Pearl River Estuary Pollution Project (PREPP) –

An Integrated Approach

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Introduction

The Pearl River Delta region, being part of the South China Sea, has experienced tremendous growth in the past couple of decades. The increased social and economic activities brought in serious deterioration of the water quality due to pollutants discharged into the Pearl River estuary system. The objectives of the Pearl River Estuary Pollution Project (PREPP) are to study the relative flux of toxic pollutants, sediment and nutrients entering Hong Kong waters from the Pearl River. The outcome of the study is to provide information for international scientific community, Hong Kong and Chinese environmental policy makers and the Hong Kong public community so that a concerted effort will be made to reduce the impact of the Pearl River pollution on Hong Kong water quality and ecological components of the ecosystem.

Background

The Hong Kong waters are seriously disturbed by industrial, agricultural and domestic pollution. From time to time, the coastal environment of Hong Kong has been the site of red-tide outbreaks and other harmful algal blooms; there have also been instances of fish kills and disruption of fish farming activities. These significant and unpredictable events can be regarded as marine environment crises. They indicated that the balance of the natural marine ecosystem is being perturbed. In view of this, the Hong Kong has laid down policy and legislation to address the quality of the environment with regard to air quality, water quality, noise, solid waste disposal.

Pearl River, being one of the largest rivers in the world, contributes to the marine pollution in Hong Kong. The Pearl River catchment covers 453,690 km^2 and annual nutrient loading in 1989 was estimated at COD (12.05 billion tonnes) and total ammonia, nitrate and nitrate of 45.3 tonnes per year. The Chinese governmental agencies at the several levels have monitored basic water quality parameters in the Pearl River and coastal area since early 1980 as part of the National Monitoring Network of Marine Environmental Pollution (Dong and Zen, 1993). In Hong Kong, the Environmental Protection Department has an extensive water quality monitoring network throughout about changes in parameters including e.g. nutrients in the water column and heavy metals in the seabed. Broom and Ng (1995) used the WAHMO model, a hydrodynamic model to investigate the influence of the Pearl River on Hong Kong waters. The concluded that "water quality in Hong Kong is heavily influenced by polluting loads, discharge and hydrodynamic characteristics of the Pearl River".

An Integrated Approach

In 1998, the Hong Kong University of Science & Technology proposed a 3-year integrated study of the water quality of the Pearl River Estuary. This interdisciplinary project would integrate marine biology, chemistry, hydrology, environmental sciences together by

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deploying various cutting edge technologies for measurements, processing and information dissemination. A schematic of the system is shown in Fig. 1.

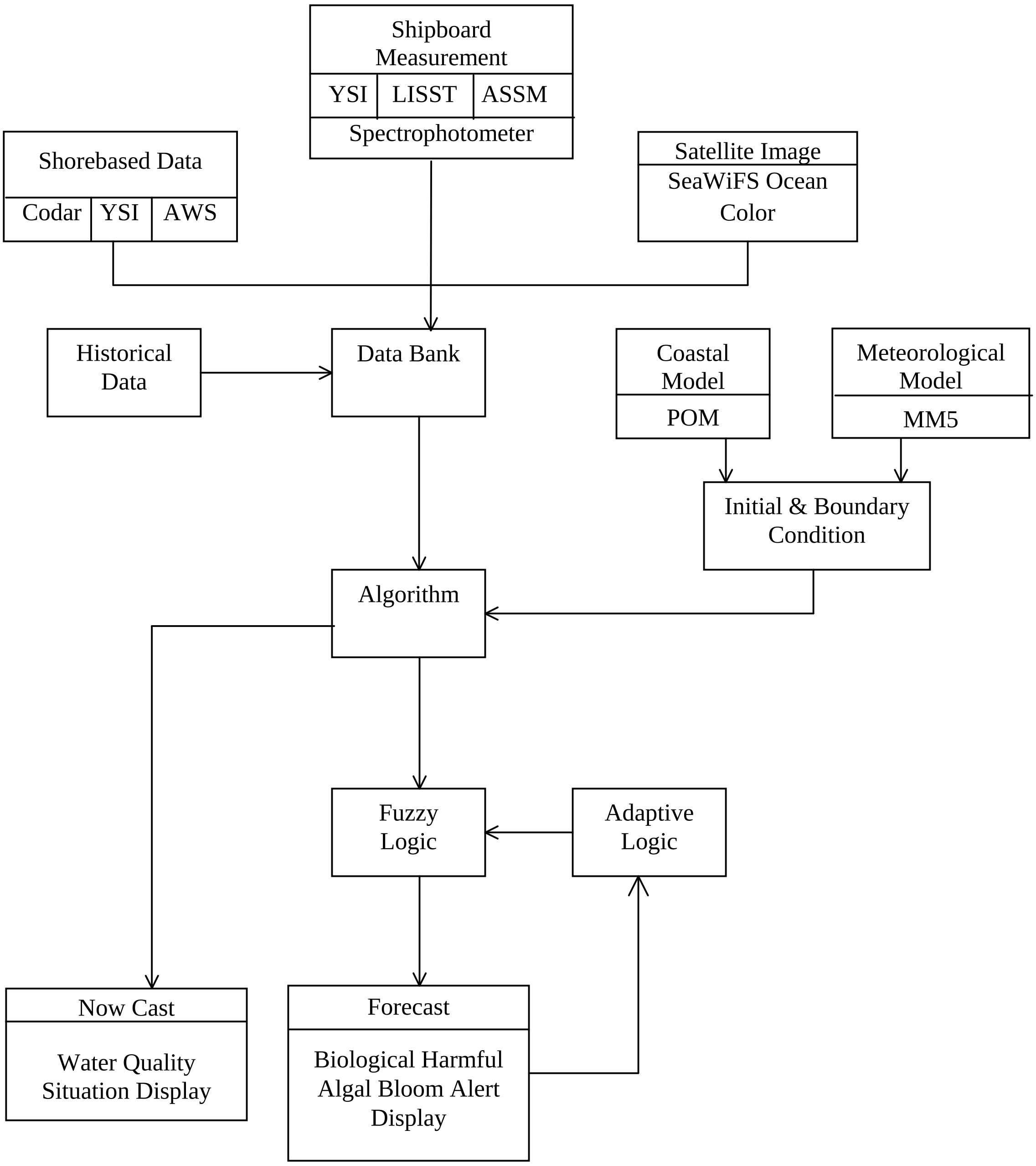

Fig. 1 Schematic of the PREPP

The schematic illustrates the relationships of the various components such as the data sources, the mathematical models, the algorithm and the output (the now cast display and the forecast display). In order to give a now cast display, the system must have the capability and the infrastructure to ingest real time data from the various sources. Can one imagine that the now cast will give information that is of yesterday ? So the real time capability becomes a critical requirement of the infrastructure. With the availability of the real time data as the boundary condition of the mathematical model, the 'predictive logic' of the system can then forecast hazardous events such as the harmful algal bloom alerts.

Measurement

- **Shorebased Data**

In order to understand the coastal situation of the South China Sea, a network of instruments has been installed in various locations. Shorebased SeaSonde HF (high frequency) radars for ocean surface current mapping have been procured from the CODAR Ocean Sensors Ltd. The Codar radar measures the ocean current on the horizontal surface area and output current display as shown in Fig. 2.

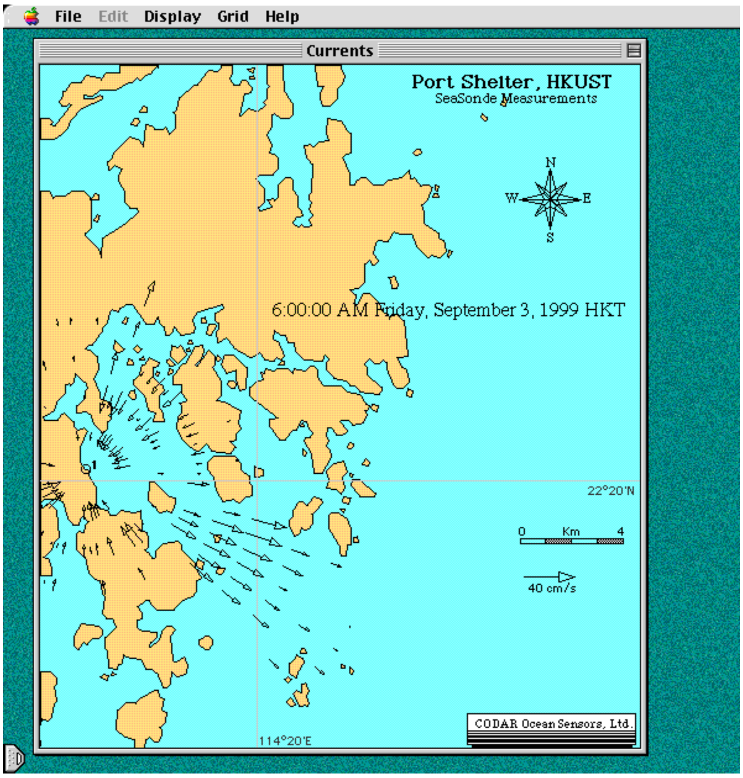

Fig. 2   Codar output indicating the ocean current

Our Codar radars were configured to a preset resolution of 3 kilometers and 32 grid range cells giving us a coverage of 96 Km. We have three sites (1) Castle Peak, Tai O, Macau for the Codar equipment. The Macau and Castle Peak sites were chosen to have an overlap coverage so that the radial current from the two sites will form a total vector current map at real time on an hourly basis. The Castle Peak site also serves as the central site which provides communication link with the two remote sites.

While the Codar radars allow us to understand the current of a surface area, we also deploy other equipments for the vertical distributions and other parameters. We have acquired Multi-parameter water quality monitor from the YSI Massachusetts and the configuration of our YSI monitoring system allow us to install various sensors for measuring different parameters. These sensors include (1) dissolved oxygen probe, (2) pH probe, (3) turbidity probe, (4) chlorophyll probe to measure these parameters at three different locations (1) Hu Men (2) Heng Men (3) MoDao Men.

Apart from the above, there are Automatic Weather Stations (AWS) installed in five strategic locations extending to the boundary of China, namely at (1) the campus of HK University of Science & Technology (2) Castle Peak (3) Hu Men (4) Heng Men (5) MoDao Men. Among the five sites, site (1) and (2) are located in Hong Kong while the other three are located in Guangdong province of China. The sensors mainly ingest wind speed, wind direction, humidity and temperature which are factors relating to the biological and chemical conditions of the coastal environment. The locations of these shorebased sensors are shown in Fig. 3.

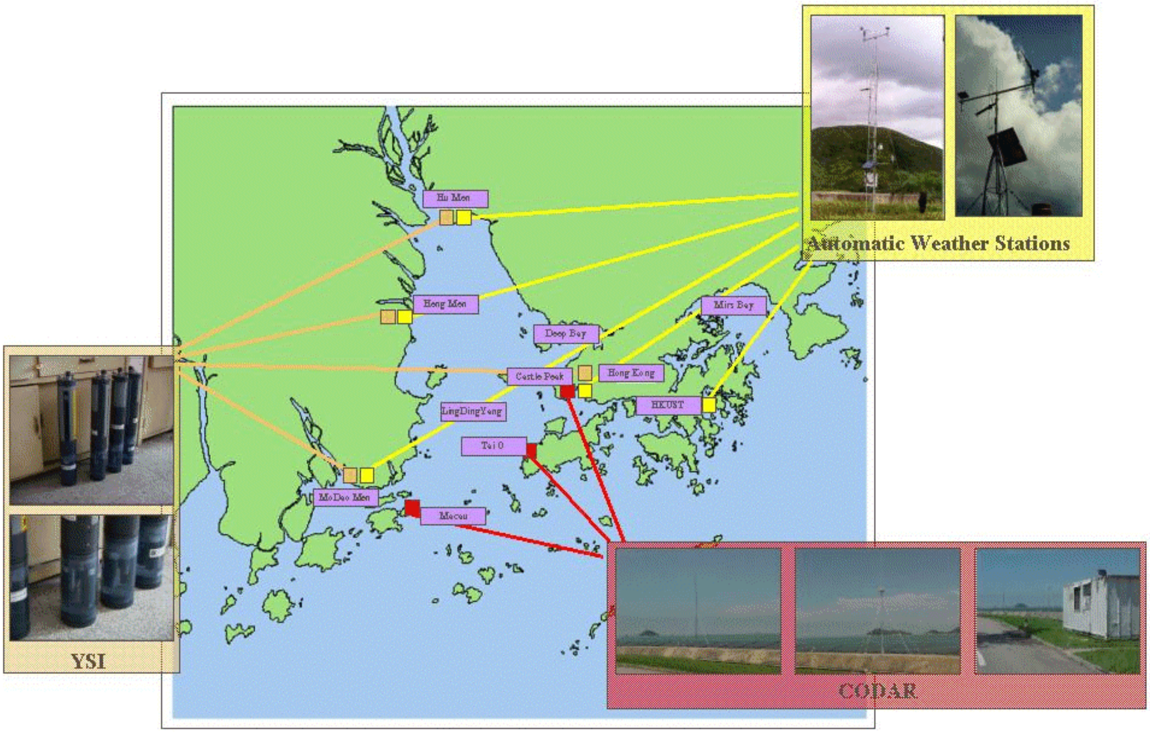

Fig. 3 Geographic distribution of our equipment

- **Shipboard Measurement**

In order to validate and complement the shorebased data, shipboard measurements were conducted for the wet and dry seasons during the project period. We have chartered a ship with a displacement of 996 tons with a cruise team of 40 people. The ship has various types of onboard measurements. The cruise last from 10-15 days taking samples from over one hundred locations along the Pearl River.

The multi-parameter water quality monitors from the YSI Massachusetts were deployed in the cruise for collecting parameters such as water temperature, salinity, dissolved oxygen, pH value, turbidity, chlorophyll. While the shorebased equipment can only take stationary measurement, the shipboard equipment provides measurement from various depths and various locations of the coastal area. There were other equipments such as the Submersible laser-scattering instrument (LISST-ST) that were used to measure the particle size distribution, settling rate and pressure. The acoustic suspended sediment monitor (ASSM-2) was used to measure the vertical suspension sediment concentration profile in the water column. The spectrophotometer in the water column also measured nutrients (NO_3^{-}N, NO_2^{-}N, NH_3-N, DTN, SiO_3^{3-}Si, PO_4^{3-}P, DTP) in the water.

- **Satellite Images**

Satellite data acquisition system was installed to collect real-time satellite image of the ocean color and sea-surface temperature. Our High Resolution Picture Transmission (HRPT) station was installed and became operational on November 21, 1994 for the reception of the SEA-viewing WIde Field-of-view Sensor (SeaWiFS) ocean color data and Advanced Very High Resolution Radiometer (AVHRR) transmissions from the NOAA polar orbiting satellites. There are also plans to acquire satellite images from the Chinese HY-1 satellite that will be launched sometimes in the year 2000.

Processing

Data from both the shorebased measurement and the shipboard measurement were integrated together with historical data that we have obtained from other government environmental agency and exported to a database, which is a *real-time* GIS (Geographical Information System) based system.

Most of the current GIS applications are static or associated attributes are to be remained constant over time. In the applications, the need to make a timely and appropriate decision corresponding to the data that are collected and updated responsively is undoubtedly important. Thus, the GIS system was designed with a web-based architecture to fetch real-time data for a dynamic decision support system and fuzzy algorithm. Conceptually, our system can be seems as a real-time GIS or an application of integrating GIS in a real-time setting. The Active Server Page, Perl script and C/C++ are selected for implementing the real-time GIS which was dynamically linked to an external database and web server. Scientists or operators can use our GIS system for data ingest monitoring through internet browser. Fig. 4 illustrates the real-time data ingest monitoring screens.

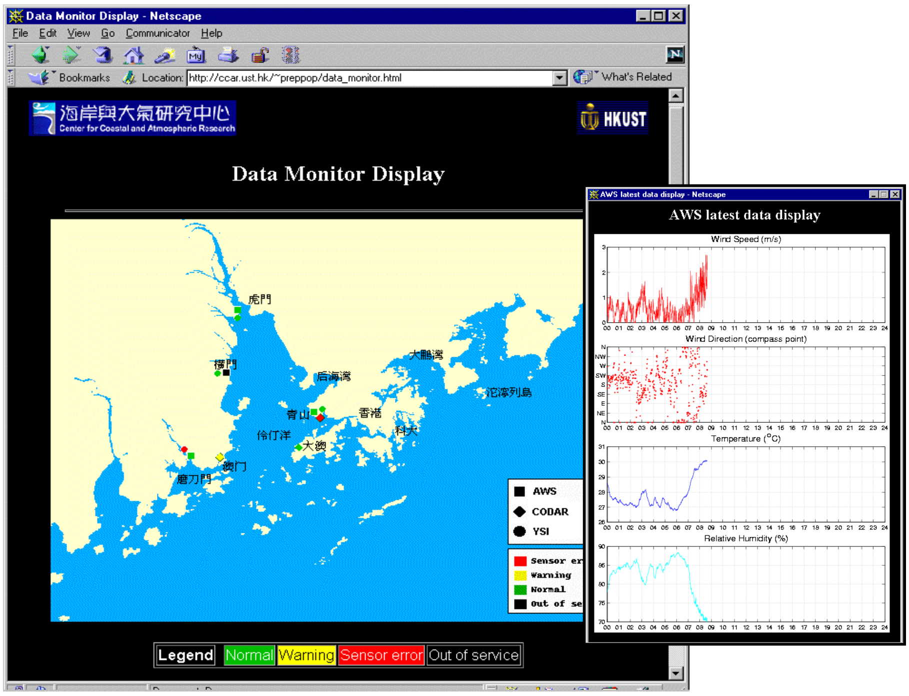

Fig. 4 GIS data ingest monitoring display

As for the real-time data management of the in-situ measurement data ingest process, the GIS has to match several system requirements. The system configuration should be joined with real-time data acquisition interface and a real-time kernel. The framework of the integrated real time dispatching/fetching information system is exhibited in the following figure.

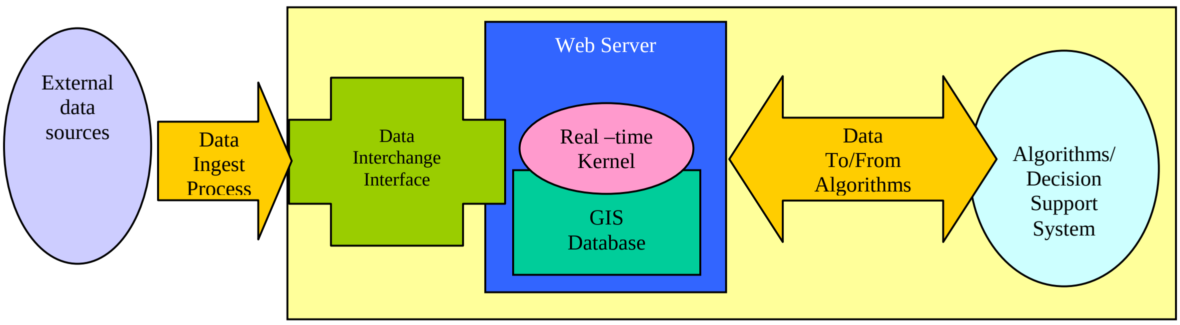

Fig. 5 System architecture

In Fig. 5, the external data source, data interchange interface, real-time interface (for monitoring and reporting), GIS software, web server, data repository are the principal components. External data source includes historical data, in-situ measurements data ingest and simulated data from the POM models. On site data are multiplexed with data-logger equipment and transmitted to our web server via dial-up or internet line and incorporated into the data repository. The data interchange interface is to convert the ingest data into a pre-defined format and to ensure the data quality.

Information dissemination

Once the GIS is invoked, it updates and fetches data to our fuzzy algorithm and decision support system to classify the water quality. The results are displayed on our web interface for monitoring operation. In the end, the GIS database is then automatically invoked again to update the results and store the data for adaptive logic system at the back end. Fig. 6 illustrates the GIS interface design for water quality display in different regions.

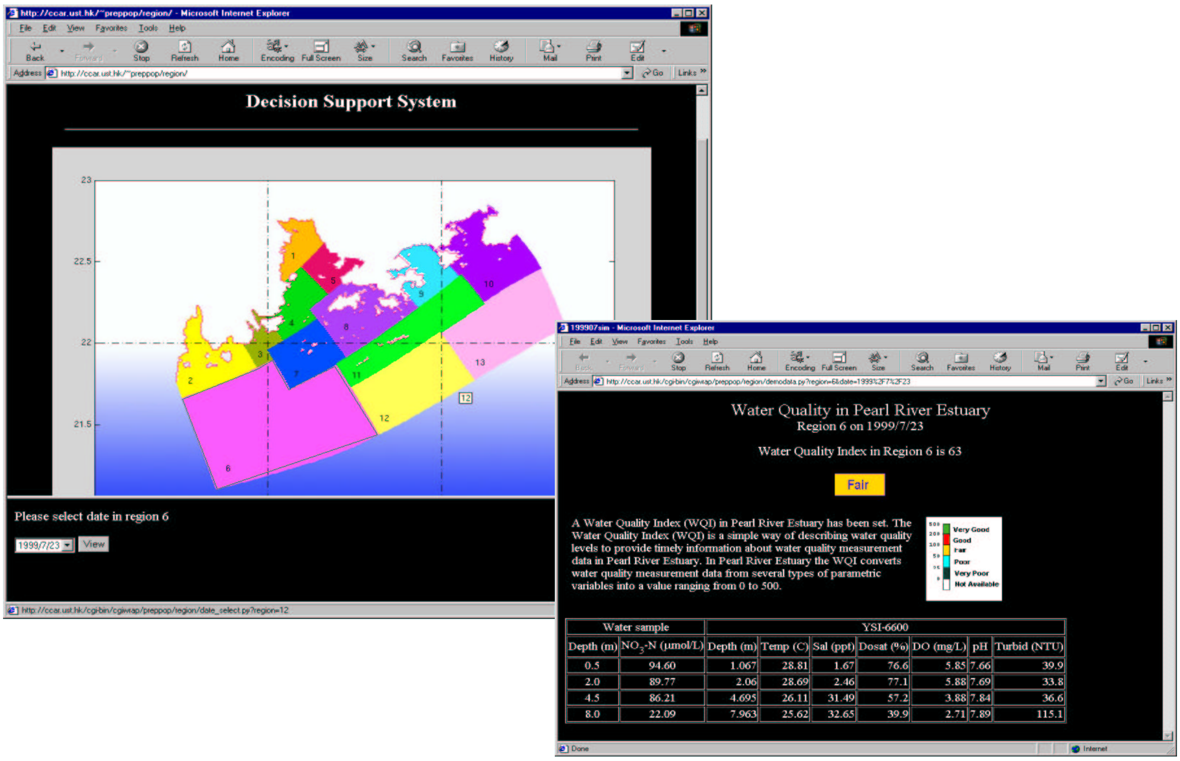

Fig. 6. GIS interface design for water quality display in different regions.

Algorithm

The core of the processing is to define a set of algorithm and display water quality situation; this is the now cast output which is to tell the scientists what is currently happening to the water quality. The software will compare the various parameters that affect the quality water quality of the same region with the previous years. The algorithm is a rule-based and case-based reasoning. It uses a set of rules to obtain a preliminary answer for the given phenomena, it then draws analogies from cases to handle exceptions to the rules. Having rules together with case as not only increases the domain coverage, it also allow innovative ways of doing case-based reasoning. The same rules that are sued for rule-based reasoning are also used by the case-based component to do case indexing and case adaptation.

The sophisticated component is the forecasting of water quality which is basically a composite index of the various parameters. The ultimate goal of this index is to let the users of the system know whether the water quality is very good, average or poor. Since the user of this index will comprise of a big population including non-scientists such as fishermen, businessmen, policy makers, this index should reflect the science and yet comprehensible since it may affect the day to day decision of the users.

There are a number of indices for different purposes, as fishermen's concern and swimmers' concern are quite different. Therefore we need to have different indices for various user groups. Each index has a pre-defined set of scientific parameters, which are classified into different fuzzy sets. There are two types of fuzzy sets: (1) one is the scientific parameters and (2) the event related parameters such as seasonal and location. These sets are characterized by a membership function. The fuzzy logic is a set of algorithm (or rules) to define the relationship of these fuzzy sets with respect to the index. In other words, the parameters will contribute to a discrete value of the membership function which may be insignificant for any alert or warning, however, a composite of these discrete values will create an index which carries a meaningful message.

The adaptive logic is the fine tunning of the system. The initial set of algorithm is a good baseline. As time goes, the system has the "self-learning" capability to build new rules and relationship of parameters.

Summary

This paper has introduced an integrated approach as a solution to a pollution monitoring in the Pearl River Estuary. In this project, a sophisticated system has been developed to integrate various formats of data from different devices and scientific models. Without this infrastructure, the data will remain as ‘islands’ of data and fail to provide the real time capability. The objective of this project is to establish a common platform for water quality data ingest, a standard architecture to process the data and also a internet environment to disseminate the information which is useful to the industry, the scientific community, the policy makers and even to the general public.

Acknowledgement

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