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Guidelines For Development of Location Specific Stringent Standards

CENTRAL POLLUTION CONTROL BOARD
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FOREWORD

The country has a large geographical area with a very wide spectrum of natural conditions and anthropogenic activities. The impact of released pollutants varies significantly from area to area depending upon the type of pollutants and the environmental conditions in respective areas. The fixed limits for pollutants needs revisit with respect to the environmental conditions and assimilative capacity of specific areas and made stringent or the release source shifted to stop irreversible damage to the environment.

The existing legislation, empowers the State Pollution Control Boards (SPCBs) to prescribe, stringent emission/discharge standards, however, the present approach of SPCBs is mainly judgmental and on the immediate impact of pollutants. The need to have guidelines is urgent, enabling the SPCBs to, (i) identify areas need for prescribing location specific stringent standards, (ii) understand the sources of pollution and their impacts, (iii) study the means of controlling pollution, and (iv) evolve the assimilative capacity based limits for the pollutants.

The Central Pollution Control Board has undertaken a project study titled, "Development of Guidelines/Rationale for Prescribing Location Specific Stringent Standards" under the, "Environmental Management Capacity Building Technical Assistance Project of the World Bank through award of a project to the Environmental Protection Training and Research Institute (EPTRI), Hyderabad. The present environmental legislations and environmental policies have been studied and the guidelines for the development of location specific stringent standards prepared are documented.

I am grateful to EPTRI for the contributed project studies and also to the Project's Consultants, Professor P.M. Berthouex and Prof. Dianna Kocurek of the University of Wisconsin, Madison, USA for their inputs.

Hope this document will cater the need of SPCBs in Prescribing Location Specific Standards.

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1.0 Introduction

1.1 Limiting Release of Pollutants

The country has a large geographical area with a very wide spectrum of natural conditions and anthropogenic activities. The natural conditions vary from the heavy rain fall areas in the east to the western dessert, and from the snow covered hills in the north to the long coast line in the South. The impact of the anthropogenic activities is therefore expected to have a large variation depending upon the type of activities and their impact on the surrounding environment. In fact even similar activities are expected to have different impact in different areas depending upon the use and the assimilative capacities of the ecology and environmental conditions of the areas. This makes it essential that the environmentally relevant activities in the areas are regulated in a way that ensures no adverse effect on the overall ecology of the area and minimum disruption of the action as that are required for the sustainability of the area as a whole. The National limits fixed for the release of pollutants are therefore required to be examined with respect to the assimilative capacity for specific areas and if required the release of pollutants are to be made stringent or even the release source itself shifted to stop any irreversible damage to the surrounding environment.

1.2 Need of Developing Location Specific Standards

There are many areas where it is just not possible to meet the ambient air or water quality standards by simply adopting the national standards notified under the Environment (Protection) Act, 1986 for emission/discharges from various sources. This is because, (i) the cumulative effort of the release of pollutants from the different sources in the areas has already resulted into exceeding of the ambient water/air quality standards, and (ii) the increased release of pollutants due to rapid growth in industrialization and urbanization even in newer areas will lead to the same situations, as the assimilative capacity of the recipient systems never increases. There is therefore, a strong need for making the emission/discharge standards stringent for areas/locations wherever necessary to ensure sustainability of the required ambient air/water quality of that area/location.

1.3 Need of Guidelines for Developing Local Specific Stringent Standards

The existing legislation though covers adequate provision empowering the State Boards to prescribe stringent emission/discharge standards while issuing the consent under the Water Act/Air Act, the judgments presently made by the SPCBs appear to be based on their respective experiences in qualitative terms for specifying stringent standards on a case to case basis. This appears to be based primarily on immediate impact of release of pollutants rather than the ultimate impact on the ambient water/air quality in terms of their long term effects. There is therefore, a strong need to have guidelines that can enable SPCBs to, (i) identify areas where there is a need for prescribing location-specific stringent standards, (ii) understand the sources of pollution and their impacts using the available input data and relevant air/water quality models, (iii) study the means of controlling pollution, and (iv) evolve location specific standards for a sustained compliance to the ambient water/air quality of the area.

1.4 Project undertaken

The study has been carried out though award of project entitled "Development of Guidelines/Rationale for Prescribing Location Specific Standards" to the Environment Protection Training and Research Institute (EPTRI) under the "Environment Management Capacity Building Technical Assistance Project" of the World Bank (WB). Prof. P.M. Berthouex of the University of Wiscousin-Madison, USA was engaged as foreign consultant to EPTRI for providing technical input throughout the project. The studies conducted covered, (i) collection and processing of the data on dry and wet inventions in respect of the three locations namely, Nakkavagu drainage basin, Medak District, Andhra Pradesh (AP); Visakhapatnem air shed, AP; and the polluted stretch of river Godavari at Rajamundy, AP. and (ii) field studies at Rajamundy for selection of the relevant stretch of the river for modeling through use of tracer techniques. The project report entitled "Development of Guidelines/Rationale for Prescribing Location Specific Standards" submitted by EPTRI to CPCB covers, details of the above studies, the approaches adopted in USA, Europe and other countries for evolving location specific stringent standards, the various Air/Water models available and their suitability for use in Indian conditions, details of the studies conducted at the above mentioned three locations and the recommended procedure for fixing location specific stringent standards.

1.5 Development of Guidelines

This has been done on the basis of the report submitted by EPTRI, the requirements of the various Acts, a review of the Air Quality Water Models with respect to selection of those which could be suitable to most of the situations in the country and the approach to be taken by the State Boards to evolve location specific stringent standards. The details of all the above exercise/information including the guidelines for development of location specific stringent standards have been compiled and presented in this document.

2.0 Environmental Legislation and Policy on Limiting Release of Pollutants

2.1 Legislation

2.1.1 Provisions under the Water (Prevention and Control of Pollution) Act, 1974

(i) Section 16 - Functions of Central Board

- 16 (2)(9) - Lay down, modify or annul, in consultation with the State Government concerned, the Standards for a stream or well.

  Provided that different standards may be laid down for the same stream or well or for different streams or wells, having regard to the quality of water, flow characteristics of the stream or well and the nature of the use of the water in such stream or well or streams or wells.

(ii) Section 17 – Functions of State Boards

- 17 (1)(f) – to inspect sewage or trade effluents, works and plants for the treatment of sewage and trade effluents and to review plans, specifications or other data relating to plants set up for the treatment of water, works for the purification thereof and the system for the disposal of sewage or trade effluents or in connection with the grant of any consent as required by this Act.

- 17 (1)(g) - lay down, modify or annul effluent standards for the sewage and trade effluents and for the quality of receiving waters (not being water in an inter-State stream) resulting from the discharge of effluents and to classify waters of the State;

- 17 (1)(h) - to evolve economical and reliable methods of treatment of sewage and trade effluents, having regard to the peculiar conditions of soils, climate and water resources of different regions and more especially the prevailing flow characteristics of water in streams and wells which render it impossible to attain even the minimum degree of dilution.

- 17 (1)(k) - to lay down standards of treatment of sewage and trade effluents to be discharged into any particular stream taking into account the minimum fair weather dilution available in that stream and the tolerance limits of pollution permissible in the water of the stream, after the discharge of such effluents.

(iii) Section 19 – Powers of State Government to Restrict the application of the Act to certain areas

- 19 (1) – Notwithstanding contained in this Act, if the State Government, after consultation with, or on the recommendation, of the State Board, is of opinion that the provisions of this Act need not apply to the entire State, it may, by notification in the official Gazette, restrict the application of this Act to such area or areas as may be declared therein as water pollution, prevention and control area or areas and thereupon the provisions of this Act shall apply only to such area or areas.

- 19 (2) – Each water pollution, prevention and control area may be declared either by reference to a map or by reference to the line of any watershed or the boundary of any district or partly by one method and partly by another.

(iv) Section 24 – Prohibition on use of stream or well for disposal of polluting matter, etc.

24(1) subject to the provisions of this Section,

(a) no person shall knowingly cause or permit any poisonous, noxious or polluting matter determined in accordance with such standards as may be laid down by the State Board to enter (whether directly or indirectly) into any stream or well or sewer or on land, or

(b) no person shall knowingly cause or permit to enter into any stream any other matter which may tend, either directly or in combination with similar matters, to impede the proper flow of the water of the stream in a manner leading or likely to lead to a substantial aggravation of pollution due to other causes or of its consequences.

(v) Section 25 – Restrictions on new outlets and new discharges

(1) Subject to the provisions of this section, no person shall, without the previous consent of the State Board, -

(a) establish or take any steps to establish any industry, operation or process, or any treatment and disposal system or any extension or addition thereto, which is likely to discharge sewage or trade effluent into a stream or well or sewer or on land (such discharge being hereafter in this section referred to as discharge of sewage); or

(b) bring into use any new or altered outlet for the discharge of sewage; or

(c) being to make any new discharge of sewage;

Provided that a person in the process of taking any steps to establish any industry, operation or process immediately before the commencement of the Water (Prevention and Control of Pollution) Amendment Act, 1988, for which no consent was necessary prior to such commencement, may continue to do so for a period of three months from such commencement or, if he has made an application for such consent, within the said period of three months, till the disposal of such application.

vi) Section 32 - Emergency Measures in case of pollution of stream or well

Where it appears to the State Board that any poisonous, noxious or polluting matter is present in any stream or well or on land by reason of the discharge of such matter in such stream or well or on such land or has entered into that stream or well due to any accident or other unforeseen act or event, and if the Board is of opinion that it is necessary or expedient to take immediate action, it may for reasons to be recorded in writing, carry out such operations as it may consider necessary for all or any of the following purposes, that is to say, -

(a) removing that matter from the stream or well or land and disposing it of in such manner as the Board considers appropriate;

(b) remedying or mitigating any pollution caused by its presence in the stream or well;

(c) issuing orders immediately restraining or prohibiting the person concerned from discharging any poisonous, noxious or polluting matter into the stream or well or on land or from making in sanitary use of the stream or well.

2.1.2 Provisions under the Air (Prevention and Control of Pollution) Act, 1981

i) Section 16 – Functions of Central Board

- 16(2)(h) – lay down standards for the quality of air

ii) Section 17 – Functions of State Board

- 17(1)(g) To lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from industrial plants and automobiles or for the discharge of any air pollutant into the atmosphere from any other source whatsoever not being a ship or an aircraft :

  Provided that different standards for emission may be laid down under this clause for different industrial plants having regard to the quantity and composition of emission of air pollutants into the atmosphere from such industrial plants;

iii) Section 19 – Power to declare air pollution control areas

- 19(1) - The State Government may, after consultation with the State Board, by notification in the Official Gazette, declare in such manner as may be prescribed, any area or areas within the State as air pollution control area or areas for the purposes of this Act.

- 19(2) - The State Government may, after consultation with the State Board, by notification in the Official Gazette, -

  (a) alter any air pollution control area whether by way of extension or reduction;

  (b) declare a new air pollution control area in which may be merged one or more existing air pollution control areas or any part or parts thereof.

- 19(3) - If the State Government, after consultation with the State Board, is of opinion that the use of any fuel, other than an approved fuel, in any air pollution control area or part thereof, may cause or is likely to cause air pollution, it may by notification in the Official Gazette, prohibit the use of such fuel in such area or part thereof with effect from such date (being not less than three months from the date of publication of the notification) as may be specified in the notification.

- 19(4) - The State Government may, after consultation with the State Board, by notification in the Official Gazette, direct that with effect from such date as may be specified therein, no appliance, other than an approved appliance, shall be used in the premises situated in an air pollution control area :

  Provided that different dates may be specified for different parts of an air pollution control area or for the use of different appliances.

- 19(5) - If the State Government, after consultation with the State Board, is of opinion that the burning of any material (not being fuel) in any air pollution control area or part thereof may cause or is likely to cause air pollution, it may, by notification in the Official Gazette, prohibit the burning of such material in such area or part thereof.

iv) Section 21 – Restriction on use of certain industrial plants

- 21(1) Subject to the provisions of this section, no person shall, without the previous consent of the State Board, establish or operate any industrial plant in an air pollution control area

2.1.2 Provisions under the Environment (Protection) Act, 1986

i) Section 3 – Powers of Central Government to take measures to protect and improve environment

- Section 3(1) - Subject to the provisions of this Act, the Central Government shall have the power to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution.

- Section 3(2)(iii) - laying down standards for the quality of environment in its various aspects;

- Section 3(2)(iv) - laying down standards for emission or discharge of environmental pollutants from various sources whatsoever :

  Provided that different standards for emission or discharge may be laid down under this clause from different sources having regard to the quality or composition of the emission or discharge of environmental pollutants from such sources

ii) Section 6 – Rules to Regulate environmental pollution

- In particular, and without prejudice to the generality of the foregoing power, such rules may provide for all or any of the following matters, namely

  (a) the standards of quality of air, water or soil for various areas and purposes;

  (b) the maximum allowable limits of concentration of various environmental pollutants (including noise) for different areas

2.1.4.1 Provisions under the Environment (Protection) Rules, 1986

i) Section 3 – Standards for emission or discharge of environmental pollutants

- Section 3(1) - For the purpose of protecting and improving the quality of the environment and preventing and abating environmental pollution, the standards for emission or discharge of environmental pollutants from the industries, operations or processes shall be as specified in [Schedule I to IV].

- Section 3(2) - Notwithstanding anything contained in sub-rule (1),the Central Board or a State Board may specify more stringent standards from those provided in [Schedule I to IV] in respect of any specific industry, operation or process depending upon the quality of the recipient system and after recording reasons therefore in writing.

- Section 3(3) - The standards for emission or discharge of environmental pollutants specified under sub-rule (1) or sub-rule (2) shall be complied with by an industry, operation or process within a period of one year of being so specified.

ii) Section 5 **-** Prohibitions and restrictions on the location of industries and the carrying on processes and operations in different areas

- Section 5(1) - The Central government may take into consideration the following factors while prohibiting or restricting the location of industries and carrying on of processes and operations in different areas

  (i) Standards for quality of environment in its various aspects laid down for an area.

(ii) The maximum allowable limits of concentration of various environmental pollutants (including noise) [or an area.

(iii) The likely emission or discharge of environmental pollutants from an industry, process or operation proposed to be prohibited or restricted.

(iv) The topographic and climatic features of an area.

(v) The biological diversity of the area which, in the opinion of the Central Government needs to be preserved.

(vi) Environmentally compatible land use.

(vii) Net adverse environmental impact likely to be caused by an industry, process or operation proposed to be prohibited or restricted

(vii) Proximity to a protected area under the Ancient Monuments and Archaeological Sites and Remains Act, 1958 or a sanctuary, National Park, game reserve or closed area notified as such under the Wild Life (Protection) Act, 1972 or places protected under any treaty, agreement or convention with any other country or countries or in pursuance of any decision made in any international conference/association or other body.

(viii) Proximity to human settlements.

(ix) Any other factor as may be considered by the Central Government relevant to the protection of the environment in an area.

2.2 National Environmental Policy, 2006 for Development of Standards

National Environmental Policy (NEP), 2006 states that Environmental Standards refer both to the acceptable levels of specified environmental quality parameters at different categories of locations (“ambient standards”) as well as permissible levels of discharges of specified waste streams by different classes of activities (“emission standards”).

It is now well understood that environmental standards cannot be universal, and each country should set standards in terms of its national priorities, policy objectives, and resources. These standards, may, of course, vary (in general, become more stringent) as a country develops, and has greater access to technologies and financial resources for environmental management. While within the country different States, Union Territories (UTs) and local bodies may adopt stricter standards, based on local consideration, they would require concurrence of the Central Government to ensure adherence to the provisions of this policy. Environmental standards also need to relate to other measures for risk mitigation in the country, so that a given societal commitment of resources for achieving overall risk reduction yields the maximum aggregate reduction in risk.

Specific consideration for setting ambient standards in each category of location (residential, industrial, environmentally sensitive zones, etc.) include the reduction in potential aggregate health risks (morbidity and mortality combined in a single measure) to the exposed population; the risk to sensitive, valuable ecosystems and manmade assets and the likely societal costs, of achieving the proposed ambient standard.

Similarly, emission standards for each class of activity need to be set on the basis of general availability of the required technologies, the feasibility of achieving the applicable environmental quality standards at the location (specific or category) concerned with the proposed emission standards, and the likely unit costs of meeting the proposed standard. It is also important that the standard is specified in terms of quantities of pollutants that may be emitted, and not only by concentration levels, since the latter can often be easily met through dilution, with no actual improvement in ambient quality. The tendency to prescribe specific abatement technologies should also be eschewed, since these may unnecessarily increase the unit and societal costs of achieving the ambient environmental quality, and in any case because a technology that is considered ideal for meeting a given emission standard may not be acceptable on other relevant parameters, including possibly other sources of societal risk.

In sum, salient features, NEP, 2006 is as follows:

- Reduction related to health, ecosystem and man-made asset;
- General availability of required technology and techno-economic feasibility;
- Ensure to achieve the ambient air quality & water quality standard (location specific); and
- Concentration as well as mass-based standards

3.0 World Scenario on Prescribing Location Specific Standards

3.1 U.S.A

3.1.1 Standards for Water Quality and Wastewater Effluents

Water quality of surface waters that receive wastewater effluents are protected by setting standards for these waters and limiting the types and amounts of pollutants discharged in effluents. In the United States, effluent limits for wastewater discharges are usually based on both in-stream water quality and technology-based effluent standards. The more stringent of the two standards for any given pollutant determines the actual effluent limit established in the discharge permit. The USEPA has established both national water quality standards and national effluent limits for many industries. Most states have established their own set of water quality standards based in part on water quality criteria developed by EPA. The state water quality standards, where they exist are used in combination with national industrial effluent limits to set permit limits for facilities within a particular state.

3.1.2 Water Quality Standards

The USEPA has established regulations that specify what states must do to establish their own water quality standards program. For states that have not developed their own water quality standards (or whose programs were deemed inadequate by the USEPA), the USEPA has established National standards for "priority" toxic pollutant (there are 126). The National requirements for water quality standard programs include, general provisions such as definitions and minimum requirements for program submittals, requirements for state water quality standards (including designated water uses, water quality criteria, and anti degradation policy), requirements for reviewing and revising state water quality standards every three years and national standards for states that have inadequate programs.

Designated uses of surface waters such as streams, rivers, lakes and bays determine the water quality standards that must be developed in order to maintain those uses. Common designated uses are public water supply, protection and propagation of fish, shellfish and wildlife, recreation, agriculture, industry and navigation. Examples of other less common uses are aquifer protection, ground water recharge, coral reef preservation, hydroelectric power and marinas.

Water quality standards include both narrative and numerical criteria. Examples of narrative criteria, taken from the USEPA's handbook for water quality standards are:

All waters, including those within mixing zones, shall be free from substances attributable to wastewater discharges or other pollutant sources that, (i) settle to form objectionable deposits; (ii) float as debris, scum, oil or other matter forming nuisance; (iii) produce objectionable color, odor, taste or turbidity; (iv) cause injury to or are toxic to or produce adverse physiological responses in humans, animals or plants; or (v) produce undesirable or nuisance aquatic life.

Numeric water quality criteria are usually concentration limits on pollutants such as metals and toxic organics, or in-stream water parameters such as dissolved oxygen, pH, chlorides and sulfates. Numeric criteria are usually established to protect aquatic life (both on an acute and longer term chronic basis) and to protect human health through direct exposure or through the ingestion of water and aquatic organisms.

National antidegradation regulations cover three levels. Tier 1 maintains and protects existing uses and water quality necessary to maintain those uses. Tier 2 protects waters whose quality is better than that necessary to protect fishable, swimmable uses. Tier 3 protects waters that are designated as outstanding national resource waters of exceptionally high quality or ecological significance.

Criteria for the protection of aquatic life are based on acute and chronic exposure periods. Criteria are based on toxicity tests for a given chemical on a variety of aquatic plants and animals. Acute toxicity tests are usually 48-hour to 96-hour tests that measure leachality or immobilization of the organism. Chronic toxicity tests are for longer periods, often greater than 28 days and measure effects on survival, growth, or reproduction. Criteria for certain chemicals may incorporate other water quality parameters that effect toxicity such as pH (ammonia, for example) and hardness (metals). Metals criteria are often given as “total recoverable” metals, which represent both the particulate and dissolved fractions. Because the dissolved form is believed to represent the form of the metal that is most available to the organism biologically (and do the most harm), the USEPA recommends that compliance with water quality standards be based on the dissolved fraction (although this dissolved fraction is translated to “total” metal for discharge permits.)

Human health criteria protect against chronic effects from long-term exposure. For example, for carcinogenic chemicals, the exposure period is assumed to be a person’s lifetime, set equal to 70 years. Criteria are usually based on human consumption of water and fish or shellfish, depending on the use of the water and whether it is non saline (fresh) or saline (estuarine/marine). For example, saline waters are not used for drinking water, so the criteria would be based on food consumption alone. Consumption of contaminated organisms is of special concern where a chemical bio-accumulates (concentrates) in the organism, such as polychlorinated biphenyls (PCBs).

The USEPA has established the concept of mixing zones for wastewater effluents in surface waters, which states typically incorporate into their water quality standards. A mixing zone is an area at the point where a wastewater discharge enters a water body Mixing zones are intended to allow a small area around the immediate discharge point where a standard may be exceeded because this small area is not harmful to the overall water body. The size of the mixing zone must be set so that it does not impair the integrity of the water body as a whole, there is no lethality to organisms passing through the mixing zone, and there are no significant health risks. Without allowing a mixing zone, concentration limits in wastewater effluents could not exceed water quality standards, which may be quite stringent and difficult and expensive to achieve with treatment technologies. The immediate area around the discharge is the "zone of initial dilution", or ZID. The ZID defines the boundary where acute aquatic life criteria apply (they may be exceeded within the ZID, but not outside of it). The secondary mixing zone, often just referred to as the mixing zone, defines the boundary where chronic aquatic life criteria apply. A mixing zone may also be defined for human health criteria, although it is usually defined as the point of complete (100%) mixing with the water body. In setting permit limits, whichever criteria for a particular pollutant and mixing zone is most stringent (acute-ZID, chronic-mixing zone, human health-complete mixing) sets the permit limit.

Many wastewater discharge permits require whole effluent toxicity (WET) tests, which test the toxicity of the effluent to aquatic organisms. The WET tests attempts to evaluate toxicity through a more holistic approach (that is, the testing of the actual effluent), rather than the single-chemical toxicity tests used to establish numeric water quality criteria. Hence, the term, "whole effluent". In a WET test, an organism is exposed to the wastewater effluent in diluted or undiluted form, depending on the type of WET test and the fraction of effluent in the water body. The organisms are evaluated for growth, survival, fecundity, or other characteristics. WET tests are one way of demonstrating the narrative water quality standards (for example, nontoxic conditions) are being met. WET tests typically use two species, one a feeder type such as the crustacean, Ceriodaphnia dubia, or water flea, and a fish such as Pimephales promelas, or fathead minnow (these are examples for non-saline waters). Marine or estuarine waters use other species common to the type of environment. WET tests may be conducted as often as each month, however, quarterly or semiannual monitoring is more common. If persistent toxicity is shown in a series of WET tests, the discharger is required to conduct a study to identify and eliminate the source of toxicity.

3.1.3 Effluent Discharge Limitations and Standards

The USEPA has developed national standards for wastewater effluents for more than 50 specific industries, covering a wide range of manufacturing activities such as food processing, metal manufacturing, electrical components, inorganic and organic chemicals, plastics and mining. There are standards for both "direct" discharges, those discharging directly into a water body, and "indirect" discharges, those that discharge to an offsite wastewater treatment facility, which itself discharges directly to a water body. Typically, standards for indirect dischargers are less stringent than for direct dischargers because additional treatment is provided by the offsite facility. Effluent standards cover common pollutants such as biochemical oxygen demand (BOD, organic materials that consume oxygen in receiving water when they are consumed by bacteria), total suspended solids (TSS) and pH and others that cover toxic pollutants (metals, organics, in organics).

There are several different categories of effluent standards. In addition to different standards for direct and indirect dischargers, there are different guidelines for existing discharges (those in existence at the time a particular standard was created) and for new dischargers (those after the standard was created).

For direct dischargers, there are effluent standards representing best practicable technology (BPT), best conventional technology (BCT), best available technology (BAT), and new source performance standards (NSPS). For indirect dischargers, there are pretreatment standards for existing sources (PSES) and pretreatment standards for new sources (PSNS). Other types of effluent standards are best management practices (BMP) and best professional judgement (BPJ). These types of standards are described more fully in the following table.

3.1.4 Types of National Effluent Standards established for Industrial Categories by the USEPA

3.1.4.1 Direct Dischargers

BPT – Best Practicable Technology

These standards apply to conventional pollutants, which USEPA defines as BOD, TSS, fecal coliform bacteria, pH and oil & grease and non-conventional pollutants such as chemical oxygen demand (COD) and ammonia.

BCT – Best Conventional Technology

These standards apply to conventional pollutants, usually BOD and TSS. BCT standards may be the same or more stringent than BPT limits if the cost of providing a higher level of treatment is reasonable, which is determined by a two-part cost/benefit test.

BAT – Best Available Technology

These standards apply to toxic pollutants and non-conventional pollutants.
NSPS – New Source Performance Standards

These standards apply to wastewater discharges that are generated by new construction or major modifications of facilities after effluent standards are proposed NSPS are usually more stringent than BPT, BCT and BAT limits because new facilities have more opportunity to install more efficient pollution control and treatment technology. NSPS standards apply to all types of pollutants (conventional, non-conventional and toxic).

3.1.4.2 Indirect Dischargers

PSES – Pretreatment Standards for Existing Sources

These standards cover all types of pollutants (conventional, non-conventional and toxic). PSES are not usually developed for BOD and TSS because they are assumed to be readily treated at offsite treatment facilities and adequately controlled by these facilities. PSES are analogous to BPT ad BAT limits for direct dischargers.

PSNS – Pretreatment Standards for New Sources

These standards cover all types of pollutants (conventional, non-conventional and toxic). PSNS are not usually developed for BOD and TSS because they are assumed to be readily treated at offsite treatment facilities and adequately controlled by these facilities. PSES are analogous to NSPS limits for direct discharges.

3.1.4.3 All Discharges

BMP – Best Management Practices

These are procedures that address maintenance and good house-keeping to minimize spills and pollutants in wastewaters.

BPJ – Best Professional Judgement

BPJ is used by permit writers in a regulatory agency when limits cannot be set entirely according to industrial categorical effluent standards. For example, BPJ is used to establish limits for wastewaters that are in a mixture of categorical streams and utility wastewaters from cooling towers, boilers and demineraliser units. BPJ is also used to set limits for pollutants not covered by effluent guidelines.

3.2 European Countries

Standards for all countries in Europe are developed by the European Union. The National Environmental Protection Authority (NEPA) of the concerned country develops the standards for the entire nation in synchronizing with the standards of the European Union. These standards are so stringent that there is hardly any need for making them more stringent at any location. However, whenever such a need arises, a five member bench consisting of (i) Judge, (ii) Environmental Lawyer, (iii) NEPA representative, (iv) Industry representative and (v) Local Regulatory representative fixes standards which meet the aspirations of the local people.

It may be summarised that the standards in Europe are evolved to meet the requirements of the most critical assimilation capacity and in case of any specific situation at a particular location; excellent balancing act is done by involving all concerned.

3.3 U.K.

Experience of UK over several decades has confirmed that the domestic sewage effluents, the Royal Commission 20:30 standard for BOD and SS provides an adequate safeguard for rivers when there is a minimum dilution of 8:1 at 95% exceedence flow. Where the dilution is less than this, more stringent conditions are normally imposed ranging from 15:20 for BOD and SS to 10:15 and as low as 5:8 where the dilution is 1:1. However, it is important to keep in mind that if other sewage effluents are discharged in the same stretch of the river, then each discharge may require more stringent standards than its dilution factor alone would suggest.

3.4 India

The discharge/emission standards are laid in the country at the National level through notification under Environment (Protection) Act, 1986 as per the provisions of this Act as described in Chapter 2.0 of this document. The Environment (Protection) Act, 1986 also empowers the State Boards to make these standards stringent for any location depending upon the local needs of the specific locations. However, there is no common approach existing. The most common decision which appears to be in practice is imposing of a condition of zero effluent discharge into surface water at locations depending upon the type of use of the surface water downstream the discharge source.

4.0 Importance and Availability of Air/Water Quality Models

4.1 Importance of Modeling

Modeling is one of the important tools for fixing location specific stringent standards. This is necessary to decide on the discharge/emission reduction needed to meet the ambient water/air quality required at the specific locations. In order to encourage and facilitate use of models, USEPA has developed models reflecting the latest state of art. These models cover a wide range of recipient systems as well as polluting sources and can be used even with minimum modeling experience. Details of the various Air/Water Quality Models developed by USEPA are presented in this chapter.

4.2 Air Quality Models

4.2.1 USEPA's Library of Models

USEPA has provided a library of models in a central computer located at the Research Triangle Park, North Carolina. The Library enables the users to have access to a set of models reflecting the latest state-of-the-art. These models do not require any programming and they can be used with minimum modeling exercise.

A review of the important models is presented in the subsequent paragraphs.

4.2.2 Model Name : BLP

4.2.2.1 General description

BLP (Buoyant Line and Point Source) is a Gaussian plume dispersion model designed to handle unique modeling problems associated with aluminium reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important.

4.2.2.2 Recommended Regulatory Use

Aluminium reduction plants which contain buoyant elevated line sources;
Rural areas;
Transport distances less than 50 kilometer;
Simple terrains; and
One-hour to one-year averaging times.

4.2.2.3 Input Requirements

Source data - Point sources require stack location, elevation of stack base, effective stack height, stack inside exit diameter, stack gas exit velocity, stack gas exit temperature, and pollutant emission rate. Line sources require coordinates of the end of the line, release height emission rate, average line source width, average building width, average spacing between buildings, and average line source buoyancy parameter.

Meteorological data-Hourly surface weather data from data obtained/recorded file or preprocessor programme RAMMET provides hourly stability class, wind direction, wind speed, temperature and mixing height, receptor locations and elevations of receptors, or location and size of receptor grid or request automatically generated receptor grid.

4.2.2.4 Output

Printed output (from a separate post processor programme) includes total concentration or, optionally, source contribution analysis; monthly and annual frequency distributions for 1-, 3-, and 24-hour average concentrations; tables of 1-, 3-, and 24-hour average concentrations at each receptor; table of the annual (or length of run) average concentrations at each receptor; Five highest 1-, 3- and 24-hour average concentrations at each receptor; and Fifty highest 1-, 3- and 24-hour concentrations over the receptor field.

4.2.2.5 Type of Model

Gaussian plume model

4.2.2.6 Pollutant Types

Primary pollutants. Does not treat settling and deposition.

4.2.2.7 Source Receptor

Treats up to 50 point sources, 10 parallel line sources, and 100 receptors arbitrarily located. User-input topographic elevation is applied for each stack and each receptor.

4.2.2.8 Plume Behavior

Uses plume rise formula of Schulman and Scire. Vertical potential temperature gradients of 0.02 Kelvin per meter for stability and 0.035 Kelvin per meter are used for stable plume rise calculations. An option for user input values is included. Transitional rise is used for line sources.

Option to suppress the use of transitional plume rise for point sources is also included. The building downwash algorithm of Schulman and Scire is used.

4.2.2.9 Horizontal Winds

Constant, uniform (steady-state) wind is assumed for an hour. Straight line plume transport is assumed to all downwind distances. Wind speed profile exponents of 0.10, 0.15, 0.20, 0.25, 0.30 and 0.35 are used for stability Classes A through F, respectively. An option for user-defined values and an option to suppress the use of the wind speed profile feature are included.

4.2.2.10 Vertical Winds

Assumed to be equal to zero.

4.2.2.11 Horizontal Dispersion

Rural dispersion coefficients are from Turner with no adjustment made for variations in surface roughness or averaging time. Six stability classes are used.

4.2.2.12 Vertical Dispersion

Rural dispersion coefficients are from Turner with no adjustment made for variations in surface roughness. Six stability classes are used. Mixing height is accounted for with multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height and uniform mixing is assumed beyond that point. Perfect reflection at the ground is assumed.

4.2.2.13 Chemical Transformation

Chemical transformations are treated using linear decay. Decay rate is input by the user.

4.2.2.14 Physical Removal

Not explicitly treated.

4.2.3 Model Name : CALINE3

4.2.3.1 General Description

CALINE3 can be used to estimate the concentrations of non-reactive pollutants from highway traffic. This is a steady-state Gaussian model and can be applied to determine air pollutant concentrations at receptor locations downwind of at-grade, fill, bridge, and cut-section highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation and receptor location. The model has adjustments for averaging time and surface roughness and can handle upto 20 links and 20 receptors. It also contains an algorithm for deposition and settling velocity so that the particulate concentrations can also be predicted.

4.2.3.2 Recommended Regulatory Use

CALINE3 is appropriated for the following applications:
Highway line source;
Urban or rural areas;
Simple terrain;
Transport distances less than 50 kilometer; and
One-hour to 24 hour averaging times

4.2.3.3 Input requirements

Source data -- up to 20 highway links classed as at-grade, fill, bridge, or depressed; coordinates of link end points; traffic volume; emission factor; source height; and mixing zone width.

Meteorological data wind speed, wind angle (measured in degrees clockwise from the y-axis), stability class, mixing height, ambient (background to the highway) concentration of pollutant.

Receptor data -- coordinates and height above ground for each receptor.

4.2.3.4 Output

Printed output includes concentration at each receptor for a specified meteorological condition.

4.2.3.5 Type of Model

Gaussian Plume Model

4.2.3.6 Pollutant types

Primary Pollutants

4.2.3.7 Source Receptor

Upto 20 highway links are treated. CALINE3 applies user input location and emission rate for each link. User-input receptor locations are applied.

4.2.3.8 Plume Behavior

Plume rise is not treated.

4.2.3.9 Horizontal Winds

User-input hourly wind speed and direction are applied.
Constant, uniform (steady-state) wind is assumed for an hour.

4.2.3.10 Vertical Winds

Assumed to be equal to zero.

4.2.3.11 Horizontal Dispersion

Six stability classes are used. Rural dispersion coefficients from Turner are used, with adjustment for roughness length and averaging time. Initial traffic-induced dispersion is handled implicitly by plume size parameters.

4.2.3.12 Vertical Dispersion

Six stability classes are used. Empirical dispersion coefficients from Benson are used, including an adjustment for roughness length. Initial traffic-induced dispersion is handled implicitly by plume size parameters. Adjustment for averaging time is included.

4.2.3.13 Chemical Transformation

Not treated.

4.2.3.14 Physical Removal

Optional deposition calculations are included.

4.2.4 Model Name : CDM

4.2.4.1 General Description

Climatological Dispersion model (CDM) is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual) arithmetic average pollutant concentrations at any ground-level receptor in an urban area.

4.2.4.2 Recommended Regulatory Use

CDM is appropriate for the following applications:

Point and area sources;
Urban areas;
Flat terrain;
Transport distances less than 50 kilometers; and
Long-term averages over one month to one year or longer.

4.2.4.3 Input Requirements

Source data - location, average emissions rates and height of emissions from point and area sources. Point source data requirements also include stack gas temperature, stack gas exit velocity and stack inside exit diameter for plume rise calculations for point sources, Meteorological data - stability wind rose (STAR deck day/night version), average mixing height and wind speed in each stability category and average air temperature, Receptor data - Cartesian coordinates of each receptor.

4.2.4.4 Output

Printed output includes concentration at each receptor.

Average concentrations for the period of the stability wind rose data (arithmetic mean only) at each receptor, and
Optional point and area concentration rose for each receptor.

4.2.4.5 Type of Model

Climatological Guassian Plume model

4.2.4.6 Pollutant Types

Primary Pollutants

4.2.4.7 Source Receptor

Primary pollutants. Settling and deposition are not treated.

4.2.4.8 Plume Behavior

CDM applies user-specified locations for all point sources and receptors. Area sources are input as multiples of a user-defined unit area source grid size. User-specified release heights are applied for individual point sources and the area source grid. Actual separation between each source-receptor pair is used. The user may select a single height at or above ground level that applies to all receptors. No terrain differences between source and receptor are treated.

4.2.4.9 Horizontal Winds

CDM uses Briggs plume rise equations. Optionally, a plume rise-wind speed product may be input for each point source. Stack tip downwash equation from Briggs is preferred use. The Bjorklund Bowers equation is also included.

4.2.4.10 Vertical Winds

Assumed to be equal to zero

4.2.4.11 Horizontal Dispersion

Pollutants are assumed evenly distributed across a 22.5 or 10.0 degree sector.

4.2.4.12 Vertical Dispersion

There are seven vertical dispersion parameter schemes, but the one recommended for regulatory applications is Briggs-urban. Mixing height has no effect until dispersion coefficient equals 0.8 times the mixing height; uniform vertical mixing is assumed beyond that point. Buoyancy-induced dispersion is included as an option. Perfect reflection is assumed at the ground.

4.2.4.13 Chemical Transformation

Chemical transformations are treated using exponential decay. Half-life is input by the user.

4.2.4.14 Physical Removal

Not explicitly treated.

4.2.5 Model Name : RAM

4.2.5.1 General Description

RAM (Gaussian-Prime Multiple Source Air Quality Algorithm) is a steady-state Gaussian plume model for estimating concentrations of relatively stable pollutants for times averaging from an hour to a day, from point and area sources in a rural or urban setting. Level terrain is assumed. Calculations are performed for each hour.

4.2.5.2 Recommended Regulatory Use

RAM is appropriate for the following applications:

Point and area sources;
Urban areas;
Flat terrain;
Transport distances less than 50 kilometer; and
One hour to one year averaging times.

4.2.5.3 Input Requirements

Source data - Point sources require location, emission rate, effective stack height, stack gas exit velocity, stack inside diameter and stack gas temperature. Area sources require location, size, emission rate and height of emissions, Meteorological data - hourly surface weather data from the preprocessor program RAMMET, which provides hourly stability class, wind direction, wind speed, temperature, and mixing height. Actual anemometer height (a single value) is also required. Receptor data - Coordinates of each receptor. Options for automatic placement of receptors near expected concentration maxima and a gridded receptor array are included.

4.2.5.4 Output

Printed output optionally includes. One to 24-hour and annual average concentrations at each receptor. Limited individual source contribution list, and highest through fifth highest concentrations at each receptor for a period, with the highest, high and the second-high values flagged.

4.2.5.5 Type of Model

Gaussian Plume model.

4.2.5.6 Pollutant Types

Primary pollutants

4.2.5.7 Source Receptor

Primary pollutants. Settling and deposition are not treated.

4.2.5.8 Plume Behavior

RAM applies user-specified locations for all point sources and receptors. Area sources are input as multiples of a user-defined unit area source grid size. User specified stack heights are applied for individual point sources. Up to 3 effective release heights may be specified for the area sources. Area source release heights are assumed to be appropriate for a 5 meter per second wind and to be inversely proportional to wind speed. Actual separation between each source-receptor pair is used. All receptors are assumed to be at the same height at or above ground level. No terrain differences between source and receptor are accounted for.

4.2.5.9 Horizontal Winds

Constant, uniform (steady state) wind is assumed for an hour. Straight line plume transport is assumed to all downwind distances. Separate wind speed profile exponents for urban cases are used.

4.2.5.10 Vertical Winds

Assumed to be equal to zero.

4.2.5.11 Horizontal Dispersion

Rural dispersion coefficients from Turner are used, with no adjustments for surface roughness or averaging time Urban dispersion coefficients from Briggs are used. Buoyancy induced dispersion is included. Six stability classes are used.

4.2.5.12 Vertical Dispersion

Urban dispersion coefficients from Briggs are used. Buoyancy-induced dispersion is included. Six stability classes are used. Mixing height is accounted for with multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point. Perfect reflection is assumed at the ground.

4.2.5.13 Chemical transformation

Chemical transformation are treated using exponential decay. Half-life is input by the user.

4.2.5.14 Physical Removal

Not explicitly treated.

4.2.6 Model Name: ISC3

4.2.6.1 General Description

ISC3 (Industrial Source Complex model) is a steady-state Gaussian plume model, which can be used to assess pollutant concentrations form a wide variety of sources associated with an industrial source complex. This model can account for the settling and dry deposition of particles, downwash, area, line, and volume sources, plume rise as a function of downwind distance, separation of point sources, and limited terrain adjustment. ISC3 operates in both long-term and short-term modes.

4.2.6.2 Recommended Regulatory Use

ISC3 is appropriate for the following applications :

Industrial source complexes;
Rural or urban areas;
Flat or rolling terrain;
Transport distances less than 50 kilometer;
1-hour to annual averaging times, and
Continuous toxic air emissions.

4.2.6.3 Input Requirements

Source data - Location, emission rate, effective stack height, stack gas exit velocity, stack inside exit diameter, and stack gas temperature. Optional inputs include source elevation, building dimensions, particle size distribution with corresponding settling velocities and surface reflection coefficients. Meteorological data - ISC3 requires hourly surface weather data from the preprocessor program RAMMET, which provides hourly stability class, wind direction, wind speed, temperature and mixing height. For ISC3, input includes stability wind rose (STAR deck), average afternoon mixing height, average morning mixing height and average air temperature, Receptor data coordinates and optional ground elevation for each receptor.

4.2.6.4 Output

Printed output options include, program control parameter, source data and receptor data, tables of hourly meteorological data for each specified day, N-day average concentration or total deposition calculated at each receptor for any desired source combinations, concentration or deposition values calculated for any desired source combination at all receptors for any specified day or time period within the day, tables of highest and second highest concentration or deposition values calculated at each receptor for each specified time period during an N-day period for any desired source combination and tables of the maximum 50 concentration or deposition values calculated for any desired source combinations for each specified time period.

4.2.6.5 Type of Model

ISC3 is a Gaussian plume model. It has been revised to perform a double integration of the Gaussian plume kernel for area sources.

4.2.6.6 Pollutant Types

ISC3 may be used to model primary pollutants and continuous releases of toxic and hazardous waste pollutants. Settling and deposition are treated.

4.2.6.7 Source Receptor

ISC3 applies user-specified locations for point, line, area and volume sources, and user-specified receptor locations or receptor rings. User input topographic evaluation for each receptor is used. Elevations above stack top are reduced to the stack top elevation, i.e., terrain chopping. User input height above ground level may be used when necessary to simulate impact at elevated or flag pole receptors, e.g., on buildings. Actual separation between each source-receptor pair is used.

4.2.6.8 Plume Behavior

ISC3 uses Briggs plume rise equation for final rise. Stack tip downwash equation from Briggs is used. Revised building wake effects algorithm is used. For stacks higher than building height plus one-half the lesser of the building height or building width, the building wake algorithm of Huber and Snyder issued. For lower stacks, the building wake algorithm of Schulman and Scire is used, but stack tip downwash and BID are not used. For rolling terrain (terrain not above stack height), plume centerline is horizontal at height of final rise above source. Fumigation is not treated.

4.2.6.9 Horizontal Winds

Constant, uniform (steady state) wind is assumed for each hour. Straight line plume transport is assumed to all downwind distances. Separate wind speed profile exponents for both rural and urban cases are used. An optional treatment for calm winds is included for short-term modeling.

4.2.6.10 Vertical Winds

Assumed to be equal to zero.

4.2.6.11 Horizontal Dispersion

Rural dispersion coefficients from Turner are used, with no adjustments for surface roughness or averaging time. Urban dispersion coefficients from Briggs are used. Buoyancy induced dispersion is included. Six stability classes are used.

4.2.6.12 Vertical Dispersion

Rural dispersion coefficients from Turner are used with no adjustments for surface roughness. Urban dispersion coefficients from Briggs are used. Buoyancy-induced dispersion is included. Six stability classes are used. Mixing height is accounted for with multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height; uniform vertical mixing is assumed beyond that point. Perfect reflection is assumed at the ground.

4.2.6.13 Chemical Transformation

Chemical transformations are treated using exponential decay. Time constant is input by the user.

4.2.6.14 Physical Removal

Dry deposition effects for particles are treated using a resistance formulation in which the deposition velocity is the sum of the resistances to pollutant transfer within the surface layer of the atmosphere plus a gravitational settling term based on the modified surface depletion scheme of Horst.

4.2.7 Model Name : UAM

4.2.7.1 General Description

UAM (Urban Airshed Model) is an urban scale three-dimensional grid type numerical simulation model. The model incorporates a condensed photochemical kinetics mechanism for urban atmospheres. The UAM is designed for computing ozone concentrations under shot-term, episodic conditions lasting one or two days resulting from emission of nitrogen oxides, volatile organic compounds, and carbon monoxide. The model treats urban VOC emissions as their carbon-bond surrogates.

4.2.7.2 Recommended Regulatory Use

UAM is appropriate for the following applications:

Urban areas having significant ozone attainment problems and one-hour averaging times.
UAM has many options; but no specific recommendations are made.

4.2.7.3 Input Requirements

Source data - Gridded, hourly emissions of PAR, OLE, ETH, XYL, TOL, ALD2, FORM, ISOR, ETOTH, MEOH, CO, NO, for low-level sources. For major elevated point sources, hourly emissions, stack height, stack diameter, exit velocity, and exit temperature. Meteorological data - hourly, gridded, divergence free, u and v wind components for each vertical level; hourly gridded mixing heights and surface temperatures; hourly exposure class; hourly vertical potential temperature gradient above and below the mixing height; hourly surface atmospheric pressure; hourly water mixing height; hourly surface atmospheric pressure; hourly water mixing ratio; and gridded surface roughness lengths. Air quality data - Concentration of all carbon bond 4 species at the beginning of the simulation for each grid cell; and hourly concentrations of each pollutant at each level along the inflow boundaries and top boundary of the modeling region. Other data requirements hourly mixed layer average, NO_2 photolysis rates; and ozone surface uptake resistance along with associated gridded vegetation (scaling) factors.

4.2.7.4 Output

Printed output includes gridded instantaneous concentration fields at user-specified time intervals for user-specified pollutants and grid levels; and gridded time-average concentration fields for user-specified time intervals, pollutants, and grid levels.

4.2.7.5 Type of Model

UAM is a three-dimensional, numerical, photochemical grid mode.

4.2.7.6 Pollutant Types

UAM may be used to model ozone formation from nitrogen oxides and volatile organic compound emissions.

4.2.7.7 Source Receptor

Low-level area and point source emissions are specified within each surface grid cell. Emissions from major point sources are placed within cells aloft in accordance with calculated effective plume heights. Hourly average concentration of each pollutant is calculated for all grid cells at each vertical level.

4.2.7.8 Plume Behavior

Plume rise is calculated for major point source using relationships recommended by Briggs.

4.2.7.9 Horizontal Winds

Same as described under the input requirements.

4.2.7.10 Vertical Winds

Calculated at each vertical grid cell interface from the mass continuity relationship using the input gridded horizontal wind field.

4.2.7.11 Horizontal Dispersion

Horizontal eddy diffusivity is to set a user specified constant value (nominally 50 m^2/s).

4.2.7.12 Vertical Dispersion

Vertical eddy diffusivities for unstable and neutral conditions calculated using relationships of Lamp et al., for stable conditions. The relationship of Businger and Arya is employed. Stability class, friction velocity, and Monin-Obukhov length determined using procedure of Liu et al.

4.2.7.13 Chemical Transformation

UAM employs a simplified version of the Carbon-Bond IV mechanism (CBM-IV) developed by Gery et al., employing various steady state approximations. The CBM-IV mechanism incorporated in UAM used an updated simulation of PAN chemistry that includes a peroxy-peroxy radical termination reaction, significant when the atmosphere is NOx-limited. The current CBM-IV mechanism accommodates 34 species and 82 reactions.

4.2.7.14 Physical Removal

Dry deposition of ozone and other pollutant species are calculated. Vegetation (scaling) factors are applied to the reference surface uptake resistance of each species depending on land use type.

4.2.8 Model Name : OCD

4.2.8.1 General Description

Offshore and Coastal Dispersion (OCD) is a straight-line Gaussian model developed to determine the impact of offshore emissions from point, area or line sources on the air quality of coastal regions OCD incorporates over water plume transport and dispersion as well as changes that occur as the plume crosses the shoreline. Hourly meteorological data are needed from both offshore and onshore locations. These include water surface temperature, over water air temperature, mixing height, and relative humidity. Some of the key features include platform building downwash, partial plume penetration into elevated inversions, direct use of turbulence intensities for plume dispersion, interaction with the overland internal boundary layer, and continuous shoreline fumigation.

4.2.8.2 Recommended Regulatory Use

OCD is applicable for over water sources where onshore receptors are below the lowest source height. Where onshore receptors are above the lowest source height, offshore plume transport and dispersion may be modeled on a case-by-case basis.

4.2.8.3 Input Requirements

Sources data - Point, area, or line source location, pollutant emission rate, building height, stack height, stack gas temperature, stack inside exit diameter, stack gas exit velocity, stack angle from vertical, elevation of stack base above water surface and gridded specification of the land/water surfaces. As an option, emission rate, stack gas exit velocity and temperature can be varied hourly.

Meteorological data - Wind direction (over water), wind speed, mixing height, relative humidity, air temperature, water surface temperature, vertical wind direction shear (optional), vertical temperature gradient (optional) and turbulence intensities (optional).

Receptor data - location, height above local ground level and ground level elevation above water surface.

4.2.8.4 Output

All input options, specification of sources, receptors and land/water map including locations of sources and receptors. Summary tables of five highest concentrations at each receptor for each averaging period, and average concentration for entire run period at each receptor. Optional case study printout with hourly plume and receptor characteristics. Optional table of annual impact assessment from non-permanent activities. Concentration files written to disk or tape can be used by ANALYSIS postprocessor to produce the highest concentrations for each receptor, the cumulative frequency distributions for each receptor, the tabulation of all concentrations exceeding a given threshold, and the manipulation of hourly concentration files.

4.2.8.5 Type of Model

OCD is a Gaussian plume model constructed on the framework of the MPTER Model.

4.2.8.6 Pollutant Types

OCD may be used to model primary pollutants. Settling and deposition are not treated.

4.2.8.7 Source Receptor

Up to 250 point sources, 5 area sources, or 1 line source and 180 receptors may be used. Receptors and sources are allowed at any location. The coastal configuration is determined by a grid of up to 3,600 rectangles. Each element of the grid is designated as either land or water to identify the coastline.

4.2.8.8 Plume Behavior

As in MPTER, the basic plume rise algorithms are based on Briggs' recommendations. Momentum rise includes consideration of the stack angle from the vertical. The effect of drilling platforms, ships, or any over water obstructions near the source are used to decrease plume rise using a revised platform downwash algorithm based on laboratory experiments. Partial plume penetration of elevated inversions is included using the suggestion of Briggs and Weil and Brower. Continuous shoreline fumigation is parameterized using the Turner method where complete vertical mixing through the Thermal Internal Boundary Layer (TIBL) occurs as soon as the plume intercepts the TIBL.

4.2.8.9 Horizontal Winds

Constant, uniform wind is assumed for each hour. Over water wind speed can be estimated from overland wind speed using relationship of Hsu. Wind speed profiles are estimated using similarity theory. Surface layer fluxes for these formulas are calculated from bulk aerodynamic methods.

4.2.8.10 Vertical Winds

Assumed to be equal to zero.

4.2.8.11 Horizontal Dispersion

Lateral turbulence intensity is recommended as a direct estimate of horizontal dispersion. If lateral turbulence intensity is not available, it is estimated from the boundary layer theory. For wind speed less than 8 m/s, lateral turbulence intensity is assumed inversely proportional to wind speed. Horizontal dispersion may be enhanced because of obstructions near the source. A virtual source technique is used to simulate the initial plume dilution due to downwash. Formula recommended by Pasquill are used to calculate the buoyant plume enhancement and wind direction shear enhancement. At the water/land interface, the change to overland dispersion rates is modeled using a virtual sources. The overland dispersion rates can be calculated from either lateral turbulence intensity or the Pasquill-Gifford curves. The change is implemented where the plume intercepts the rising internal boundary layer.

4.2.8.12 Vertical Dispersion

Observed vertical turbulence intensity is not recommended as a direct estimate of vertical dispersion. Turbulence intensity should be estimated from boundary layer theory as default in the model. For very stale conditions, vertical dispersion is also a function of lapse rate. Vertical dispersion may be enhanced because of obstructions near the source. A virtual source technique is used to simulate the initial plume dilution due to downwash. Formula recommended by Pasquill are used to calculate buoyant plume enhancement. At the water/land interface, the change to overland dispersion relates is modeled using a virtual source. The overland dispersion rates can be calculated from either vertical turbulence intensity or the Pasquill-Gifford coefficients. The change is implemented where the plume intercepts the rising internal boundary layer.

4.2.8.13 Chemical Transformation

Chemical transformations are treated using exponential decay. Different rates can be specified by month and by day or night.

4.2.8.14 Physical removal

Physical removal is also treated using exponential decay.

4.2.9 Model Name: EDMS

4.2.9.1 General Description

Emissions and Dispersion Modeling System (EDMS) is a combined emissions/dispersion model for assessing pollution at civilian airports and military air bases. This model produces an emission inventory of all airport sources and calculates concentrations produced by these sources at specified receptors. The system stores emission factors for fixed sources such as fuel storage tanks and incinerators and also for mobile sources such as automobiles or aircraft. EDMS incorporates an emission model to calculate an emission inventory for each of the airport source and a dispersion model, the Graphical Input Microprocessor Model (GIMM) to calculate pollutant concentration produced by these sources at specified receptors. The GIMM, which processes point, area, and line sources also incorporates a special metrological preprocessor for processing up to one year of hourly data. The model operates in both screening and refined mode, accepting up to 170 sources and 10 receptors.

4.2.9.2 Recommended Regulatory Use

EDMS is appropriate for the following applications :

Cumulative effect of changes in aircraft operations;
Point source and Mobile source emissions at airports or air bases;
Simple terrain;
Transport distances less than 50 kilometers; and
1-hour to annual averaging times.

4.2.9.3 Input requirements

All data are entered through a runtime version of the Condor database which is an integral part of EDMS. Typical entry items are source and receptor coordinates, percent cold starts, vehicles per hour, etc. Some point sources, such as heating plants, require stack height, stack diameter, and effluent temperature inputs. Wind speed, wind direction, hourly temperature, and Pasquill-Gifford stability category (P-G) are the meteorological inputs. They can be entered manually through the EDMS data entry screens or automatically through the processing of previously loaded hourly data.

4.2.9.4 Output

Printed outputs consist of a monthly and yearly emission inventory report for each source entered and a concentration summing report for up to 8,760 hours (one year) of data.

4.2.9.5 Type of Model

For its emissions inventory calculations, EDMS uses algorithms consistent with AP-42 emission factors. For its dispersion calculations, EDMS uses the GIMM model, which uses a Gaussian plume algorithm.

4.2.9.6 Pollutant Types

EDMS inventorises and calculates the dispersion of carbon monoxide, nitrogen oxides, sulfur oxides, hydrocarbons, and suspended particles.

4.2.9.7 Source Receptor

Upto 170 sources and 10 receptors can be treated simultaneously. Area sources are treated as a series of lines that are positioned perpendicular to the wind. Line sources (roadways, runways) are modeled as a series of points. Terrain elevation differences between sources and receptors are neglected. Receptors are assumed to be at ground level.

4.2.9.8 Plume Behavior

Plume rise is calculated for all point sources (heating plants, incinerators, etc.) using Briggs plume rise equations. Building and stack tip downwash effects are not treated.

Roadway dispersion employs a modification to the Gaussian plume algorithms as suggested by Rao and Keenan to account for close-in vehicle-induced turbulence.

4.2.9.9 Horizontal Winds

Steady state winds are assumed for each hours. Winds are assumed to be constant with altitude. Winds are entered manually by the user or automatically by reading previously loaded annual data files.

4.2.9.10 Vertical Winds

Assumed to be equal to zero.

4.2.9.11 Horizontal dispersion

Four stability classes are used (P-G classes B through E). Horizontal dispersion coefficients are computed using a table lookup and linear interpolation scheme. Coefficients are based on Pasquill as adopted by Petersen. A modified coefficient table is used to account for traffic-enhanced turbulence near roadways. Coefficients are based upon data included in Rao and Keenan.

4.2.9.12 Vertical dispersion

Four stability classes are used (P-G- classes B through E). Vertical dispersion coefficients are computed using a table lookup and linear interpolation scheme. Coefficients are based on Pasquill as adopted by a Petersen. A modified coefficients table is used to account for traffic-enhanced turbulence near roadways. Coefficients are based upon data from Rao and Keenan.

4.2.9.13 Chemical Transformation

Chemical transformations are not accounted for.

4.2.9.14 Physical Removal

Deposition is not treated.

4.2.10 Model Name: CTDMPLUS

4.2.10.1 General Description

Complex Terrain Dispersion Model Plus Algorighms For Unstable Situations (CTDMPLUS) is a refined point source Gaussian air quality model for use in all stability conditions for complex terrain applications. The model contains in the entire technology of CTDM for stable and neutral conditions. However, CTDMPLUS can also simulate daytime, unstable conditions, and has a number of additional capabilities for improved user friendliness. Its use of meteorological data and terrain information is different from other EPA models; considerable details for both types of input data is required and is supplied by preprocessors, specifically designed for CTDMPLUS. This model requires the parameterization of individual hill shapes using the terrain preprocessor and the association of each model receptor with a particular hill.

4.2.10.2 Recommended Regulatory Use

CTDMPLUS is appropriate for the following applications:

Elevated point sources;
Terrain elevations above stack top;
Rural or urban areas;
Transport distances less than 50 kilometers; and
One hour to annual averaging times when used with a port-processor program such as CHAVG.

4.2.10.3 Input Requirements

Source data - For each source, source location, height, stack diameter, stack exit velocity, stack exit temperature, and emission rate; if variable emissions are appropriate, hourly values for emission rate, stack exit velocity, and stack exit temperature.

Meteorological data - Hourly averaged values of wind, temperature and turbulence data for creation of the basic meteorological data file ("PROFILE"). Meteorological preprocessors then create a SURFACE data file (hourly values of mixed layer heights, surface friction velocity, Monin-Obukhov length and surface roughness length) and a RAWIN sonde data file (upper air measurements of pressure, temperature, wind direction, and wind speed).

Terrain data - User inputs digitized contour information to the terrain preprocessor, which creates the TERRAIN data file (for up to 25 hills).

4.2.10.4 Output

Produces a concentration file in either binary or text format (user's choice), and a list file containing a verification of the following model inputs, i.e.
Input meteorological data from SURFACE and PROFILE;
Stack data for each source;
Terrain information;
Receptor information;

Source-receptor location (line printer map);
In addition, if the case-study option is selected, the listing includes
Meteorological variables at plume height;
Geometrical relationships between the source and the hill;
Plume characteristics at each receptor, i.e., distance in alone-flow and cross-flow direction, effective plume-receptor height difference, effective σx and σy values, both flat terrain and hill induced (the difference shows the effect of the hill), concentration components due to WRAP, LIFT and FLAT.

If the user selects the TOPN option, a summary table of the top 4 concentrations at each receptor is given. If the ISOR option is selected, a source contribution table for every hour will be printed.

4.2.10.5 Type of Model

CTDMPLUS is a refined, steady-state, point source plume model for use in all stability conditions for complex terrain applications.

4.2.10.6 Pollutant types

4.2.10.7 CTDMPLUS may be used to model non-reactive, primary pollutants.

4.2.10.8 Source Receptor

Up to 40 point sources, 400 receptors and 25 hills may be used. Receptors and sources are allowed at any location. Hill slopes are assumed not to exceed 15 degrees, so that the linearized equation of motion for Boussinesq flow are applicable. Receptors upwind of the impingement point or those associated with any of the hills in the modeling domain require separate treatment.

4.2.10.9 Plume Behavior

The basic plume rise algorithms are based on Briggs recommendations as in CTDM. A central feature of CTDMPLUS for neutral/stable condition is its use of a critical dividing-streamline height (Hc) to separate the flow in the vicinity of a hill into two separate layers. The plume component in the upper layer has sufficient kinetic energy to pass over the top of the hill while streamlines in the lower portion are constrained to flow in a horizontal plane around the hill. Two separate components of CTMDPLUS compute ground-level concentrations resulting from plume material in each of these flows.

The model calculates on an hourly (or appropriate steady averaging period) basis how the plume trajectory (and, in stable/neutral conditions, the shape) is deformed by each hill. Hourly profiles of wind and temperature measurements are used by CTDMPLUS to compute plume rise, plume penetration A formulation is included to handle penetration into elevated stable layers based on the Briggs convective scaling parameters.

4.2.10.10 Horizontal Winds

CTDMPLUS does not simulate calm meteorological conditions. Both scalar and vector wind speed observations can be read by the model. If vector wind speed is unavailable, it is calculated from the scalar wind speed. The assignment of wind speed (either vector or scalar) at plume height is done by either interpolating between observations above and below the plume height, or extrapolating (within the surface layer) from the nearest measurement height to the plume height.

4.2.10.11 Vertical Winds

Vertical flow is treated for the plume component above the critical dividing streamline height (Hc).

4.2.10.12 Horizontal Dispersion

Horizontal dispersion for stable/neutral conditions is related to the turbulence velocity scale for lateral fluctuation 'sigma-V for which a minimum value of 0.2 m/s is used. Convective scaling formulations are used to estimate horizontal dispersion for unstable conditions.

4.2.10.13 Vertical Dispersion

Direct estimates of vertical dispersion for stable/neutral conditions are based on the observed vertical turbulence intensity, e.g., σ-z (standard deviation of the vertical velocity fluctuation). In simulating unstable (convective) conditions, CTDMPLUS relies on a skewed, bi-Gaussian Probability Density Function (PDF) description of the vertical velocities to estimate the vertical distribution of pollutant concentration.

4.2.10.14 Chemical Transformation

Chemical transformation is not treated.

4.2.10.15 Physical Removal

Physical removal is not treated and complete reflection at the ground/hill surface is assumed.

4.3 Proportional Scaling Models

4.3.1.1 Rollback Model

These models are also known as "Rollback Methods". In its most basic form, rollback assumes that the concentration (i) of any long lived pollutant at any point is equal to the background concentration (b) of that pollutant plus some linear function (k)of the total emission rate (e) of that pollutant in the area which influences the concentration at that point. This means:

$$Ci=b+ke \qquad (1)$$

Where,

'Ci' is the ambient concentration of one specific pollutant at the *i* th point, normally expressed in µg/m3, 'b' is the irreducible background concentration of that pollutant for air uninfluenced by those nearby emitters which influence the concentration at point *i*, normally in $\mu g/m^3$, 'k' is a proportionality factor, which takes into account the meteorology, location of all emitters as seen from point *i*, and the other factors which influence the source-receptor interaction at that point. Its normal dimensions are $(\mu g/m^3)/(g/s)$ and 'e' is the total emission rate of all emitters of that pollutant within the geographical area modeled, normally a city or a metropolitan area; its normal dimensions are g/s.

For standard settling purposes one proceeds by solving equation (1) for e, and defining the allowable emission rate as,

$$e_{allowable} = (c_{allowable} - b)/k \qquad (2)$$

Where the 'allowable' subscript indicates that the allowable emission rate is that which produces the allowable concentration at the point of interest. If we further assume that $c_{allowable}$ is the applicable ambient air quality standard for that specific pollutant, which we will call 'std', then we may write :

$$e_{allowable} = (std-b)/k \qquad (3)$$

To solve this equation, we need the value of k. From the discussion of eq. (1) it is clear that k is not a single constant for a given city but a function of location within the city. It is higher for points near major emission sources than those far from them. In American Air pollution Law, the standards must be met at every point, so we need the value of k corresponding to the highest value of c. Solving Eq. (1) for this value we find,

$$K = (C_{max} - b)/e \qquad (4)$$

Here C_{max} is the highest pollutant concentration in the region of interest. Substituting the value of k from Eq. (4) into Eq. (3) we find

$$e_{allowable} = e\ (std - b) / - (C_{max} - b) \qquad (5)$$

The next manipulation commonly made is to write:

$$e_{allowable} = \text{(population) (allowable emission per unit of population)} \qquad (6)$$

Here the appropriate population may be a population of residence or automobiles, or industries, etc. similarly one replaces the 'e' in Eq. (5) with,

$$e = \text{(population at time of measuring } C_{max}\text{) (emission per unit of population at the time of measuring } C_{max}\text{)} \qquad (7)$$

Dividing both sides of Eq.(5) by 'e', and making these substitution, we find :

$$\frac{\text{(Population) (Allowable emission per unit of population)}}{\text{(Population at time of measuring } C_{max}\text{))(Emission per unit of population at time of measuring } C_{max}\text{)}}$$

$$= (std-b) / (C_{max}\ b) \qquad (8)$$

We then simplify this by defining

$$gf \text{ (growth factor)} = \frac{\text{(Population)}}{\text{(Population at the time of measuring } C_{max}\text{)}} \qquad (9)$$

and

$$ef \text{ (emission factor)} = \frac{\text{(Allowable emission per unit of population)}}{\text{(Emission per unit at the time of measuring } C_{max}\text{)}} \qquad (10)$$

Substituting these in Eq. (8) and solving for 'ef' we find :

$$ef = (std-b) / gf\ (C_{max} - b) \qquad (11)$$

Finally we define the required "Percent Reduction in emissions per unit of population" as :

$$R = 100\% \, (1 - ef)$$

$$= \left[100\% \quad 1 - \frac{(std - b)}{gf\ (C_{max} - b)} \right]$$

$$= \left[100\% \quad \frac{gf - std + b(1 - gf}{gf\ (C_{max} - b)} \right] \qquad (12)$$

Eq. (12) which is the basic result of the linear assumption of Eq. (1)) appeared too complex to the early workers in air pollution, so they simplified it by changing the denominator of Eq. (11) from gf (C_{max} -b) to (gf C_{max} -b). Making this change we get,

$$R = 100\% \quad \frac{(gf \,.\, C_{max} - std)}{(gf \,.\, C_{max} - b)} \qquad (13)$$

Which is the simple "rollback" or "proportional" model

Where,

R	is the percent reduction needed
gf	is the growth factor
C_{max}	is the highest pollution concentration in the region
b	is the background concentration
std	is the standard to be attained (national standard)

4.3.2 Limitations of Rollback Model

Roll back model is though widely used because it is simple, easily understood and requires very little input data; it has some major limitations that are as follows:

(i) It is purely a theoretical model for which no experimental verification has ever been attempted in a metropolitan area.

(ii) If the emissions influence climate (e.g. by changing in the turbidity of the atmosphere) the linear assumption in Eq. (1) would probably prove false.

(iii) If pollutant disappearance (e.g. by agglomeration or photochemical reaction) is not a linear function of pollutant concentration (which is probably not) then a non-linear relationship between emissions and concentration is expected.

(iv) The application of the equation requires that we know the value of C_{max}. In general usage, one substitutes the highest observed concentration $(C_{max})ds$ for C_{max}. These two will be the same if one of the air quality measuring stations is located at the point of maximum concentration. The assumption is non-conservative, i.e. leads to less stringent regulations than would be used if the true value of C_{max} were known.

(v) The growth factor (gf) as used here assumes that all emission rates will grow without changes in other significant parameters (e.g. distribution of emissions, city size, stack heights, etc.).

(vi) If the air quality standard to be met is a short term standard, which is most severely tested by meteorological situations which mix the pollutants thoroughly in finite volume of air (for example under inversion conditions in a completely enclosed valley) then the growth factor as shown in the simple model is probably satisfactory if the boundaries of the area considered are the same as the boundaries of the area whose emissions are trapped in this body of air.

4.4 Water Quality Models

4.4.1 Streeter Phelps Model

Streeter and Phelps conducted studies of self purification of rivers on the Ohio River in the year 1925 and developed a mathematical formulation of oxygen assuming that the rate of de-oxygenation is proportional to the unsatisfied oxygen demand at any time and the rate of atmospheric re-oxygenation is proportional at any time to the oxygen deficiency at that time. The above can be expressed in the form of equation:

$$\frac{dD}{dt} = k_1L - k_2D_1$$

where,

D = dissolved Oxygen deficit in mg/l at a point after a time of flow t days from the beginning
L = ultimate BOD
k_1 = BOD reaction rate constant
k_2 = re-aeration coefficient

This equation may be used in variety of ways, but is only valid when there is no change in dilution or pollution load in the stretch being studied. Many other factors affect the oxygen balance – deposition of organic matter from suspension and later resumption, BOD additions in the surface run-off, BOD demand of bottom deposits, removal of BOD by bubbling gases from bottom deposits, photosynthesis, nitrification etc. To take into account all these factors, many variants of the original Streeter and Phelps equation have been proposed and like wise methods for the determination of the re-areation coefficient k_2. This model is a steady state model, which relates time variant inputs to a time invariant inputs state, which is observed through time variant measurements.

4.4.2 Model Name: CE-QUAL-ICM

4.4.2.1 Type of Model/Application

May be applied to most water bodies in 1-,2-, or 3-d, Unsteady flow. Predicts time-varying concentrations of water quality constituents. Advective and dispersive transport. Considers sediment diagenesis. Benthic exchange. Finite difference.

4.4.2.2 Model Processes

Temperature, salinity, DO-carbon balance, Nitrogen cycle, Phosphorus cycle, silicon cycle, Phytoplankton (upto 3 species), Zooplankton, Bacteria, First-order decay, sediment process rates may be input or simulated using the diagnosis sub-model.

4.4.2.3 Method/Techniques

CE-QUAL-ICM incorporates detailed algorithms for water quality kinetics. Interactions among state variables are described in 80 partial-differential equations that employ over 140 parameters. An improved finite-difference method is used to solve the mass conservation equation for each cell in the computational grid and for each state variable. The state variables can be categorized into six groups namely the physical, the carbon, the nitrogen, the phosphorus, the silica and the dissolved oxygen (DO) cycles.

4.4.2.4 Limitations

Although, the model has full capabilities to simulate state-of-the-art water quality kinetics, it is potentially limited by available data for calibration and verification. In addition, the model may require significant technical expertise in aquatic biology and chemistry to be used appropriately.

4.4.2.5 Input

Geometric data to define the finite difference representation of the water body have to be defined and approximately 140 are parameters needed to specify kinetic interactions. Initial and boundary conditions have to be specified.

4.4.2.6 Output

Temperature, salinity, inorganic suspended solids, diatoms, blue-green algae and other phytoplankton, dissolved, labile and refractory components of particulate organic carbon, organic nitrogen and organic phosphorus, ammonium, nitrite, and nitrate, total phosphate, dissolved oxygen, chemical oxygen demand, dissolved silica and particulate biogenic silica.

4.4.3 Model Name : CE-QUAL-RIV1

4.4.3.1 Type of Model/Application

River and estuaries. Far-field. One-dimensional, branching. Unsteady flow. Predicts time-varying concentrations of water quality constituents. Advective and dispersive transport. Finite difference.

4.4.3.2 Model Processes

Temperature, Salinity, DO-BOD, Nitrogen cycle, Phosphorus cycle, Phytoplankton in water column, Benthic algae and Macrophytes, Bacteria, First-order decay.

4.4.3.3 Method/Techniques

CE-QUAL-RIV1 was developed to simulate transient water quality conditions associated with highly unsteady flows that can occur in regulated rivers. The model consists of two codes: RIV1H, a stand-alone hydraulic routing code, and RIV1Q, a water quality code that uses output from RIV1H to provide dynamic water quality simulation.

4.4.3.4 Limitations

Applicable only to situations where flow is predominately one-dimensional. The program may exhibit numerical instability under certain conditions.

4.4.3.5 Input

RIV1 requires river geometry and boundary conditions to perform hydraulic calculations. Geometric data include locations of control structures, streambed elevations, river cross-sections and distance between nodes. Manning's coefficients are used to describe channel roughness. Boundary conditions include initial flow rates and stages, lateral inflows or withdrawals, and boundary conditions defined by discharge, stage, or a stage-discharge rating curve.

RIV1Q requires initial instream and inflow boundary water quality concentrations, meteorological data from temperature computations and rate coefficients

4.4.3.6 Output

Dissolved oxygen, carbonaceous biochemical oxygen demand, temperature, organic nitrogen, ammonia nitrogen, nitrate nitrogen, orthophosphate, dissolved iron, dissolved managanese, coliform bacteria.

4.4.4 Model Name : CE-QUAL-W2

4.4.4.1 Type of Model/Application

May be applied to most water bodies in 1-D or laterally averaged 2-D. Unsteady flow. Predicts time-varying concentrations of water quality constituents. Advective and dispersive transport. Finite difference.

4.4.4.2 Model Processes

Temperature, Sallinity, DO-carbon balance, Nitrogen cycle, Phosphours cycle, Silicon cycle, Phytoplankton, Bacteria, First-order decay.

4.4.4.3 Method/Techniques

CE-QUAL-W2 is a two-dimensional, longitudinal/vertical, hydrodynamic and water quality model. The hydrodynamic and water quality routines are directly coupled. However, the water quality routines can be updated less frequently than the hydrodynamic time step, which can reduce the computational burden for complex systems.

4.4.4.4 Limitations

The model assumes lateral homogeneity and therefore it is best suited only for the relatively long and narrow water bodies exhibiting strong longitudinal and vertical water quality gradients. It may not be appropriate for large water bodies. Only one algal compartment is included, and algal succession cannot be modeled. No zooplankton or macrophytes are modeled. Simplified sediment oxygen demand component are based on first-order decay.

4.4.4.5 Input

Geometric data are required to define the finite difference representation of the water body. Initial and boundary conditions have to be specified. Required hydraulic parameters include horizontal and vertical dispersion coefficients for momentum and temperature/ constituents. The Chezy coefficient are used to calculate boundary friction. Simulation of water quality kinetics requires the specification of approximately 60 coefficients. Finally, data required to provide boundary conditions and assess model performance during calibration.

4.4.4.6 Output

The hydrodynamic component of the model predicts water surface elevations, velocities, and temperatures. Water quality constituents that may be modeled include a conservative tracer, inorganic suspended solids, coliform bacteria, total dissolved solids, labile and refractory dissolved organic matter, algae, dissolved oxygen, ammonia-nitrogen, nitrate nitrogen, phosphorus, total inorganic carbon, pH, carbonate, and total iron.

4.4.5 Model Name :CH3D-WES

4.4.5.1 Type of Model/Application

Hydrodynamic model developed for the Chesapeake Bay 9US Program. Physical processes impacting circulation and vertical mixing that can be modified include tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation.

4.4.5.2 Model Processes

CH3D-WES makes hydrodynamic computations on a curvilinear or boundary-fitted platform grid. Deep navigation channels and irregular shorelines can be modeled because of the boundary-fitted coordinates feature of the model. Vertical turbulence is predicted by the model and is crucial to a successful simulation of stratification, desertification, and anoxia. A second-order model based upon the assumption of local equilibrium of turbulence is employed.

4.4.5.3 Method/Techniques

Capabilities of CH3D are illustrated by its application to the Chesapeake Bay. The numerical grid employed in the Chesapeake Bay model had 734 active horizontal cells and a maximum of 15 vertical layers, resulting in 3,992 computational cells. Grid resolution is 1.52 m vertical and approximately 10 km longitudinal and 3 km lateral. The x, y coordinates of the grid are transformed into the curvilinear coordinates to allow for better handling of the complex horizontal geometries. Velocity is also transformed so that its components are perpendicular to the coordinate lines, thus allowing boundary conditions to be prescribed on a boundary-fitter grid in the same manner as a Cartesian grid. Major tributaries are modeled three-dimensionally in the lower reach of the bay and two-dimensionally in the constant width in the upper reach.

4.4.5.4 Limitations

Considerable technical expertise in hydrodynamics is required to use the model effectively.

4.4.5.5. Input

Basic inputs required are time-varying water surface elevations, salinity, and temperature conditions at the ocean entrance and at freshwater inflows at the head of all tributaries. Time-varying wind and surface heat exchange data must also be prescribed at one or more locations. All input data, including initial conditions, bathymetry, boundary, and computational control data are input from fixed files.

4.4.5.6 Output

The CH3D-WES model can be used to predict system response to water levels, flow velocities, salinities, temperatures, and the three-dimensional velocity field. Predictions can be made for each cell of the grid at a specified time interval.

4.4.6 Model Name : CORMIX

4.4.6.1 Type of Model/Application

May be applied to most water bodies. Near-field and far-field hydrodynamic mixing processes. Single port, multi-port, and surface discharges. Includes effects of plume boundary interaction. Can also be applied to tidal environment

4.4.6.2 Model Processes

Computation of physical parameters and length scales to allow hydrodynamic classification of the given discharge/ambient situation into one of many possible generic flow configurations. Detailed numerical prediction of effluent plume characteristics.

4.4.6.3 Method/Techniques

CORMIX predicts plume geometry and dilution characteristics within receiving water's initial mixing zone and allows analysis of toxic or conventional pollutant discharges into diverse water bodies. The model is able to consider non-conservative pollutants with first-order decay and wind effects on thermal plume mixing. Submodels within the CORMIX system can be used to predict the geometry and dilution characteristics of effluent flow from different discharging systems. The first sub model considers a submerged, single port diffuser of arbitrary density discharging into a water body that may have ambient stratification of different types. The second sub model applies to commonly used types of submerged multi-port diffuser discharges under the same general effluent and ambient conditions as the first sub model. The third sub model considers buoyant surface discharges that result when an effluent enters a larger water body laterally through a canal, channel, or near-surface pipe.

4.4.6.4 Limitations

All CORMIX sub models assume steady-state ambient and discharge conditions. CORMIX gives limited quasi-steady state predictions in unsteady tidal environments.

4.4.6.5 Input

All inputs are entered interactively and include complete specification of the site or case, ambient conditions, discharge characteristics, level of output detail, and regulatory definitions.

4.4.6.6 Output

The output consists of qualitative description and detailed quantitative numerical predictions. Qualitative information includes physical information and insight into the reasoning employed by the system and flow class descriptions. The post-processor CORGRAPH is included to give 2-D sketch graphics of resulting plumes. The FFLOCATR post-processor can be used to compare field dye test data to plume predictions when detailed ambient cross-section data are available. Quantitative output provides details on the effluent plume trajectory and mixing and regulatory compliance.

4.4.7 Model Name : DECAL

4.4.7.1 Type of Model/Application

Coastal water bodies. Two-dimensional, depth-averaged steady, point source loadings. Steady, tidally driven flow. Analytical, steady-state predictions. Advective and dispersive transport.

4.4.7.2 Model Processes

Particle deposition and accumulation of organic material in sediments employing a second-order rate law. Metal and trace organic chemical accumulations in sediments. Carbon fixation by phytoplankton. First-order decay of organic material in water column and sediment.

4.4.7.3 Method/Techniques

In DECAL, the removal of organic material from the water column is assumed to occur primarily within the time scale of one to several days. Transport, particle dynamics, and organic carbon cycling are described by averaging over a daily period to account for tidal oscillations. The user can specify long-term net drift. The water column consists of a well-mixed surface and lower layer, separated by a pycnocline region. The daily-averaged discharge of effluent is distributed over an extended spatial domain by tidal oscillations. Particle deposition rates are determined from coagulation and settling kinetics and are described by a second order dependency on mass concentration. Carbon fixation by phytoplankton is expressed by measured productivity rates. Decomposition of organic material in the water column and sediments is described by first-order decay.

4.4.7.4 Limitations

Plume entrainment, tidal oscillations and mixing in the surface and lower waters are assumed to be instantaneous. Diffusion through the pycnocline and horizontal dispersion are not considered significant over travel distances larger than about 15 miles. The distribution of daily-averaged sewage discharge is assumed to be uniformly distributed over the tidal excursion ellipse.

4.4.7.5 Input

Waste flow characteristics (flow rates and effluent solids concentrations), outfall diffuser location and geometry, background oceanographic information (total water column depth, height of the lower layer, and rate of photoplankton primary production), short term tidal oscillations, and long-term non-tidal flows.

4.4.7.6 Output

Output from DECAL is given as sets of contour plots for suspended particle concentrations in the lower water layer, for the daily-averaged deposition rates of organic material, or for organic accumulation of particles in sediments.

4.4.8 Model Name : DYNHYD5

4.4.8.1 Type of Model/Application

Well-mixed unstratified rivers and estuaries (one-dimensional). Variable tidal cycles, wind, and unsteady inflows.

4.4.8.2 Model Processes

DYNHYD5 solves the one-dimensional equations of continuity and momentum for a branching or channel-junction (line-node) computational network. Most applications of DYNHYD5 will use a simulation time step on the order of 30 seconds to 5 minutes due to stability requirements. However, the hydrodynamic output file created by DYNHYD5 may be stored at any user-specified interval for use by a water quality simulation program. This interval may range from 1 to 24 hours, depending on the type of water quality simulation desired. If interest focuses on tide-induced transport, a 1- to 3-hour interval should be used. On the other hand, with long-term simulations, a time interval of 12 to 24 hours would be appropriate.

4.4.8.3 Method/Techniques

DYNHYD5 solves one-dimensional equations describing the propagation of a long wave through shallow water using an explicit two-step Runge-Kutta procedure. The continuity equation, based on the conservation of volume, is used to predict water heights (heads) and volumes. The equation of motion, based on the conservation of volume, is used to predict water height (heads) and volumes. The equation of motion, based on the conservation of momentum, predicts water velocities and flows, and includes terms accounting for local interia, convective interia, gravitational acceleration, frictional resistance, and wind stress along the channel axis.

4.4.8.4 Limitations

Applicable only to situations where flow is predominantly well-mixed vertically and laterally (one dimensional). Assumes that channels can be adequately represented by a constant top width with a variable hydraulic depth. Assumes that wavelength is significantly greater than the depth, and bottom slopes are moderate. Difficult to apply to small rivers or streams with steep hydraulic grades.

4.4.8.5 Input

Data requirement include a description of the physical geometry and the forcing functions. For junction elements, initial surface elevation, surface area and bottom elevation must be given. For channel elements, length, width, hydraulic radius, channel orientation, initial velocity, and Manning's roughness coefficient are required. Seaward boundary elevations can be described by an average repetitive tidal function or by specifying the high and low tidal heights versus time for multiple tidal cycles.

4.4.8.6 Output

The model reports time-variable channel flows and velocities as well as junction volumes and depths throughout the computational network at user-specified print intervals.

4.4.9 Model Name : DYNTOX

4.4.9.1 Type of Model/Application

One-dimensional rivers and streams. Steady-state predictions. Explicitly accounts for duration and frequency of loadings using a probabilistic framework.

4.4.9.2 Model : Processes

Effluent mixing with upstream flow, including consideration of incomplete lateral mixing at discharge point. First-order decay.

4.4.9.3 Method/Techniques

The fundamental analytical solution in DYNTOX assumes a steady-state condition over the course of the day. The model allows the use of three probabilistic simulation techniques to calculate the frequency and severity of in stream toxicity at different effluent discharge levels. The three procedures considered are continuous simulation approach, the model is run for a specified period of recorded history and the results are analyzed for frequency and duration. In the Monte Carlo method, inputs are described by probability distributions. Random input sets are then used to repeatedly execute the model and describe the model output in terms of a probability distribution. Both the continuous simulation and Monte Carlo methods produce probability distributions of calculated daily downstream concentrations from which the recurrence interval of any concentration of interest can be obtained. Probability distributions of running averaged concentrations for any time period of interest an also be obtained. The lognormal analysis requires all inputs to be described by lognormal distributions, which allows computation of exceedence probabilities for the toxic concentration at the point of mixing through numerical integration.

4.4.9.4 Limitations

Simulates only steady-state conditions. Dispersion is assumed to be negligible in the longitudinal direction. Does not consider daughter products of processes. Kinetic reactions are restricted to first-order loss of total pollutant. The lognormal analysis is limited to one effluent discharge without decay.

4.4.9.5 Input

Upstream boundary data describing flow and concentration in the river upstream of the discharges, water quality standards, time of travel between outfalls, and effluent data. Drainage area ratios can be specified for each reach of the system under study to account for non-point sources of water entering the stream. Depending on the simulation method used, additional model parameters upstream and effluent data specific to the method are required. The continuous simulation and Monte Carlo methods require a first-order decay rate.

4.4.9.6 Output

DYNTOX provides tabular and graphic outputs indicating the return period (in years) of water quality standard violations below each discharge and the percent of time that predicts receiving water quality falls in different concentration ranges as well as the return period for selected concentrations.

4.4.10 Model Name :EFDC

4.4.10.1 Type of Model/Application

General purpose three-dimensional hydrodynamic and transport model applicable to rivers, lakes, reservoirs, estuaries, wetlands, and coastal regions. Model simulates tidal, density and wind driven flow; salinity; temperature; and sediment transport. Two built-in fully coupled water quality/eutrophication sub models are included in the codes, as well as a toxicant transport and fate model.

4.4.10.2 Model Processes

The EFDC model solves the vertically hydrostatic free-surface, variable-density, turbulent-averaged equations of motion and transport equations for turbulence intensity and length scale, salinity, and temperature in a stretched, vertical coordinate system, and horizontal coordinate systems that may be Cartesian or curvilinear-orthogonal. Equations describing the transport of suspended sediment, toxic contaminants, and water quality state variables are also solved. Multiple size classes of cohesive and non-cohesive sediments and associated deposition and resuspension processes and bed geomechanics are simulated. Toxic pollutants are transported in both the water and sediment phases in the water column and bed. The built in 20 state variable water quality model is based on the CEQUAL-ICM reaction kinetics. The 10 state variable reduced water quality model is functionally equivalent to WASP5. Other model features include: drying and wetting, hydraulic structure representation, vegetation resistance, and Lagrangian particle tracking. The model also accepts radiation stress fields from wave refraction-diffraction models which allow simulation of long shore currents and sediments transport.

4.4.10.3 Method/Techniques

EFDC uses a finite difference scheme with three time levels and an internal-external mode splitting procedure to achieve separation of the internal shear or baroclinic mode from the external free-surface gravity wave or barotropic mode. An implicit external mode solution is used with simultaneous computation of a two-dimensional surface elevation field by a multicolor successive over relaxation procedure. The external solution is completed by calculating of the depth-integrated barotropic velocities using the new surface elevation field. Various options can be used for advective transport in EFDC. These include the "centered in time and space" scheme, and the "forward in time and upwind in space" scheme.

4.4.10.4 Limitations

Considerable technical expertise in hydrodynamics is required to use the model effectively. Expertise in eutrophication processes is required to use the water quality component.

4.4.10.5 Input

Input data to drive the model include open boundary water surface elevation, wind and atmospheric thermodynamic conditions, open boundary salinity and temperature, volumetric inflows and inflowing concentrations of sediments and water quality state variables. Input file templates are included with the source code and the user's manual to aid in input data preparation.

4.4.10.6 Output

The model outputs include water surface elevation, horizontal velocities, salinity, temperature, sediment concentration, and toxicant concentration Water quality concentration can also be predicted in a variety of formats suitable for time series analysis and plotting, horizontal and vertical plane vector and contour plotting, and three dimensional slice and volumetric visualization. Post-processing software is available to convert generic output files for use by a number of scientific visualization applications.

4.4.11 Model Name : EXAMS II

4.4.11.1 Type of Model/Application

Streams/rivers and lakes/reservoirs in one or two or three dimensions. Steady flow, steady-state/quasi-dynamic predictions. Advective and dispersive transport. Considers benthic exchange. Inputs may be steady or variable.

4.4.11.2 Model Processes

First-order decay, daughter products. Process kinetics. Equilibrium sorption. Pore water advection. Local sediment mixing.

4.4.11.3 Method/Techniques

EXAMS II is an interactive system that uses the principle of mass balance and mathematical models of the kinetics and processes governing the transport and transformation of chemicals to provide predictions of their probable fate and persistence in aquatic ecosystems. The hydrologic transport processes considered are advection and dispersion. The transformation processes are photolysis, hydrolysis, biotransformation, oxidation, and sorption with sediments and biota. Secondary daughter products and subsequent degradation of these products are also considered. EXAMS II includes separate mathematical models of the kinetics of the physical, chemical, and biological processes governing transport and transformation of chemicals. An advantage in using the model is its ability to accept standard water quality parameters, chemical data, and system characteristics for which information is readily available.

4.4.11.4 Limitations

Designed to evaluate consequences of long-term, primarily time-averaged chemical loadings, thus transient effects cannot be analysed. Chemicals are assumed not to radically change the environmental variables that drive their transformations. Sorption isotherms are assumed to be linear and biotransformation kinetics are assumed to be second-order rather than Michaelis-Menton-Monod.

4.4.11.5 Input

Basic inputs include system geometry and hydrology specification, a set of chemical loadings on each sector of the ecosystem, and parameters that define the strength of the advective and dispersive transport pathways. Although, EXAMSII allows for the entry of extensive environmental data, the program can be run with a much reduced data set when the chemistry of a compound of interest precludes some of the transformation process. Chemical parameters include molecular weight, solubility, and ionization constants of the compound. Sediment sorption/bio-sorption, volatilization, photolysis, hydrolysis, oxidation, and bio-transformation processes may also be specified.

4.4.11.6 Output

The output includes summary tables of input data and predictions of chemical exposure, fate, and persistence. The exposure summary includes expected (long-term chronic, 96-hour acute, 21-day chronic) environmental concentrations due to a specified pattern of chemical loadings. The fate summary gives the distribution of chemicals in the system and the relative dominance of each transport and transformation process. Plots of longitudinal and vertical concentration profiles can be obtained.

4.4.12 Model Name: FLUX/PROFILE/BATHTUB

4.4.12.1 Type of Model/application

Lakes and reservoirs. Mass loading computation. In-lake data description/assessment. Nutrient and water balance computation. Models of eutrophication-related responses. Steady-state, empirical models. Assessment and evaluation of selected management alternatives.

4.4.12.2 Model Processes

Nutrient and water balances in a segmented hydraulic network. Nutrient sedimentation. Algal (Chlorophyll) response to flushing, light, and nutrient concentration. Hypolimnetic oxygen depletion.

4.4.12.3 Method/Techniques

FLUX- Provides an estimation of tributary mass discharges (loadings) from sample concentration data and continuous (e.g. daily) flow records. Five estimation methods are available and potential errors in estimates are quantified.

PROFILE – Facilitates analysis and reduction on in-lake water quality data. Algorithms are included for calculation of hypolimnetic oxygen depletion rates and estimation of area weighted, surface-layer mean concentrations of nutrients and other eutrophication response variables.

BATHTUB – Applies a series of empirical eutrophication models to morphologically complex lakes and reservoirs. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. Eutrophication-related water quality conditions (total phosphorous, total nitrogen, chlorophyll a, transparency, and hypolimnetic oxygen depletion) are predicted using empirical relationships derived from assessment of reservoir data.

4.4.12.4 Limitations

Applications of BATHTUB are limited to steady-state evaluation of relationship between nutrient loading, transparency and hydrology, and eutrophication responses. Short-term responses and effects related to structural modifications or response to variable other than nutrients cannot be explicitly evaluated.

4.4.12.5 Input

BATHTUB requires information describing watershed characteristics, water and nutrient loads, lake or reservoir morphology, and lake or reservoir water quality.

4.4.12.6 Output

FLUX- Graphic and tabular displays allows users to evaluate input data and calculate results.

PROFILE – Graphic and tabular displays allow users to evaluate and summarize lake or reservoir water quality data.

BATHTUB – Model outputs include tabular and/or graphic displays of segment hydraulics, water and nutrient balances, predictions of nutrient concentrations, transparency, chlorophyll a concentrations, and oxygen depletion. Statistics relating observed and predicted values are provided.

4.4.13 Model Name PHOSMOD

4.4.13.1 Type of Model/Application

Modeling framework designed to assess the impact of phosphorus loading on stratified lakes. Allows rapid generation and analysis of phosphorus loading scenarios.

4.4.13.2 Model Processes

Lake stratification into two segments the water layer and a surface sediment layer. Computes total phosphorus and hypolimnetic oxygen concentrations, taking sediment, water interactions into account.

4.4.13.3 Method/Techniques

PHOSMOD uses a modeling framework described by Chapra and Canale for assessing the impact of phosphorus loading on stratified lakes. A total phosphorus budget for the water layer is developed with inputs from external loading and recycling from the sediments and considering losses due to flushing and settling. In the sediment layer, total phosphorus is gained by settling and lost by recycling and burial. The sediment to water recycling is dependent on the levels of sediment total phosphorus and hypolimnetic oxygen, with the concentration of the latter estimated with a semi-empirical model.

4.4.13.4 Limitations

Steady-state analysis. Developed to assess long-term trends only.

4.4.13.5 Input

Lake stratification periods and morphometry, initial lake total phosphorus, sediment parameters, initial hypolimnetic DO concentrations, settling and burial rates for sediments, time series of flow and inflow phosphorus concentrations, print and calculation times. Observed data, if available, may also be input for display with outputs.

4.4.13.6 Output

Tabular and graphical output of lake total phosphorous, percentage of total phosphorous in sediment, hypolimnetic DO concentrations, days of anoxia at specified print intervals.

4.4.14 Model Name : PLUMES

4.4.14.1 Type of Model/Application

May be applied to most deep water bodies. Near-field hydrodynamic mixing processes. Point source buoyant or submerged discharges. Single or multiple inputs.

4.4.14.2 Model Processes

Consists of two initial dilution models (RSB and UM) with two far-field algorithms automatically initiated beyond the initial dilution zone. Incorporates the flow classification scheme of the CORMIX modeling system and provides recommendations for model usage under a range of mixing conditions.

4.4.14.3 Method/Techniques

PLUMES incorporates two relatively sophisticated initial dilution models (RSB and UM) and two relatively simple far field algorithms.

RSB is based on experimental studies on multiport diffusers in stratified currents. UM is the latest in a series of models first developed for atmospheric and freshwater applications and later for marine applications. Outstanding UM features are the Lagrangian formulation and the projected area entrainment (PAE) hypothesis, which is a statement of forced entrainment i.e. the rate at which mass is incorporated into the plume in the presence of current. The Lagrangian formulation offers comparative simplicity that is useful in developing PAEs. The far-field algorithms are relatively simple implementations of dispersion equations applied to near shore coastal waters, and confined channels

4.4.14.4 Limitations

RSB is an empirical model developed from experimental studies under stable ambient stratification, and it may have limited application in situations where ambient layers are unstratified or unstable. The PAE hypothesis, which was developed for plumes discharged to open, unbounded environments, free from interference, is assumed to be valid in UM. The far-field algorithm in PLUMES are relatives simplistic compared to the initial dilution models.

4.4.14.5 Input

Port geometry, spacing, and total flow. Plume diameter and depth, effluent salinity and temperature. Ambient conditions in receiving water and far-field distance.

4.4.14.6 Output

CORMIX flow classification, pollutant concentration and dilution ratios at various points in the plume.

4.4.15 Model Name : QUAL2E

4.4.15.1 Type of Model/Application

Water quality/eutrophication. Far-field. Stream/river 1-D, branching. Steady flow. Steady-state/quasidynamic (diurnal variations in meteorological inputs). Advective/dispersive transport. Finite difference.

4.4.15.2 Model Processes

Temperature, Salinity. BOD-DO, Nitrogen cycle, Phosphorous cycle, Chlorophyll a is modeled as the indicator or planktonic algae biomass; benthic algae is not considered. Conservative constituent. Non-conservative constituent. First-order kinetics of constituents. Uncertainty analysis.

4.4.15.3 Method/Techniques

QAUAL2E permits simulation of several water quality constituents in a branching stream system using an implicit backward-difference, finite-difference solution to the one-dimensional advective-dispersive equation. The stream is conceptually represented as a system of reaches of variable length, each of which is subdivided into computational elements that have the same length in all reaches. A mass and heat balance is applied for every element. Mass may be gained or lost from elements by transport processes, external sources and sinks, or internal sources and sinks. The UNCAS component allows quick implementation of uncertainty analysis using sensitivity analysis, first-order error analysis, or Monte Carlo simulation.

4.4.15.4 Limitations

Considers only steady flow. Only time-varying forcing functions are the climatologic variables that primarily affect diurnal temperature and dissolved oxygen.

4.4.15.5 Input

The stream is represented by a network of headwaters, reaches and junctions. Twenty-six parameter covering the physical, chemical and biological properties have to be specified for a reach.

4.4.15.6 Output

Dissolved oxygen, Biochemical Oxygen Demand, temperature, chlorophyll 'a', ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, organic nitrogen, organic and dissolved phosphorous, coliforms, arbitrary non-conservative constituents, three conservative constituents.

4.4.16 Model Name : RIVMOD-H

4.4.16.2 Type of Model/Application

Applicable to rivers, streams, tidal estuaries, reservoirs and other water bodies where the one-dimensional assumption is appropriate. Considers time-varying lateral inflows.

4.4.16.2 Model Porcesses

RIVMOD-H solves the one-dimensional equations of unsteady flow using a fully implicit finite difference method. The model can be used for flow routing only or can be linked with a water quality modeling package.

4.4.16.3 Method/Techniques

RIVMOD-H solves the governing flow equations using a numerically efficient fully implicit scheme that overcomes the restriction of the Courant gravity wave criterion, permitting the use of longer time steps in comparison with explicit schemes. The numerical solution scheme is very flexible and allows the specifications of a weighting factor for fully explicit, fully implicit, or any other combination of implicit-explicit solutions. The model has the capability of handling flow or head as boundary conditions. The specifications of head as a boundary condition allow the use of the model where an open boundary is required (e.g. an estuary or a river flowing into a lake). The model has been soft-linked to the WASP5 and SWMM models as part of the LWWM modeling system.

4.4.16.4 Limitations

May be inappropriate in situations where large lateral or vertical gradients exist. Neglects the effect of eddy diffusivity. Assumes hydrostatic pressure distribution valid at every point in the channel, and that the water surface slope is small.

4.4.16.5 Input

Data requirements for RIVMOD-H include channel morphometry, bed elevations, and initial and boundary conditions. If cross-sectional topography data are available, separate software can be used to generate exponential rating functions for cross-sectional area and wetted perimeter as a function of depth. The model then uses these relationships to automatically calculate the area and wetted perimeter as the water depth changes. This feature allows the model to use natural cross-sections and therefore simulation results should be closer to the natural behavior of the stream.

4.4.16.6 Output

Time-varibale water surface elevations or stages and discharges for unsteady flows at specified cross-sections and time intervals.

4.4.17 Model Name : SMPTOX4

4.4.17.1 Type of Model/Application

Streams/rivers in one dimension. Steady flow. Steady-state predictions. Advective and dispersive transport. Considers benthic exchange. Capability to simultaneously model multiple chemicals.

4.4.17.2 Model Processes

First-order decay. Equilibrium sorption. Sediment processes may be input.

4.4.17.3 Method/Techniques

SMPTOX4 is a steady-state, one-dimensional analytical model for predicting suspended solids, dissolved and particulate toxicant concentrations in the water column and streambed resulting from point source discharges into streams and rivers. Three levels of complexity are available within the model. At the simplest level, only total toxic pollutants can be predicted. The next level can be used to predict toxic water column concentrations but interactions with bed sediments are not considered. The third level allows prediction of pollutant concentrations is dissolved and particulate phases for the water column and bed sediments, as well as the total suspended solids concentrations. SMPTOX4 allows quick data input and easy access to graphical output, sensitivity analysis, and uncertainty analysis. SMPTOX4 also contains a database of chemical properties for many chemicals of concern.

4.4.17.4 Limitations

Steady-sate predictions only. Non-point source loadings cannot be simulated. Does not consider daughter products or processes. Process kinetics is not simulated.

4.4.17.5 Input

Flow, total pollutant and suspended solids concentrations, geomorphic parameters, physical/chemical coefficients and rates. Observed pollutant concentrations may be input for use during model calibration.

4.4.17.6 Output

Model calculations for total, dissolved, and particulate concentrations for the toxicant in the water column and bed sediments, and suspended solids concentration in the water column at incremental river miles throughout the length of the stream.

4.4.18 Model Name : TOXMOD

4.4.18.1 Type of Model/Application

Modeling framework designed to assess the impact of toxic organic compounds on lakes and impoundments. Allows rapid generation and analysis of scenarios.

4.4.18.2 Model Processes

Lake idealized as a well-mixed reactor (water layer) underlain by a well-mixed sediment layer. Computes sediment and water concentration of toxicant.

4.4.18.3 Method/Techniques

TOXMOD is based on an extension of a modeling frame work presented by Chapra to asses the impact of toxic organic compounds on lakes and impoundments. A steady-state mass balance is developed for solids and toxics. Toxics are partitioned into dissolved form for both water and sediment layers, further subdivided into a component associated with dissolved organic carbon. Particulates in the water layer are subdivided into abiotic and biotic suspended solids. Burial and resuspension are considered for both dissolved and particulate forms while diffusion acts selectively on the dissolved fraction.

4.4.18.4 Limitations

Steady-state analyses. Developed to asses long-term trends only.

4.4.18.5 Input

Lake depth and surface area, sediment thickness and area, solids mass balance data, including settling and burial rates for sediments, dissolved organic carbon concentrations; sorption and volatilization coefficients and decay rates of toxicant, initial toxicant concentration, time series of flow and inflow toxicant concentrations, print and calculation intervals. Observed data, if available, can also be input for display with outputs.

4.4.18.6 Output

Tabular and graphical output of sediment and water toxicant concentration at specified print intervals.

4.4.19 Model Name: TPM

4.4.19.1 Type of Model/Application

Primarily applicable to small coastal basins and tidal creeks. May be applied to marinas where tidal forces are predominant with oscillating flow (e.g., an estuary or a tidal river). Steady-state model capable of simulating up to 23 water quality variables.

4.4.19.2 Model Processes

Simulates physical transport processes in times of the concept of tidal flushing. Relatively detailed kinetic model that allows a more complete description of the eutrophication process. Includes a sediment process model that considers the depositional flux of particulate organic matter, its diagnosis and the resulting sediment flux.

4.4.19.3 Method/Techniques

TPM predicts the longitudinal distribution of conservative and non-conservative substances at slack-before-ebb (high slackwater). The model is best applied to an elongated embayment or tidal creek, where the creek is branched and/or freshwater discharge is negligibly small. The basic assumptions in the model are that the tide rises and falls simultaneously throughout the water body and that the system is in hydrodynamic equilibrium. Kinetic processes included in TPM are based on the formulations in CE-QUAL-ICM. Twenty-three state variables are considered including total active metal, fecal coliform bacteria, and temperature. The sediment process model in TPM has 16 water quality related model state variables and fluxes. Benthic sediments are represented as two layers in the sediment model. The lower layer is permanently anoxic, while the upper layer may be oxic or anoxic depending on dissolved oxygen concentration in the overlying water.

4.4.19.4 Limitations

The water body being simulate must be in hydrodynamic equilibrium. Only applicable to water bodies where tidal forces are predominant with oscillating flow. The model therefore is not applicable to marinas located on a sound or an open sea.

4.4.19.5 Input

Two basic types of input data are required- geometric and physical. Geometric data define the system being simulated, including the returning ratio, initial concentration, and boundary conditions. Physical data include water temperature, reaction rates, point and non-point sources, and initial and boundary conditions for water quality parameters modeled.

4.4.19.6 Output

Temperature, salinity, inorganic suspended solids, diatoms, blue-green algae and other phytoplankton, dissolved, labile, and refractory particulate organic carbon, organic nitrogen, and organic phosphorous ammonium, nitrite and nitrate, total phosphate, dissolved oxygen, chemical oxygen demand, dissolved silica, particulate biogenic silica, total active metal and fecal coliform bacteria.

4.4.20 Model Name: WASP 5

4.4.20.1 Type of Model/Application

May be applied to most water bodies in one, two, or three dimensions. Can be linked with simulated hydrodynamics. Predicts time-varying concentrations of water quality constituents. Advective and dispersive transport. Considers benthic exchange. Finite difference.

4.4.20.2 Model Processes

Temperature, Salinity, Bacteria, DO-BOD. Nitrogen cycle. Phosphorus cycle. Phytoplankton. First-order decay, daughter products. Process kinetic. Equilibrium sorption. Net resuspension/deposition.

4.4.20.3 Method/Techniques

WASP5 is a general purpose modeling system for assessing the fate and transport of conventional and toxic pollutants in surface water bodies. The model simulates time-varying processes of advection and dispersion, considering point and diffuse mass loading, and boundary exchange.

WASP5 includes two sub models for water quality/eutrophication and toxics, referred to as EUTRO5 and TOXI5 respectively. In EUTRO5, the transport and transformation of up to eight state variables in the water column and sediment bed may be simulated. In TOXI5, the transport and transformation of one to three chemicals and one to three types of particulate material can be simulated

4.4.20.4 Limitations

There is a potential for instability or numerical dispersion in the user-specified computational network.

If chemical concentrations in the water body are much higher than trace level, the assumption of linear partitioning and transformation in TOXI5 begins to break down.

Zooplankton dynamics are not simulated in EUTRO5 although their effect may be described by user –specified forcing functions that vary in space and time.

Intermediate-level method for computation of sediment oxygen demand and benthic nutrient fluxes.

4.4.20.5 Input

The water body must be divided into a series of completely mixed computational segments. Loads, boundary concentrations and initial concentrations must be specified for each state variable. Forcing functions must be specified for time and spatially variable parameters.

In TOXI5, up to spatially variable environmental variables, such as pH and light extinction, may be specified as needed. In addition, up to 17 time-variable functions may be used to study diurnal or seasonal effects on pollutant behavior. In EUTRO5, up to 16 spatially variable environmental parameters, 60 rate constants and 14 time-variable functions can be specified.

4.4.20.6 Output

TOXI5 provides time-variable chemical concentrations for every segment at the specified output time interval. Chemical concentrations are reported for the dissolved and sorbed phases, and as neutral and ionic concentrations.

EUTRO5 reports a set of state variable concentrations, forcing functions and process rates for every segment at the specified output time interval. Variable concentrations include dissolved oxygen, carbonaceous biochemical oxygen demand (BOD), ultimate BOD, phytoplankton carbon and chlorophyll a, total nitrogen, ammonia, nitrate, organic nitrogen, total inorganic nitrogen, organic phosphorous and inorganic phosphorus.

4.5 Proportional Scaling Model

This model is based on Proportional Scaling methods known as “Rollback Methods”. This model found its application extensively in Air Pollution control to calculate the degree of improvement in air quality needed for attainment of SPCB Standards. This is discussed extensively under section 4.3. This model in its basic form assumes that the concentration of any long lived pollutant at any point is equal to the background concentration of that pollutant plus some linear function of the total emission rate of that pollutant in that area, which influences the concentration at that point. This model can be utilized effectively for finding out the degree of improvement required in water quality for attaining the Location Specific Standards.

5.0 Selection of Air/Water Quality Models for Indian Conditions

5.1 Selection of Air Quality Model

5.1.1 General Basis for Selection

Select all models which appear to be suitable for dealing with the type of the location/recipient system for which stringent standards are to be prescribed. Screen the input data requirement of these models and select a model that is most suitable for the location/recipient system.

5.1.2 Air Quality Model Recommended for Indian Conditions

Most of the air quality models are of two types (i) Gaussian plume model and (ii) numerical models which rely on numerical solutions of the K-theory equations (advection-diffusion equation). The Gaussian plume models are attractive for their simplicity in terms of input parameters and computational requirements. The numerical models perform better in some situations but require more detailed information, particularly on wind speed and direction and their computational requirements are much larger. Considering the scarcity of data in Indian conditions, the Gaussian Plume Model (GPM) is recommended for air quality modeling calculations.

This recommendation is in agreement with the published research according to which the Gaussian diffusion model is though valid only for long diffusion times and for homogeneous stationary conditions, this type of model has been found useful for many practical applications. In practice the contributions of all sources (point, area and line) to the concentration at a given receptor are calculated separately and then added to give the total concentration. This superimposition capability adds flexibility and it is the important advantage of the Gaussian technique. An addition to its inherent simplicity is its easy use and short computations times.

It is, therefore, clear that a model based on Gaussian diffusion equation is the most suitable for modeling in Indian conditions. This seen with the limitations and availability of the input data requirements of the various available models. It can be concluded that the ISC3 Industrial Complex Model is the most suitable model for the Indian conditions.

It is, therefore, recommended that the Model ISC3 may be selected for modeling in most situations.

5.1.2.1 Selection of Water Quality Model

The experience in use of Water Quality models is limited in our country. The National Environmental Engineering Research Institute, Nagpur and National Institute of Hydrology, Roorkee are the two important Institutions which have used water quality models. Both these two institutions have used QUAL2E Model.

The model QUAL2E is therefore recommended, as this is a comprehensive and versatile stream water quality model. One of the important aspects of using this model is that it lends the modeler to perform uncertainty analysis. Another important aspect of the model is that it guides the user in the calibration process which is essential for use of this model.

6.0 General Approach for Prescribing Stringent Standards

6.1 Overall Guidelines

The general approach established by CPCB for prescribing location specific stringent standards following the strategy of controlling the pollution to the best possible extent first followed by exploring the use of the natural assimilative capacity has been depicted in *Figure 6.1*.

6.2 Data on Receiving Environment

6.2.1 Identification of areas where the national standards are required to be made stringent

Standards notified at the national level are required to be made stringent, where, (i) ambient water quality requirement/criteria in respect of designated-best-use is not meeting, (ii) the ambient air quality is not meeting as per the requirement (standards), and (iii) location-specific sensitive uses (as notified by the concerned authority) requires additional parameters to be controlled for example in case of monuments, sanctuaries etc.

Areas where the above three conditions does not apply, only national standards shall prevail.

6.2.2.1 Selection of monitoring locations

Water Quality Monitoring

- Review of the area for the type of industries and drainage pattern;
- Selection of first monitoring point at the end of wastewater stream (drain) before disposal into natural water bodies;
- Selection of monitoring stations at the end of each tributary/waste stream joining the main stream depending on the type of industries situated up-stream;
- Upon analyzing the samples, establishing the pollution load additions from each waste stream (drain);
- Then back integrating into the sub-branches (sub-drains) for details on pollution load contribution;

- These values shall be compared with the source inventory data and be brought into conformity. This process will ensure cross checking of pollution load contribution;

- Analytical results will become the basis for deciding parameters of concern and variations; and

- Frequency of monitoring shall correspond to the degree of concentration variations for the identified pollutant(s).

Air Quality Monitoring

- Entire area under the air shed may be visualized into suitable size of girds;

- Based on topography, buildings, roads, sensitivity etc. these grids may be formed into few groups having similarity;

- Selection of the ambient air quality near centre of the each group area;

- Examination of inter-dependability (coefficient of correlation of monitored ambient air quality data between these two stations close to one station with other stations in the area;

- Those stations, which exhibit inter-dependability, may be treated as belonging to that area, those does not exhibit correlation may be merged with adjacent area or a separate region;

- By doing the same, the number of monitoring stations can be reduced and an area correlation factors can be established to cater to the entire area of the air shed; and

- In the absence of such a detailed programme, distance of GLC max of each major point source can be determined through prediction and a circle may be drawn. Looking at all such circles and distributed area sources in the region, likely areas, where maximum conc. Can occur, can be identified for locating the monitoring station(s).

6.2.3 Prioritization of Pollutants

When there are economic implications of any development, prioritization has its own importance. Controlling one pollutant in an identified area, in general requires technological improvements, which will add burden to the source industries/establishments. Therefore, prioritization process is important to mobilize resources (money, people, knowledge, equipment etc.) in a feasible manner. In this section, three modes of prioritization are

discussed w.r.t. parameters. Similar methods may be used for prioritizing the hotspots, parameters, action programmes etc.
There could be many models to prioritise the hot spots of relative importance, i.e.

- Assigning differential weightage to the attributes as per the Locational demand
- Assigning weighted averages of the attributes for priority ranking, or
- Through an algorithm to define degree of pollution etc.

However, the first model, i.e. assigning differential weightage to the attribute as per the Locational demand, may be a suitable option for the purpose, which is discussed in detail as follows:

Model: Assigning differential weightage to the attributes as per the Locational demand

The attributes relevant to the location varies depending on the techno-scientific concerns/social expectations and of-course relative weightages, as well. Therefore, in this model, attribute-specific weightage (max. marks) can be allocated and a few experts may be compiled to arrive at the prioritization of pollutants. A model format for water pollutants is given below:

S.No.	Attribute		Pollutants			
			A	B	C	D
1	Annual mean exceedance factor (15)					
2.	Frequency of violation (10)					
3.	Potential health implications (30)	Persistency				
		Acute toxicity				
		Bio concentration factor				
		Recorded/likely health implications (reversible/irreversible)				
		Toxicity etc.				
4.	Extent of damage to environment (25)	Eutrophication				
		DO depletion				
		Salinity				
		Reduction in crop yield				
		Drinking water contamination				
		Effect on flora &fauna				
		Interference with location sensitivity - tourism, monuments, sanctuaries etc.				
5.	Public complaints (20)	Indication of degree of awareness and concern				
Total score per hundred						

Exceedance factor is a measure to ascertain compliance with ambient air quality on the basis of the annual mean concentrations. This measure is an aggregate representation of the ambient air quality for a parameter in an area.

$$\text{Exceedance Factor (EF)} = \frac{\text{Observed Annual Mean Concentration of the pollutant}}{\text{Annual standard for the respective pollutant in designated area}}$$

The degree of criticality is dependent on the frequency of violation and is calculated as:

$$\text{Frequency}: \frac{\text{No.of monitored values whose concentrations are exceeding the prescribed standards of violation}}{\text{Total number of monitored values}}$$

The annual averages in case of ambient air qualities are considered fairly representative. However, when the studies are focusing on an industrial area, there could be occasional spikes of severs concentrations which may not reflect significantly in annual average. Therefore, the parameter carries its significance.

Adequate number of samples shall be collected and analysed for interpretation, i.e. once a month for river, lakes & coastal water and once a year for groundwater.

		Frequency of Violation	
		Higher than ≥ 50%	Less than ≤ 5%
Exceedence factor	Critical	Priority-I	Priority-II
	High	Priority-II	Priority-III

Classification of air quality in respect of Exceedance Factor (Critical Pollution (C): EF, 1.5. High Pollution (H) : 1.0 < EF < 1.5)

6.3 Data on Contributing Sources

At a selected monitoring station, inventorisation of contributing sources is required to be carried out, in order to orient the studies for exploration of choice of advanced control technologies and their feasibility, each establishment/unit-wise. Besides, source apportionment (industrial, line, area, natural etc.) facilitates visualization of the magnitude of the issue and to set focus on the control programme.

6.3.1 Estimation of Pollution Load: Steps

Water pollution Load

1. Identification of industries relevant to the priority pollutant;
2. Sketching the disposal network and sampling stations to know the stream quality;
3. Recording of all the relevant industries & the existing EPS's, adequacy, efficiency, reliability etc.;
4. Monitoring the pollutants over a period to account for all variations- identify the areas & concerned industries;
5. Establishing the industries of concern;
6. Setting monitoring frequency for treated wastewater-Frequency commensurate with degree of toxicity and quantum of discharge;
7. Asking for Environmental Audit (comprehensive) by a third party and setting up of the best feasible updation and time frame;
8. Imposing bank-guarantee, penalty as appropriate to induct discipline; and
9. Monitoring at set ambient stations to record improved status.

Air pollution Load

1. Listing of all air polluting industries concerned to priority pollutant;
2. Taking into consideration of ventilation coefficient, categorise entire air shed;
3. Applying decision matrix for prioritization of industries;
4. Taking into consideration of stack heights, meteorology and geographical features run the model to predict critical locations, where ambient air quality is likely to exceed;
5. Locating monitoring stations at all those likely points;
6. Monitoring the pollutants;
7. Establishing relation between monitored and predicted values;
8. Finding out relative share of the industries for the pollutant;

9. Studying the industries for the pollutant control system including its efficiency and reliability;

10. Asking for comprehensive environmental audit; and

11. Arriving at best practicable technology for further control.

6.4 Determination of Feasible Technological Improvement Best Technical Judgement)

Prime solution to the issue of location-specific demand is to explore the technologies. Defining levels of technologies is often qualitative. For example, US defines MACT, BACT, RACT, GACT, BDT, LAER etc. but ultimately the people at implementation level are confused with the terminology and more often these are considered as the same. Therefore, instead of going into many levels, it has been worked out to have only three levels of technologies viz.

- Best Practicable Technology or BAT (corresponding to MINAS of CPCB),
- As Low As Reasonably Achievable or ALARA (To be defined by a technical committee on case by case basis), and
- Best Available Technology or BAT (one demonstrated elsewhere as the best).

These are precisely discussed in the subsequent paragraphs.

6.4.1 Minimal National Standards based on Best Practicable Technologies

Minimal National Standards are established considering many attributes. Of them, the prime criterion is the best practicable technology. This means among the available choice of technologies, a set of combination of treatment units is chosen as best feasible control technology scheme and the corresponding achievable end-of-the-pipe concentrations are the limits. As these standards are notified at national level, these are the base limits and all the respective industries in entire country are required to comply. Therefore, the first step in any identified area is to ensure that all the industries are having the best practicable technology and the systems are working to its efficiency.

6.4.2 As low as reasonably achievable standards

As the national standards are developed considering the national average scenario of industry category, often there is a scope for the individual industries to achieve stricter value than the stipulated standards. Therefore, by assessment of the individual units, the scope for further technological improvement can be established. Many a times, even though it looks simpler, enforcement of same reduction percentages by every industry is not an economically sound practice and is always constrained by the availability of the technology. In all the cases of individual industries, possibilities for technological, operating, attitudinal improvement for pollution control are available, which are varying based on the degree of commitment. Therefore, the feasible additional technology based achievable value can be termed as, “As Low As Reasonably Achievable” (ALARA) standards (BPT+).

6.4.3 Best available technologies

A review of best technologies available in the world will facilitate the maximum reduction in pollution achievable at the tail end. But, often the availability and cost of such technologies may be prohibitive. However, in this case, BAT may be interpreted as the best demonstrated technology elsewhere and practicable.

6.4.4 Selection of the level of control technologies

The level of requirement of technologies is established in many ways, but primarily, it is a means to protect the various uses of the environment. The one widely considered aspect is the level of risk. Quantitative assessment of risk demands detailed inventory of the location and fine tuned (high degree prediction) models. Therefore, the ambient quality requirements may be kept as the bench mark requirement to back calculate the required reduction levels at the source. But there are many attributes to be kept in balance, which are discussed in subsequent paragraphs.

On the basis of impact:

There are concepts, which states, how to choose a level of control technology on the basis of impact. A precise discussion is given below:

- Whenever risk due to a facility is more than one in ten thousand (10^{-4}), there shall not be any negotiation on the basis of cost but best available technologies need to be explored for installation.

- Whenever, risk levels are less than one in one million (10^{-6}), the best practicable technologies may serve the purpose.

- If the risk level is in-between, we need to consider BPT i.e. something more than best practicable technology, which may or may not be the best available technology. This means, the process considers economic feasibility as well, while arriving at as low as reasonably achievable' tail end concentrations.

It is often a difficult task to establish the risk factor, as such the risk factor is for entire industrial agglomeration and subsequently for individual industry. Such an exercise to identify the degree of improvement required by each industry involves huge back-up studies, besides choice of technologies and affordability.

Therefore, keeping this risk based criteria in the background, a feasible mechanism has been worked out to assign the aforesaid three levels of technologies to each industry considering size of the industry (indication of turn over), degree of pollution generation, present cost of pollution control and additional affordability to have better technologies. These aspects are discussed in subsequent sections.

6.4.5 Assessment of the level of existing control technologies and options for improvement

A detailed study on existing status of pollution control in the industry, choice for further improvement, present level of annual burden due to pollution control and addition affordable burden are to be assessed for taking appropriate decisions regarding as low as reasonably achievable standards. Therefore, best feasible option is to prepare comprehensive environmental audit report through recognized auditors or to frame technical group to assess the same.

A model format, for collection of information is given in Table 1.

6.4.6 Guiding tool to decide level of control technologies

One can plot the logic diagram using any level of attributes for simplifying the decision process. A plot considering three factors with two levels (high & low), i.e. relative contribution in total load after meeting MINAS, requirement of improvement due to demand of the location and economic affordability is shown below:

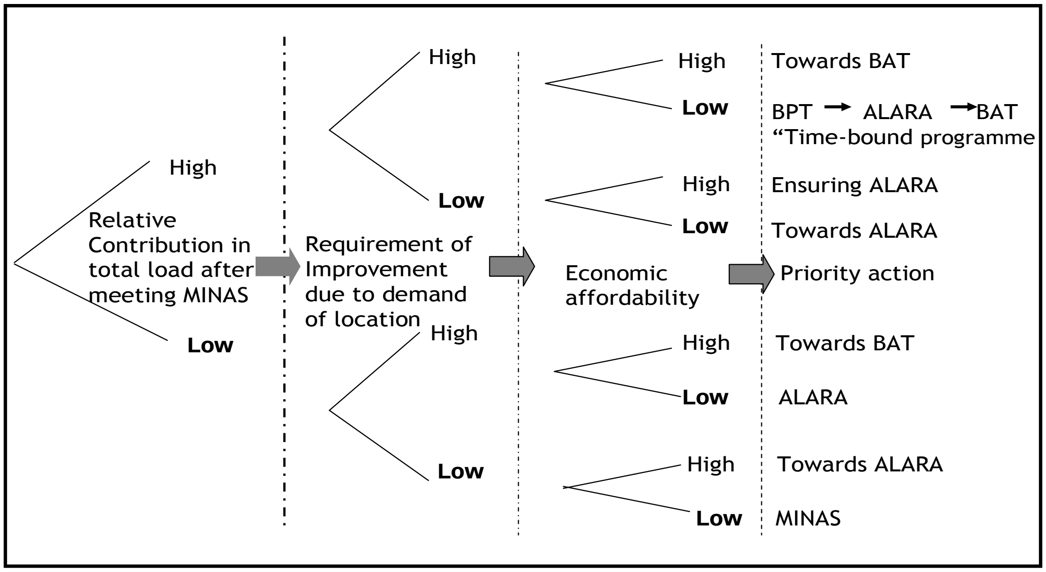


Figure 6.1: Guiding tool to decide level of Control Technology

Table 1: Model Format for Information Collection

	EXISTING STATUS	INDUSTRY			
		A	B	C	D
	Category of Industry (major/medium/small)				
	Status of pollution load generation before treatment				
B P	Expected efficiency (%) in terms of reduction of pollutants				
T	Present level of attainment				
	Cost of treatment (Amortized capital cost + operation & maintenance costs), i.e. Annual Burden (AB)				
	Annual Burden (AB)/Annual Turn-over (AT)				
	Pollution load after treatment				
	CHOICE FOR IMPROVEMENT				
	Options for improvement				
A	Additional cost due to improvements				
L	Revised AB/AT				
A R A	Recommended scheme comprising treatment units, corresponding achievable standards (as low as reasonably achievable - ALARA)				
	Pollution load after treatment				

Besides above qualitative assessment to explain the approach, a three level matrix shown below, has been developed for guidance.

Scale Of Operation and Annual Turn-over Implications for Adoption of Technology			
Annual Burden	**Small scale industry (SSI**	**Medium scale industry**	**Large scale/major industry**
HIGH (≥ 3% of Turnover)	Banning the production in small-scale operations (Red Category)	Not much scope for improvement in economic terms (Orange category O++)	ALARA to BAT →Gradual improvement (Orange category O+)
MEDIUM (1 to 3% of turn over)	May be discouraged/strict vigilance. Slight corruption (Orange category O++)	MINAS to ALARA -> Long term improvement (Green category G+++)	MINAS to ALARA →short term (Green category G++)
LOW (≤ 1% of turn over)	Formulation industry MINAS (Green category G+++)	MINAS to ALARA Short-term improvement (Green category G+)	MINAS→ ALARA→ BAT (Green category G+)

In the above Table, the size of the industry (corresponds to turn-over and perhaps quantity of pollution load generation) and annual burden (annualized investment and operation & maintenance costs of pollution control facilities) to annual turnover ratio has been considered to illustrate the scope for improvement. Such a classified guiding tools drives to set time-bound implementation programmes and desired frequency of cross checks.

6.4.7 Assessment of cumulative pollution load

After assessing the individual industries/establishments, with the support of comprehensive environmental audit and feasible technological improvement and the corresponding achievable limits shall be finalized and be made the Consent conditions. Once this is made, the cumulative pollution load addition to the receiving environment can be assessed to visualize the possible reduction by the steps taken. The resultant pollution load shall then be compared with the assimilative capacity of the receiving environment.

6.5 Determination of Assimilative Capacity of the Receiving Environment

Assimilative capacity is the maximum pollution load that can be stabilized in the environmental medium (air/water/land) without affecting its designated-best-use. The designated-best-use is the most exacting (e.g. Class C in Yamuna in Delhi) amongst the prevalent anthropogenic usages. The phenomena governing the assimilative capacity include dilution, dispersion and removal due to physico-chemical and biological processes.

6.5.1 Assessment of assimilative capacity of water bodies

Assimilative capacity of water environment in a receiving body is the maximum amount of pollution load that can be stabilized without affecting its designated use. The basic phenomena governing the assimilative capacity of surface water resources include self-purification capacity. The assimilative capacity for the conservative substances is estimated through mass balance involving measurement of stream flows during critical season. The methodology for non-conservative substances incorporates decay and reaction kinetics. Cumulative effects need to be included if multiple inlets of wastes are involved. Considerations of Locational options for activity siting are important in ensuring ecosystem integrity.

Many municipalities do not have sewage treatment plants and, therefore, untreated or partially-treated wastewaters besides treated industrial wastewaters are discharged into nearby sinks, usually the water bodies. The surface water bodies have the self-purification capacity, i.e. whenever the organic matter is discharged into water bodies, in the immediate stretches, the level of depletion of the dissolved oxygen would be very high and it even reaches to anaerobic conditions, which lead to migration of the aquatic organisms/loss of diversity, ecological and aquatic species. However, as it progresses to the down stream, due to the availability of dilution, diffusion, degradation, the concentrations of the pollutants reduce and the dissolved oxygen levels gradually rises. As the rate of re-oxygenation of the water bodies is proportional to the difference between the saturation dissolved oxygen (DO) level and the depleted DO, the natural system has its own mechanism to attain its saturation DO. This mechanism of replenishment of the dissolved oxygen in natural water bodies helps in stabilizing the organic matter. Therefore, the resultant oxygen sag curve due to the DO depletion and re-aeration is estimated by using appropriate models in order to maintain minimum DO in the water bodies for the survival of the aquatic organisms, i.e. at least 4 mg/l.

To ensure this minimum dissolved oxygen in the water bodies, how much pollution load a stream can take up, can be estimated by several mathematical models. However, each model requires data back up, constants, coefficients etc., which often turn out to be serious limitation in getting appropriate predictions. Therefore, the modeling is primarily considered for the purpose of likely scenarios under the various discharge conditions, but not to use it as a sole basis for deciding the allowable load. There will not be any replacement of the actual monitoring. However, the cost involved in regular monitoring is often high and when the variations are not significant it may not be economical. Therefore, once the set of required data is generated by the actual monitoring, on the basis of such data-back up, future predictions or the likely scenarios under the various combinations of disposal alternatives can be predicted to visualize the diffusion profiles.

If the present level of data bank available with the State Pollution Control Boards is of any indication, it is not possible to run data-intensive model for all the parameters. Therefore, from the Qual2E model, features can be made redundant, where the data is not available. As a result the reliability of the predictions may be low but over a period of time, reliability will improve and the model may also be fine-tuned to suit the location-specific features by validation. However, when relatively smaller discharges are added to the main stream, the possibility of complete mixing are limited, and is a big constraint in using models. Therefore, in such situations, the concept of influence zone may be used.

The general steps involved in the study of river dynamics and assessment of its assimilative capacity are shown in *Figure 6.2*.

6.5.1.1 Concept of Zone of Influence

If the present scenario of the infrastructure for sewage treatment in the country is of any indication, the direct disposal of the municipal sewage through open storm water drains will continue to reach the surface water bodies for future years also. Therefore, in such situations, the immediate zones in the receiving water bodies are likely to get severely affected and their impact may reduce with the distance from the entry point due to the flow mixing/dilution. The BOD limit of 30 mg/l has been established with the premise that a minimum of 10 times dilution is available in the receiving water bodies in order to attain the desired concentration of 3 mg/l in the receiving water body. However, the minimum distance at which this 10 times dilution occur is to be determined.

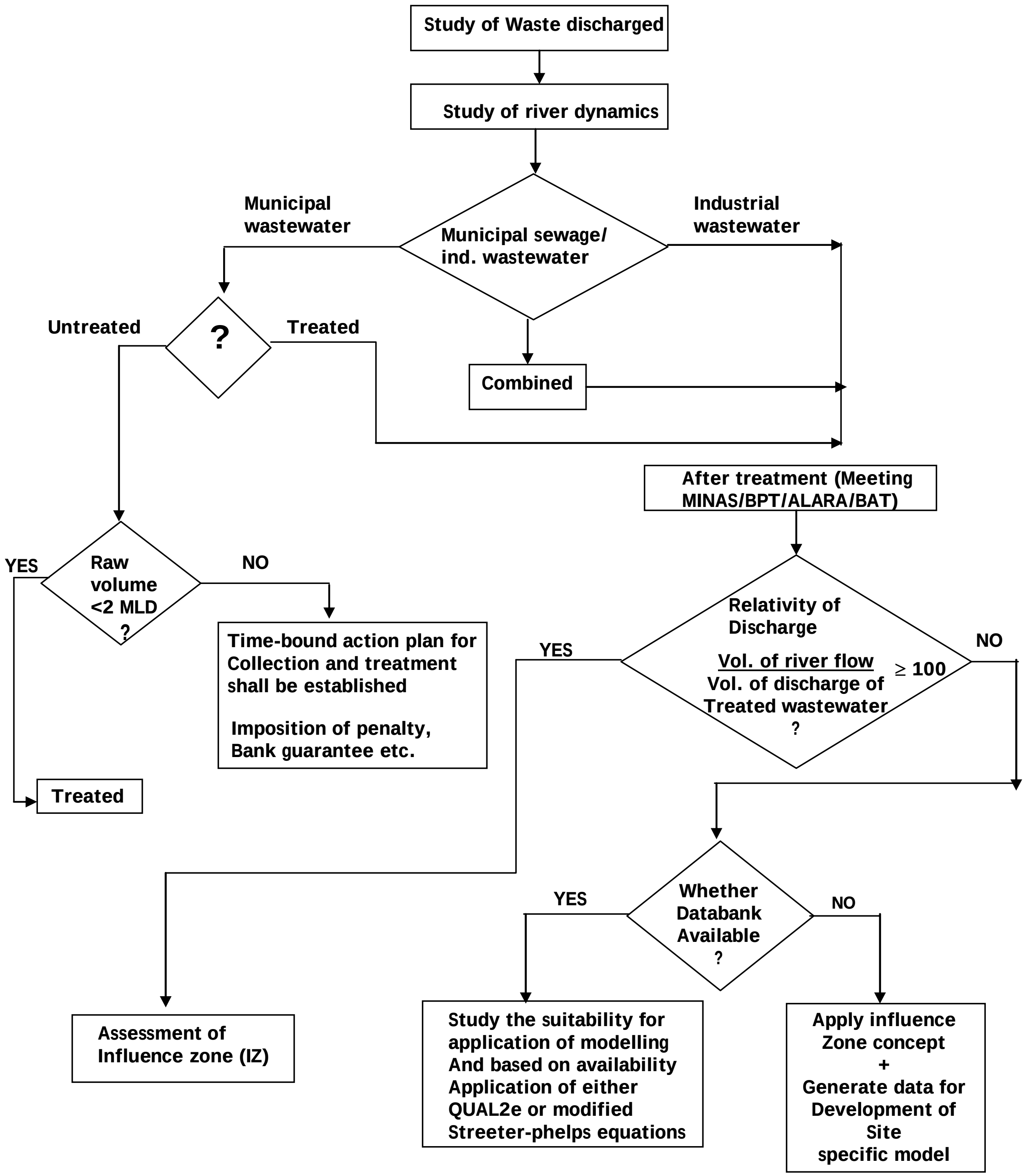


Figure 6.2: Steps involved in the study of River Dynamics and Assessment of its Assimilative Capacity

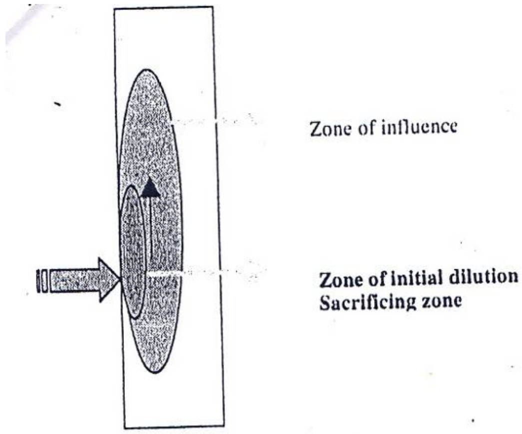


Fig 6.3 : Zone of Initial Dilution and Zone of Influence

One of the approaches could be to sacrifice/restrict the use in a specified zone and the ambient quality criteria can be expected the edge of such zones.

For determination of the zone of initial dilution and zone of influence, a simple and uniform procedure may be followed. With this idea, a feasible approach is drawn and it is shown in Figure 6.3. It may be seen that a grid is formed for actual sampling of waters and thus the actual concentration profiles may be drawn later on with the monitored values. The advantages with the type of actual monitoring is that the Indian rivers and lakes do not have defined cross sections, as these are not lined ones, besides the effluent does not mix with the entire width of the channel at the place of the discharge. Size of the grid shall commensurate with the accessibility to the banks for actual monitoring, adequacy to plot the contours of equal concentrations for prediction of likely distances, which fall under the zone of initial dilution and zone of influence. These two zones will vary from situation to the situation as the shape of the zones depends on, (i) stream flow, (ii) bay, estuary and reservoir, (iii) effluent flow, (iv) stream geometry, and (v) discharge structures (diffusers etc.).

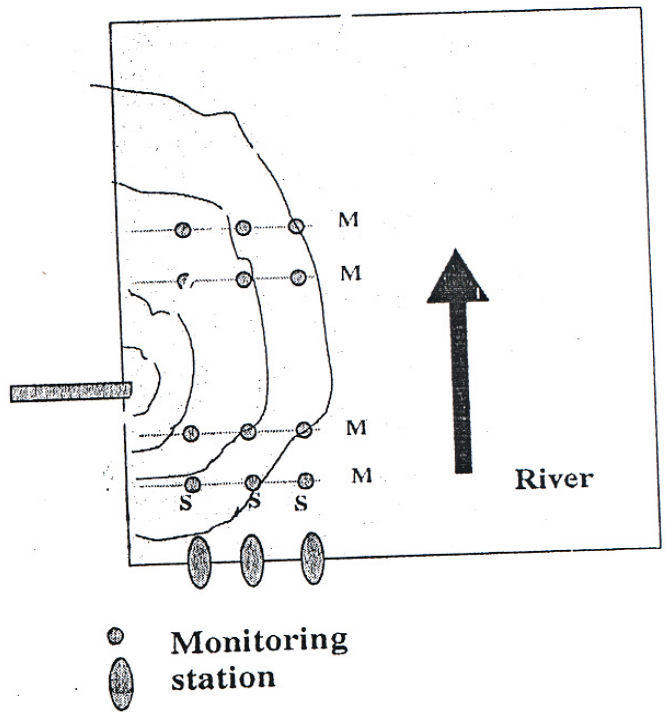


Fig 6.4: Distance of Zones on all the directions

Distance of the zones on all the directions can be determined as shown in the *Figure 6.4*. It represents the cross-sectional view at 'AA' as shown in this Figure. It can be seen that there is a sudden reduction in the concentration of the drain as soon as it meets the stream, which can be attributed to the settleable biodegradable solids content in the wastewater, which typically settle due to their specific gravity. Therefore, the principle phenomenon acting is the dilution and discrete settling of the solids but essentially not the degradation process and the remaining portion refers to the gradual diffusion and degradation in the down stream side. Therefore, a simple tangent to the initial settling touches at a distance X from the point of discharge typically represents the distance of the initial dilution, as the aquatic organisms do migrate from this zone due to the higher concentrations and depleted DO concentrations in the water. Whereas the zone of influence shall extend upto the level where the BOD becomes equal to 3 or the desired level as per the designated-best-use criteria.

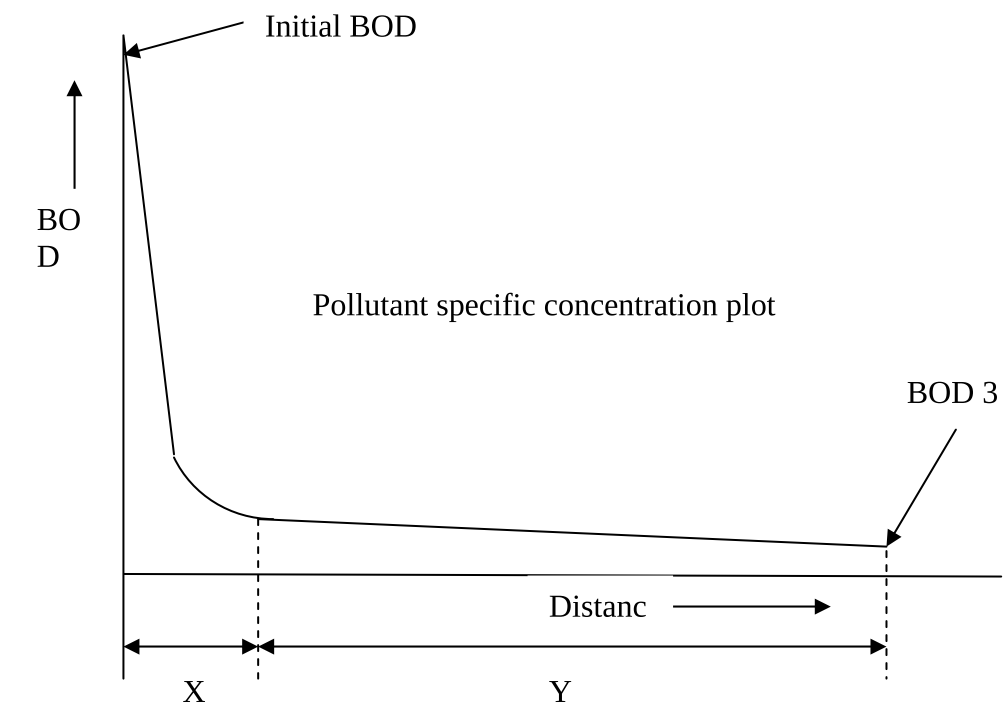


Figure 6.5

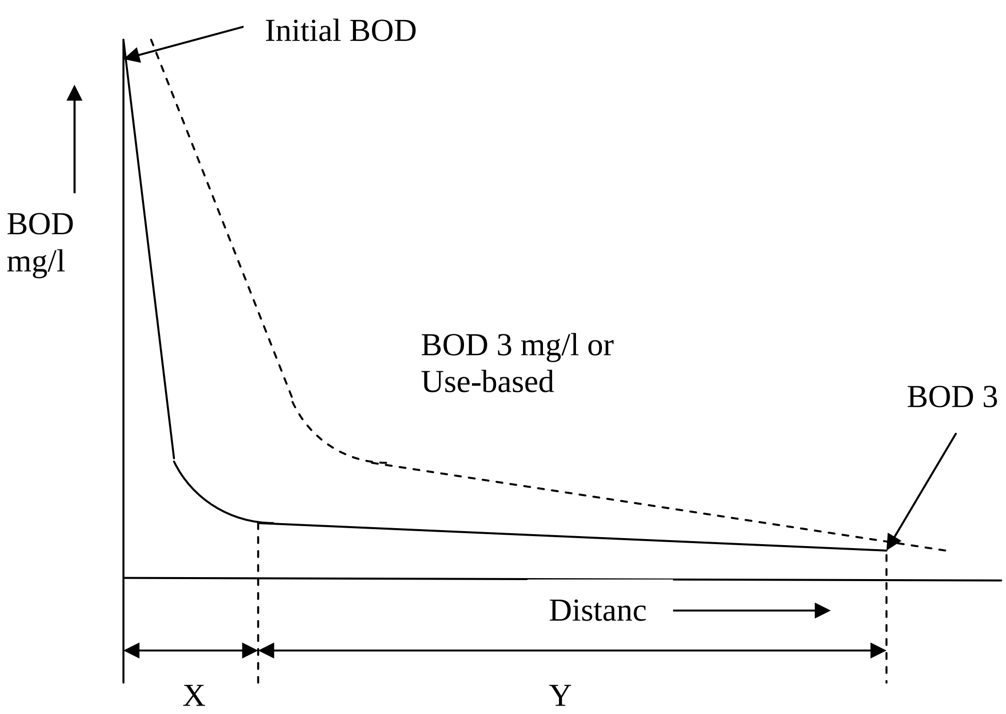


Figure 6.6

It implies that for the particular parameter BOD, zone of influence is up to a distance of X + Y. This zone is not suitable for various designated-best-uses. Therefore, the choice with the regulatory authorities in this case, is to regulate the allowable distances of X and Y, say X<25 m and Y<100 m. The reduction in X & Y can be achieved by proper engineering measures for enhanced diffusion and by reducing the source strength through control measures. The immediate raising question would be how much pollution load is to be reduced/allowed to attain the desired concentrations at the regulated distance of restricted zone? The two options by which the allowable load can be established are as follows:

Option I : Establishing correlation between the profile of specific parameter of concern with the profile of dye (preferably rodamine B) concentration, at a given rate of dye application (the rate of continuous dye application shall be governed by attainment of minimum dye detection concentrations at the distance Y.) The dotted line represents the dye concentration, which represents only physical dilution/diffusion. Therefore, a strong correlation may not be established, but the reasonable estimates could be made.

Option II: The following equation is established considering the first part of the equation represents the discrete settleable BOD in the initial phase and the second portion of the reaction represents the first order degradation:

$$S = S_{o-x} [1-(Vs/D)t + S_{o-y} e^{-kt}]$$

Where, S: remaining BOD; S_{o-x} : Settleable portion of BOD; Vs: Settling velocity of solids; D: stream depth; t; time; So-y: BOD at the distance X; k: Decay coefficient

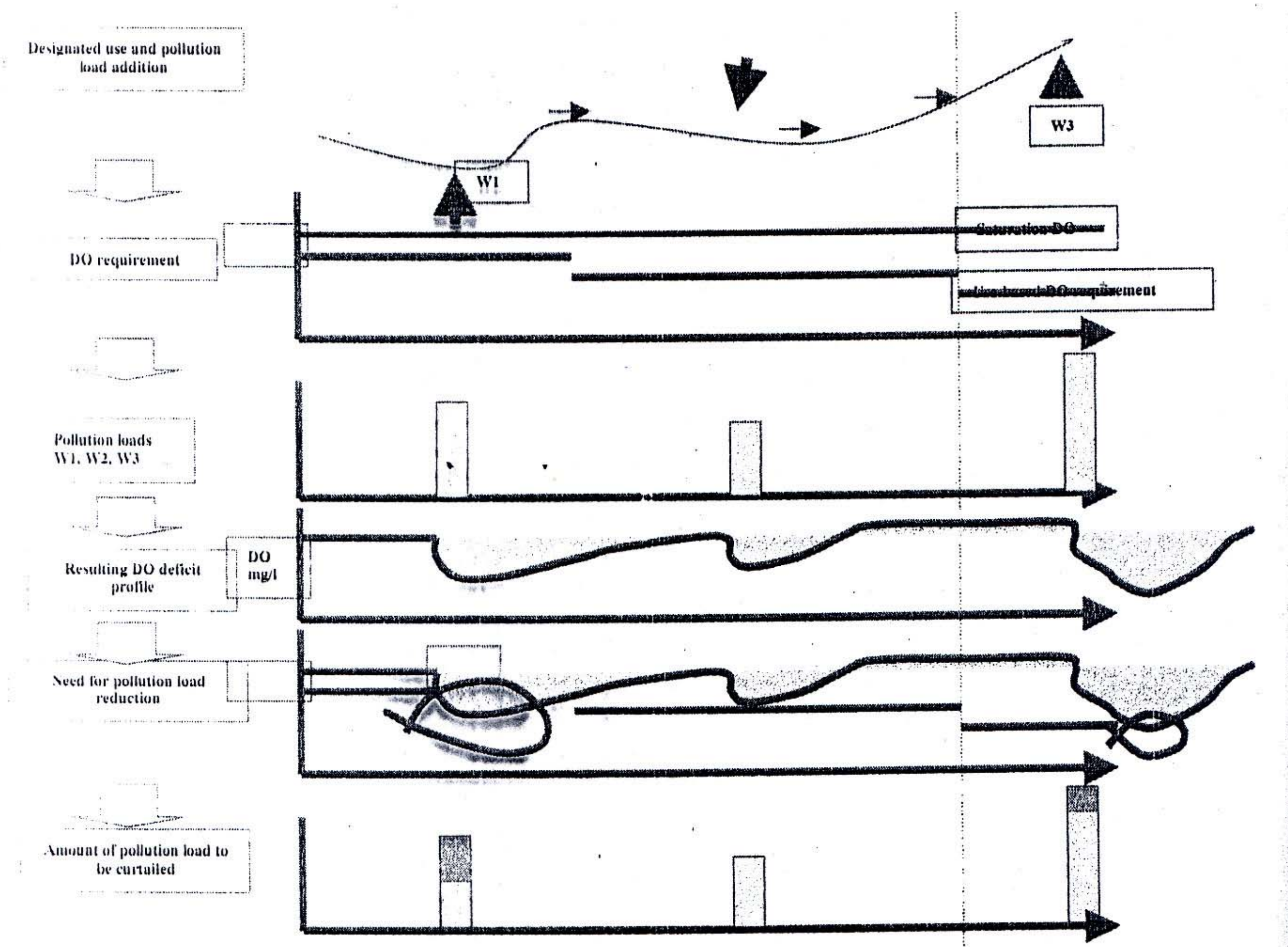
This equation fairly represents the degradation profile of the recipient body when mixed, thus may be explored. However, from the concept it is clear that the shape and distances of the zones depends on various factors, also requiring the exercise to be repeated in all the critical seasons/flow conditions. The focus of this exercise is to restrict the specific activities in these zones and to reduce the size, for the benefit of environment protection/designated-best-use protection/aquatic organism in the water bodies. In no case the size shall extend to the entire width of the stream as it restricts the movement of aquatic organisms.

6.5.1.2 Water Quality Modelling

Entire river can be classified in to few stretches based on their designated-best –use criteria. Once the use requirement is known, the actual levels at those stretches are to be monitored and the stretches, where the DO and other criteria pollutants are not meeting the use-based required quality are termed as polluted stretch. As every time monitoring is a costly affair, once sufficient data are available, the mathematical models can be made use of to predict the likely concentrations. This classification of the stretches is illustrated in the *Figure 6.7.* This figure illustrates, the amount of pollution reduction corresponds to the use-based requirement but not on the basis of quantum comparison with other sources.

6.5.1.3 Application of Qual 2E model

Qual 2E model is opined as the reasonably best applicable for our conditions. However, the amount of data requirement to run this model is often a big constraint. Therefore, wherever the data is sufficiently available, this model shall be adopted for predictions of concentrations, and hence, efforts must be made to generate the required data for running the model for better predictions as the time passes.



This figure illustrates, the amount of pollution reduction corresponds to the use-based requirement but not on the basis of quantum comparison with other sources.

Figure 6.7

6.5.1.4 Data requirement for Qual2E Model

Classs	Parameters
Geographic information and temporal information	Number of reaches, reach length, junction locations, headwater or not, latitude, longitude, standard meridian, basin elevation, period of simulation within the year calendar
Compartment and flow characteristics	Compartment size and flow type, dispersion coefficient, coefficient and exponent of the velocity for flow calculation, coefficient and exponent of the flow for stream depth calculation, manning's coefficient, incremental inflow per reach, headwater flows, water quality characteristics of point sources
Climatic data for light limitation	Dust attenuation coefficient, solar radiation factor, light average factor, criteria for light average from solar radiation, fraction of cloud cover, absolute solar radiation
Climatic data for temperature calculations	Two evaporation coefficients, dry and wet bulb temperatures, barometric pressure, wind speed
Temperature	Temperature coefficient for : BOD decay, BOD settling, re-aeration, SOD uptake, organic N decay, organic N settling, ammonia decay, ammonia source, nitrite decay, organic P decay, organic P settling, Dissolved P source, algal growth, coliform decay and three arbitrary non-conservative constituents, initial temperature per reach
Nitrogen cycle (values per reach)	Ammonia oxidation coefficient, nitrite oxidation coefficient, nitrogen content in algae coefficient, benthos source rate for ammonia nitrogen, organic nitrogen settling rate, rate constant for the hydrolysis of organic nitrogen to ammonia, nitrification inhibition coefficient, initial values per reach for the four components of the nitrogen cycle and at the headwater
Phosphorus cycle (values per reach)	Organic phosphorus settling rate, benthos source rate for dissolved phosphorus, rate constant for the decay of organic phosphorus to dissolved phosphorus, initial values per reach for the four components of the

	phosphorus cycle
Algae	Maximum specific algae growth rate, respiration rate, Michaelis-Menten nitrogen half saturation constant, Michaelis-Menten half-saturation constant for light, non-algal light extinction coefficient, linear algal self-shading coefficient, linear algal self-shading coefficient, non-linear algal self shading coefficient, algal preference factor for ammonia, algal settling rate, ratio of chlorophyll-a to algal biomass, fraction of algal biomass that is nitrogen, fraction of algal biomass that is phosphorus, light saturation coefficient, initial Chl-a value per reach and at the headwaters types of nutrient and light limitation functions
Dissolved Oxygen	O2 production per unit of algal growth coefficient, O_2 uptake per unit of algae respired, benthic oxygen demand, carbonaceous de-oxygenation rate constant, criteria for the type of re-aeration, type of re-aeration calculations, re-aeration coefficient and associated coefficient and exponent, initial DO value per reach and at the headwater
BOD	Rate loss of BOD due to settling, initial BOD values per reach and at the headwater, type of BOD: BOD_5 or ultimate BOD
Arbitrary non-conservative constituent	Arbitrary non-conservative settling rate, benthal source rate for arbitrary non-conservative settling rate, arbitrary non-conservative decay coefficient
Coliforms	Coliform die-off rate

6.5.2 Assessment of Assimilative Capacity of the Air Environment

Assimilative capacity of air environment is the maximum amount of pollution load that can be discharged without violating the best-designated use of the air resource in that region e.g. industrial sensitive etc. The phenomena governing the assimilative capacity of air environment include dilution, dispersion, deposition and absorption. The assimilative capacity assessment is based on quantification of air pollutants' removal mechanisms in an air shed viz. dilution/diffusion, rain/smog/fog, photo-chemical reactions, and attenuation by vegetation.

6.5.2.1 Ventilation Coefficient

Air pollution assimilation potential of an air shed is estimated as the Ventilation Coefficient (VC), which is an indicator of horizontal (avg. wind velocity) as well as vertical mixing (mixing height). Therefore, based on VC, different zones of air pollution potential may be classified as low medium and high i.e. VC<6000 m^2/sec; VC in the range of 6000-12,000 m^2/sec. and VC greater than 12,000 m^2/sec. respectively.

For the purpose of measurement of VC, mixing height can be determined by extending the dry adiabatic lapse rate from the surface temperature to its intersection with the early morning temperature soundings. The height of the point of intersection from the ground is termed as Mixing Height. These surface temperatures may be obtained from the urban regions, where the mixing height is to be determined. The place of temperature soundings may be chosen so that (preferably suburbs) sounding is free from urban interferences. Mixing height/depth and average wind speed may be assessed during winter (3 months) and summer (3 months). As mixing depth is not expected to change at shorter distances, one station representing about 25 sq km may be considered as the representative. Once the ventilation coefficient data are available, with the comparison of exceedance factor data, many inferences can be drawn as shown in the three-level matrix shown below:

	Ventillation Coefficient		
Exceedance Factor	**Low**	**Medium**	**High**
Low	Sensitive zone not fit for air polluting activities	Fuel change, ALARA	Strict surveillance can solve the problem
Medium	Activity modification/restricting sp. Growth/fuel quality improvement/traffic diversions etc.	Fuel change ALARA+	Moderately polluted requires stringent measures
High	Shifting of sensitive operations	Moderately polluted requires stringent measures	Heavily polluted stretch rigorous vigilance with closure are inevitable

6.5.2.2 Guidelines for conducting air quality modeling

Attainment of satisfactory air quality is generally predicted through dispersion modeling and the conventional practice for ambient air quality predictions is through application of Gaussian Plume Model and its available variations. Therefore, for the purpose of location specific standards also, it is felt easier to adopt the same modeling practice to come out with the reasonable percent contributions by the various point sources in the vicinity at the point where the ambient air quality standards are not meeting.

The Central Pollution Control Board has brought out guidelines for conducting air quality modeling through its publication under the Programme Objective Series No. PROBES/70/1997-98. As these guidelines are already in place, same may be followed for the purpose of modeling. However, the utility of the modeling for the purpose of location-specific standards is further discussed here.

The inventory data can be visualized in a plot as shown in Figure 6.8, where line sources and point sources are shown as circles and rectangular represents the areas where the ambient air quality standards are not meeting. The simplest approach suggested for the purpose is to collect the data through inventory and by taking appropriate indigenous emission factors, the quantum of line sources and aerial sources can be estimated in each grid. If the information availability is a constraint, the major point sources with considerable pollution load may be identified. Parallel, with the support of extensive ambient air quality monitoring in the study area/air shed, the points where the ambient air quality is exceeding can be identified.

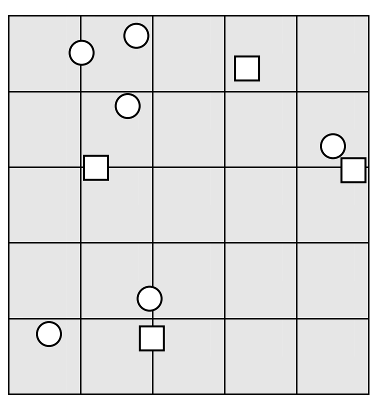


Figure 6.8

Once the major point sources, background ambient air quality and air quality violating areas are identified, then simple Gaussian plume model may be used for prediction of likely concentrations due to each individual point source at the point of ambient air quality violation. Thus, the likely concentration due to each of the point-polluting source at a given point, considering others are not emitting, can be ascertained. Therefore, the addition of all the predicted concentration due to point sources and with the addition of individual contributions and the background concentration gives the predicted total concentration at the point where the ambient air quality is not meeting. Once the actual monitored concentration at that conditions of modeling is known, these can be compared and the predicted concentrations can be corrected accordingly.

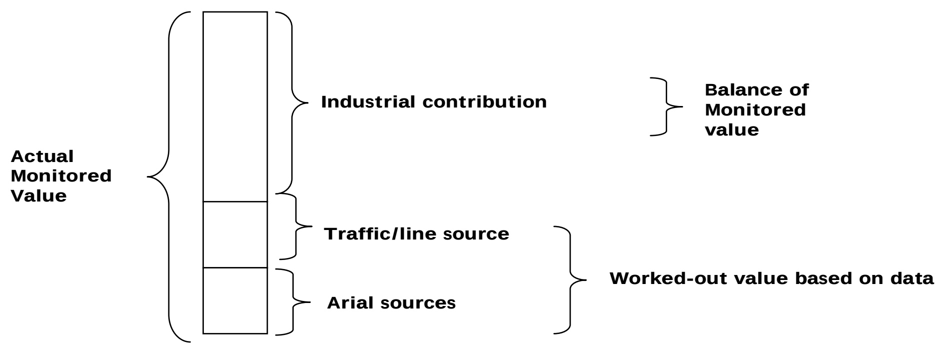


Figure 6.9

Thus, the share of each industry in violation of ambient concentration for a pollutant at the chosen point can be ascertained and can be used as an effective tool to force the industry to go for enhanced control of that particular pollutant considering the choice for technological improvement as well as the economic cushion.

6.5.2.3 Application of the ISC3 Model

ISC3 model has been identified as a reliable model and can be taken up for the modeling in Indian situations. However, enhancement of the reliability of the predictions depends on the data back-up, which is often a constraint in many areas. Therefore, efforts must be made to collect the data required for running of ISC3 model in all the areas for the purpose of air quality modeling as a base requirement for the settling of location-specific standards.

Data Requirement for ISC3 Model

(i) Industries

Small and medium scale industries contribute significant share of industrial emissions. Most of the State Pollution Control Boards are presently able to cover the medium and large-scale industries and only a few sectors of small-scale industries. In view of this, not much data is available on the small-scale sector. Even in the case of medium and large-scale industries, the data available are not so reliable in many cases, as the industries do not strictly adhere to the data given by them in the consent application. Stipulations made in the consent orders may be used as input to the model for determining further improvement requirement. However, it is possible only when there is a strict enforcement supported by monitoring. In case of industries whose consent applications are pending with the State Pollution Control Boards for one reason or other, the data given by them in their consent application submitted to the State Pollution Control Board may be considered.

In the case of most of the small-scale industries, the input data has to be estimated. The methodology for estimation is as follows:

a) Divide the entire area where they are located into suitable grids;

b) Obtain the fuel used in that area by the industries from concerned departments and by field surveys.;

c) Calculate the emission in that grid using emission factors; and

d) Feed the data to the computer assuming that this emission is let out through a 30 m high stack located at the center of the grid.

ii) Commercial sources and Residential Sources

Data on the fuel usage may be collected from the concerned offices, such as the civil supplies department. Using the emission factors, calculate total emissions and include them as area source.

iii) Vehicular Emissions

Number and category of vehicles may be obtained from Roads and Transport Authority (RTA). The emissions can be estimated using CPCB established emission factors. This data are used in the model as a line source.

iv) Meteorology Data

Meteorology data are very important inputs to the model. Hence, it is desirable to collect the data generated at the site and the worst scenario. In absence of such site-specific data, the data available with the nearest IMD station may be collected after satisfying that the data is applicable to the site.

v) Default values of the Model

These values are to be determined for each site. In case it is not possible to determine any one or more of the site-specific default values locally, the values available for nearest area in the literature may be taken. Under no circumstances, these values are left blank as otherwise the model picks up system default values, which may differ very widely, from the site-specific values.

vi) Validation/calibration of the Model

A model is required to be adequately evaluated and validated to ensure its reliability. Often these studies are time-consuming and expensive. Therefore, in the absence of such a validation exercise, calibration method has to be explored.

The advantage of model calibration is that it does away with the rigorous evaluation and validation procedures of a model for application in a particular situation. Using this method, it is possible to overcome the problems, such as errors and inaccuracies related to stochastic nature of the atmospheric process etc.

From the above, it is clear that calibration is valid for a particular city. This is mainly due to differences in the input data in the model between the two cities. In the same city, there are regions where the ambient air quality shows strong interdependence between the ambient air quality stations. If these areas are delineated and calibration is done for each of the areas separately, the accuracy of predictions may increase considerably. The method of delineation is presented below.

Based on the topography, vegetative cover, buildings, roads etc. the area may be divided into three or four manageable regions. Select the ambient air quality near the centre of each of the areas and examine the inter-dependability is the correlation coefficient for monitored ambient air quality between these stations. If the value is between 0.63 to 0.76 (for observations of 10), the stations are interdependent. Those stations, which exhibit inter-dependability, shall be treated as belonging to that area. In case of others, they may be merged with an adjacent area or formed a separate region. The basis of merging with the adjacent station or forming a separate region is the inter-dependability of the concerned stations as explained above.

Regression analysis may be carried out for the maximum actual monitored values and maximum predicted values during the same period for the central station of each region. Using the linear model developed, calculate the actual values based on the predictions in that region.

6.6 Best Professional Judgement

This section deals with the compatibility of the results obtained by application of methodologies suggested in the previous sections, in a specific location. If the pollution load after the treatment (PLAT), i.e. the pollution load after optimization is less than the allowable level of pollution load (ALPL) as determined from the assimilative potential (Section 6.5), then the situation is normal. Therefore, the brought-out optimization measures (Section 6.4) may be formulated into a legal agreement and subsequently the consent conditions for implementation. Whereas, when PLAT is higher than ALPL, the situation demands measures other than just technological means and as such, represents a severe pollution condition, which requiring a holistic approach to tackle the issue. The interactive dimensions of the issue is given in Figure 6.10. It can be seen that health, environment, economics and technology have to be balanced in such a way that issue of pollution load exceeding the assimilative capacity can be handled. As such sufficient legislative support and effective constant enforcement are essential to keep the wisdom of the decision makers intact and to convert the wisdom into practice by the industries and others in the region.

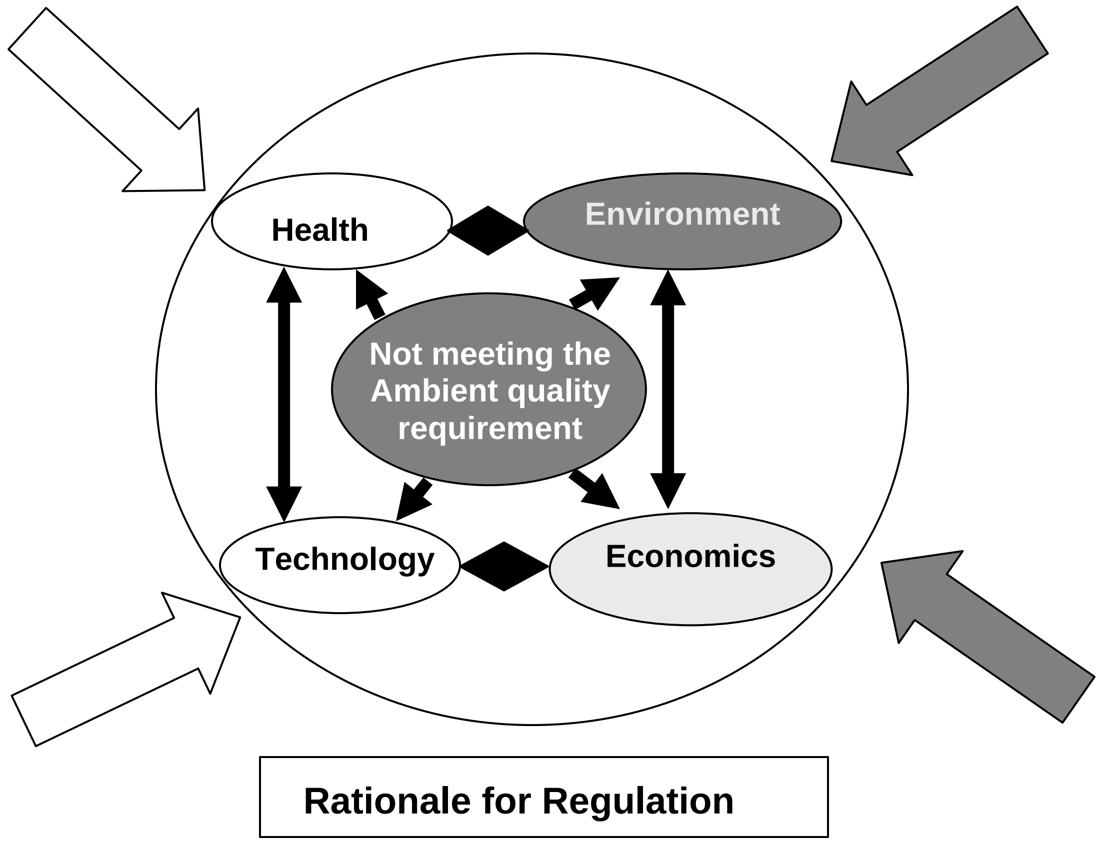


Figure 6.10

Three choices available for exploration are:

- Three levels of technological choices
- Choice of economic instruments
- Administrative requirements

Each of the choices are discussed in the subsequent sections.

6.6.1 Technological choices

Level – I : Control at source (Industries, municipalities, vehicles etc.)

- Cleaner process technologies & cleaner production
- Resource conservation, recycling, reuse, renovation, recovery
- Segregation of waste streams and providing corresponding treatment
- Tertiary and specific treatments

Level – II : Further treatment

- Common/combined effluent treatment plants with better treatment control and to have benefit of scale of operation

- Further treatment in STPs to explore dilution due to the volume of sewage

- Land treatment, recharge for reclaiming the wastewaters etc.

Level – III : Others

- Enhancing stack heights

- Maximising the assimilative capacity (diffuser, dispersed small inlets to avoid peak conc.)

- Providing diffusers at outlets

- Routing the discharge points downstream of sensitive use to maximize the benefit of assimilative capacity

- Economic trade-off between pollution control Vs. assimilative capacity in a fair way (enhancing supportive capacity in place of pollution control may be cheaper beyond a level of control)

- Sensitivity of the receiving water body Vs. reliability of the control technology etc.

- Exploration of alternative disposal sites

- New industries shall have the best available control technologies

- No more expansion of the existing industrial units/restricting new polluting industries, which have impact on the environmental parameter of concern in view of the assimilative capacity

- Shifting of industries or specific operations to other suitable locations

- Changing the use pattern of receiving body by creating alternative means for economic reasons subjected to having ecological and social acceptance etc.

- As a last resort, to curtail/ban specific potential activities, which pose major problem in meeting the assimilative capacity etc.

6.6.2 Choice of Economic Instruments

- Environmental charges on residual pollution
- Incentives such as concessions on import duties to those industries which switch-over to BAT
- Continuation of grants for common treatment facilities and extending the same for common disposal facilities and common hazardous waste incineration systems
- Funding/soft loans for effluent channels upto sea, wherever feasible, to maximize the economic benefit and to avail dilution
- Emission trading possibilities once MINAS/ALARA is achieved by all concerned
- Deep pocket effect – rich can invest better for pollution control, hence, expecting more from the rich
- Grand-father clause – Sympathetic view in retrofitting in old industries, as is not readily feasible in many cases

6.6.3 Administrative requirements

(i) State Pollution Control Boards may identify three levels of auditors based on the sophistication in order to cater to red, orange and green categories of industries respectively. The industries in identified areas shall get their plants audited every year or at any other frequency set by the Board based on specific requirement. There shall be mechanism to list and enlist the auditors based on competence.

(ii) State Boards/Committees may constitute a Core Technical Committee comprising of not less than 5 and not more than 7 experts with the following composition:

- One professor of a university as the Chairman
- One officer from the Central Pollution Control Board
- One CSIR nominee (preferably from NEERI)
- At the most three nominated experts having related professional qualifications and experience
- One officer from the concerned SPCB as the Member Secretary

(iii) The Committee shall

- Set boundaries of the study area and priority pollutants for control;
- Identify the location of monitoring stations in an identified area and frequency of monitoring;
- Assess the comprehensive environmental audit reports submitted/presentations made;
- industries/establishments/their representative to explore the choice of technological improvement and to set as low as reasonably achievable standards;
- Prescribe minimum desired frequency of inspection/checks based on complexity and concern; and
- Review the progress periodically and amend the decisions for the desired enforcement

iv) Pollution Control Board officials may be organized, according to responsibilities into a few groups, such as groups conducting inventory, modeling, air & water quality standards and permitting. These groups shall work together to ensure enforcement

- Inventory group responsible for collection and analysis of effluent & emission data of the industries, traffic and distributed sources, sewage etc.
- Modeling group responsible for applying models for air shed & water bodies and evaluating modeling performed by industries
- Water & air quality standards group responsible for developing standards implementation procedures and assessing impact of emissions and wastewaters on ambient environment
- Permitting group responsible for preparing permits for emission sources including emission limits and control technologies.

APPENDIX - I

1.0 Modeling Studies conducted for the polluted stretch of River Godavari - Near Rajahmundry

1.1 Study Area and Polluting

The stretch of Godavari river near Rajahmundry is polluted mainly due to the discharge of untreated sewage at various locations. Other sources of pollution are industrial effluents, washing of clothes in the river and defecation along the river bank.

The Godavari river is about 2 km wide. The wastes entering the river flow into the river only for a short distance and then flow along the bank until they are assimilated by the river. In order to use the QUAL 2E model for such a situation, the boundary conditions have to be determined.

1.2 Determination of Boundary Conditions

Literature survey indicated that Rhodamine-B dye (the USEPA's website may be referred for other compounds recommended as tracers) is most suitable for this purpose. A reconnaissance survey of the river was undertaken to select a point source which can be utilized for demonstrating the use of the model. Finally, a channel, which conveys sewage from Aryapuram area of the town, was selected. One reason for selecting this channel was that it is a masonary channel with regular cross section and located upstream of the drinking water supply intake. The other reason is that wastes entering the river upstream of this entry point are assimilated by the river.

A kg of Rhodamine-B dye was mixed in about 10 litres of water and released continuously for about 15 minutes in the channel on the weir. Since sewage is already entering from the channel into the river, a visual inspection of the stretch was carried out by conducting a reconnaissance survey using is motorboat in order to assess the extent of horizontal flow of sewage across the river. This indicated that the maximum horizontal flow is about 45 m. Based on this observation, sampling locations were fixed as shown in the *Figure A-1*.

A long rope was taken and knots were made at 15 m, 30 m and 45 m. One end of the rope was held by a person on the river bank and the rope at the 15 m knot was held by a person in a boat. Similarly the 30 m knot by held by a person in the second boat and the 45 m knot was held by a person in the third boat. The person standing on the bank guided the three boats to get positioned at the sampling points fixed as shown in the figure.

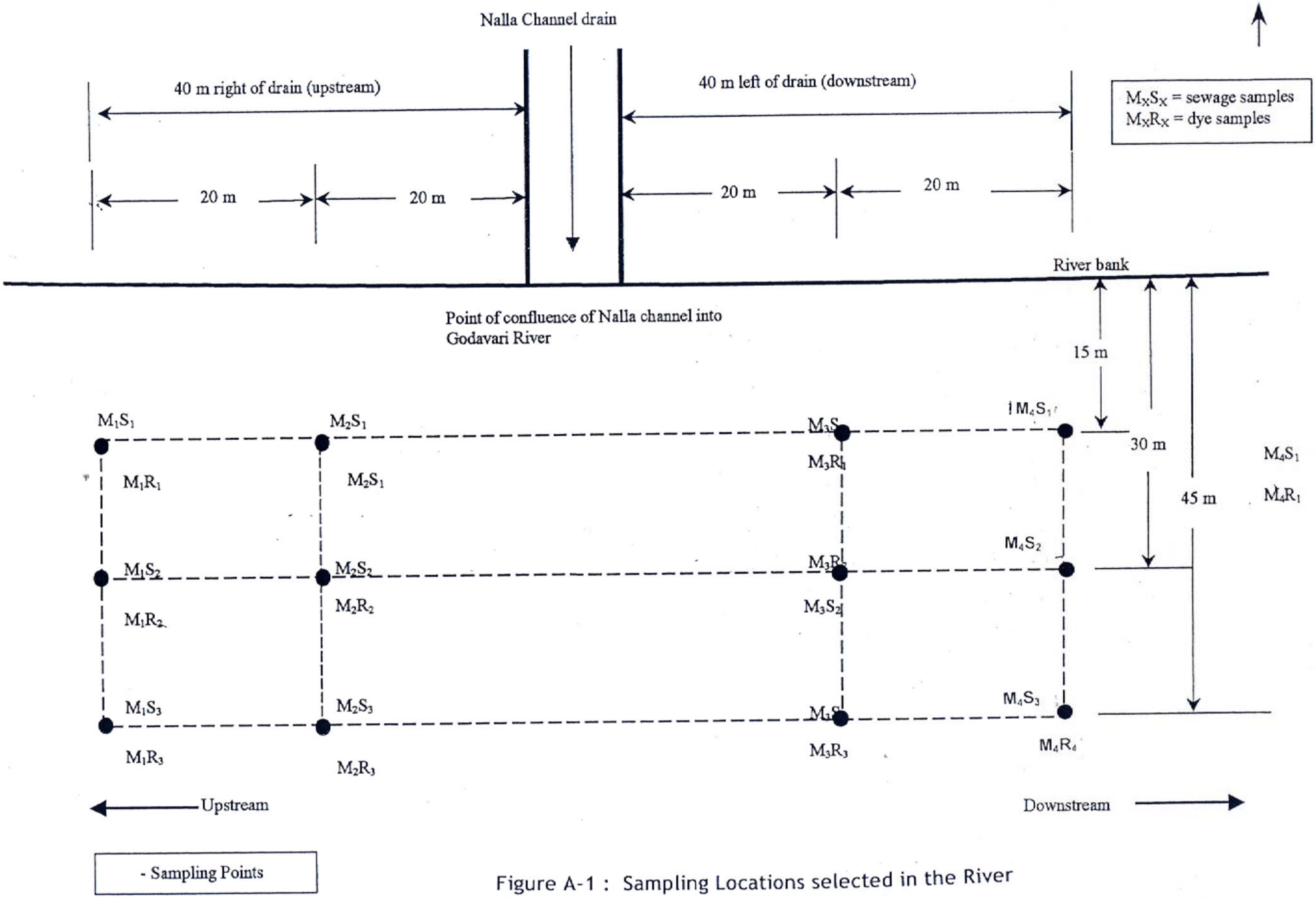


Figure A-1 : Sampling Locations selected in the River

At each location, two sets of samples were collected – one set for the analysis of parameters pertaining to sewage and another set for determining for Rhodamine-B concentration. Both the samples were brought to EPTRI laboratory for analysis.

In the absence of fluorometer, indirect method using GC as suggested by NEERI was used. Unfortunately, the method has not given any results. Hence, the boundary conditions were fixed based on the sewage samples collected. The results are presented in the Table below.

Sample	**BOD (mg /l)**	**COD (mg /l)**
M_1S_1	11	22
M_1S_2	9	19
M_1S_3	7	14
M_2S_1	20	50
M_2S_2	11	25
M_2S_3	6	17
M_3S_1	22	51
M_3S_2	15	40
M_3S_3	14	33
M_4S_1	11	28
M_4S_2	6	16
M_4S_3	7	18

Since the normal BOD of Godavari water is 3 mg/l, trend analysis was carried out to find out the distance at which BOD of 3 mg/l occurs. The results of the trend analysis showed that the effluent entering the river flows across the river upto a distance of 80 m. The average depth of the river upto this width is about 5 m.

The parameters taken for use in this model and their value are as follows:

Velocity of the river	=	0/083 m/s
Width of the river	=	80 m
Depth of the river	=	5 m
Avg. flow rate	=	32 m^3/s
BOD of river	=	3 mg/l
BOD of channel	=	200 mg/l
Flow rate of the channel	=	2 m^3/s
DO of river	=	8 mg/l
DO of channel	=	0 mg/l

The values calculated based on the above parameters are as follows:

Dispersion constant (K) = Dx/(HU*) = 543

(Ref. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E – UNCAS : Documentation and User Model EPA/600/3-87/007 May 1987, pp. 17.)

Where,

Dx is the longitudinal dispersion (ft^2/s) = $0.011\ U^2W^2/(HU^*)$

(Ref. Technical Guidance Manual for development of TMDLs Book 2 : Streams and Rivers. EPA/823-B 97-002 March 1997, pp A-19.)

U* is the shear velocity (ft/s) = $\sqrt{(gHS)}$

(Ref: Technical Guidance Manual for development of TMDLs Book 2 : Streams and Rivers, EPA/823-B 97 – 002 March 1997, pp 3-7)

'S' is the slope of the stream bed = $[(Un)/(1.486\ H^{2/3})]^2$

(Ref : The Enhanced Stream Water Quality Models QUAL2E and QUAL2E – UNCAS : Documentation and User Model, EPA/600/3-87/007 May 1987, pp 17.)

H - river depth (ft)
U - average velocity (ft/s)
W - river width (ft)
g - acceleration due to gravity (ft/s^2)
n - Manning's roughness coefficient

K_d is the B.O.D. decay rate = $103\ Q^{-0.49}$ = $0.38\ day^{-1}$

Q - flow rate (ft^3/s)

(Ref: Technical Guidance Manual for development of TMDLs Book 2 : Streams and Rivers, EPA/823-B 97-002 March 1997, pp A-23.)

Reaeration coefficient = $12.9\ U^{1/2}/H^{3/2}$ = $0.11(day^{-1})$

(Ref. Technical Guidance Manual for development of TMDLs Book 2 : Streams and Rivers, EPA/823-B 97-001 March 1997, pp A-28.)

Coeff. Of velocity = Q/U = 0.0025

Coeff. Of depth = Q/H = 0.15

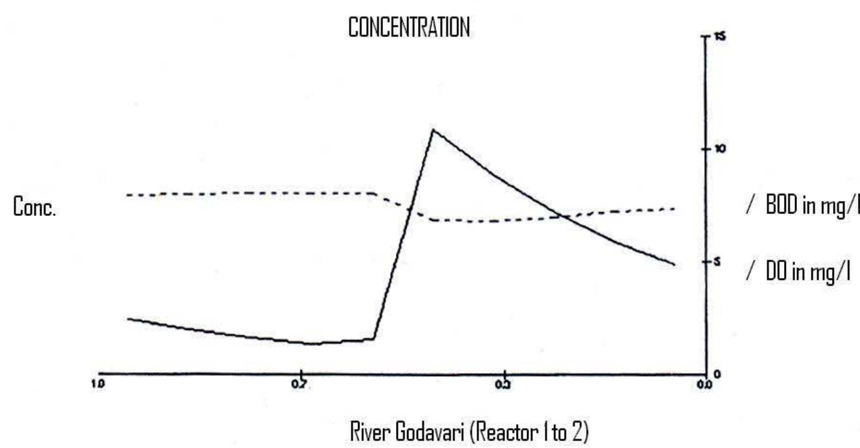
The model default values are as follows:

(i) Coefficient for converting BOD_5 to BOD_u = 0.23 base e, (day $^{-1}$)

(ii) Temperature correction values

a.	BOD decay	=	1.047
b.	BOD settling	=	1.024
c.	DO Reaction	=	1.024
d.	DO SOD uptake	=	1.060

The output obtained from the above values for the study at Rajamundry is given below:



APPENDIX - II

1.0 Modeling Studies conducted for Visakhapatnam Air Shed

1.1 Study Area and Polluting Sources

The city Visakhapatnam, which is located in the east coast of India, was selected for the study due to its typical location, geographical and meteorological conditions etc. The study area covers municipal Corporation of Visakhapatnam, neighboring municipalities and city out growth area. In the study area, the major sources for the air pollution are identified and corresponding emission loads were available. Also, the details of the major sources of air pollution in the study area are:

- Industries
- Vehicular traffic
- Households

Of the various air pollutants generated from these sources, suspended particulate matter, sulphur dioxide and oxides of nitrogen were only considered in this study, as the actual ambient air quality values monitored by APPCB during the then previous two years were far below the permissible values. These values were also confirmed by NEERI, based on their studies during April-May 2002.

1.2 Data Collection

The available data required for carrying out air quality modeling was collected from different sources. Micrometeorological data such as wind speed and direction, ambient temperature and humidity etc. including ambient air quality for three months covering the three seasons were collected from the Combine Met Office of Eastern Naval Command. In addition, ambient air quality data were also collected from APPCB and the EIA reports.

The relevant data pertaining to major industries in the bowl area were collected from Zonal Office, APPCB. Similarly data pertaining to category of vehicles, vehicles registered vehicles on road. Using these data, the emissions from vehicles were estimated using the emission factors given by CPCB.

The kerosene distribution details in urban and district wise basis were collected form the special rational officer, Civil supplies. Using these data, kerosene emissions of the study area were also estimated. The contribution from the use of firewood and cow-dung cakes in the area were not significant and no special efforts were therefore made to collect this data.

All the required data pertaining to small and medium scale industries is available with the district industrial centre of APHC. The available data on medium scale industries were collected.

Digitized maps of the land use, terrain features and transport paths of the study region, available with the GIS section of EPTRI were utilized for identifying the uniform terrain. Formats used for collection of information are shown below:

Format-I

Selected Data Collection Format for Meteorological Parameters:

Sl. No	Date and Time	Wind speed (m/s)	Wind Direction (Degrees)	Ambient Temp. (^oK)	R.H. (%)	Stability (1-6)	Mixing Height (mts)	Rain fall (mm)	Cloud cover (Octas)

Format-II

Data Collection Format for Emission Sources:

S.No.	Stack location	Stack Height (m)	Stack Diameter (m)	Stack gas temp. (K)	Stack gas Velocity (m/s)	Flow rate (m^3/s)	Pollution Conc. (mg/m^3) SPM SO_2 NO_x

Format-III

General Data Collection Format for a particular location:

S.No.	Reference Location	AAQ St. Loc. code	Date and Time	Met. Details	Emission Details	AAQ	Type of the area	Add. information

1.3 Air Quality Modeling for the Study Region

Visakha city airshed area is the study region. This falls in between Kailasa, Yarada and Simhachal hill regions on three sides and sea on the fourth side. The region is at an elevation of 20 MSL.

One of the important inputs to the model is the emission from industries. These vary depending on the production capacity, which varies depending on a number of factors. Under many circumstances, no industry is expected to exceed the limits prescribed in the consent. Hence the emissions permitted as per consent conditions for all major industries were utilized as input. These inputs data for SO_2, SPM and NO_x in respect to the 8 major industrial units (Unit 1 to Unit 8) are summarized in *Table A 2.1*.

The particulars of stack of major industries in the study area are compiled and given in *Table A 2.2*. Other inputs such as vehicular sources is presented in *Table A 2.3*.

Table A 2.1 : Permissible Air Pollution Loads of Major Industries in Visakhapatnam, as per consent

Industry *	SO_2	SPM	NO_x
Unit 1	86.805	10.7175	45.833
Unit 2	32.407	12.499	--
Unit 3	5.6596	10.694	17.696
Unit 4	19.05	39.583	--
Unit 5	10.995	--	--
Unit 6	3.819	--	--
Unit 7	168.054	321.2942	96.064
Unit 8	--	0.1504	--
Total	**326.789**	**394.937**	**159.593**

Source : APPCB, ZO, Visakhapatnam

***** (The name of the eight major units of the area have been coded as unit 1 to unit 8 for the purpose of this publication).

Table A 2.2 : Stack Details of Major Industries in Visakhapatnam V

Industry	Stack No.	Stack ht (mts.)	Stack dia (mts)	Velocity (m/s)	Temp (°K)	SO_2 (g/s)
Unit 1	1	60	2.5	8	503	12.9
	2	60	1.6	7	5.2	3.7
	3	60	1.3	7	510	5.4
	4	60	3.0	7	449	5.4
	5	80	2.3	6	448	22.7
	6	60	2.5	7	449	36.7
Unit 2	1	69	1.9	10	473	16.2
	2	43	0.99	10	473	16.2
Unit 3	1	30	3.5	10	353	3.5
	2	30	3.7	10	373	2.1
Unit 4	1	35	5	15	369	19.1
Unit 5	1	33	1.0	10	478	1.75
	2	25	0.6	10	478	1.1
	3	30	1.6	10	623	0.3
	4	30	0.6	10	623	7.8
Unit 6	1	40	0.37	5	573	3.82

Since the problem in Vizag is only with excess SO_2 predictions have been carried out for SO_2 levels and the output results showing maximum concentrations predicted using ISC3 model is presented in *Table A 2.4* and *A 2.5* The reference point is taken as Mindi.

The monitored values (actual values) during the winter season in various parts of the city are available with APPCB under NAAQM project. Some data is also available in EIA reports prepared by some of the industries in the city This data is collected and presented alongwith predicted values in the *Table A 2.6.*

Table A 2.6

Location	Actual Values (Avg.)	Actual values (peak)	Predicted values
Mindi (N1)	25	84	6.8
P. Barracks (N2)	17	126	65.2
Marripalem (N3)	15	46	14.1
HPCL (4)	10	52	66.9
ESI (5)	12	64	129.1
Central Warehousing Center (6)	51	63	93.5

From the above it is seen the actual values are much lower than the predicted values. This may be either due to some major factories not working at full production levels or some industries not working due annual shut downs.

Since the actual values are far below the permissible levels the predicted values are used for demonstrating the use of “Roll back model”. For this purpose irreducible background level concentrations are required. This is calculated by running the ISC3 model without considering industrial emissions. These are presented alongwith data obtained in the *Table A 2.7*.

Table A 2.7

Location	Excluding Ind. Emissions
Mindi (N1)	6.8
P. Barracks (N2)	23.2
Marripalem (N3)	8.2
HPCL (4)	11.6
ESI (5)	12.3
CWC (6)	22.0

The irreducible concentration is 23.2 ug/m^3 and the maximum concentration is 129.1 ug/m^3 and the National Standard for SO_2 is 120 ug/m^3 for industrial area.

Using the Roll Back Model,

$R = 100 \times (129.1 - 120) / (129.1 - 23.2) = 8.6$

From this it seen that the emissions from each source are required to be reduced by 8.6% during winter.

The revised emissions

S.No.	Industry Name	Stack No.	SO_2 (g/s (Existing)	SO_2 (g/s) (Proposed)
1.	Unit 1	1	12.9	11.8
		2	3.7	3.4
		3	5.4	4.9
		4	5.4	4.9
		5	22.7	20.7
		6	36.7	33.5
2.	Unit 2	1	16.2	14.8
3.	Unit 3	1	3.5	3.2
		2	16.2	14.8
4.	Unit 4	1	19.1	17.5
5.	Unit 5	1	1.75	1.6
		2	1.1	1.0
		3	0.3	0.2
		4	7.8	7.2
		2	2.1	1.9
6.	Unit 6	1	3.8	3.5

Predicted GLC's of SO2 for Visakhapatnam Air Shed

Location	Revised GLCs
Mindi (N1)	6.8
P. Barracks (N2)	61.6
Marripalem (N3)	13.4
HPCL (4)	62.6
ESI (5)	11.9
CWC (6)	87.6

From this, it can be seen that with the reduction of 8.6%, the ground level concentrations meet the standards.

The next step is to examine whether the suggested reduction can be obtained from all the industries.

The ambient air quality emission studies for SO_2 emissions, carried out by NEERI during April – May 2002 are presented in *Table A 2.8*.

Table A 2.8

Ambient Air Quality Status _ Visakhapatnam
Summer Season (April - May 2002)

SO_2 Concentrations

S.N	Site Name	Min	Percentile Values						Max	Arithmetic		Geometric	
			10	30	50	70	90	95		Mean	S.D.	Mean	S.D.
1.	Divisional Fire Office	6	6	11	29	41	60	89	102	32.0	25.7	22.2	254
2.	Hi Pallet Ltd.	6	6	20	38	50	75	98	105	39.8	29.2	27.9	261
3.	Kancharlapalem	6	6	13	18	20	28	33	45	18.1	9.8	15.4	183
4.	Mindi	6	6	6	6	6	12	26	32	9.1	6.7	7.8	164
5.	Naval Park	6	6	6	8	14	32	38	59	14.6	12.8	11.2	199
6.	Police Barracks	6	6	6	25	30	56	79	88	26.8	23.6	18.0	258
7.	Port House Colony	6	6	6	6	15	58	63	105	20.4	25.2	12.0	260
8.	Port Office	6	6	17	32	61	99	110	156	46.6	39.8	30.3	281
9.	Seethammadhara	6	6	6	12	20	30	68	127	20.9	26.1	13.6	236
10	Srihari Puram	6	6	6	6	8	34	36	41	11.7	11.1	8.9	197

Table A 2.3 : Vehicular Emissions in Visakhapatnam

S.No	Category of vehicles	Registered vehicles	Vehicles on Road	Emission factors		Emissions			
				CO (g/km)	HC (g/km)	CO (TPD)	HC (TPD)	NO_x(TPD)	PM(TPD)
1.	**TRANSPORT**								
a.	(APSTRTC, Bus Service)	872	872	249	3	1.302768	0.156960	1.8969	0.062522
b.	Private	1008	985	24,9	3	1.471590	0.177300	2.14237	0.07062
2.	**GOOD CARRIAGES**								
a.	Good Vehicles	5875	5406	32.6	3.7	10.574136	1.200132	11.75805	0.387610
b.	Medium goods vehicles	1538	1447	24.9	3	2.161818	0.260460	3.147225	0.10374
c.	Light vehicles	909	843	17.3	2.7	0.875034	0.0364176	1,833525	0.06044
d.	Three wheelers	1307	1152	15	10	0.518400	0.345600	0.09802	0.000264
3.	**TRACTOR TRAILORS**								
a.	Heavy vehicles	365	314	32.6	3.7	0.614184	0.069708	0.68295	0.022513
b.	Medium vehicles	1266	1135	24.9	3	1.695690	0.204300	2.468625	0.081436
c.	Light vehicles	396	278	17.3	2.7	0.288564	0.0120096	0.60465	0.01993
4.	**CONTRACT CARRUAGES**								
a.	All India transport buses	8	5	24.9	3	0.007470	0.000900	0.010875	0.000358
b.	Maxi cabs (upto 13 seaters)	147	141	17.3	2.7	0.146358	0.0060912	0.306675	0.010109
5.	**TAXI CABS**								
a.	Auto rickshaw	12911	11270	15	10	5.071500	3.381	0.807075	0.002592
6.	Private service vehicles	500	383	24,9	3	0.572202	0.068940	0.833025	0.027461

7.	School buses	196	169	24,9	3	0.252486	0.030420	0.365575	0.012117
8.	**VEHICLES NOT COVERED BY LIFE TAX**								
a.	Tractors	213	19	24.9	3	0.028386	0.003420	0.041325	0.001362
b.	Omni buses	885	75	24.9	3	0.112050	0.013500	0.163125	0.005377
c.	Rigs	20	1	32.6	3.7	0.001956	0.000222	0.002175	0,000071
d.	Crabes	207	19	32,6	3,7	0.037164	0.004218	0.041325	0.001362
e.	Road rollers	4		32,6	3,7				
f.	Fire engines & Fire tenders	14	2	24.9	3	0.002988	0.000360	0.00435	0.000144
g.	Loaders	164	9	32.6	3.7	0.017604	0.001998	0.019575	0.001363
h.	Others	41	4	24.9	3	0.005976	0.000720	0.0087	0.00028
9.	**CARS (FOUR WHEELERS)**								
a.	Motor cars	19029	19029	17.3	2.7	19.752102	0.8220528	13.796025	0.025.12
b.	Jeeps	2113	2113	17.3	2.7	2.193294	0.0912816	1.531925	0.004859
10.	**TWO WHEELERS INCLUDING SIDE CARS**								
a.	Upto 60 cc	71960	71960	15	10	32.382	21.588	5.2171	0.01655
b.	Beyond 60 cc	177403	177403	15	10	76.831350	53.220900	12.86171	0.040802
	Total					**156.916854**	**81.6969108**	**62.539775**	**0.9590**

APPENDIX-III

1.0 Modelling Study of the Self purification Capacity of the River Yamuna

1.1 The Study Area

The uncontrolled addition of wastes into the River Yamuna has deteriorated its water quality to such an extent that the river stretch between Wazirabad and Okhla in the Union Territory of Delhi was classified in the 1978-79 study as 'E' i.e. suitable for irrigation, industrial cooling and controlled wastewater disposal, even though the designated-best-use for the river stretch is bathing This warrants the river water quality to be improved from Class 'E' to Class 'B', the designated class for bathing water.

1.2 The Study Details

The two pollutants which have caused this degradation of water quality are coliform bacteria and organic matter. Both of these are added to the river in varying quantities through 17 major drains. The observations and analysis presented in the following sections estimated the self-purification capacity of the river with respect to these two parameters.

Death rate of coliform bacteria. The rate of decrease of coliform count in flowing water is described by a first-order equation:

$$N = N_o \, .e^{-k_b t} \qquad (1)$$

Where, N_o and N are coliform counts initially and water travel time t, respectively, and where Kb is influenced by a change in temperature of the river water according to the following equation:

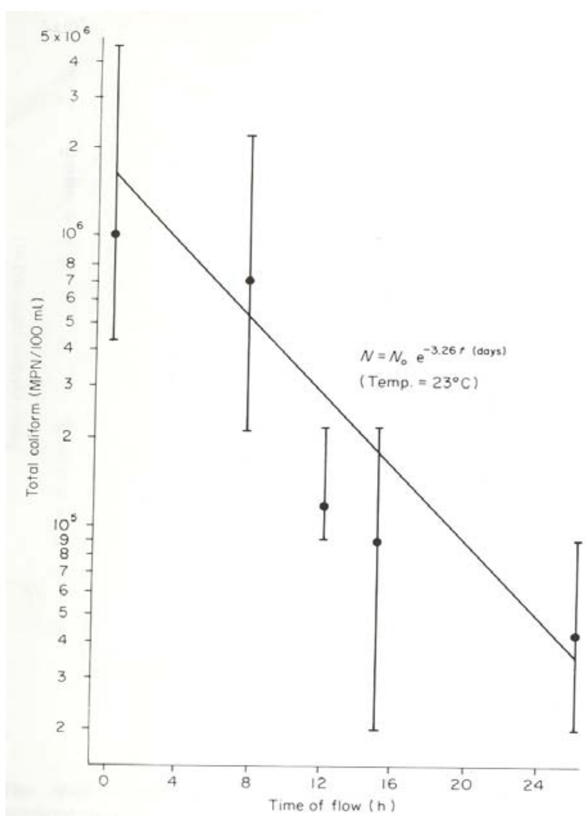
$$K_b(T_1) = K_b \, (T_2) \, (1.036)^{T_1 - T_2} \qquad (2)$$

Where, $K_b(T_1)$ and K_b (T_2) are decay rate constants at temperature T_1 and T_2 are decay rate constants at temperature T_1 and T_2 C, respectively. Its value can be determined from the slope of a plot of log number of bacteria versus time of flow on the basis of the above equation.

The stretch of the river between Wazirabad and Okhla receives microbial inputs from a number of both point and non-point sources.

Theoretically it is possible to analyse such a situation on the basis of Eqn. (1), if the inputs are quantified. Considering the limitation of method of coliform determination, sampling errors and uncertainties in quantifying, non-point inputs, conclusions from analysis of dta from the stretch of the Yamuna between Wazirabad and Okhla will have low reliability. It was, therefore, decided to study the death rate of the organisms in Gurgaon Canal which receives water from the Yamuna through Agra Canal about 5 km downstream of Okhla Barrage (Delhi).

Figure A 3.1 and A 3.2 show the bacterial counts plotted according to Eqn. (1) and curves of best fit. The death rate constant for total and faecal coliforms are determined as 3.26 and 2.47 per day respectively, in the 14.6 km stretch of the Gurgaon Canal. While considering the death rate constant for a faecal coliform it is seen that the coliform MPN concentration decreases by one order of magnitude in log scale for each day travel time. Therefore, if the concentration in the Yamuna is taken as 106/100 ml after confluence of the Najafgarh drain (the largest sewage input drain) on the basis of 1978-79 reports, it is expected to decrease to about 105/100 ml at Okhla (the downstream station in about one day's travel). The coliform count will not decrease to an acceptance level at Okhla (less than 5000/100 ml for Class C rivers) even if the microbial load through Najafgarh drain is curtailed by 70%.



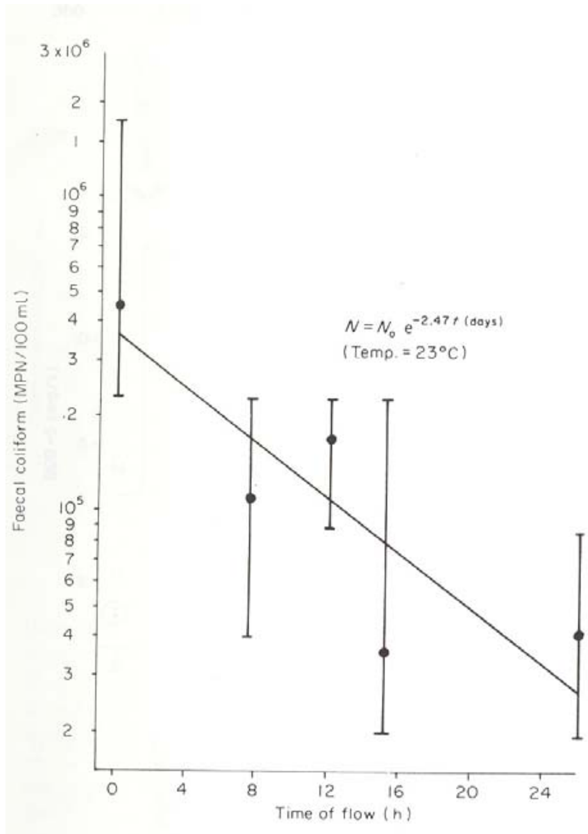


Fig. A 3.1 & A 3.2 : Disappearance of fecal coliforms in the Gurgaon

BOD and DO profiles. Aerobic decomposition of organic matter in the river exerts a demand on its oxygen resources. The BOD and DO profiles respectively are given by

$$L = L_0 e^{-k_1 t} \qquad (3)$$

$$D = \frac{K_1 L_0}{K_2 - K_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + D_0 e^{-k_2 t} \qquad (4)$$

Where L_0 and L are final BOD in mg/l initially and after travel time t, respectively, K_1 and K_2 are deoxygenation and reaeration rate constant per day, respectively, and D_0 and D are oxygen deficits in mg initially and after travel time *t*, respectively.

The deoxygenation constant for the river is evaluated from the slope of an arithmetic log plot of Eqn. (3) as shown in Fig. A 3.3. It shows the observed BOD_5 values using 75% of drain BOD_5 as non-settleable BOD_5, input to the riverine system.

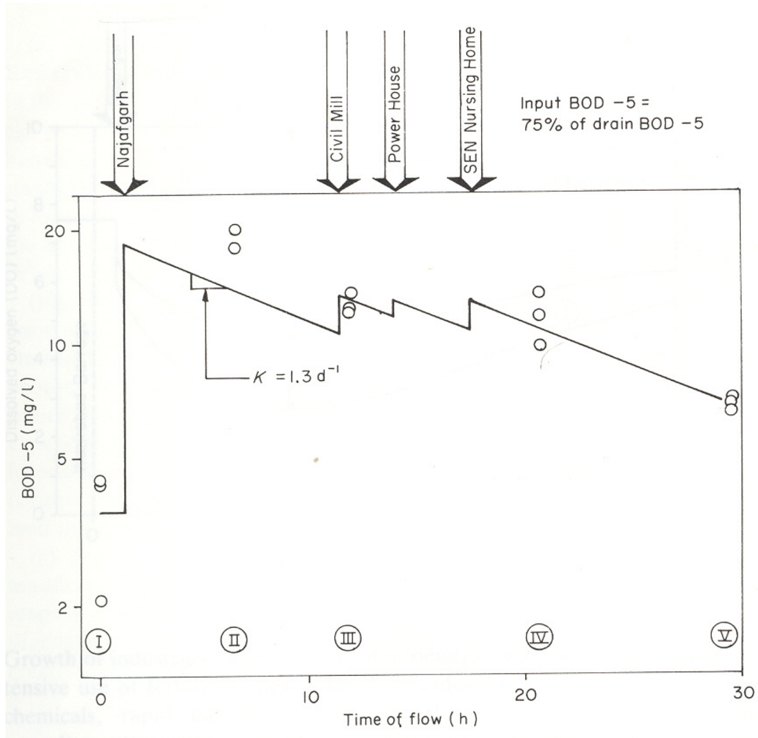


Fig. A 3.3 Observed (O) and calculated (-) BOD-5 profile at five sampling stations between Wazirabad and Okhla

The river deoxygenation rate is equal to 2.8 according to :

$$K_2 \quad \frac{294\,(D_{L(T)}\,U)^{1/2}}{H^{3/2}} \tag{5}$$

Where, ($D_{L(T)}$ is the diffusion constant at temperature T°C (m^2/d), U is average velocity (m/s) and H is average depth (m). The diffusion constant is given by :

$$D_{L(T)} = 1.76 \text{ X } 10^{-4} \text{ X } 1.037^{\,T-20}\ m^2/d \tag{6}$$

The river deoxygenation rate constant varies with temperatures as :

$$K_{T1} - K_{T2}(1.056)_{T - T2} \tag{7}$$

Where, K_{T1} and K_{T2} are deoxygenation rate constants at temperature T_1°C and T_2°C respectively.

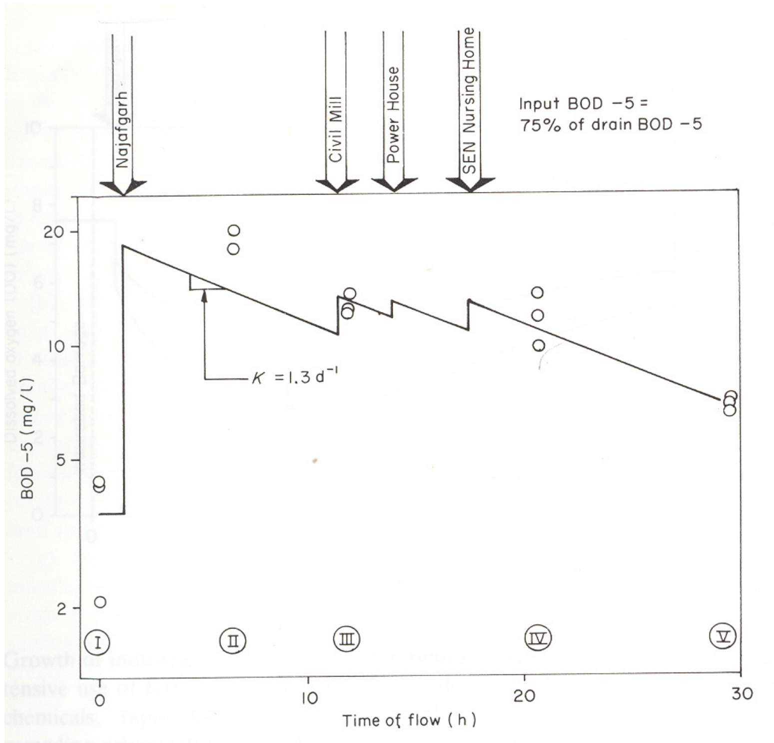


Fig: A 3.4 Observed (O) and calculated (-) BOD-5 profile at five sampling stations between Wazirabad and Okhla

From a laboratory simulation, the ultimate BOD_5 value (Lo) was calculated and found to be 8.6 mg/l. Applying the deoxygenation rate, reoxygenation rate and ultimate BOD value in Eqn. (4) (Fig. A 3.4) is generated. It shows the observed dissolved oxygen (DO and the calculated DO profile. Figure 13.5 shows the DO profiles at 30^{o}C for wastewater discharge from Najafgarh drain only, for 50 and 70% diversion of drain wastewater (curve 1 and 2 respectively). It is seen that although a 50% diversion may be adequate to improve the water quality during the winter season, during summer and critical DO concentration is likely to go below 3 mg/l. 70% containment of the flow in Najafgarh drain, however, would result in a DO profile above 4 mg/l.

It is, therefore, concluded that MINAS could be stricter and can be considered as location-specific by optimization of pollution load in terms of assimilative capacity.

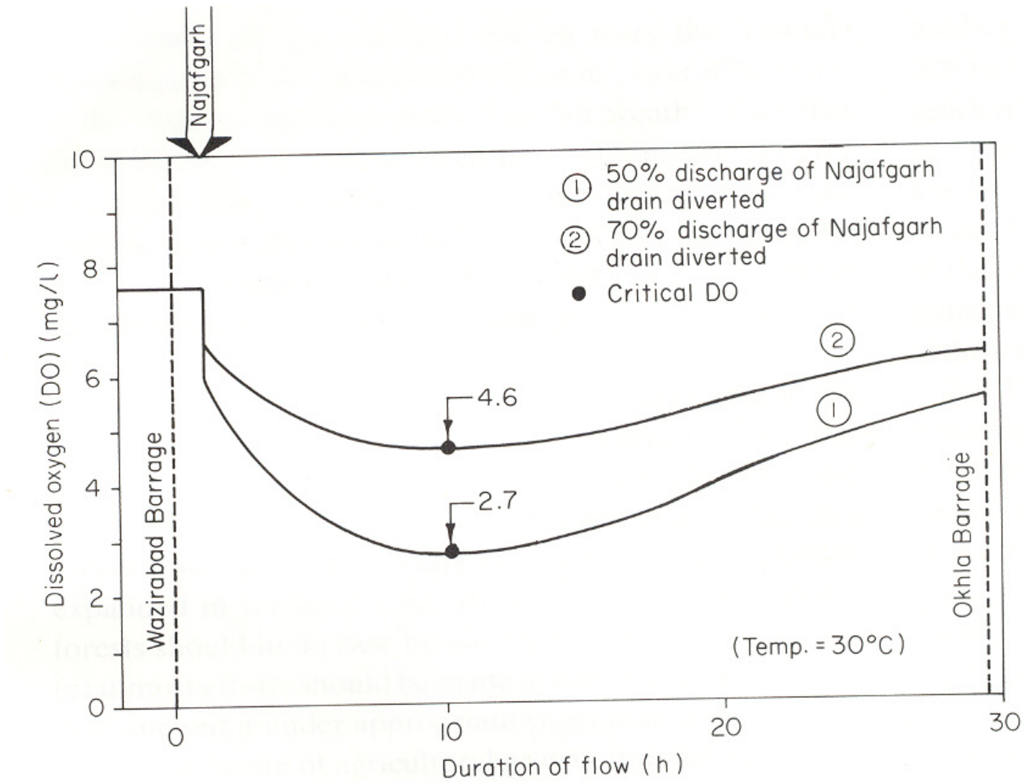


Fig. A 3.5: Predicted DO profiles for reduced BOD loads at 30 °C