Harbour Area Treatment Scheme: Moving Forward

Introduction

The Hong Kong harbour is a valuable resource for the people of Hong Kong. Like all coastal cities, Hong Kong is both a user of the harbour and a steward of its resources for future generations. The Harbour Area Treatment Scheme (HATS), formerly known as the Strategic Sewage Disposal Scheme, is the most important programme undertaken by the Government to enhance the water quality and environment of the harbour area, helping Hong Kong to continue its development as one of the world's most populous and advanced cities.

Pollution reduction achieved so far:

- ***95% of households*** **are now served by the public sewerage system**
- **The number of gazetted beaches with poor or very poor water quality dropped to *7* by *2001*, compared with *17* in *1995*.**
- **About *1.84 million cubic metres per day (m ^{3}/day), or 73%* of Hong Kong's total wastewater flows, now receives proper treatment**
- ***70% of sewage*** **around the Victoria Harbour receives chemical treatment at Stonecutters Island**
- ***600 tonnes of sludge*** **per day from the HATS Stage I catchment that used to pollute our waters is now prevented from entering the harbour**
- **Water quality of the eastern harbour has improved since Stage I's full commissioning in late 2001 as reflected by a *90% reduction* in bacteria and *15 to 20% increase* in dissolved oxygen.**
- **Collection and treatment system in Tolo Harbour has resulted in a drop in the occurrence of red tides from *43* in *1988 to 16* in *2000***

HATS is a massive infrastructure programme that comprises four stages. We have completed Stage I, which is already treating about 70% of the sewage around the harbour. A number of important trials and studies are now being conducted to help us decide the best way forward for the remaining stages of HATS. As part of these trials and studies, our experts will be applying certain criteria to various options to help decide on the best way forward. The purpose of this document is to tell you about these trials and studies, and explain how your opinion on the proposed water quality criteria can help the Government conduct these studies which will shape the way forward for HATS.

These trials and studies will finish by the end of 2003. The Government will then undertake full-scale public consultation on the various options and way forward, in preparation for implementation of the most favourable option. Until then, we will give you updated information on our progress at key junctures of the project.

History of HATS

Stage I Commissioning

Stage I of HATS, comprising a sewage treatment plant and a deep tunnel sewage collection system, has already been fully commissioned. Stonecutters Island Sewage Treatment Works has been in operation since 1997. In December 2001, 23.6km of deep tunnels were commissioned. These tunnels collect sewage from all of Kowloon, Tseung Kwan O and parts of eastern Hong Kong Island, and deliver it to Stonecutters Island for chemical treatment. Now, about 1.3 million cubic meters per day of sewage is being treated at Stonecutters Island. Additional information on the background to HATS is available at http://info.gov.hk/cleanharbour/

New Trials and Studies Recommended

In 2000, an International Review Panel (IRP), an independent panel of experts appointed by the Government, reviewed plans for the remaining stages of HATS. These final stages involve collection and treatment of sewage from the northern and western districts on Hong Kong Island, as well as arrangements for discharge of treated effluent. The IRP considered that the remaining stages of the project might best be implemented using a different scheme than that proposed earlier. By proposing the use of compact biological treatment technology to provide a very high level of treatment it identified four options (see maps below). Each of these four options involved discharging the highly treated effluent into the harbour waters. The IRP considered that all offered the same or better environmental protection than the earlier scheme but at lower overall costs. The IRP also identified the trials and studies that the Government should conduct to verify the effectiveness of compact sewage treatment technology in Hong Kong and decide on the best option for the next stages of HATS.

Trials and Studies Underway

In November of 2001, the Government commissioned CDM, a locally-based environmental engineering consultant, to evaluate the environmental and engineering aspects of the IRP recommended options. Working in conjunction with international and local experts, CDM is carefully reviewing key scientific, technological and socio-economic issues arising from the IRP options. The study team will report on the relative merits of each option, so as to help the Government and community make a decision on the best way forward for HATS.

Option A: All Treatment at Stonecutters Island

Option B: Treatment at Stonecutters Island and Lamma Island

Option C: Treatment at Stonecutters Island and Sandy Bay

Option D: Treatment at Sandy Bay, North Point and Stonecutters Island.

Public Involvement

It is important that the people of Hong Kong, the ultimate owners and beneficiaries of HATS, are involved in its implementation and are part of the decision-making process. We thus welcome comments on the future proposals, and on the trials and studies.

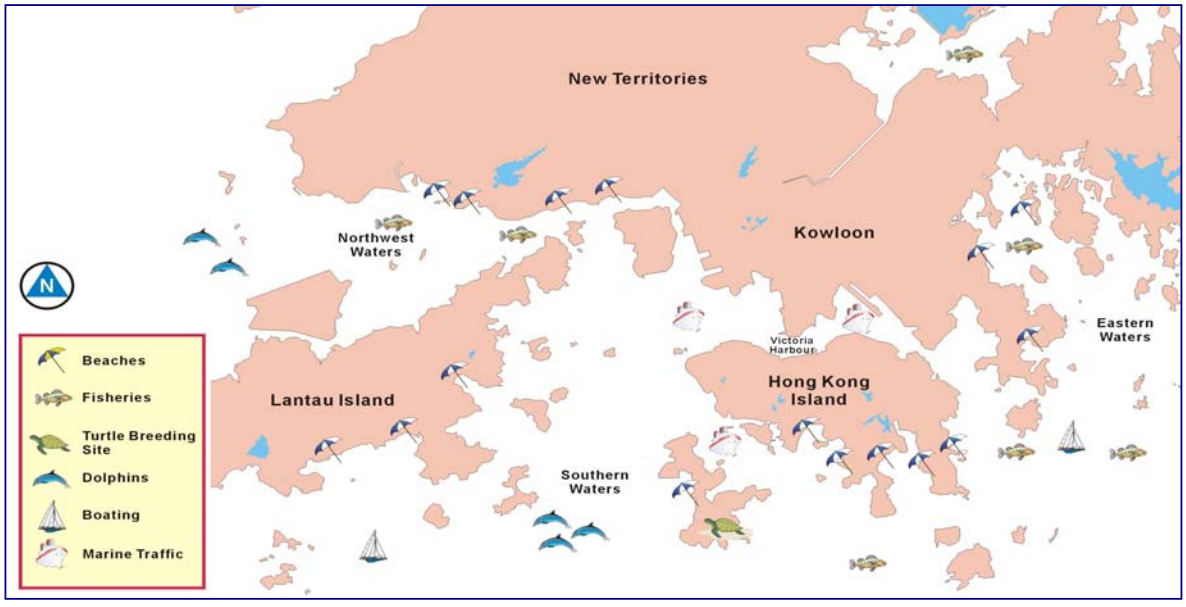
Key Challenges

HATS is a major investment for Hong Kong and will protect the water quality and environment of the harbour area for many years to come. As with any other important public works project, HATS will require significant investment of financial resources. Therefore, it is important to carefully balance the benefits of the project with the financial cost to the community. In weighing up the choices the benefits of taking action, and the associated direct financial costs, would need to be weighed against the often intangible cost of doing nothing, that is the cost of allowing the continued degradation of arguably Hong Kong's most precious asset and an important part of its brand identity. Achieving the right balance between cost and benefit is one of the principal objectives and the main challenge of these trials and studies.

The key to balancing harbour water quality goals and cost is to understand that Hong Kong's waters encompass a large area with multiple uses. We also have a responsibility to protect the ecology of our waters, so there may be different approaches to different areas, for example by achieving higher standards of treatment for discharges. In general terms we will want to provide a high level of treatment for effluents discharged into the water bodies used for more sensitive purposes (e.g., boating, habitats of important marine species, gazetted beaches). This high level of treatment may not be required for water bodies with less sensitive uses (e.g. commercial marine traffic). By adopting different approaches to different water bodies, we can properly allocate financial resources to meet our water quality needs, based on the uses of the water bodies concerned.

Uses of Hong Kong Waters

As you can see in the map below, the harbour and surrounding waters are divided into four main areas.



The main types of use of water bodies in Hong Kong are:

Fishery resources including fish culture for human consumption

Sensitive habitat including areas of special significance for the protection of important marine life such as corals, turtles and dolphins

Recreation including swimming, water skiing, windsurfing, boating, sailing

Scenic including enjoyment of the harbour views

Commercial including marine traffic and shipping

Table 1 shows these areas and the relative importance of each use to each area.

We have responded to these multiple uses by setting baseline water quality standards for the entire harbour area and surrounding waters. Such baseline standards comprise accepted scientific parameters such as the level of dissolved oxygen and ammonia. These baseline standards can be adjusted for particular areas if necessary. Of course, any increase in water quality standards will result in a corresponding increase in the level and cost of sewage treatment as indicated in the table below.

Table 2, below, shows the general relationship between uses, levels of treatment and cost.

Table 2: Relationship between Uses, Treatment Levels and Cost

Harbour Uses	Treatment Level Needed	Relative Cost
Fishery resources	High	$$$$
Sensitive Habitat	High	$$$$
Recreation	Standard/High	$$$
Scenic	Standard	$$
Commercial	Low	$

Table 1: Levels of Use in the Harbour and Surrounding Waters

Area	Fishery Resources	Sensitive Habitat	Recreation	Scenic	Commercial
Victoria Harbour				//	////
Eastern Waters	///	///	///	//	/
North Western Waters	///	//	/	/	///
Southern Waters	///	///	//	//	/

Assessment Criteria

The environment is not static. Therefore, the uses of our harbour and surrounding waters and the treatment levels required to support those uses may change occasionally with time and circumstances. Any changes in the uses may have an impact on our decisions on the level(s) of sewage treatment to be adopted and these changes may in turn affect the capital and recurrent costs of the next stages of HATS.

As we move forward to evaluate the IRP options, we will develop a set of assessment criteria to assess the performance of each of the IRP options. The criteria will reflect the uses in the harbour waters to be protected, as well as broader engineering, social and economic considerations. **Table 3** shows the criteria we have in mind.

remove the higher the cost will be. Thus there is an obvious link between uses, water quality criteria, and the eventual agreed scheme or schemes that are likely to be acceptable to the people of Hong Kong. It may be that we want to apply a very high use level and stringent water quality criteria in one area, but a lower use level and less stringent water quality criteria in another. **Table 4** on the following page shows typical harbour uses and the significant factors associated with each one.

On the basis of the various uses of the harbour areas as set out in Table 1 above, we have developed a set of proposed water quality criteria described fully in the Annex attached to this document. We welcome the views of all interested parties on these criteria. We recognise that the details in the Annex are highly technical. We believe, nevertheless, that the concept -

Table 3: Likely Initial Assessment Criteria

Marine Water Quality Criteria	Onshore Environmental Criteria
Π *Protection of Bathing Beaches*	Π *Noise*
Π *Protection against Toxic Impacts*	Π *Air*
Π *Protection against Harmful Algal Blooms*	Π *Traffic*
Π *Protection of Areas of Special Significance*	Π *Land Use Compatibility*
	Π *Visual Impacts*
	Π *Protection of Areas of Special Significance*
Engineering Criteria	**Socio-Economic Criteria**
Π *Compatibility with Other Development Plans*	Π *Capital Cost*
Π *Construction Issues*	Π *Operating Costs*
Π *Operational Issues*	Π *Net Present Values*
Π *Flexibility*	Π *Job Creation*

Although there will be many relevant criteria, the significant ones are those which apply to marine water quality. To reach the highest quality standards to protect the most sensitive uses we need to remove the greatest amounts of pollutants from the sewage. The more pollutants we have to

that we need to establish water quality criteria to protect uses that are consistent with the aspirations of the community - is of significance to everyone. In this spirit, we also welcome feedback on what aspirations you have for our harbour and surrounding waters.

Table 4: Harbour Uses and Associated Significant Factors		
Harbour Use	**Examples of Uses**	**Factors**
Fishery Resources	Π Fish farming operations Π Fish spawning for native (wild) fisheries	Π High dissolved oxygen, to allow fish to breathe Π Low concentrations of dangerous substances, such as ammonia and metals to prevent toxic effects on fish Π Low nutrients such as nitrogen and phosphorus to prevent harmful algae
Sensitive Habitat	Π Corals Π Turtle nesting grounds Π Dolphin and porpoise habitats	Π High dissolved oxygen, to allow marine life to breathe Π Low levels of dangerous substances, such as ammonia and metals to prevent toxic effects
Recreation	Π Swimming Π Water contact sports, for example windsurfing	Π Low levels of *E. coli*, which is a measure of bacterial contamination by sewage indicating the likelihood of users contracting minor disease from contact with the water
Scenic	Π Enjoyment of harbour views	Π Little suspended matter to ensure good visibility and lack of odours
Commercial	Π Marine traffic and shipping Π Cooling water for air conditioning Π Water for toilet flushing	Π Freedom from large floating debris Π Moderate dissolved oxygen which prevents odours in the system. Π Reduced *E. coli* to guard against health risks from contaminated water in the cooling and flushing systems.

Contact Us

The study team aims to furnish the Government and the community with the technical, engineering, environmental, and financial information they need to make decisions that will enhance and preserve the Hong Kong Harbour Area for themselves and future generations. As part of this process we have prepared this document, which is issued with the Government's agreement.

We will be sharing more information with you in the course of this project.

Meanwhile, should you have any views on the proposed water quality criteria set out in the Annex, please send your comments by 27th July, 2002 to:

HATS Project Team

CDM International Inc.

4305-12 Metroplaza Tower 1

223 Hing Fong Road, Kwai Fong

***or* fax us at 24249114**

***or* e-mail us at: hats@cdm.com.hk**

TECHNICAL ANNEX

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to set out for consultation and discussion various water quality criteria that are proposed for use in the Engineering and Environmental Feasibility Study (EEFS) of the Harbour Area Treatment Scheme (HATS), formerly known as the Strategic Sewage Disposal Scheme (SSDS).

In November 2000, an International Review Panel (IRP) convened by the Government to review the remaining stages of SSDS recommended consideration of four alternatives. The IRP further recommended a number of studies and trials to evaluate those four options. One of those studies is the EEFS. The others involve pilot scale trials of compact sewage treatment technologies suitable for use in Hong Kong, investigations into the most appropriate approach for the future procurement of the HATS project, and studies of the capacities of the Stage I HATS works already constructed.

This paper is being circulated as an annex to a more general information document. That document describes in broad terms the background of the HATS project, the options being evaluated as part of the EEFS work, the uses of Hong Kong waters, and the criteria likely to be used in the evaluation of the options. The intended audience of this document is those stakeholders with specific scientific training and interest in the issue of water quality, and the relationship between water quality and the uses of Hong Kong's waters.

Other criteria associated with the engineering issues, landside environmental impacts, the social impacts and the financial assessments of the HATS project will be part of the overall evaluation of the HATS project, and will be dealt with separately.

1.2 CENTRAL ISSUES

The principal objective of the HATS project is the improvement of the quality of Hong Kong waters consistent with the long term uses of the receiving waters, balanced appropriately with the costs and other environmental and social impacts of a project of this scale. In order to assess the IRP options with respect to water quality, it is necessary to develop criteria against which the impacts of the various options may be measured.

Water quality objectives for Hong Kong were originally developed in the late 1980's, concurrent with the then ongoing sewage planning. Work done at that time established a variety of receiving water quality objectives, taking into consideration the uses of the receiving waters, the then current state of knowledge concerning the impacts of various constituents on ecosystem functionality and observed concentrations of contaminants of interest in Hong Kong waters.

As part of the Environmental Impact Assessment of the SSDS, project-specific water quality criteria were derived. This effort resulted in the use of an expanded set of marine water quality criteria, reflecting advances in the understanding of the sensitivity of nearby water bodies.

The brief of the HATS EEFS requires that further consideration of the water quality criteria be undertaken and proposed for consultation with stakeholders. In partial fulfilment of that requirement, the EPD has conducted a further review of the work done in 1998. The EPD has considered studies undertaken locally with respect to these issues, has considered comments made with respect to water quality criteria as part of the IRP review process and

has consulted with other governmental organizations with an interest in these matters. The EPD has also sought input from the HATS Monitoring Group, a committee chaired by the Secretary for the Environment and Food, which includes four members of the Advisory Council on the Environment, and the three local members of the IRP. Based on those efforts, the EPD has passed a revised set of water quality criteria to the consultant for further refinement as necessary, and for consultation.

Although covered in greater detail in later sections of this document, the highlights of the work of EPD are as follows:

- That modifications to the water quality criteria for dissolved oxygen ought be proposed, based on work undertaken locally on the environmental impacts of dissolved oxygen on local species, combined with reference to work overseas
- That modifications to the water quality criteria for nitrogen ought be proposed, considering the ecological function of various segments of Hong Kong's coast
- That specific recognition should be given to the uncertainties associated with the potential for eutrophication associated with the proposed water quality criteria for nutrients
- That in general the criteria for other pollutants as proposed for use in the Strategic Sewage Disposal Scheme (SSDS) Environmental Impact Assessment are appropriate for use in this EEFS undertaking.

Later sections of this document cover these issues in greater detail.

1.3 OPPORTUNITIES FOR INPUT

Specific water quality criteria for evaluation of the IRP options will be developed over the course of the EEFS. As currently envisioned, opportunities for discussion of the criteria will be:

- Through an initial consultation meeting of invited parties to be held on 22nd June 2002 in the auditorium (Room 401) at North Point Government Offices.
- Through written responses to this document to be delivered to CDM at the address included at the end of the document not later than 27th July 2002.

After the receipt of comments, by the autumn a revised document setting out the final listing of water quality criteria to be adopted for the purposes of this EEFS will be circulated to all stakeholders, together with a compilation of the comments received.

1.4 ORGANIZATION OF THE REPORT

This document is organized into seven sections covering the following topics:

Section 1 Introduces the general purpose of the report together with an identification of the key issues, and a schedule for discussion of the criteria

Section 2 Presents the background to the development of Water Quality Objectives and water uses in Hong Kong, and the tools available to the EEFS for assessment of the water quality criteria

Section 3 Presents a discussion of the proposed criteria for Dissolved Oxygen

Section 4 Presents a discussion of the proposed criteria for Nitrogen and Phosphorus

Section 5 Presents a discussion of the proposed criteria for the protection of aquatic life

Section 6 Presents a discussion on the proposed microbiological water quality criteria

Section 7 Presents conclusions with respect to this document

2 BACKGROUND

2.1 ROLE OF WATER QUALITY CRITERIA

Water quality planning and management in Hong Kong, as in many jurisdictions, is intended to preserve or restore, where necessary, uses of local waters. These can range from the use or enjoyment of waters by humans – such as for bathing beaches and commerce, to the need to enhance sustainability, and protect locally important wildlife.

In order to guide the development of water quality management plans, the Government has developed a variety of Water Quality Objectives (WQOs). The WQOs are numerical measures of ambient water quality that are established to protect the uses of the receiving waters. Since the uses can vary from area to area, WQOs can also vary from area to area. For example, waters used as bathing waters require protection against bacterial contamination, whereas waters used for commercial navigation do not. Thus bathing beaches have a WQO for *E. coli*. Waters used solely for commercial navigation on the other hand, do not. **Figure 1** shows the general distribution of important marine related ecological and human resources that are intended to be managed according to the WQOs.

These WQOs are viewed as goals that reflect the long-term health and well being of Hong Kong's waters. They are not necessarily used as benchmarks for specific projects such as HATS, although the WQOs may be used in that manner in some instances. To assess project specific impacts, water quality criteria are developed and applied to assess the relative impacts of alternatives. Water quality criteria reflect the fact that sewage effluents may contain contaminants in amounts that are above the WQOs, but which can be met within acceptably small distances from the point of discharge. Water quality criteria may also be used in those conditions where the ambient conditions (in the absence of impacts from the HATS discharge) exceed WQOs, and thus cannot be met in the short run by project specific actions, but rather require larger scale, longer term actions.

2.2 APPLICATION OF WATER QUALITY CRITERIA

Water quality criteria are commonly applied to the mixture of effluent and ambient waters at one of two locations: either at the edge of the zone of initial dilution, or at the edge of a pollutant-specific mixing zone.

The zone of initial dilution encompasses a small area in the immediate vicinity of the point of discharge. As Hong Kong wastewater is usually less dense than seawater, when it is discharged it rises towards the surface, is swept along by prevailing currents and mixes with the surrounding water. Within a short space of time, it achieves neutral buoyancy, being completely mixed with the surrounding seawater. In most instances, the zone of initial dilution is generally confined within a few water depths of the point of release. For example, in water 10 metres deep, complete mixing, and thus the outer edge of the zone of initial dilution, is usually achieved within about 30 metres of the point of discharge. For the purposes of assessing the HATS discharges, it is proposed that criteria established for conservative toxic substances should be met at the edge of the initial dilution zone.

Beyond the zone of initial dilution, wastewater contaminants will undergo further dilution and dispersion. If they are not conservative substances, they will also undergo further chemical and biological changes. The area where this happens may be considered as the mixing zone. Eventually the effect of the wastewater discharge will no longer be measurable, and the influence of the wastewater on surrounding water quality will no longer be

distinguishable. Prior to reaching that point, there will be a boundary at which the water quality meets the criteria that are derived for this study. The distance within which each criterion is not met will vary with the nature of the substance, or its effect. In assessing the application of mixing zones to specific substances, it is important that the mixing zone be as small as possible, and that it should avoid any uses that might be adversely impacted by the contaminant.

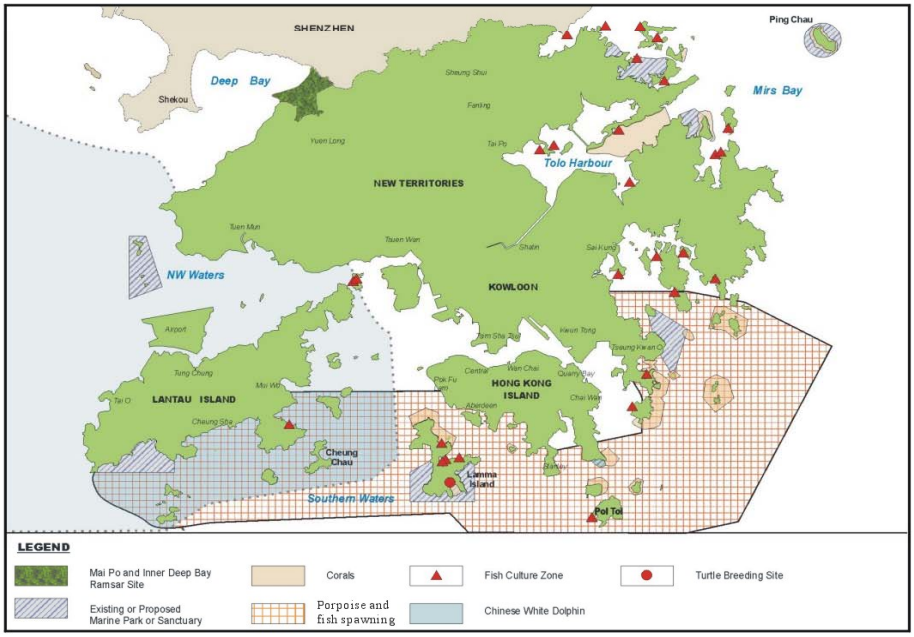
2.3 ASSESSMENT TOOLS

In the application of these water quality criteria to the IRP alternatives, the EEFS will use a variety of data sources and analytical tools. It is not the intent of this paper to discuss these tools or data in detail, but it is believed that an understanding of the tools that will be used is useful for reviewers of this criteria document.

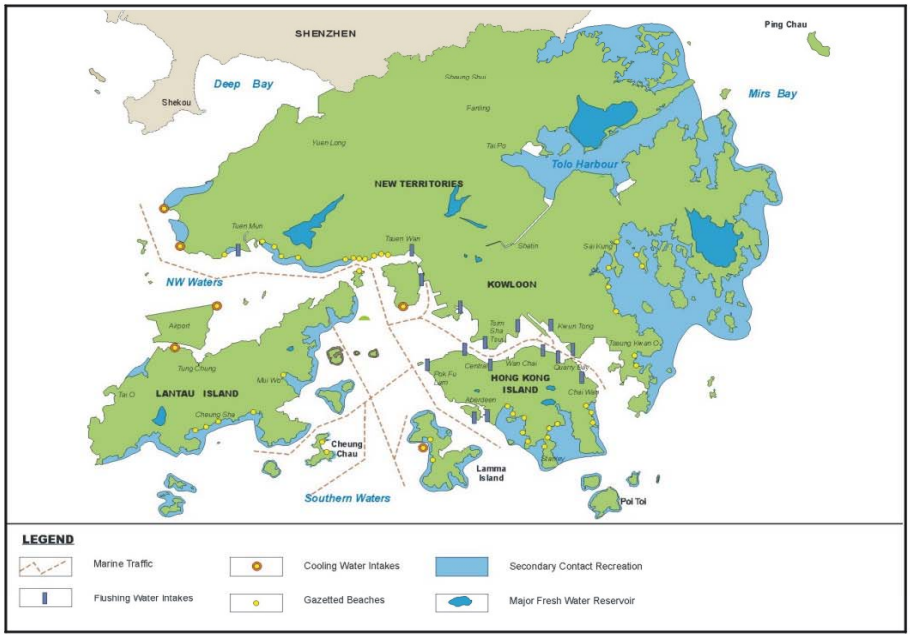
Water quality forecasts will be made using two different, but related tools. The estimated concentrations of pollutants at the edge of the zone of initial dilution will be modelled using VISJET, a program that estimates initial dilution as a function of the geometry of the outfall, ambient current speeds, density stratification and estimated effluent flow rates. Estimated pollutant concentrations at the edge of the zone of initial dilution will be developed using estimated effluent concentrations and estimated dilutions. By varying inputs such as density profiles, effluent flow rates and pollutant mass emission rates, it will be possible to develop a distribution of predicted effluent quality over the year for comparison with the criteria applied at the edge of the zone of initial dilution.

Estimates of water quality outside the zone of initial dilution will be made using a three-dimensional numerical water quality model tool Delft3D. This tool has been developed to evaluate a variety of environmental projects throughout the Hong Kong Region for projects including land reclamation, dredging, as well as wastewater treatment. It includes both hydrodynamic and water quality modules that cover an extensive portion of the Pearl River Estuary, from which nested models have been used to evaluate various projects in the region. The application of the model in Hong Kong waters has gone through extensive calibration and verification. Adjustments to the model's configuration for the HATS EEFS will be made in order to provide detailed spatial resolution in the areas of greatest interest, and to ensure that future land reclamation projects have been properly included in the geometry of the model.

Information concerning the character of the receiving waters, the nature of the HATS effluent, and important characteristics of the ecology of the region will be derived from a variety of sources. The EEFS study will take into consideration routine environmental monitoring conducted by various government departments, ongoing special studies especially those commissioned with respect to the impact of the commissioning of the full Stage I system, and trials of compact treatment technologies currently being conducted at Stonecutters Island.



Natural Resources



Human Uses of Marine Waters

Environmental Protection Department	Environmental and Engineering Feasibility Assessment Studies in Relation to the Way Forward of the Harbour Area Treatment Scheme	
CDM	Figure 1	Locations of Natural Resources and Human Uses of Marine Waters

3 CRITERIA FOR DISSOLVED OXYGEN

A proper level of dissolved oxygen in the water column is fundamental to the maintenance of a healthy, balanced ecosystem. Significantly depressed levels of dissolved oxygen can lead to reduced levels of survival, growth and reproduction of resident species, malodourous waters, and unsightly aesthetic conditions. For these reasons it is important to maintain a proper level of dissolved oxygen in the receiving waters. This section sets out proposed criteria for dissolved oxygen in the receiving waters of Hong Kong, and the rationale in support of these criteria. The discharge of wastewater can impact on the balance of oxygen in the receiving waters in several ways. Firstly, sewage contains both carbonaceous and nitrogenous compounds that serve as food sources for microbial populations commonly found in receiving waters. The microbes consume oxygen in the conversion of these compounds to carbon dioxide and nitrate nitrogen. The amount of such oxygen-demanding substances in untreated wastewater is significant: the ultimate oxygen demand of most raw wastewater is in the region of 300 mg/L, most of which is exerted over a relatively short period measured in days. With the recent commissioning of the Stage I tunnel system, almost 300,000 kg/day of oxygen-demanding substances formerly discharged to Victoria Harbour are now removed by the Stonecutters Island treatment plant.

Secondly, sewage contains nutrients that, under conditions favourable to growth, can stimulate the production of algae. Excessive production of algae can adversely impact receiving water dissolved oxygen concentrations in two ways. Algae produce oxygen in the light, and consume oxygen in the dark. It is possible for algal productivity to become so high that daytime dissolved oxygen concentrations become supersaturated, but that during the dark, oxygen consumption by algal respiration can lead to severely depressed oxygen conditions. Additionally, when algae die, their decomposition exerts additional oxygen demands similar in nature to that of wastewater.

Because of the importance of dissolved oxygen in the environment and the potentially significant effect of sewage on dissolved oxygen balance, careful attention is paid to dissolved oxygen in water quality planning. The desired level of dissolved oxygen in the receiving water is one of the essential steps for determining the level of wastewater treatment for carbonaceous and nitrogenous oxygen-demanding substances, and for the control of nutrients to mitigate excessive algal productivity.

3.1 PRIOR CRITERIA AND BASIS

Dissolved oxygen objectives for local waters were established in 1988 as part of the Sewage Strategy Study. The objectives developed in that project were based on reviews of information from other jurisdictions, notably the UK, EC member states, Japan and elsewhere. Following this, statutory objectives were set according to various uses as follows:

For Mariculture:

> Not less than 5 mg/L calculated as a column average for 90% of the sampling occasions.
>
> Within 2m of the bottom not less than 2 mg/L, 90 % of the time.

For General Marine Life:

> Not less than 4 mg/L, calculated as a column average for 90% of the sampling occasions.

Within 2m of the bottom, not less than 2 mg/L, 90 % of the time.

For Industrial Use:

Not less than 2 mg/L 90 % of the time.

As part of the EIA for the SSDS, dissolved oxygen objectives were again reviewed in relation to their proposed use as project-specific criteria. The SSDS determined that the objectives were reasonable for the evaluation of project alternatives, and adopted them as water quality criteria.

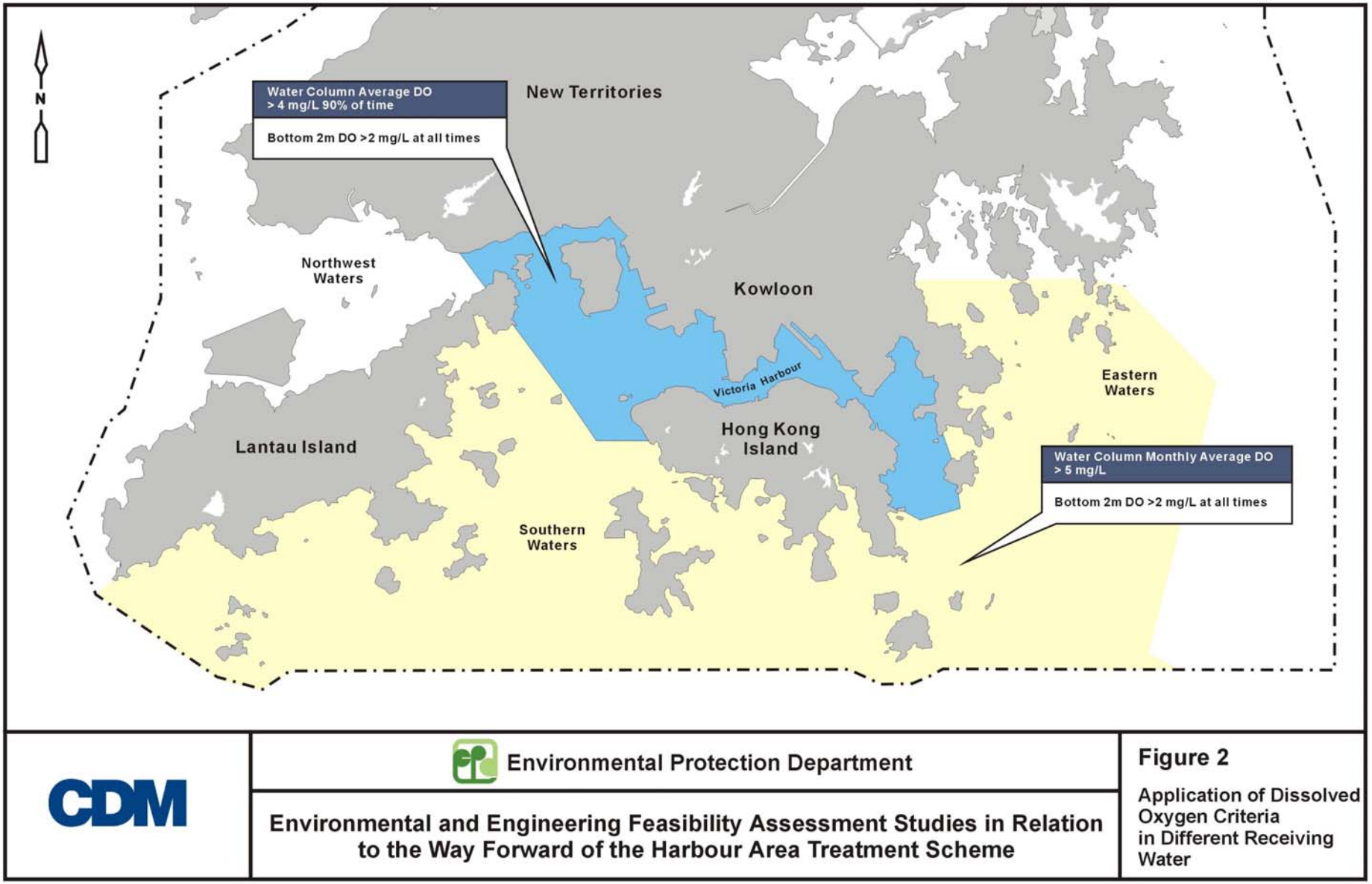
3.2 SUGGESTED CRITERIA FOR HATS EEFS

In conjunction with the planning and conduct of the HATS EEFS assignment, the EPD and associated governmental agencies undertook an evaluation of the dissolved oxygen criteria for suggesting, where warranted, changes to prior criteria. The results of these investigations were also scrutinized by the HATS Monitoring Group.

As a result of these deliberations, the Government has recommended for use in the EEFS that the dissolved oxygen criteria should vary according to the use of the waters, as follows:

- In the Harbour area marked blue in **Figure 2**, the criteria are proposed to be 4mg/L as a water column average to be met 90% of the time, and 2mg/L within the bottom 2m of the water column to be met at all times.
- For the area marked yellow, the criteria should reflect the recommendations presented in the Agriculture, Fisheries and Conservation Department's Consultancy Agreement No 62/98 entitled "Consultancy Study on Fisheries and Marine Ecological Assessment Criteria". This means an average of 5 mg/L in each month of the year and a minimum of 2mg/L at all times.

These changes reflect the work undertaken as part of the AFCD consultancy, which explicitly considered work conducted elsewhere and specific toxicity testing using locally important species to develop criteria. In that regard, the AFCD work enhances the DO criteria by specifically incorporating locally relevant species and effects into what had previously been extrapolations from other jurisdictions. It should be noted that the AFCD consultancy study acknowledges that the 5 mg/L limitation may be too restrictive in some cases, and not protective enough in others. The study suggests that the application of this criterion should be undertaken with specific reference to local conditions and knowledge. The 2 mg/L criterion is, however taken as more absolute, because it is based on the prevention of acute impacts.


N
Water Column Average DO
> 4 mg/L 90% of time
Bottom 2m DO >2 mg/L at all times
New Territories
Northwest
Waters
Kowloon
Victoria Harbour
Eastern
Waters
Hong Kong
Island
Lantau Island
Water Column Monthly Average DO
> 5 mg/L
Bottom 2m DO >2 mg/L at all times
Southern
Waters
CDM
Environmental Protection Department
Environmental and Engineering Feasibility Assessment Studies in Relation to the Way Forward of the Harbour Area Treatment Scheme
Figure 2
Application of Dissolved Oxygen Criteria in Different Receiving Water

3.3 FURTHER CONSIDERATIONS WITH RESPECT TO DISSOLVED OXYGEN

The suggested criteria proposed for the EEFS studies incorporate, for the first time in Hong Kong, a dissolved oxygen standard that is absolute. Whereas criteria had historically been established in terms of a frequency of occurrence, the new criteria establish a limit for the bottom two metres that must always be met. Historical water quality data indicate dissolved oxygen in Hong Kong waters can be very low at times. There are indications that some of these events are related to the onshore incursion of low DO oceanic waters, and are not the result of local wastewater discharges. For this reason, the EEFS study, while acknowledging the potential for some lowering of DO below the 2 mg/L criteria, will not explicitly use these episodic offshore events for evaluations of the IRP options. Considered opinions and comments with respect to this issue are sought from the reviewers of this document.

Both the USEPA and the Australian and New Zealand Environment and Conservation Council (ANZECC) have recently evaluated their dissolved oxygen criteria. The ANZECC approach for DO (and other pollutants, for that matter) involves setting trigger values for slightly disturbed ecosystems below which impairment is assumed not to exist, and above which management actions are suggested. For moderately or highly disturbed ecosystems, the ANZECC guidelines do not establish specific numerical values for dissolved oxygen, but rather suggest management actions that seek to restore physical and biological functionality, taking into consideration a variety of site specific conditions.

The USEPA has recently issued guidance for the development of dissolved oxygen criteria for marine waters from Cape Hatteras to Cape Cod on the eastern US coast. These criteria were developed based on concentration-response relationships between dissolved oxygen and juvenile and adult survival, growth effects and larval recruitment effects. Using these approaches, the guidance manual recommends a survival based limit of 2.3 mg/L DO and a growth effect guideline of 4.8 mg/L. This general approach and findings are relevant to the EEFS investigations in that they validate the conceptual model of a lower, survival based dissolved oxygen criteria, that should never be violated, and a chronic criterion that is established as a guideline value, subject to modification on a case by case basis. And although the values themselves were derived for a different oceanic region, they are not dissimilar to those adopted for Hong Kong waters.

4 CRITERIA FOR NITROGEN AND PHOSPHORUS

Nitrogen and phosphorus are nutrients for algal communities in receiving waters. When discharged into waters with the proper combination of water column stability, temperature, light energy, and other micronutrients they can give rise to algae growth and blooms. In some cases, the growths may be deemed beneficial, forming an essential part of the food web, and supporting the ecosystem. In other cases it appears possible that these nutrients might give rise to harmful algal blooms that may be both aesthetically unpleasing, deleterious to fish culture operations, toxic to animals and humans and may be the cause of significant hypoxia events. (Scientific opinion on the exact role of nutrients in harmful algal blooms remains undetermined however).

4.1 PRIOR CRITERIA AND RATIONALE

Water quality objectives for different forms of nitrogen were established in 1988 as part of the Sewage Strategy Study. Objectives were established by regressing observed values of total inorganic nitrogen (TIN) against chlorophyll *a* for various water bodies. The TIN limits were then set such that chlorophyll *a* values in the receiving waters would be held to 10 ug/L.

In general, the regression approach produced what appeared to be linear relationships for a number of water bodies, including Tolo Harbour, Port Shelter and Junk Bay. For some locations, notably Deep Bay, Victoria Harbour, Southern Waters and Northwest Waters, there was no apparent trend.

Subsequent to the study, statutory objectives for various bodies of water were set as follows:

- For the enclosed and semi-enclosed regions such as Port Shelter and Southern Waters, a depth and annual averaged value of not more than 0.1 mg TIN/L
- For the enclosed and semi-enclosed regions such as Junk Bay and Northwest Waters, a depth and annual averaged value of not more than 0.3 mg TIN/L
- To maintain water quality in the well flushed regions of Victoria Harbour, the Western Buffer Zone, and Northwest waters, an objective of 0.4 mg TIN/L

The first two objectives were set at levels that had been shown to result in a chlorophyll *a* concentration of 10 ug/l; the latter criterion was, in general tied in with the highest value observed in Victoria Harbour Waters. The study noted that a dose-response relationship between TIN and chlorophyll *a* similar to that observed in Tolo Harbour and Port Shelter appeared to exist in sensitive embayments, but that no such relationship existed in the offshore regions.

As part of the SSDS EIA, nutrient criteria were again reviewed. As a result of this review, the EIA concluded that water quality criteria should be established at levels of 0.2 mg/L TIN for southern waters (consistent with the highest observed values of earlier investigations), 0.3 mg/L TIN for Mirs Bay, 0.4 mg/L TIN for Victoria Harbour and the Eastern and Western Buffer Zones and 0.5 mg/L for northwest waters. A limitation of total inorganic phosphorus was set at 1/10th the level of the TIN criteria.

Although criteria for nutrients were established, the EIA was clear to say that it believed that nutrient limitations were considered to be long-term water quality objectives, and that high

loadings of nutrients from other sources made the use of nutrients as criteria for decision-making between treatment options difficult.

4.2 SUGGESTED CRITERIA FOR EEFS HATS

In conjunction with the planning and conduct of the HATS EEFS assignment, the EPD and associated governmental agencies undertook an evaluation of the nutrient criteria for the purpose of suggesting, where warranted, changes to prior criteria. The results of these investigations were also scrutinized by the HATS Monitoring Group. As a result of these deliberations, the following criteria were suggested:

- In the Victoria Harbour, the Western Buffer, and the Eastern Buffer Water Control Zones (area marked blue on **Figure 3**), an annual average concentration of total inorganic nitrogen of 0.4mg/L and an annual average concentration of orthophosphate phosphorus of 0.04mg/L.
- In the Southern Water Control Zone and in the fish spawning grounds of Mirs Bay (both areas marked in yellow on **Figure 3**), an annual average concentration of total inorganic nitrogen of 0.2mg/L and annual average concentration of orthophosphate phosphorus of 0.02mg/L.
- For the Junk Bay Water Control Zone (area marked pink on **Figure 3**), an annual average concentration of total inorganic nitrogen of 0.3mg/L and an annual average concentration of orthophosphate phosphorus of 0.03 mg/L.
- For the Port Shelter Water Control Zone (area marked light green on **Figure 3**), an annual average concentration of total inorganic nitrogen of 0.1mg/L and an annual average concentration of orthophosphate phosphorus of 0.01mg/L.

Although specific numeric criteria have been suggested for use in the HATS EEFS, it has also been noted that attention should be drawn to the uncertainty relating to these proposals given the lack of research on the susceptibility of the Harbour area to eutrophication. The consultant should therefore specifically consider the risk (if any) attached to adopting these criteria and advise on the desirability, feasibility and implications of reducing any risk by aiming to achieve higher levels of nutrient removal than these criteria might demand.

4.3 DISCUSSION WITH RESPECT TO NUTRIENT CRITERIA

As noted above, the original criteria for nitrogen were based on attempts to correlate observed values of inorganic nitrogen with observed values of chlorophyll *a*. Subsequent versions of the criteria have, in large part, brought this same concept forward, with minor modifications to the area to which the criteria apply.

But over the past decade there have been significant advances in the understanding of algal dynamics, and in the development of tools to assess the factors that impact algal systems. The issue of nutrient induced hypoxia and exacerbated harmful algal bloom persistence due to sewage discharges has received significant attention. As a result models, such as the Delft3D model mentioned earlier have been developed to simulate the biological and physical processes that influence the creation, dispersion, death and decay of algae. They have been applied successfully in a number of places to begin to understand the complex interrelationships between all the variables that influence algal dynamics.

Moreover, in Hong Kong waters a significant body of routine analytical data has been collected that begins to present a picture of algal systems that change in time and space across a year. Light limitation appears to exist in Victoria Harbour where high levels of

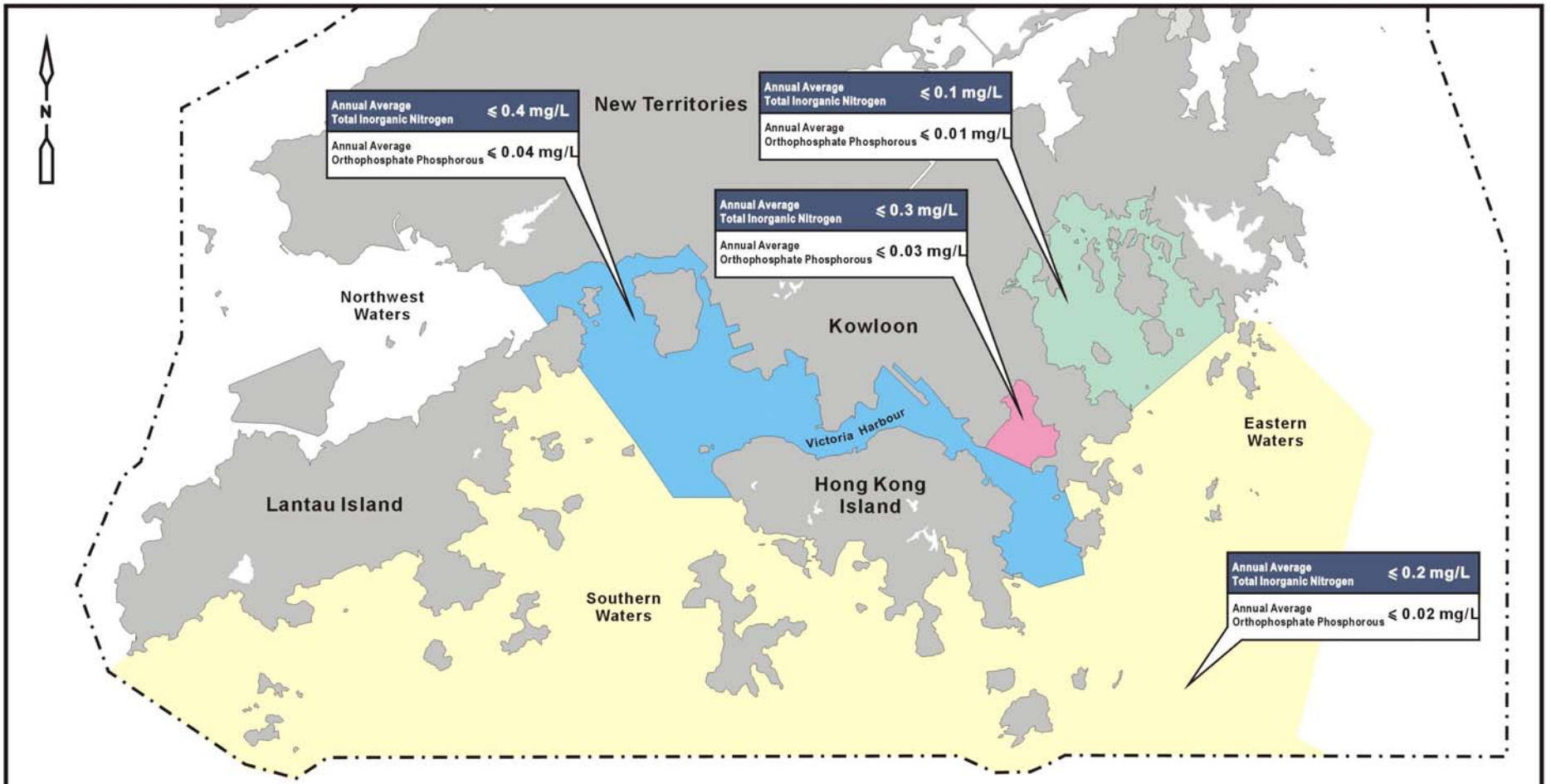
nutrients should have otherwise stimulated significant algal production. Nitrogen limitation appear to exist in eastern, oceanic waters consistent with the pattern of nutrient limitations elsewhere. And possible phosphorus limitation in seasons when freshwaters associated with the Pearl River significantly change the character of Hong Kong waters.

In concert with the advances in technology and data, the regulatory approach concerning the development of nutrient criteria has evolved. Most recently, for example, the USEPA has issued a technical guidance manual for the development and application of nutrient criteria in estuarine and coastal marine waters (USEPA 2001). That document does not offer specific numeric criteria for nutrients. Rather, the guidance manual suggests that a multiple step process ought to be undertaken which results in the development of a management approach tailored to each specific estuarine setting. The key elements of the management strategy include:

- The development of reference conditions appropriate to the estuary under study. Under EPA's guidance manual, the intent of this activity is to identify the ambient, minimally impacted nutrient condition of the watershed.
- The formulation of Regional Technical Assistance Groups (RTAGs) comprised of local governmental officials, academics and others interested in and knowledgeable of the nutrient dynamics of the estuary. The purpose of the RTAGs is to provide technical assistance and support to the development of criteria
- The creation of necessary tools to develop and evaluate specific criteria. These can vary from estuary to estuary, and might be as simple as data analysis tools, or as complicated as linked hydrodynamic and water quality numerical models. The tools are used to attempt to define those concentrations or loads that impair beneficial uses

The central thrust of this approach is that the criteria are derived in consideration of specific local conditions, recognizing that no single criterion will be able to satisfactorily establish nutrient limitations for all estuaries. It is suggested that the general construction of this approach is applicable to the HATS project. General reference conditions have been established by the analysis conducted in the 1980's and proposed as initial criteria for consideration, as a result of the consultants coordinating with government scientists. We are now seeking input from the local scientific community. Eventually, the EEFS will evaluate the impacts of nutrient loadings, taking into account the criteria and the impacts of the discharge on receiving waters.

Within this broad framework it is proposed that there may be no single criterion applicable to development of HATS effluent limits for nutrients, but rather the application of a procedure to define and resolve the issue.



CDM

Environmental Protection Department

Environmental and Engineering Feasibility Assessment Studies in Relation to the Way Forward of the Harbour Area Treatment Scheme

Figure 3

Application of Nutrient Water Quality Criteria in Different Receiving Water

5 CRITERIA FOR THE PROTECTION OF AQUATIC LIFE

The discharge of metals and other toxic compounds into harbour waters can disrupt the receiving ecosystem. Criteria for the protection of aquatic life are used to assess the impacts of HATS discharges on the receiving waters. In this section the criteria as developed in the SSDS EIA are presented for consultation.

5.1 PRIOR CRITERIA AND RATIONALE

Criteria for the protection of aquatic life were originally considered in the development of the 1988 Sewage Strategy Study. At that time, however, there were no specific criteria proposed for use in the evaluation of alternatives. Rather, it was recommended that certain dangerous substances be monitored and that consideration be given to the impacts of those substances on the receiving waters. In the 1998 SSDS EIA, specific numeric criteria were developed for assessment and evaluation of the impact of the discharge on receiving waters. The criteria were of two types:

- Those that were applied at the edge of the zone of initial dilution, an area in close proximity to the discharge itself. These are generally the more acutely toxic of the constituents
- Those that were applied at the edge of a mixing zone. As described earlier, a mixing zone is not a specifically defined space, but rather is that zone within which the concentration of the constituent of concern has diminished to the level of the criterion. Criteria applied at the edge of a mixing zone are chronically, rather than acutely toxic.

For this EEFS assessment process the criteria as used in the EIA are proposed for use. The criteria are as presented below. Table 1 contains those criteria applicable to the edge of the zone of initial dilution. Table 2 presents those criteria applicable to the edge of the mixing zone.

Table 1. Proposed Water Quality Criteria at Edge of Initial Dilution Zone

PARAMETER	**Value**	**Period/Type**
Unionised ammonia	≤ 0.021 mg/L ≤ 0.035 mg/L ≤ 0.233 mg/L	annual average 4-day average 1-hour average
pH	6.5 – 8.5, and change < 0.2	at least 90% of occasions
Temperature	change ≤ 2℃	at least 90% of occasions
Suspended Solids	Increase < 10 mg/L	at least 90% of occasions
Sulphide	< 0.02 mg/L	at least 90% of occasions
Cyanide	< 0.005 mg/L	at least 90% of occasions
Total residual chlorine	< 0.013 mg/L	Daily maximum
Surfactants	< 0.03 mg/L	at least 90% of occasions
Copper	< 0.005 mg/L	at least 90% of occasions
Nickel	< 0.005 mg/L	at least 90% of occasions
Total chromium	< 0.05 mg/L	at least 90% of occasions
Zinc	< 0.02 mg/L	at least 90% of occasions
Mercury	<0.00021 mg/L	at least 90% of occasions
Arsenic	< 0.02 mg/L	at least 90% of occasions
Phenol	< 0.005 mg/L	at least 90% of occasions
Acute toxicity	0.3 acute toxicity units[1] (derived from LC_{50} values based on whole effluent toxicity tests)	One hour average condition not to exceed this value

[1] USEPA Technical Support Document for Water Quality-Based Toxics Control (March 1991), from which one acute Toxicity Unit (TU) is defined as *TU (acute) = 100/LC_{50}*, where LC_{50} = % of effluent which gives 50% survival of the most sensitive of the range of species tested

Table 2. Additional Water Quality Criteria at Edge of Mixing Zone

Parameter	**Value**	**Period/Type**
Chronic toxicity	≤ one chronic toxicity unit (TU), as determined in accordance with USEPA Procedures[2]	4-day average chronic toxicity exposure
Total residual chlorine	< 0.008 mg/L	Daily maximum
Sedimentation Rate	<10 mg/cm²/day	Daily maximum
One chronic toxicity unit is defined as ***TU (CHRONIC) = 100/NOEC*** *(chronic)*, where NOEC is the No Observed Effect Concentration, based on the most sensitive of the range of species tested		

6 MICROBIOLOGICAL WATER QUALITY CRITERIA

Because direct contact with waters contaminated with sewage can lead to the transmission of a variety of diseases, limitations are often set on the microbiological quality of waters. Common public health practice is to set limitations on the density (number per 100 ml) of an indicator organism as a measure of the degree of sewage contamination, and thus a measure of the danger of pathogen exposure. In Hong Kong, bathing water quality is evaluated using *E coli* as the measure of pathogen contamination. *E. coli* is an indicator bacterium widely used for this purpose.

The microbiological water quality criteria used in the SSDS EIA were based on the water quality objectives for bathing waters and recommendations for the quality of waters abstracted for toilet flushing and for cooling systems. It is proposed to continue to use these as the criteria in the HATS EEFS study.

6.1 PROPOSED MICROBIOLOGICAL WATER QUALITY CRITERIA

Water Quality Objectives for Hong Kong were originally established on 1988, based on epidemiological studies conducted in the 1980's. Those studies involved interviews with 18,000 swimmers at 9 beaches located throughout the region to determine the incidence of disorders associated with swimming in water containing various levels of coliform organisms. That work established a relationship between the geometric mean density of *E. coli* and minor gastrointestinal and skin disorders. This information was then used to establish a beach grading and scoring system that provides swimmers and public health officials with an understanding of the current quality of bathing waters and the inter-annual trends in the general microbiological health of swimming waters.

The relationship between the geometric mean coliform concentration and observed rates of minor illness are presented in Table 3. For determining annual compliance with water quality objectives, the EPD considers beaches that exhibit an annual mean coliform count of less than 180 per 100 mL to be in compliance with the bathing water quality objective.

Table 3 E. coli Concentration and Incidence of Minor Illness

E. coli density per 100 mL	**Incidence of Minor Illness per 1,000 swimmers**
24 or Less	Not detectable
25 to 180	Less than 10
181-610	11-15
611 or more	Greater than 15

For the EEFS the proposed microbiological criteria are as presented in Table 4. For bathing waters, the value for the water quality objective is adopted directly. For those areas where the routes of transmission are less direct, or the potential for exposure more remote, the

criteria, as presented in the EIA will be set at 610 per 100 ml. To provide a nominal level of protection for industrial and toilet flushing uses, a value of 20,000 per 100 mL is proposed.

Table 4 Proposed Water Quality Criteria for Microbiological Contaminants

Parameter	Value	Period/Type	Where Applicable
E. coli	< 180/100 ml	Geometric mean	Bathing waters
	< 610/100 ml	Geometric mean	Secondary contact recreation and mariculture zones
	< 20,000/100 mL	$\underline{>}$ 90% of occasions	Flushing or industrial use

7 CONCLUSIONS

Implementation of Stage I of the HATS project has significantly improved sewage disposal in Hong Kong. For the first time, approximately 1,300,000 cubic metres per day of domestic and commercial wastes generated in Kowloon and in parts of Hong Kong Island are now receiving modern sewage treatment. But more needs to be done, including providing treatment to the remainder of wastes generated on Hong Kong Island, and deciding what level of treatment ultimately needs to be provided to these wastes.

The HATS EEFS project, in concert with other trials and studies recommended by the IRP, will address the treatment issues. In so doing, it is critical that the EEFS evaluation team use proper criteria for the assessment of the impacts of the IRP options, particularly with respect to water quality.

Over the course of the past decade, water quality criteria have been developed and applied to sewage planning in Hong Kong, most recently in 1999 as part of the SSDS EIA. Those criteria have relied on locally important knowledge, and on the evaluation of similar criteria used in other jurisdictions. As part of the HATS project planning, the Government has undertaken further investigations in certain topics and has used these investigations, together with prior studies to propose water quality criteria for the HATS project.

After reviewing the information passed to us from the Government, the prior studies, and relevant recent work done elsewhere, we have concluded that the criteria as presented in this document provide a proper foundation for the assessment of water quality impacts of the IRP options. We acknowledge that these criteria often represent starting points with respect to environmental evaluations, and that it will ultimately be the criteria, coupled with site specific analyses that will point out important differences between options.

We ask those who are interested in these topics to share their views with us. We will be pleased to receive comments on these criteria through 27th July 2002 either via email at hats@cdm.com.hk, by fax to 2424 9114 or by regular post to:

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