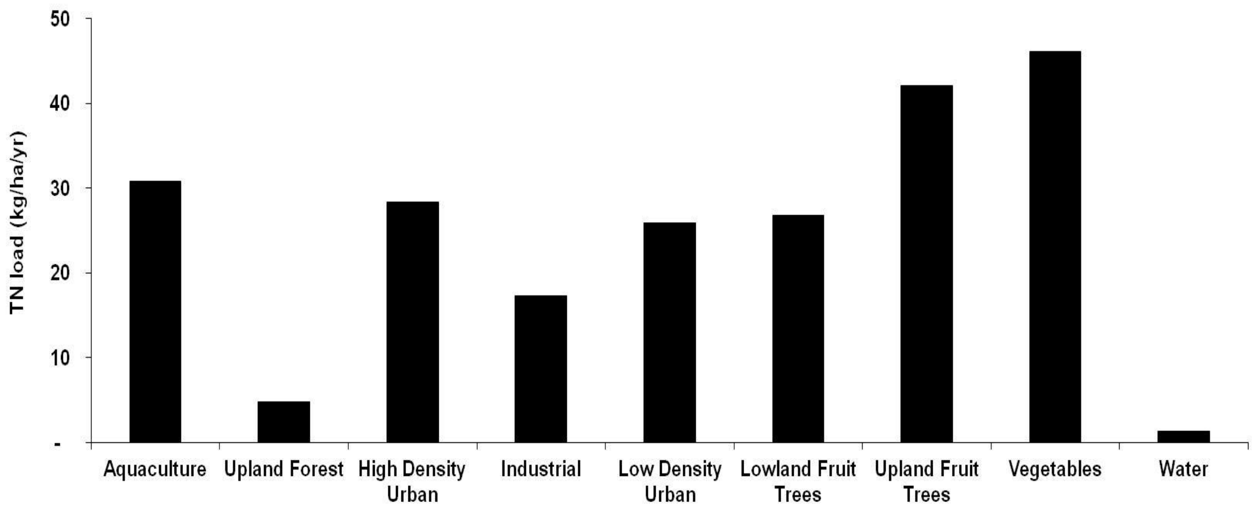


Figure 7: TN load per unit area (kg/ha/yr)

Scenario Model Results

Figure 8 below shows the results from the scenario modelling.

Scenario 1 - Improved Point Source Management: Upgrading of the remaining 20% of low density urban areas from traditional septic systems to domestic waste units in conjunction with the connection of the Dongshan STP to the main sewage network could achieve a 9% reduction in average annual TN and 13% reduction in TP load to the Lake. The majority of this load (90%) is attributed to the removal of the STP.

Scenario 2 - Improved Diffuse Source Management: The combined efforts of improved management practices in vegetable and upland fruit growing (9% and 2% for TN and TP respectively) and aquaculture practices (9% and 23% for TN and TP respectively) showed improved diffuse source management can have a large impact on TN and TP reduction.

Scenario 3 – Construction of the Wetland: The construction of a large wetland could reduce exports by approximately 13% and 16% of TN and TP respectively.

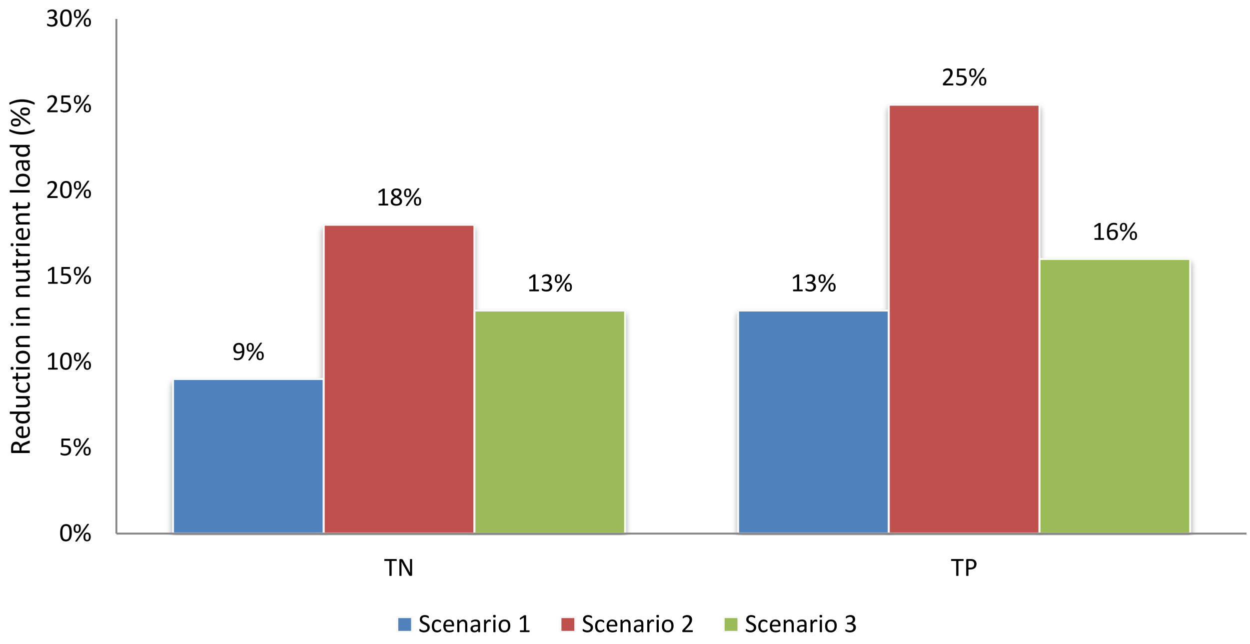


Figure 8: Scenario modelling results

Model Improvements

Improved monitoring and on-farm research will help to validate and reduce the uncertainty in modelled estimates. Long term water quality monitoring data — in particular sub-daily runoff measurements and storm runoff event nutrient monitoring would improve model predictions significantly.

Table 5 and Table 6 suggest some monitoring and research actions which would be useful for future work.

Table 5: Monitoring Requirements

Monitoring	Use
Sub-catchment scale monitoring of flow and speciated nutrients for single land-use areas (in particular upland trees) and catchment outlet monitoring	Improve confidence in model generation rates and model validation
Continuous flow monitoring on the major streams and canals entering the Lake	Improve estimates of rainfall runoff
High frequency monitoring of speciated nutrients over the wetter months, at locations where continuous flow is monitored	Provide a greater understanding of the temporal variability in water quality and improved estimates of nutrient loads

Table 6: Research Requirements

Research	Use
Water quality from vegetable production	Confirm assumed improvement in water quality from using lower fertilizer inputs
Denitrification processes from the farm to lake entry	Understand contribution of denitrification processes
Nutrient removal rates and efficiency of large scale wetlands under local climatic conditions	Improve understanding of wetland efficiency under local climatic conditions
Water quality of aquaculture practices, particularly crab farming	Improvement in water quality between conventional and modern aquaculture practices
Feasibility of releasing aquaculture pond water over a longer time period than the current one (1) month period, e.g. two (2) months	Consideration of alternative aquaculture management practices to allow more time for denitrification to occur prior to release of pond water
Feasibility of releasing aquaculture pond water over an extended period of time	Consideration of alternative aquaculture management practices to increase the volume of water passed through the wetland

3. Model Applications and Policy Directions

The management of Lake Tai Basin is a challenge that requires long-term commitment. Significant gains have been achieved to date. The Lake Tai Master Plan provides a solid basis and broad scale assessment of the relative contributions of pollutant sources to Lake Tai, both spatially and by industry. This modelling exercise supports that planning process. It demonstrates how Source IMS could be used to explore pollutant generation sources and the relative changes in nutrient inputs to the Lake resulting from alternative management strategies at a finer scale. It also offers insights into current data and research needs.

The following policy directions and recommendations for future work have been identified by the Source IMS Working Group and senior government officials involved in the ACEDP Lake Tai Project for consideration by Lake Tai policy-decision makers.

Policy directions: Catchment Modelling and Management

1. Develop partnerships and modelling governance mechanisms to support catchment modelling:

- Support the continuation of the Source IMS Project Working Group– the owners of the model. Ensure that this Working Group continues to have a strong mix of policy decision makers, managers and scientists.
- Establish a co-operative research centre (Centre for Excellence) to ensure input from a range of specialists (i.e. modellers, limnologists, hydrologists); linkages with research institutions; and policy orientated outputs.

2. Strengthen the Dongshan Peninsula Source IMS:

- Conduct monitoring in the sub-catchment to collect necessary flow and nutrient data (see Table 5) to support continued calibration and refining of the base model.
- Conduct further research to confirm assumptions and address additional questions raised by scenario modelling (see Table 6)

3. Build capacity in the development and application of Catchment-scale nutrient modelling:

- Establish a nutrient modelling training centre and training program in collaboration with AUS Cluster to improve local capacity for catchment scale modelling.
- Use the Dongshan Peninsula Source IMS as a basis for this training.
- Draw on past experiences, success stories and new technologies in modelling and monitoring both locally (e.g. TBA's Distributed Waste Load Model) and internationally (e.g. Melbourne Water experiences and the Great Barrier Reef Monitoring and Modelling Programs.)

4. Raise awareness of the policy and management application of catchment modelling:

- Disseminate experiences from the Dongshan Source IMS demonstration to government agencies and other stakeholders across the Basin to raise awareness about the use of modelling for policy development and management decision making.

5. Catchment management practices:

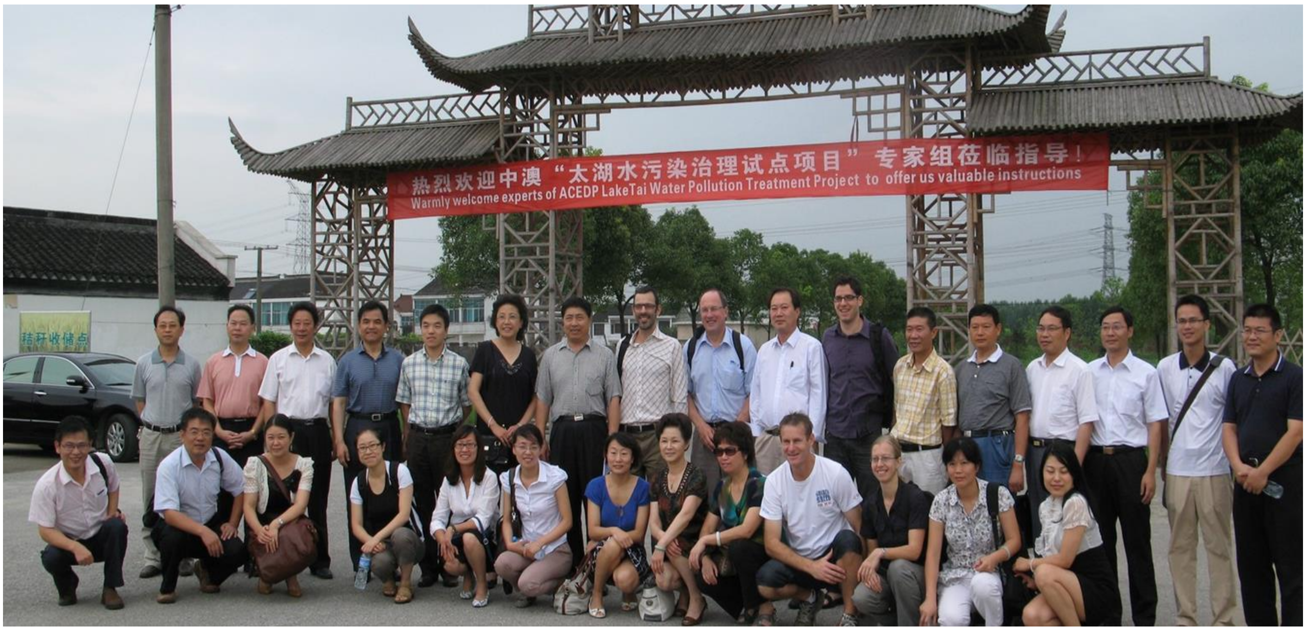
- Utilise the results of the revised Dongshan Source IMS to inform current/proposed agriculture, aquaculture and urban management practices on the Peninsula.

6. Inform sub-catchment and Basin policy and planning:

- Draw on relevant results of the Dongshan Source IMS base model (e.g. run-off; land use contributions etc) and scenarios (e.g. agriculture, aquaculture and urban management practices) to inform the Lake Tai Master plan review process.
- Draw on relevant data and information gaps identified during the Dongshan Source IMS to inform monitoring programs and the research agenda across the Basin.

7. Explore opportunities to apply the model in other parts of the Lake Tai Basin:

- Potential for application of Source IMS across Suzhou and the Lake Tai Basin including using Source IMS as a platform for integrating other models such as TBA's Distributed Waste Loading Model.
- Potential for application of Source IMS in other catchments across China such as the XinAnJiang Basin.



Extension 1 Kick-off workshop: visiting Xingeng Demonsation Farm, July 2012

4. Bayesian Network Demonstration for Xingeng Demonstration Farm

Introduction

Intensive vegetable production is one of many agricultural industries aiming to mitigate their contribution to the non-point source pollution entering Lake Tai, particularly nitrogen (N). A Bayesian Network model was developed for Xingeng Demonstration Farm in the Lake Tai region. The aim of this study was to investigate and demonstrate causal relationships and the effects of different mitigation strategies on N exports from vegetable farms in the Lake Tai catchment of eastern China.

The Bayesian Network provided a new concept and perspective on the nutrient issue. It gave an analysis of the outputs, laid the foundations for future work, provided directions, and served as an effective tool.

(Mr. QIN, Wei, Suzhou Agricultural Committee, Ex1 Policy Workshop, January 2012)

Bayesian Networks

Bayesian Networks are an alternative to conventional modelling that have been used extensively in natural resource sciences to examine complex relationships in data poor environments and for investigating multi-factor problems such as those associated with resource management. They provide a graphical representation of "cause and effect" relationships with the strength of the interdependencies (causal links) represented as conditional probabilities.

Bayesian Networks consist of the following components:

Nodes: Nodes represent variables with defined properties called 'states'. These can be 'parent' (independent) or 'child' (dependent) nodes.

Directed/causal links (arcs): Directed links represent dependencies between variables and connect parent and child nodes.

Conditional Probability Table (CPT): The CPT quantifies the strength of the dependencies (causal links) associated with each node, which considers all combinations of parent node states, represented as conditional probabilities.

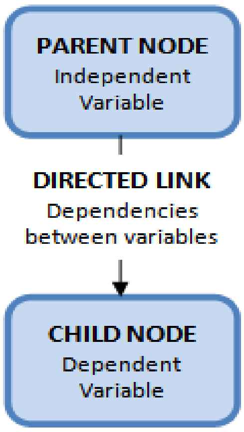


Figure 9: Bayesian

Prior Probabilities: The prior probability distribution defined in the CPT relates to the general properties of the environment (i.e. region) and system (i.e. type of farm).

Posterior Probabilities: As evidence of state values for specific nodes is received and added to the network, the prior probability distributions of the other nodes are "conditioned" (i.e.

modified) using basic laws of conventional probability theory. The new probabilities are referred to as posterior probability distributions.

Flexibility in data acquisition is a major benefit of Bayesian Networks. Conditional probability tables can be developed through direct data analyses (e.g. for probability of rainfall), elicitation of expert opinion (e.g. consultation with farmers), Monte Carlo simulations where deterministic relationships are known and, where sufficient data is available, machine learning techniques.

Xingeng Village Farm

Xingeng Village Farm is in Wanting town, Xiangcheng district, on the plains east of Lake Tai and south of the Wangyu River in the northwest corner of Suzhou city (N 31°26', E 120°28') (Figure 10). The village has a population of 5,375 and covers an area of 480 ha, 330 ha of which is used for agriculture.

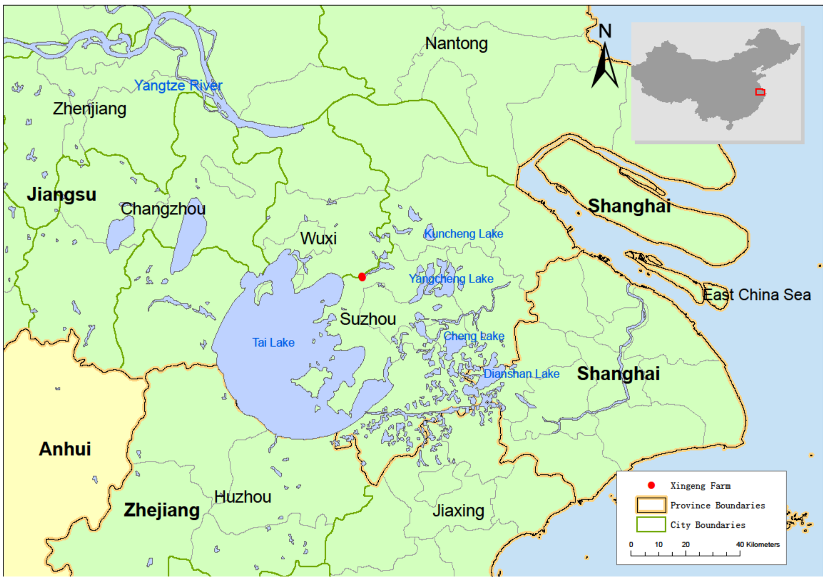


Figure 10: Xingeng Village Farm location

The village is a modern agriculture demonstration area where the main crops are rice and vegetables. This demonstration addressed a 6.7 ha area used for organic vegetable production of which 4 ha was covered by poly-film greenhouses, 0.7 ha by multi-span greenhouses, 1 ha by insect nets, and 1 ha was exposed land. Project site characteristics are outlined in Table 7.

Table 7: Main project site characteristics

Total Production Area	6.7 ha
Plot Area	0.024-0.288 ha
Average annual temperature	16°C
Annual no. of frost-free days	230 days
Non-cloudy hours	> 2000 hrs
Annual mean rainfall	1,200 mm, 65% during Mar-Aug
Irrigation water use	Not available
Topsoil structure and type	Well-structured light clay/ loamy clay
Topsoil depth	200 mm
Annual fertiliser application	650 kg N/ha and 220 kg P/ha

Network Development Process

The process used to develop the Bayesian Network for Xingeng Farm is presented in Figure 11 including information gathering; model development; model testing and validation; model application; results interpretation and client engagement.

Collecting information at Xigeng Farm, October 2011

A Bayesian Networks Project Working Group and Project Steering Committee were established comprising of Australian experts from the Victorian Department of Primary Industries and Earth Systems; and Chinese officials and scientists from Suzhou Municipality and the Nanjing Institute of Geography and Limnology (NIGLAS). The Working Group provided a communication link between the local farmers and Australian experts via bi-weekly phone conferences. Examination of the network structure in collaboration with the local water managers and farmers was an integral part of the network development process.

A series of workshops and training activities were conducted both in China and Australia to build capacity for the development and use of the Bayesian Network model. Two site visits were undertaken to conduct initial research and assist in developing and modifying the Bayesian Network for Xingeng farm. Chinese and English papers were sourced and reviewed extensively in the collation of model input parameters.

Cause and effect diagram

An initial "cause and effect" diagram was developed using NETICA, version 4.08 (Norsys Software Corp., Vancouver, Canada) software.

To constrain intra-annual variation the network was conceptualised using an annual time-step. At Xingeng farm vegetable production areas are surrounded by drainage channels approximately 1 m deep. Consequently, the network was conceptualised as applying at the "plot" scale, where a plot is defined as a hydrologically isolated production area. Using this definition plots on Xingeng Village farm varied between 0.024 and 0.288 ha in size.

Knowledge gathering activities yielded limited empirical data and deterministic relationships on which the initial diagram could be based. Consequently, the initial cause and effect diagram was conceptualised as having transport and source factors responsible for nutrient generation, similar to documented P indices and post-mobilisation mitigations (i.e. wetlands, drainage reuse, eco-ditches). However, unlike index systems, the Bayesian Network facilitated the incorporation of more complex "cause and effect" relationships.

A participatory approach

A strength of the Bayesian Network is its ability to incorporate expert opinion into conditional probability tables when data is lacking; and to ground-truth the Network at various stages of development.

At this stage in the project the initial "cause and effect" diagram was reviewed at a specially convened workshop in Xingeng Village attended by the Steering Committee and Working Group members in addition to four (4) farmers from Xingeng Village. At the workshop the assumptions underlying the diagram were discussed and evaluated. This examination comprised a two-step process: (a) determining the appropriateness or otherwise of the "cause and effect" diagram's structure; and (b) collecting information regarding node values and relationships.

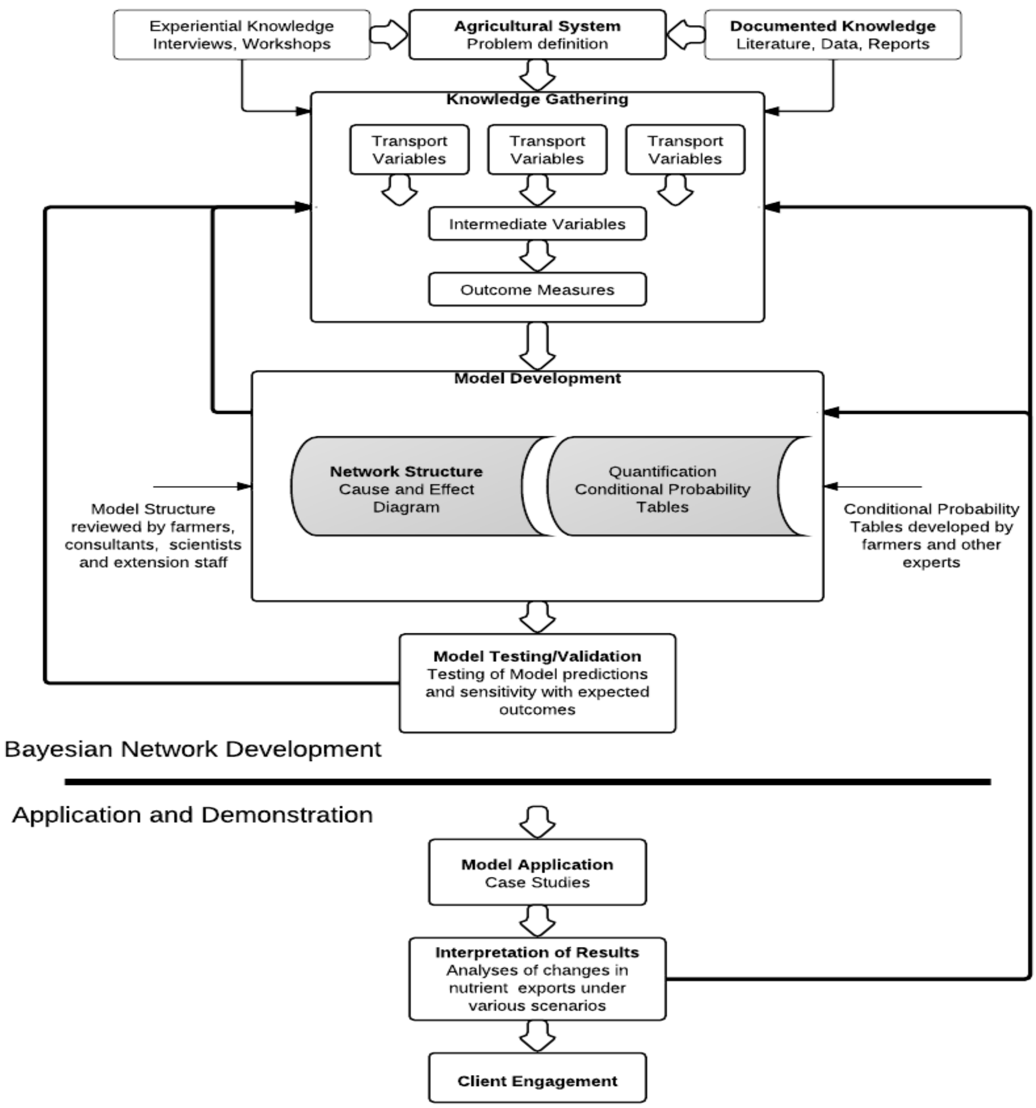


Figure 11: Development of the Bayesian Network

After the initial 'cause and effect' diagram was reviewed by the Steering and Working Committees and local farmers, the final diagram consisted of the components as described below in Table 8, with a transport factor, a source factor, three post-mobilisation mitigation strategies and three output factors.

Table 8: Network components and main nodes

Component	Description	Main Nodes	Driving factors
Transport	Variables that affect the mobility of Nitrogen in the farm	Runoff	Annual rainfall Water imports Evaporation Crop Factor
Source	Variables that contribute to Nitrogen entering the farm system	Nitrogen additions	Irrigation water quality Fertilizer rates Atmospheric inputs Crop removal
Post Mobilisation Mitigation strategies	Mitigation strategies that promote Nitrogen removal	Eco-ditches Wetlands Reuse of drainage water	Eco-ditch length Eco-ditch efficiency Wetland/Land ratio Wetland efficiency Reuse proportion
Output factors	Variables that contribute to amount of Nitrogen leaving the farm	Nitrogen concentration Export efficiency Total Nitrogen Exports	Runoff Potential nitrogen load Mitigations

Xingeng Village farm utilised Post Mobilisation Mitigation strategies to promote nitrogen recycling on the farm and reduce nitrogen outputs. Descriptions of these measures are provided in Table 9 below. It is noteworthy that the recycling system at Xingeng Village farm has some of the attributes of a wetland. For example, it is likely, given the organic load in the drainage water, that the recycling pond is facilitating denitrification, thereby yielding additional benefits over and above those associated with water recycling alone.

Table 9: Descriptions of Post Mobilisation Mitigation strategies used on Xingeng Village farm

Post Mobilisation Mitigation Strategies	Characteristics	Advantages	Disadvantages
Eco-ditches	Reduce flow velocity Plants and denitrification processes remove N as water flows down the channel	Easy to maintain Produce high quality effluent Natural, low energy system	Relies on existence of drainage infrastructure and appropriate site characteristics Materials may not be available
Wetlands	Inflow and infiltration controlled Plants and denitrification processes remove N as water flows through the wetland	Easy to maintain Produce high quality effluent Natural, low energy system Attract native animals	Space constraints Materials may not be available Requires specific site characteristics Materials may not be available
Reuse of Drainage Water	A certain proportion of used water is reused N is removed by crops	Reduces water usage Reduces additional N inputs Low energy system	Requires establishment of appropriate infrastructure for which there may be space constraints There is a potential production risk depending on recycled water quality

Quantifying the Network

To quantify the network, firstly the nodes and their states (represented as numerical ranges to allow for uncertainty) were defined. The relationships between parent (independent) nodes and child (dependent) nodes and their states were documented in the Conditional Probability Tables of each node (CPT). Quantitative data and deterministic equations, mainly derived from conservation of mass, were used where possible. Other important deterministic equations not based on conservation of mass related to *Wetland Efficiency*, *Gaseous Emissions* and *Nitrogen Concentration*. Where deterministic equations were used, the numerical ranges assigned to states potentially distorted subsequent probability distributions. To accommodate the use of non-linear deterministic equations the number of states was often expanded in child nodes and the numerical ranges assigned to states were not uniform.

The final network is presented in Figure 12. A full description of each node, its states and the sources of data used for developing the CPT's are presented in the detailed paper (Nash et al 2012).

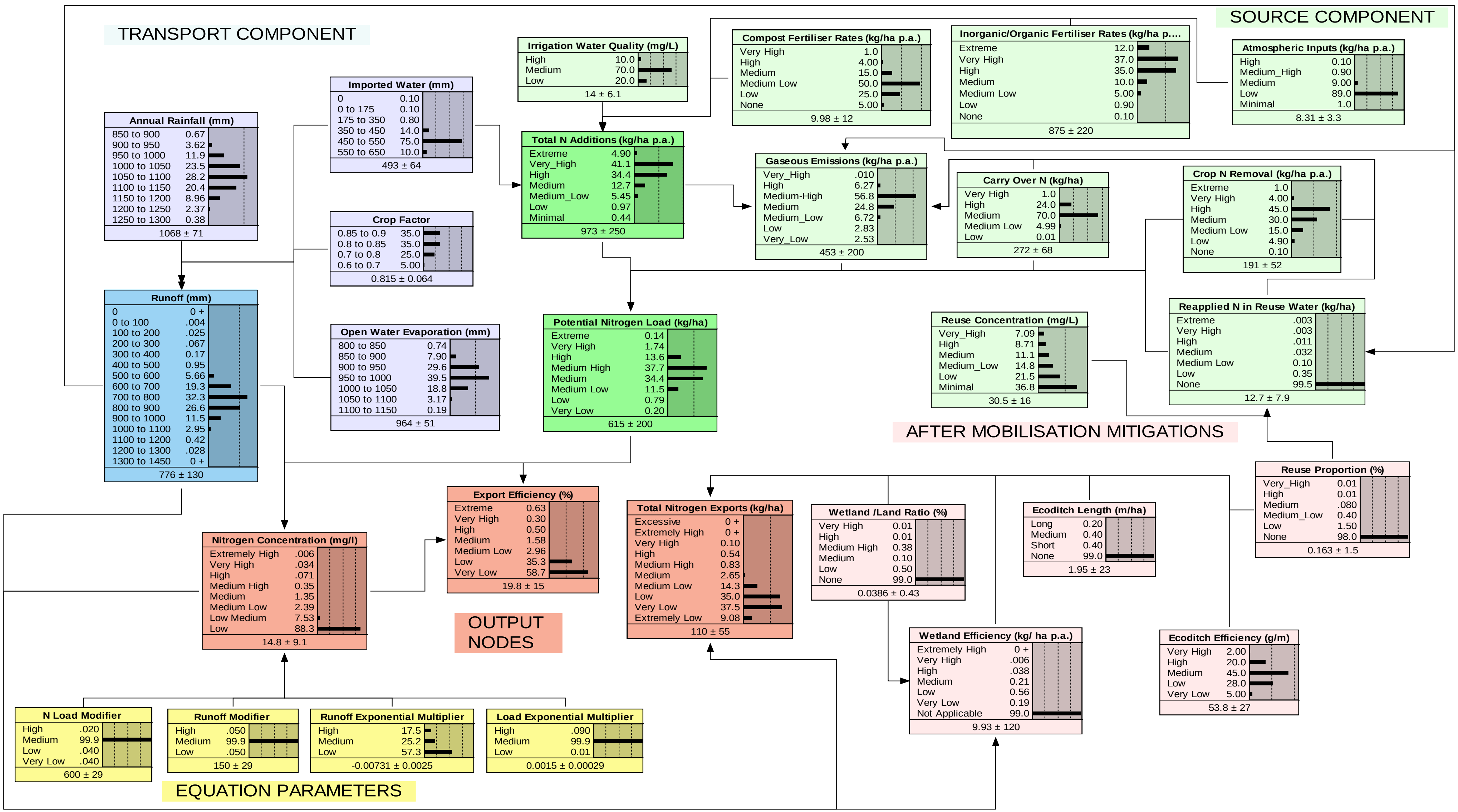


Figure 12: Final Bayesian network of nitrogen exports from vegetable production on the Xingeng Village Farm

Validation

As there was no comprehensive data set that could be used for formal validation, the network was assessed by examining a limited number of case studies, and comparing the network output with the expectations of experts familiar with these systems.

The "Sensitivity to Findings" function of the NETICA software was used extensively as part of this quasi-validation process to examine specific relationships within the network and to compare those relationships with observed data and the assumptions used in their development.

Network Analysis and Application

The factors influencing nitrogen exports from vegetable farming systems in the Lake Tai region are complex and interrelated, and likely to be highly variable. The lack of quantitative information that could be used to develop the network, in addition to the large error estimates, suggest that the network should be used primarily for analyses of general trends rather than absolute predictions of nodal values, especially at the margins.

Bayesian Networks provide a useful way of representing the complexity of vegetable farming systems, comparing management interventions and potentially, for communicating concepts as part of a participatory learning program.

Sensitivity Analysis

The sensitivity of the primary Output nodes, *Nitrogen Concentration* and *Total Nitrogen Exports*, to Transport, Source and After Mobilisation Mitigation nodes can show the relative importance of the factors affecting N exports. The 10 most important factors are shown in Table 10 below.

Table 10 Sensitivity analyses of the Nitrogen Concentration and Total Nitrogen Exports (Top 10)*

Rank	Total Nitrogen Concentration	Total Nitrogen Exports
1	Nitrogen Concentration	Total Nitrogen Exports
2	Total Nitrogen Exports	Nitrogen Concentration
3	Runoff	Runoff
4	Imported Water	Export Efficiency
5	Potential Nitrogen Load	Potential Nitrogen Load
6	Annual Rainfall	Runoff Exponential Multiplier
7	Export Efficiency	Imported Water
8	Gaseous Emissions	Annual Rainfall
9	Runoff Exponential Modifier	Wetland Efficiency
10	Crop Factor	Wetland/Land Ratio

* The full sensitivity analysis is provided in Nash et al (2012).

Key observations are as follows:

- Nitrogen Concentration was most sensitive to Total Nitrogen Exports and vice versa reflecting the computational relationship between the two.
- Nutrient transport factors (i.e. runoff volume) are probably more important than source factors (i.e. fertiliser rate) in determining N exports (loads and concentrations), suggesting that irrigation management needs to be considered as part of an overall mitigation strategy.
- Low sensitivity of Nitrogen Concentration to Total N Additions (ranked 11th) compared to Gaseous Emissions highlights the potential importance of denitrification in these systems and warrants further investigation.

Scenario Analysis

In the absence of alternative data, the Xingeng Village farm was used as a basis for a series of case studies to investigate the properties of the network and the effects of different farming systems, including potential mitigation measures. The twelve different scenarios examined using the Bayesian Network are shown in Table 11.

Key observations from the scenario results include:

Effects of Post Mobilisation Mitigation[1]

Compared to current practice, the Network suggests that an absence of After Mobilisation Mitigations (Table 11, No. 4) is likely to be associated with similar *Nitrogen Concentration* and *Export Efficiency* at the plot scale, but significantly increased *Total Nitrogen Exports* (i.e. Medium-Low compared with Very-Low). Overall, the network suggests that eco-ditches are probably the most effective of the After Mobilisation Mitigations (Table 11, No. 7).

- Effect of Source Management

According to the Network scenarios, source management, such as reducing fertilizer application had a small effect on Nitrogen concentration exports (Medium-low to low). However, it must be noted that the Network does not consider cumulative effects of nutrient inputs as it is based on an annual time-step.

- Cumulative management changes

The Network suggests that cumulative impacts of higher than usual Inorganic/Organic Fertiliser Rates, Compost Fertiliser Rates, Carryover N and Imported Water (Table 11, No. 9) have little effect on Total Nitrogen Exports but lower Nitrogen Concentration and Export Efficiency compared to the current situation. While this may seem counter-intuitive, it is consistent with the sensitivity analysis (see Nash et al 2012) and reflects the importance and complexity of the interactions between the factors contributing to N exports as shown in the Bayesian Network.

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[1] Investigating the effects of mitigation strategies using a Bayesian Network is somewhat more difficult than with conventional process models (see Nash et al 2011).

Table 11: Case studies of the vegetable Bayesian Network

No.	Description	Nitrogen Concentration (mg/L)	Export Efficiency (%)	Total Nitrogen Exports (kg/ha p.a)
1	Current practice	Medium-low(32±9)	Low (25±11)	Very low (47±33)
2	Current Practice larger wetland	Medium (57±14)	Low (35±10)	Very low (43±36)
3	Optimum Eco-ditch Efficiency Using prior probabilities for Wetland Efficiency	Medium-Low(25±17)	Very Low /Low (20±13)	Very Low (31±25)
4	No After Mobilisation Mitigations	Low-Medium(25±17)	Very-Low /Low (20±13)	Medium -Low (128±77)
5	Single Reuse Effect Using prior probabilities for Wetland Efficiency	Low-Medium(26±18)	Very-Low (19±13)	Low (73±48)
6	Single Wetland Effect Using prior probabilities for Wetland Efficiency	Low-Medium(25±17)	Very-Low /Low (20±13)	Low (63±48)
7	Single Eco-ditch Effect	Low-Medium(25±17)	Very-Low /Low (20±13)	Very- Low (36±32)
8	Single Effect of Lower Fertilizer No After Mobilisation Mitigations	Low (17±10)	Medium-Low (42±27)	Low (92±50)
9	High Fertilizer , Carryover N and Imported Water	Low (13±6)	Low (15±11)	Medium -Low (117±51)
10	High Fertilizer and Carryover N Medium Gaseous Emissions	Medium- Low (64±38)	Low (21±12)	Medium-High (254±130)
11	Very High Nitrogen Concentration No After Mobilisation Mitigations	Very- High (120-160)	Low (27±12)	Very-High/ High (300±130)
12	Extremely-High Total Nitrogen Load No After Mobilisation Mitigations	Very- High (116±31)	Medium- Low (43±10)	Extremely- High (600-800)

Diagnostic analysis

The network was used to investigate the combination of factors most likely to lead to a Very-High Nitrogen Concentration and Extremely-High Total Nitrogen Exports (see Table 11, Nos. 11 and 12).

- The network suggests that a Very-High Nitrogen Concentration is most likely to occur when Runoff is lower due to lower Imported Water and the Potential Nitrogen Load is higher due to Low, as compared to High Gaseous Emissions.
- The network suggests that Extremely-High Total Nitrogen Exports will occur in years of slightly less than average Runoff, when there is an Extreme Potential Nitrogen Load as a result of Very-High or Extreme Inorganic/Organic Fertiliser Rates and slightly reduced Gaseous Emissions (i.e. Medium compared to High).

5. Network Applications and Policy Directions

Nitrogen exports from vegetable production systems in the Lake Tai region of China are an important local issue. While it is not within the scope of this initial project to provide a series of detailed recommendations for on-site mitigation of N exports from vegetable farms in the Lake Tai region, the Bayesian Network does suggest a number of general principles that can be used to guide the development of mitigation strategies. Further, the network identifies key areas where additional information should be collected to refine our understanding of the processes leading to N exports, improve our ability to model N exports and thereby, improve the probability that the farming systems we are utilising have acceptable environmental impact levels.

The following policy directions and recommendations for future work have been identified by the Bayesian Network Working Group and senior government officials involved in the ACEDP Lake Tai Project for consideration by Lake Tai policy-decision makers.

Policy directions: Farm-scale management

1. Develop partnerships and governance mechanisms to support farm scale nutrient generation modelling:

- Support the continuation of the Xingeng Bayesian Network Working Group and Steering Committee. Ensure that these structures continue to have a strong mix of policy decision makers, managers and scientists.
- Establish a co-operative research centre (Centre for Excellence) to ensure input from a range of specialists (i.e. modellers, limnologists, hydrologists); linkages with research institutions; and policy orientated outputs.

2. Strengthening the Xingeng Bayesian Network with better data:

- The following data acquisition activities are recommended to better understanding of the factors affecting N exports from these systems and strengthen the Xingeng Bayesian Network:
- Nutrient budgeting - Collect input and output data for specific production areas (i.e. plots defined by the drains). Analyses of this data, when combined with selected analyses amendments on produce, will provide an approximate nutrient budget for different areas of the farm.
- Within farm flow monitoring – establish a farm based flow monitoring system and conduct a range of water balance studies to collect information on plant water use and drainage from vegetable production.
- Within farm nutrient monitoring – establish a farm based nutrient monitoring system and conduct a runoff monitoring study (integrated with the flow monitoring study).
- N loss pathways – collect basic soil physical data relating to infiltration rates and hydraulic conductivities to help strengthen understanding of where N is being mobilised (i.e. surface soil, subsoil, above or below the root zone).

3. Build capacity both in the development, use and application of modelling:

- Establish a training centre and participatory learning programs for both technician and farmer participants to improve local capacity for farm scale nutrient modelling and management.

4. Raise awareness of the role of farm scale nutrient modelling in policy and management decision making:

- Disseminate experiences from the Bayesian Network demonstration to government agencies and other stakeholders across the Basin to raise awareness about the use of modelling for policy development and management decision making.

5. On-farm management:

- Use the Network to develop and demonstrate individual solutions for the Xingeng farm and for other specific farming enterprises, and in doing so use the Network to quantitatively estimate the costs and benefits of particular on-farm solutions.

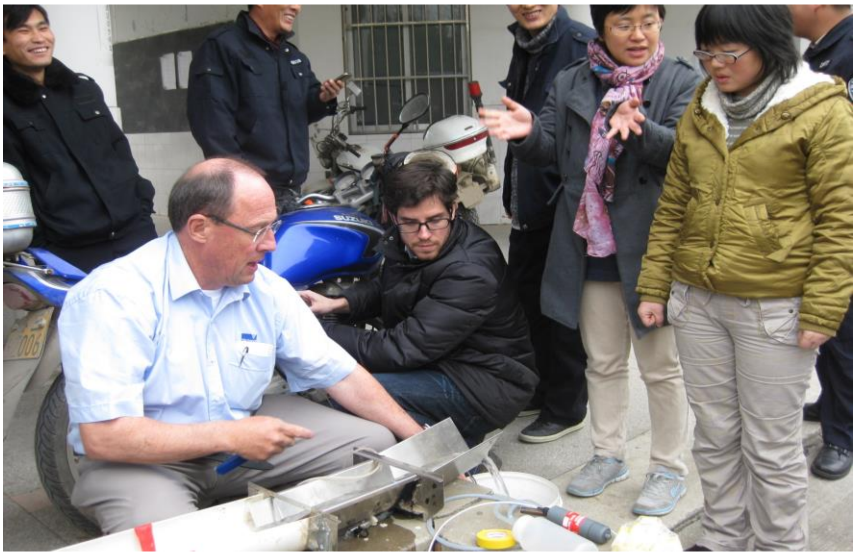
6. Policy applications of a strengthened Network:

- Review and strengthen agricultural/nutrient control policies (e.g. Lake Tai Master Plan; Suzhou Plan for underground nutrient interception dams) and relevant management materials (e.g. guidelines) with a focus on:

- After mobilisation mitigations – for example eco-ditches, giving consideration to: a) ground water management and possible effects on productivity and denitrification; b) optimising denitrification; and c) cost benefit analysis of mitigation measures.
- Mitigation of transport factors – especially ensuing optimisation of water application/irrigation to achieve agronomic and environmental goals for specific crops and production systems
- Mitigation of Source factors (already featuring strongly in current Lake Tai policy), giving consideration to: a) the overall N budget for the system; b) the timing of production to coincide with N mineralisation from organic matter; c) targeted fertiliser application; d) use of nitrification inhibitors; and e) possible N fixation by leguminous vegetables.
- Explore potential for development of compensation mechanisms whereby farms that invest in better management practices are rewarded for their efforts.

7. Explore opportunities to apply the model in other parts of the Lake Tai Basin:

- Conduct regional prioritisation of vegetable farms for mitigation of N exports. Such an application would require extension staff to visit and assess individual farms. While this would be time consuming, the data collected during those visits would be extremely useful in defining the prior probabilities in the network and therein regional norms against which individual farms should be assessed.
- Explore potential for the development of Bayesian Networks for other farm types common in the Lake Tai Basin (e.g. fruit trees).
- Explore potential for linking Bayesian Networks with broader catchment models such as Source IMS.



Demonstrating cost effective monitoring equipment for Xingeng Farm, January 2012

The way forward: Water and Wastewater Centre for Excellence

Chinese and AUS Cluster partners have recently agreed to establish a Water and Wastewater Centre of Excellence in the Lake Take region under a five (5) year cooperation agreement between the AUS Cluster, NDRC ICC and Suzhou Municipality.

The Centre will develop and coordinate a comprehensive water and wastewater program for Suzhou with linkages across the Lake Tai Basin and greater China. Programmatic areas would include:

- Lake Science and Algae Management;
- Catchment-wide nutrient pollution control;
- Design and optimisation of biological wastewater treatment; and
- Biological process control and energy efficiency.

The catchment-wide nutrient pollution control component of the Centre will support actioning of policy directions listed in the sections above and will aim to:

Become a centre for nutrient modelling - creating linkages between policy decision makers, managers, technicians and researchers and promoting the development and use of decision support systems for the management of Lake Tai.

Become a centre for monitoring system refinement - starting with further development and refinement of basic demonstration models, developed from extension activities of Lake Tai Water Pollution Treatment Project.

Become a resource centre for knowledge generation and sharing by promoting a coordinated data gathering and research agenda; facilitating dissemination and communication activities, and providing technical support for current/future nutrient control projects.

Become a centre of nutrient modelling and management education and training by conducting training programs on nutrient modelling (e.g. Source IMS and Bayesian Networks), ideally specifically designed for local projects.

References

This document has been compiled drawing on information from the following Project publications:

Black, D., Walbrink, P., Waters, D., Carrol, C., and Balckmore, J. (Ewater Cooperative Research Centre 2011) - Guidelines for Water Management Modelling – Towards best-practice model application, September 2011, Canberra.

Nash,D., Waters, D., Buldu, Andres., Wu,Y., Lin, Y., Yang, W., Song, Y., Shu,J., Qin, W. and Hannah, M. (2012) - Using a Bayesian network to investigate environmental management of vegetable production in the Lake Tai region of China, Lake Tai Water Pollution Treatment Project, ACEDP.

Rossrakesh, S. and Pierotti, S. (2011). - An Evaluation of PortsE2 – A water quality decision support system utilising the E2 (Source Catchments) framework, July 2011, Melbourne Water.

Waters, D., Jiao, F., Chen, M., Yang, J., Pape, S., Zhang, H., Jun, L. and Nash, D. (2012). - Application of Source IMS water quantity and quality model to investigate nutrient management options for the Dongshan Peninsula, China., Lake Tai Water Pollution Treatment Project., ACEDP.

These documents are available on the ACEDP website: www.acedp-partnerships.org