Regional water quality management for the Dong Nai River Basin, Vietnam

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Abstract A three-year study that started solely as an industrial pollution reduction effort in Dong Nai Province of Vietnam expanded into an ongoing regional river basin water quality management effort. The project was a cooperative effort between the United Nations (UNDP and UNIDO) and the Federal and Provincial governments in Vietnam. A comprehensive approach was used to assess the impacts and strategies for reducing industrial, municipal and agricultural pollution to the water, air and land. The strategy was based upon use of knowledge in four subject areas, economics, ecology, technology and institutions, integrated within a framework for regional environmental quality management, sometimes called Areawide Environmental Quality Management (AEQM). Dong Nai Province encompasses a major developing area immediately north of Ho Chi Minh City. The land area chosen for the AEQM study is the 1,400 square kilometre region in and around Bien Hoa that drains into the Dong Nai River. The Dong Nai River serves many purposes including navigation, fisheries and a water supply for both the Province and Ho Chi Minh City. Extensive industrial and residential development was underway and was projected to increase in the coming decade. A strategy for the control of pollution from liquid, gaseous and solid wastes for the period 1998 to 2010 in Dong Nai Province was developed.

Keywords Environmental management; river basin; Vietnam; water quality models

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Introduction

In 1996, a United Nations sponsored project entitled "Industrial Pollution Reduction in Dong Nai" commenced in conjunction with the Department of Science, Technology and Environment (DOSTE) of Dong Nai Province in Vietnam (UNIDO, 1999). The purpose of the project was to reduce wastewater and other forms of pollution in Dong Nai Province in order to support the desired beneficial uses of the Dong Nai River and the land area in the Province. Another objective included enhancing the capacity of the Province to monitor and manage the environment on a continuing basis after the completion of the study. A combination of international consultants, national consultants and the staff of DOSTE performed the study.

The framework that was selected for use in the study was Areawide Environmental Quality Management or AEQM (Bower *et al*., 1994). AEQM is a comprehensive, regional approach for analysis and planning. The approach was used to develop a strategy for the control of pollution from liquid, gaseous and solid wastes for the period 1998 to 2010 in Dong Nai Province. The strategy included pollution prevention and control activities, improvement in the provincial government's monitoring and regulatory responsibilities, and a multi-province regional approach to environmental planning. Though this paper focuses primarily on the water quality aspects of the AEQM analysis, the project also encompassed air quality and solid waste issues.

Technical activities conducted during the study included field water quality and hydraulic investigations, and hydraulic and water quality modeling of the Dong Nai River.

Options that were investigated included enhanced pollution prevention activities, construction of a major interceptor sewer, and construction of a wastewater treatment plant. Each option was investigated in terms of costs and water quality impacts. When the project began, the Provincial environmental agency expressed interest only in local activities that could affect the environment within the Province. Pollution generation from upstream provinces or discharges located immediately across the river in another province were considered to be outside of the sphere of interest. Over the course of the project, awareness of regional interactions increased, the need for studying the environmental interactions throughout the river basin became apparent and the concepts of regional environmental planning came to be accepted by officials of Dong Nai Province, adjoining provinces, and federal agencies. Major outcomes of the study were an expanded area-wide environmental management plan, increased awareness of the regional nature of environmental issues and on-going multi-province coordination on water and other environmental issues.

Fundamentals of AEQM

Today, there is great interest in finding a way to effectively plan the future of a region in a manner that provides a balance between economic growth, environmental quality and social equity. In other words, more jobs with higher income for all people are wanted without destroying the natural resources for the use/enjoyment by our future generations. This is the meaning of sustainability. A sustainable community is one that takes care to balance present jobs and money with environmental quality for the future. These ideas are included in the planning and management approach of Areawide Environmental Quality Management (AEQM). AEQM is practical and it may be used by municipal and provincial leaders to identify and evaluate alternative environmental futures for their communities. Of course, there is nothing magic about it. The strength of AEQM comes from the integration of information from economics, ecology, institutions and technology. The approach helps one to understand more clearly what the environmental advantages and disadvantages of different community development plans may be. The primary components of an AEQM analysis are listed below.

- **Case (or scenario)**. A case represents a possible future development situation by a group of people living and working in a region to provide goods and services that generate an income for the people while polluting the environment. A case is generally a combination of two types of indicators: socio/economic (usually represented by population growth and industrial growth) and meteorologic/ hydrologic (e.g. wet season or dry season). An AEQM study is generally composed of a group of cases sometimes called a set of possible future situations.
- **Environmental objective**. A description of the conditions of living and non-living systems in a defined region desired by a particular organization, usually a government, is defined as an environmental objective. Frequently, these descriptions are provided in a quantitative form and are called standards such as a dissolved oxygen level at 6.0 mg/l or higher, or in qualitative terms, such as specifying that the surface waters of the region should be "fishable and swimmable".
- **Management strategy**. A management strategy is a set (combination) of measures that could be implemented to achieve a selected environmental objective. Measures may include both structural approaches (e.g. construction of a sewer) and non-structural types (e.g. development or enforcement of regulations). Among the management strategies identified to meet an environmental objective for a particular case, the one that has the lowest cost is specified as the least cost strategy. This management strategy may or may not be politically or institutionally feasible.
- **Incentive**. Incentives are measures that are used to stimulate actions. Examples include

charges, standards, subsidies, fines, jail sentences, and the provision of technical information.

- **Time horizon**. It is the time period for the consideration of alternative futures in an AEQM analysis. Typically, time horizons are fifteen or twenty years. Shorter times, for example, five year intervals, are often used for planning more limited activities.
- **Study area**. It is the land/water area used for an AEQM study. This area is often selected according to watershed boundaries in order to readily include surface water runoff estimates in the analysis. The boundary of the study area for air pollution is usually larger in order to include significant distant air pollution sources.
- **Simulation**. Computer based calculation procedures that use mathematical assumptions and limited field data to generate more general estimates are referred to as simulations. An example is an estimate of the dissolved oxygen profile in a river that receives municipal and industrial wastewater from a number of sources located at different points along the river. This is in contrast with optimization procedures that lead to clearly defined minimum or maximum values for an answer. An example of an optimization procedure is to apply a set of rules for operating each one of a group of sewage treatment plants located in a single river system at different levels in order to obtain the lowest regional cost.

Study area

Dong Nai Province encompasses a major developing area immediately north of Ho Chi Minh City. The land area chosen for the AEQM study is the 1,400 square kilometre (540 square mile) region in and around Bien Hoa City that drains into the Dong Nai River. Bien Hoa City is a rapidly industrializing city of approximately a half million people. The Dong Nai River serves many purposes including navigation, fisheries and a water supply for both the Province and Ho Chi Minh City. Extensive industrial and residential development is currently underway and is projected to increase in the coming decade.

The Dong Nai River System is one of the three largest systems in Vietnam (Mekong, Red, Dong Nai) and covers approximately 36,000 square kilometres (14,000 square miles) in the southern part of Vietnam. The river system is composed of the mainstem Dong Nai River and four major tributaries: La Nga, Be, Saigon and VamCo Rivers. The Dong Nai River and La Nga River combine upstream of the major Tri An Reservoir. Immediately downstream of Tri An, the Be River and Dong Nai River combine. The Dong Nai River then flows through Bien Hoa City, and finally combines with the Saigon River before reaching the sea. A tributary loop in the Dong Nai River called the Cai River in the Bien Hoa area is important because of the magnitude of industrial and domestic inflows entering the river at that point. Tidal effects can be observed in the Dong Nai River almost up to the confluence with the Be River and elevated salinity is found as far upstream as Bien Hoa. There are several hydraulic interconnections between the Saigon River and the Dong Nai mainstem in the 30 kilometres reach of the Dong Nai River upstream of its confluence with the Saigon River. Due to these interconnections and the tidal effects, the flow patterns in this stretch of the river is very complex. A schematic representation of the Dong Nai River from Tri An Reservoir to the South China Sea is shown in Figure 1. A detailed schematic of the river in the vicinity of Bien Hoa is presented in Figure 2.

Precipitation varies significantly over the Dong Nai Basin and throughout the year. Average precipitation over the basin is approximately 2,000 mm/year (78″/year). The wet season extends from approximately May through October with the dry season covering the remainder of the year. During the dry season, average streamflow in the Dong Nai River (near Bien Hoa) is approximately 250 m^3/s (8,800 cfs). During the wet season this average increases to 750 m^3/s (26,000 cfs).

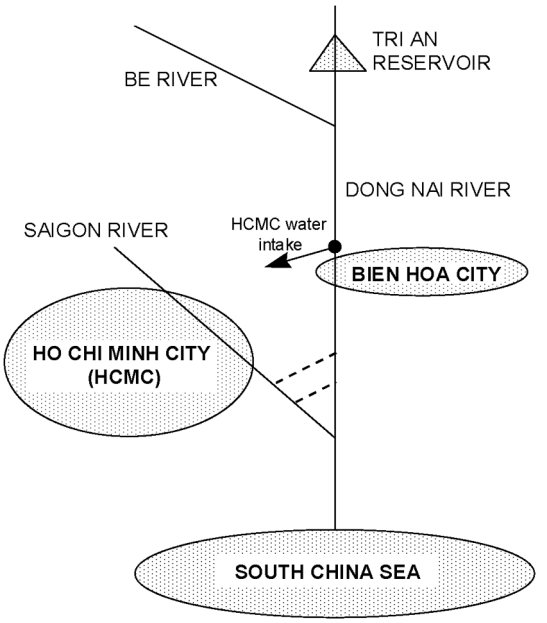

Figure 1 Schematic representation of the study area

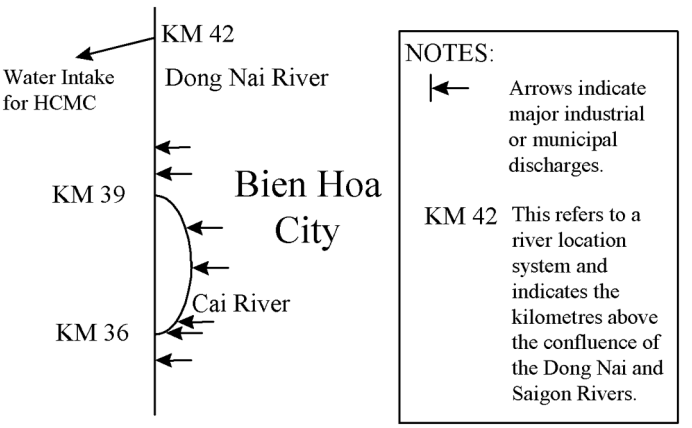

Figure 2 Schematic representation of the Dong Nai River in the vicinity of Bien Hoa

Water quality assessment methods

Various monitoring and modeling tools were used in the water quality assessment portion of the AEQM study. Water quality sampling of the river provided a picture of the water quality in the river in the vicinity of and upstream of Bien Hoa at different times of the year. Modeling provided the capability to assess the likely water quality in the river resulting from alternative management plans under differing hydrologic conditions.

In the study of the Dong Nai River, three separate modeling procedures were applied: 1) the use of a simplified spreadsheet of the dissolved oxygen sag curve to determine the assimilative capacity; 2) application of the QUAL2 water quality model to study the impacts of specific management schemes; and 3) use of the CORMIX mixing zone model to study mixing downstream of major discharges. Each of these modeling procedures served a role in assessing the likely impacts of future development and management schemes on the water quality of the Dong Nai River.

An assimilative capacity assessment was performed in order to define the maximum level of pollution that may be introduced into the environment (by natural or human activities) while still supporting the desired uses. For the Dong Nai River, a simplified spreadsheet model was developed and applied to determine the assimilative capacity under a range of hydrological conditions. This model is a steady-state, one-dimensional model with hydraulic conditions averaged over the tidal cycle. It represents the interaction between biochemical oxygen demand (BOD) and dissolved oxygen (DO).

QUAL2E (Brown and Barnwell, 1987) is a widely used riverine water quality model distributed by the U.S. Environmental Protection Agency. The model is a steady-state, one-dimensional model that may be used to simulate a variety of parameters including conservative substances, and all or part of the DO-BOD-nitrogen-phosphorus cycle. Rivers are represented by a branching network composed of a series of reaches. Reaches are delineated based on common hydraulic conditions and confluences with tributaries. In applying QUAL2E to any river, assumptions and approximations are necessary. For the Dong Nai River, major approximations include the one-dimensional analysis, flow and velocity averaged over a tidal cycle, and elimination of loops in the river (i.e. when the river splits into two channels that later come together).

The third modeling technique applied in the study was the CORMIX (Cornell Mixing Zone Expert System) model (Jirka *et al.*, 1996). Whereas QUAL2E is a one-dimensional model used to predict the water quality over zones that are typically 1 kilometre long, CORMIX is designed to provide more detailed predictions on the mixing zones downstream of a specific discharger. In mixing zones, the concentration of a specific parameter may vary vertically and quite rapidly as one moves away from the effluent pipe or channel. This can result in very high localized concentrations in the receiving stream in the vicinity of the discharge. CORMIX can be used to test the impact of different discharge pipe/channel designs under differing streamflow scenarios, stream and effluent temperature conditions, and differing discharge flow/velocity cases. CORMIX was applied to represent existing discharge conditions at a major discharger and downstream of a tributary.

Water quality assessment results

Sampling showed BOD concentrations of 4–8 mg/l in July and 4–12 mg/l in May throughout the upper basin. It also suggested the presence of a slight dissolved oxygen sag in the Dong Nai River in the section between Tri An Reservoir and Bien Hoa. The sampling study also indicated the presence of a significant level of BOD (4–8 mg/l) in the river immediately upstream of Bien Hoa and dissolved oxygen levels at the site of 5.2–6.6 mg/l. These values indicate that upstream sources influence the water quality of the river before it reaches Bien Hoa. Future routine sampling is required to confirm these results under a wider range of conditions.

Even though the assimilative capacity analysis is a relatively simplified and approximate method, there are several very important conclusions that can be drawn from the results.

1. The Dong Nai River assimilative capacity exceeds the current loadings to the river for most likely parameter values. However, the difference between current loadings and the assimilative capacity is considered to be less than was previously thought suggesting that actions need to be taken in the very near future to assure that the water quality does not degrade.
2. Upstream flow rate and water quality have a very significant impact on the assimilative capacity that is available to the Bien Hoa area. Upstream development or projects that reduce flow or degrade the water quality could reduce or even eliminate the available assimilative capacity in the Bien Hoa area.

3. The assimilative capacity varies very significantly based on the stream standard that is selected. For a stream standard corresponding to National Class or Provincial Class A (DO = 6) for the stream section downstream of Hoa An Bridge, the upstream loading is likely to be the controlling influence and little or no assimilative capacity will be available for the discharges in the Bien Hoa area. For National class B (DO = 2 mg/l) or Provincial Class B (DO = 3 mg/l), the assimilative capacity is much greater.
4. There is uncertainty in several of the key factors that affect the assimilative capacity including the upstream flow rate and water quality condition, and the deoxygenation and reaeration rate. A routine stream and effluent sampling program should be instituted to develop a database that can be used to reduce this uncertainty.

AEQM assessment results

Within the context of the AEQM analysis, QUAL2E was applied to study two different management strategies: (1) No new investments in environmental quality control; and (2) Additional governmental investments of approximately $750,000 per year in enforcement, waste audits, and low interest loans. The second strategy was assumed to result in a 50% reduction in industrial pollution. The case that was simulated assumed high population and industrial growth under critical dry season hydrologic conditions. Analysis was performed for the year 2010. An additional computer calculation was made based upon an assumed reduction in BOD loadings to the Dong Nai River above Bien Hoa. Two alternative environmental objectives were considered: Provincial water quality standard A associated with use of the river as a drinking water source and standard B which is a lower use category. DO standards for A and B are 6 mg/l and 3 mg/l respectively.

Due to the relatively high flow (dilution capacity) in the Dong Nai River, the assessment showed virtually no change in Dong Nai River water quality associated with the second strategy of reduction of existing industrial plant discharges. In both cases, the river meets the DO level B stream standard of 3.0 mg/l. However, neither strategy results in stream standard A being met for DO. The only way to potentially achieve the level A stream standard was to reduce the pollution in the Dong Nai River above Bien Hoa. An assessment of the Cai River, a tributary to the Dong Nai River in Bien Hoa, found that the river is in danger of significant deterioration unless significant new investments in municipal waste water collection and/or treatment are undertaken. One alternative to construct an interceptor sewer to avoid discharges to the Cai River appeared especially promising to improve the water quality in the Cai River.

It should be noted that the analysis of the Dong Nai River water quality was focused on BOD and DO Clearly persistent toxics from industry, transportation activities, and agriculture also impact on river quality. To the extent that pollution reduction programs at existing industries reduce these concentrations, there may be significant improvements in river water quality associated with these activities. However, at the time of the study, there were no data to measure the potential discharge of persistent toxics, or the current levels in the river. Subsequent to the completion of the project there have been disturbing reports that there are elevated levels of Agent Orange, the defoliant used during the Vietnam War in the 1960s, in the Bien Hoa area and in fish caught in the Dong Nai River (*The Economist*, 2002).

Summary and conclusions

The analysis clearly illustrated the need for a regional approach such as AEQM to environmental management for the Bien Hoa study area. Concentrating on industrial discharges only will not be sufficient to maintain the quality of the Dong Nai River. Management of upstream sources, outside of the study area, as well as domestic sources within the study

area will be necessary to achieve even the level B stream standards in the Dong Nai River and especially in the Cai River.

The project was formally completed in 1999. In the intervening time there have been some changes in the situation and some impacts resulting from the project. Notably, the economy in Vietnam and Asia has been depressed and the growth that was envisioned at the start of the project in the mid 1990's has not materialized. This has both lessened the pressure for pollution prevention and reduction, and has resulted in less availability of funding for such endeavors. As a result, the recommendations that required significant funding have not been undertaken. On the positive side, the study has certainly heightened the awareness in Dong Nai Province and surrounding provinces concerning the regional nature of environmental problems. Planning tools and methods that emphasize regional issues such as GIS are being employed. Cooperative environmental management studies among the provinces are presently being considered and decisions made at the provincial level take into account the larger regional picture.

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