Global foundations for reducing nutrient enrichment and oxygen depletion from land based pollution, in support of the

Global Nutrient Cycle

Preliminary Pollution Reduction Opportunity Analyses for the Manila Bay Watershed, Pampanga Province, and Cavite Province

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Partners:

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About the GEF-Global Nutrient Cycle Project

Project objective: to provide the foundations (including partnerships, information, tools and policy mechanisms) for governments and other stakeholders to initiate comprehensive, effective and sustained programmes addressing nutrient over-enrichment and oxygen depletion from land based pollution of coastal waters in Large Marine Ecosystems.

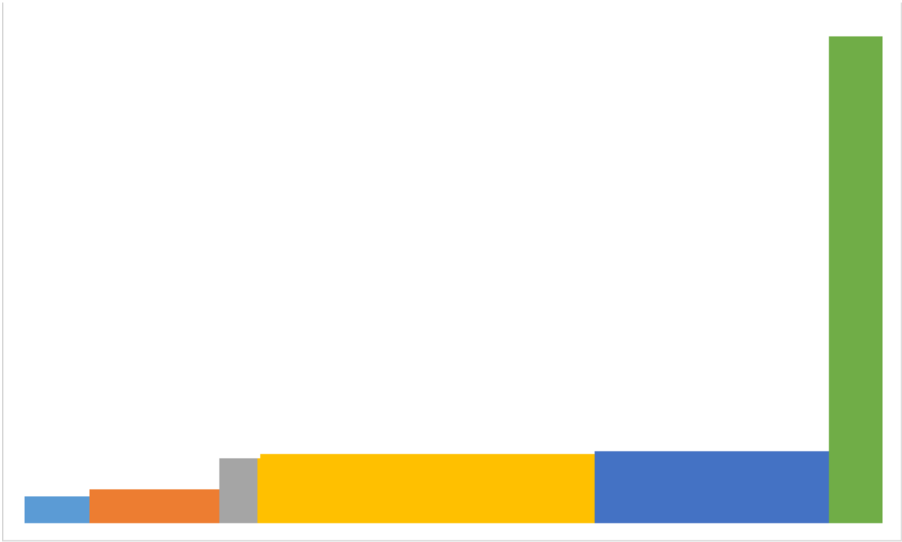
Core project outcomes and outputs:

- the development and application of quantitative modeling approaches: to estimate and map present day contributions of different watershed based nutrient sources to coastal nutrient loading and their effects; to indicate when nutrient over-enrichment problem areas are likely to occur; and to estimate the magnitude of expected effects of further nutrient loading on coastal systems under a range of scenarios
- the systematic analysis of available scientific, technological and policy options for managing nutrient over-enrichment impacts in the coastal zone from key nutrient source sectors such as agriculture, wastewater and aquaculture, and their bringing together an overall Policy Tool Box
- the application of the modeling analysis to assess the likely impact and overall cost effectiveness of the various policy options etc brought together in the Tool Box, so that resource managers have a means to determine which investments and decisions they can better make in addressing root causes of coastal over-enrichment through nutrient reduction strategies
- the application of this approach in the Manila Bay watershed with a view to helping deliver the key tangible outcome of the project – the development of stakeholder owned, cost-effective and policy relevant nutrient reduction strategies (containing relevant stress reduction and environmental quality indicators), which can be mainstreamed into broader planning
- a fully established global partnership on nutrient management to provide a necessary stimulus and framework for the effective development, replication, up-scaling and sharing of these key outcomes.

Project partners:

- Chilika Development Authority
- Energy Centre of the Netherlands
- Global Environment Technology Foundation
- Government of India - Lake Chilika Development Authority
- Government of the Netherlands
- Government of the Philippines
- Government of the United States
- Intergovernmental Oceanographic Commission of UNESCO
- International Nitrogen Initiative
- Laguna Lake Development Authority
- Partnerships in Environmental Management for the Seas of East Asia
- Scientific Committee on Problems of the Environment
- University of Maryland
- University of the Philippines
- University of Utrecht
- Washington State University
- World Resources Institute

Implementing Agency: United Nations Environment Programme
Executing Agency: UNEP- Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)



Preliminary Pollution Reduction Opportunity Analyses for the Manila Bay Watershed, Pampanga Province, and Cavite Province

WORLD RESOURCES INSTITUTE

January 2017

Introduction

This report presents the first output of the Manila Bay Pollution Reduction Opportunity Analysis (PROA) model for Manila Bay. A PROA is a cost-effectiveness analysis that estimates the potential of available control measures to reduce discharged nitrogen and phosphorus loads and the annualized cost per kilogram of annual reduction for each of the measures. The results are graphed in a simple but powerful bar chart that clearly indicates where the best solutions may lie.

Six PROAs were produced. Nitrogen and phosphorus PROAs were produced for the entire Manila Bay watershed, as well as nitrogen and phosphorus PROAs for Pampanga and Cavite provinces. This report also describes the data input sources used for the PROAs, as well as the assumptions made in constructing the PROAs.

These PROAs are the initial output of the PROA model. The reliability of the results is low due to the fact that very little local data is currently available. Hence, a number of assumptions had to be made in all areas—wastewater treatment plant capital and operating costs and nutrient removal efficiencies; agricultural Best Management Practices (BMPs), their costs and efficiencies; and information and data on phosphate detergent bans.

Because of the lack of local data, the preliminary PROA analysis also relied heavily on international reference data. The reference data should be considered as proxy data for this first iteration of the PROAs. The PROA results must be recognized as very much a product of the proxy data and the assumptions, both of which should be replaced in the long run with local data to improve the reliability of the model.

The selected control options are: upgrading existing wastewater treatment plants (WWTPs) to provide nitrogen and phosphorus nutrient removal capabilities and providing nutrient removal capabilities in all new WWTPs; installing grass and forested buffers, constructing or restoring wetlands, and implementing enhanced nutrient management in the agricultural sector; and implementing a phosphate detergent ban. The selected control options are based primarily on international experiences and best professional judgement (BPJ). These choices should be reviewed by local experts and changed as needed to better match the PROAs to local conditions and preferences.

Finally, outputs from the Nutrient Load Model (NLM) on existing nitrogen and phosphorus loads was used as inputs to the PROA analysis. However, detailed NLM data, such as assumed coefficients for fertilizer nitrogen and phosphorus loss rates were not used. More work is needed to more completely link the NLM and PROA analyses and adjust the PROA model to better conform to NLM inputs and assumptions.

While caution is needed in interpreting the results of these PROAs, and far-reaching decisions based on these preliminary results should be avoided, they may still provide some preliminary insight into where the most cost-effectiveness measures might lie. Then, as more local data is collected and the scientific understanding of nutrient pollution sources and their impacts on Manila Bay increases over time, the PROAs can be steadily improved.

Manila Bay Watershed Nitrogen and Phosphorus PROAs

The Manila Bay nitrogen PROA is shown in Figure 1. Note that the X-axis of the six PROAs are not necessarily of the same scale.

Figure 1. Manila Bay Nitrogen PROA

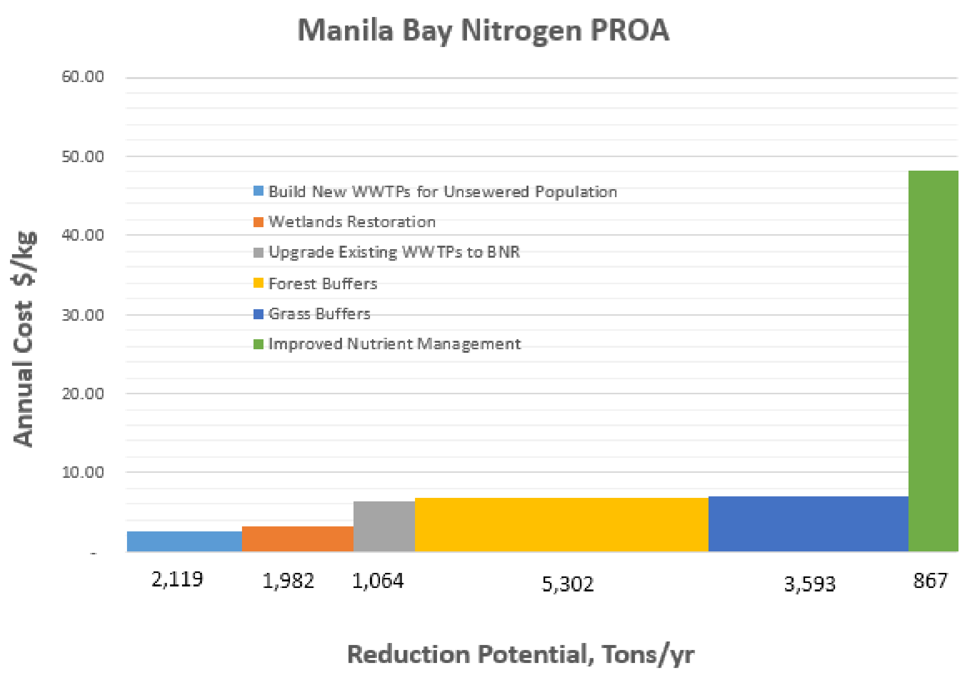
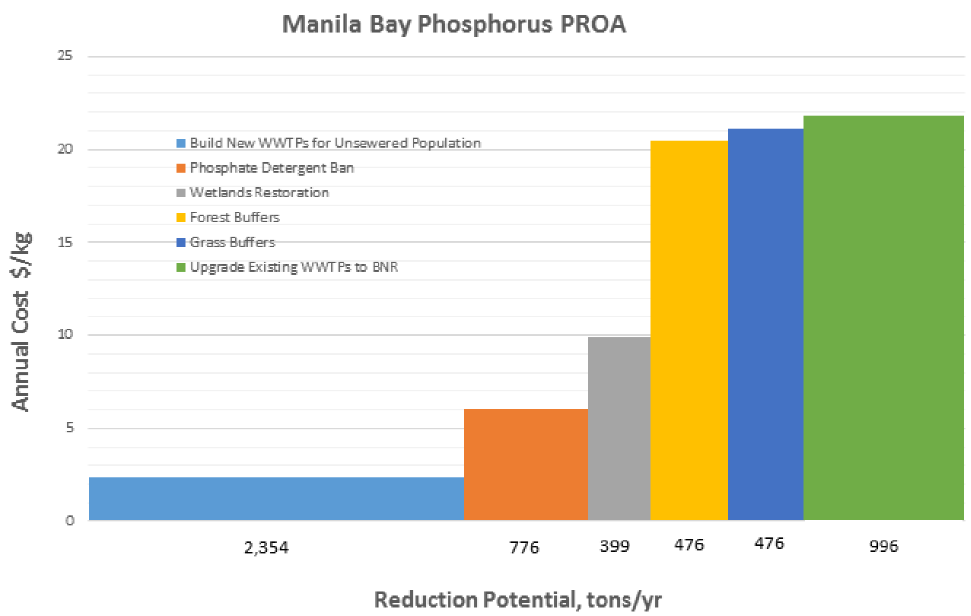


Figure 2. Manila Bay Phosphorus PROA



Discussion

Reduction Potential—Nitrogen

There is significantly more reduction potential in the agricultural sector than the wastewater sector in the Manila Bay watershed.

Forest and grass riparian buffers have the greatest potential for reducing nitrogen discharges in the agricultural sector. Constructed and/or restored wetlands also have significant potential.

The largest reduction opportunity in the wastewater sector is the construction of new wastewater treatment plants to serve currently unsewered urban populations. Upgrading existing wastewater treatment plants serving the urban sewered population also has significant potential. However, it is smaller than that for new wastewater treatment plants because the unsewered population is significantly larger than the sewered one. Overall in the watershed, new wastewater treatment plants result in about twice the reduction potential of upgrading existing ones.

Reduction Potential—Phosphorus

Unlike with nitrogen, there is significantly more phosphorus reduction potential in the wastewater sector than the agricultural sector. Contributing factors are probably the low phosphorus fertilizer use compared to nitrogen, and the relatively low mobility of phosphorus in the environment.

As with nitrogen, the largest reduction potential in the wastewater sector, and overall, is the construction of new wastewater treatment plants to serve currently unsewered urban populations.

The second largest potential is provided by upgrading existing wastewater treatment plants.

A phosphate detergent ban (PDB) is not far behind WWTP upgrades. A PDB would significantly reduce the phosphorus concentration in domestic sewage (for this analysis, it was assumed that the reduction would be 2.75 mg/L).

The wastewater treatment plants currently serving the sewered urban populations were not designed for phosphorus removal. Therefore reductions in influent phosphorus concentrations and loads would translate directly into reductions in discharged concentrations and loads. If these WWTPs were later upgraded for phosphorus removal, the benefits of the PDB would be replaced by removal by the WWTPs.

The same calculation was applied to sewage generated by urban unsewered populations whose sewage is discharged more-or-less directly to surface waters. A PDB would reduce the phosphorus concentrations and loads (again assuming a reduction in the phosphorus concentration of 2.75 mg/L) to these waters. As with urban sewered populations, the PDB benefit would be replaced if new WWTPs with phosphorus removal capabilities were built to serve the unsewered urban population.

The benefit of a PDB is expected to be lower in unsewered rural areas because of the low mobility of phosphorus in the natural environment due to factors such as its low solubility and adherence to soil particles. The PROA model assumed that only 50 percent of the phosphorus from laundry detergents would be delivered to surface waters.

More certainty can be attached to the nutrient reduction benefits of a phosphate detergent ban than to the other options. There is no doubt that it would have an immediate benefit throughout the watershed.

A key point to understand about the graphs is that the reduction potentials of the six options cannot simply be added together to obtain a total potential. The agricultural options in both the nitrogen and phosphorus PROAs are applied to the same sources of loads, hence should be considered as alternative measures with different efficiencies. The wastewater options, on the other hand, are applied to different nitrogen and phosphorus sources, urban sewered and urban unsewered populations, and the reduction potential can be added. The reductions of a PDB can also be added, but then must be reduced as existing wastewater treatment plants serving urban sewered populations are upgraded and new ones serving urban unsewered populations are built.

Unit Costs

The unit costs in all of the PROAs are from the Reference Database and based on international experience. None are specific to the Manila Bay watershed, therefore great care must be taken in drawing conclusions about cost-effectiveness.

The same options and BMPs were used in all of the PROAs, hence the unit costs, and the height of the bars are the same in every PROA. The unit costs are shown in Table 1.

Table 1. Annualized Unit Costs of Control Options, $/kg/year

Option	**Nitrogen**	**Phosphorus**
Build New WWTPs for Unsewered Urban Population	2.60	2.34
Wetlands Restoration	3.30	9.90
Upgrade Existing WWTPs for Nutrient Removal	6.43	21.84
Forest Buffers	6.82	20.46
Grass Buffers	7.04	21.12
Phosphate Detergent Ban (Urban areas, rural areas)*	--	3.58 / 7.16
Improved Nutrient Management	48.18	--

* Different because of 1.0 and 0.5 delivery factors in urban and rural areas, respectively.

Building new wastewater treatment plants to reduce the unsewered urban population has the lowest unit cost for nitrogen and phosphorus. The reason is that nutrient removal would be only one of the reasons for reducing the amount of untreated sewage being discharged, others being protection of public health and reducing the discharge of oxygen-demanding substances to surface waters. Hence, only a portion of the capital costs are assigned to nitrogen and phosphorus in the PROA. It should be stressed that this option provides very important public health and environmental benefits in addition to reducing nutrient discharges.

Pampanga Nitrogen and Phosphorus PROAs

Figure 3. Pampanga Nitrogen PROA

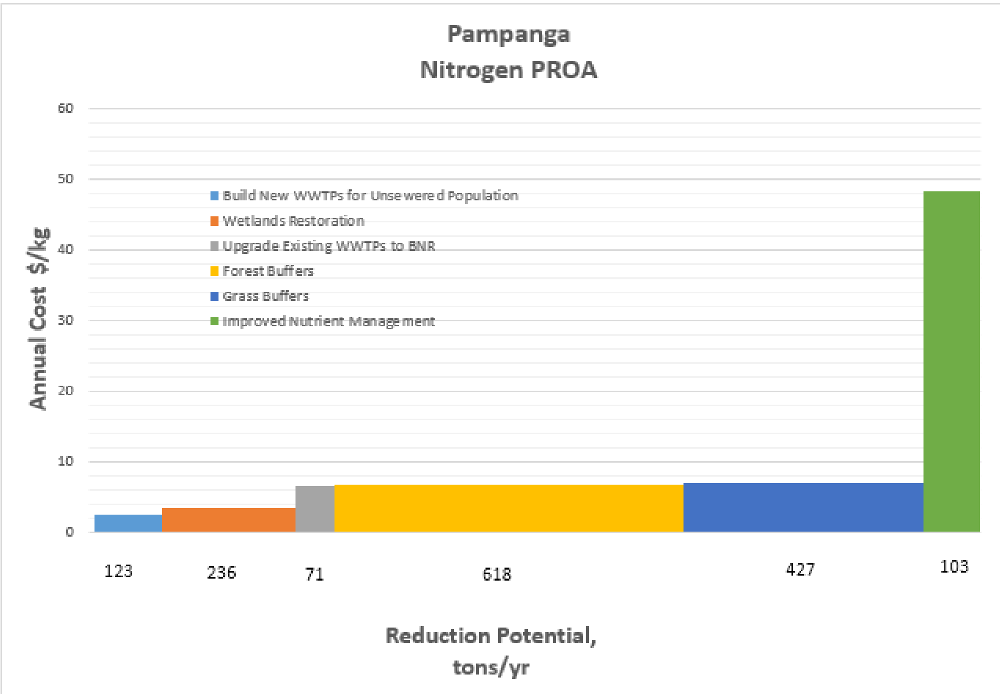
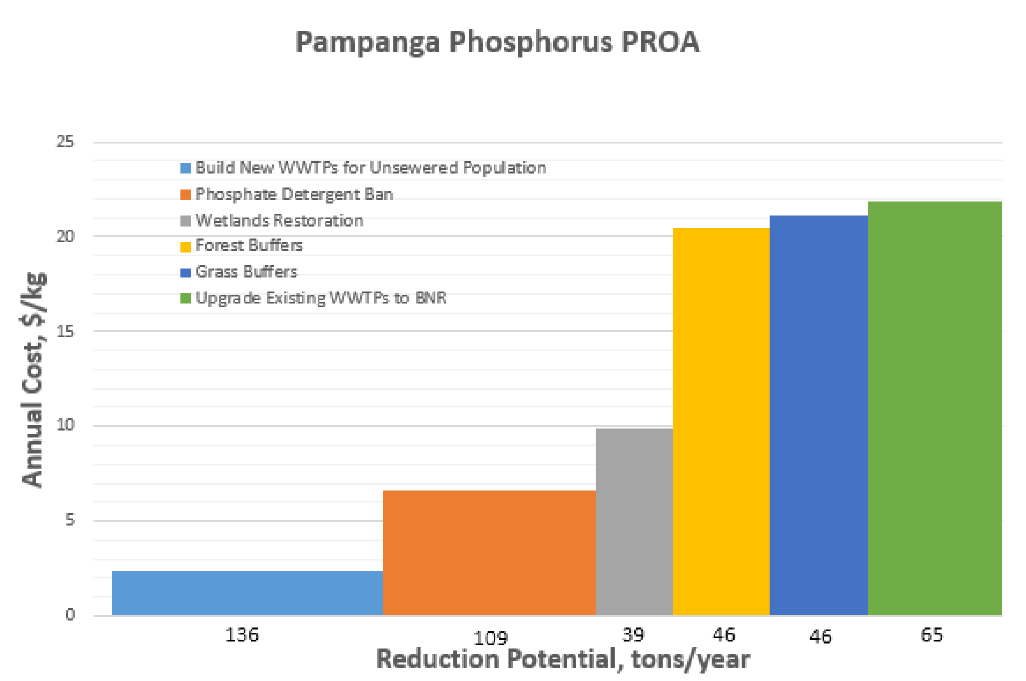


Figure 4. Pampanga Phosphorus PROA



Discussion

The Pampanga nitrogen and phosphorus PROAs differ from the Manila Bay Watershed ones only in scale. The relative nitrogen and phosphorus reduction potentials are about the same. All of the above observations about the Manila Bay PROAs apply to the Pampanga PROAs.

Cavite Nitrogen and Phosphorus PROAs

Figure 5 Cavite Nitrogen

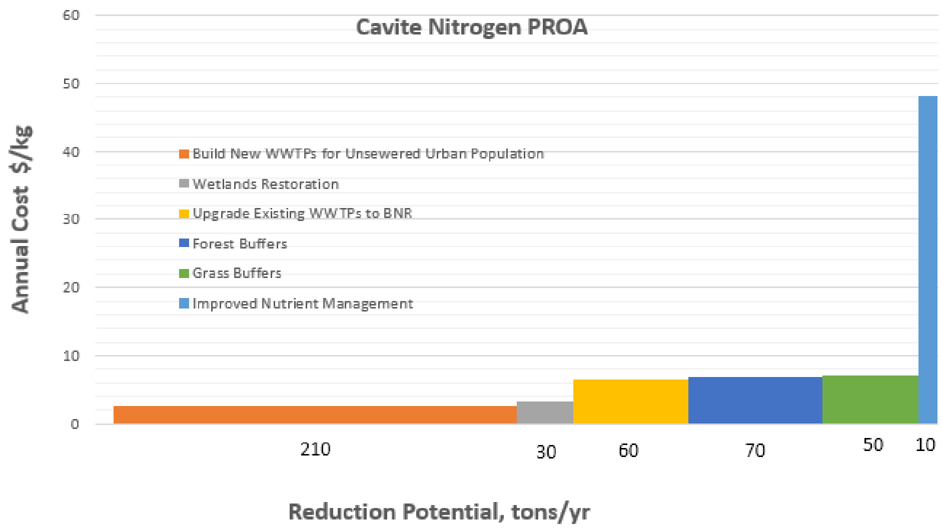
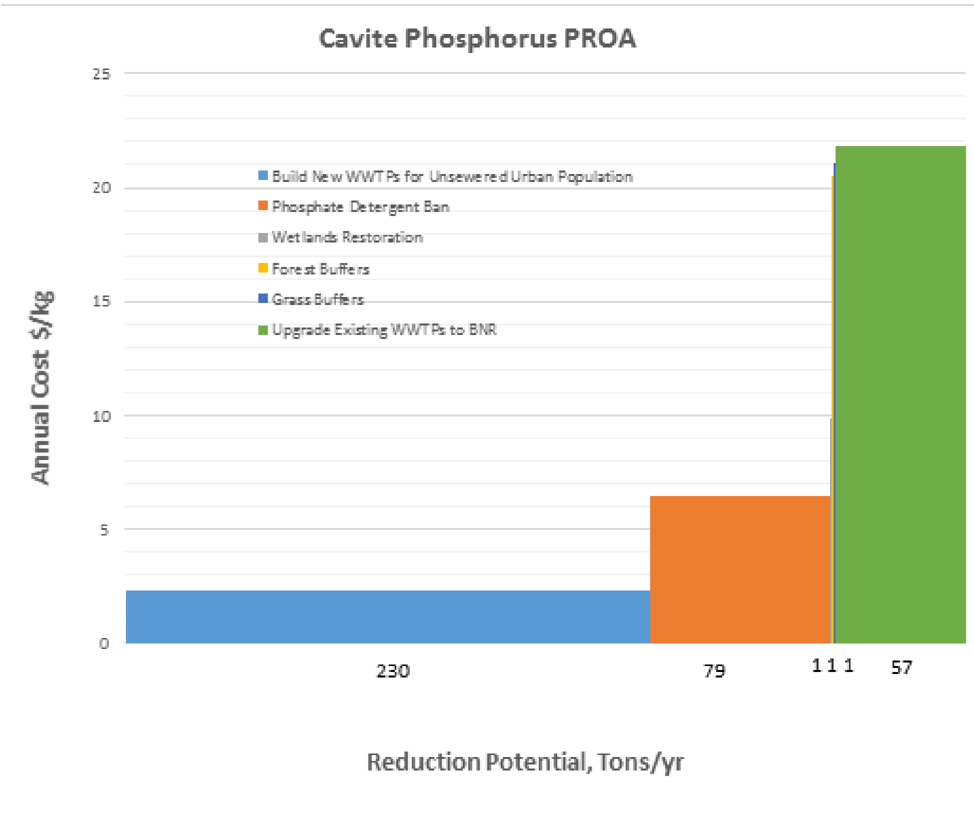


Figure 6. Cavite Phosphorus PROA



Discussion

The Cavite PROAs indicate that the reduction potential in the wastewater sector and for a PDB are significantly larger than the reduction potential in the agricultural sector for both nitrogen and phosphorus. The main reason for this is that there is far less fertilizer use than in Pampanga, especially phosphorus fertilizer use, which is almost non-existent.

Another difference is the relative reduction potential of building new wastewater treatment plants to serve the unsewered urban population versus the potential of upgrading existing wastewater treatment plants serving the sewered urban population. A significantly smaller percentage of Cavite’s urban population is currently sewered than in Pampanga or the Manila Bay watershed as a whole—19 percent versus 30 percent and 27 percent respectively.

Appendix

I. Inputs

A Nutrient Load Model input file containing data by province provided by Lara Soto provided much of the data. Data used is:

1. Population
2. Percent of population that is urban
3. Percent of population that is sewered and connect to a wastewater treatment plant
4. Total nitrogen and phosphorus fertilizer application, kg/yr

From this data, the following were calculated.

1. Urban population
2. Urban population connected to wastewater treatment plants
3. Urban population not connected to wastewater treatment plants

II. Assumptions

Phosphate Detergent Ban

- Due to phosphorus' relatively low mobility in the environment (Maki, 1948), the PROA model allows entry of a delivery factor. There are no appropriate literature values, so 50 percent was used. Research is needed on this.
- 2.75 mg/L of domestic wastewater phosphorus concentration is from phosphate detergents (Lee and Jones, 1984 and 2007)
- No info on cost of PDB. Assumed 1 USD per household per year.

Wastewater Treatment

- Untreated domestic wastewater nitrogen concentration is 15 mg/L
- Untreated domestic wastewater phosphorus concentration is 11 mg/L
- Target effluent concentrations for WWTP upgrades are 3 mg/L nitrogen and 0.1 mg/L phosphorus. (Based on cost data availability in reference database)
- Target effluent concentrations for new WWTPs are 6 mg/L nitrogen and 1.0 mg/L phosphorus. (Based on cost data availability in reference database)
- Twenty percent of the capital cost for new WWTPs is attributable to nutrient removal, split evenly between nitrogen and phosphorus.

Agriculture

- Fertilizer loss rate for nitrogen is 20 percent
- Fertilizer loss rate for phosphorus is 10 percent

Miscellaneous

- Location of discharges and delivery factors were not considered. This can be addressed in future modifications.
- Per capita water use is 58 l/d, Inocencio et al, 1999) of which 20 percent is consumptive use (BPJ)
- Per capita water use is lower in unsewered urban areas and is 48 l/d (BPJ) of which 20 percent is consumptive use (BPJ)
- Adjusted data for Tarlae and Bataan by visual estimate of percent of province in the Manila Bay watershed, 30 percent for Tarlae, 50% for Bataan

III. References

Inocencio, A., Padilla, J. and Javier Esmyra (1999). Determination of Basic Household Water Requirements. Philippine Institute for Development Studies

Lee, G. F. and Jones, A.(1986,2007), Originally published as "Detergent phosphate bans and eutrophication," Environmental Science and Technology 20:330-331 (1986). Updated in January 2007. http://www.members.aol.com/annejlee/DetergentPBan.pdf. Published by the American Chemical Society.

Maki, A. W.; Porcella, D. B.; Wendt, R. H. Water Res. 1984, 18, 893-903.