BenMAP

Environmental Benefits Mapping and Analysis Program

Case Study: Mumbai

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Foreword and Acknowledgements

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BenMAP Case Study on Mumbai: Overview

The Environmental Benefits Mapping and Analysis Program (BenMAP) is primarily intended as a tool for estimating the health impacts, and associated economic values, associated with changes in ambient air pollution. BenMAP combines health impact functions, which relate a change in the concentration of a pollutant with a change in the incidence of a health endpoint, with estimates of air quality. BenMAP also calculates the economic value of health impacts.

BenMAP also serves as a Geographic Information System (GIS), allowing users to create, utilize, and visualize maps of air pollution, population, incidence rates, incidence rate changes, economic valuations, and other types of data.

BenMAP can thus be used for a variety of purposes, including:

- Generating population/community level ambient pollution exposure maps;
- Comparing benefits associated with regulatory programs;
- Estimating health impacts and costs of existing air pollution concentrations;
- Estimating health benefits of alternative ambient air quality standards; and
- Performing sensitivity analyses of health or valuation functions, or of other inputs.

A wide range of persons can use BenMAP, including scientists, policy analysts, and decision makers. Advanced users can explore a a variety of options, such as using the map querying features and exploring the impacts of different health impact and valuation functions.

In this case study, we would like to show you how to use BenMAP and apply it to a particular city, in this case Mumbai, India. Accompanying this document is a CD with which you can install BenMAP on your computer, following the installation instructions provided in the next section. The following sections of this case study provide step-by-step instructions detailing how to perform an analysis of Mumbai using BenMAP. Each problem set contains a related group of tasks, which will explain the basic BenMAP functions, and also some guidance on using BenMAP at a more advanced level. All of the problem sets use data that will be installed automatically on your hard drive when you install BenMAP. The dafault location for this *Sample Data* is C:\Program Files\Abt Associates Inc\BenMAP 2.2\Sample Data\Mumbai.

Introduction

Particulate matter levels in Mumbai have been at unhealthy levels for a number of years, and have regularly exceeded the ambient air quality standard. Other measured air pollutants, such as sulfur dioxide and nitrogen dioxide, are generally considered to be less of a problem, and ozone is not measured, as the levels are considered negligible.

In 2000 Mumbai moved to switch highly polluting vehicles to natural gas, and this likely contributed to a reduction in ambient particulate matter levels in the city. The movement of some industry outside of the city also presumably contributed as well. Other factors, such as increased population, have tended to increase ambient particulate matter levels. The net effect appears to be that ambient levels of particulate matter less than 10 microns in diameter (PM10) have held steady or in some cases declined over time.

If there has been a decline in PM10, then this would have contributed to a reduction in premature mortality, respiratory illness, and other adverse health effects of particulate matter. Using BenMAP and the available data, we will attempt to determine if there has been a change in PM10 concentration, where it might have occurred, and its potential impact on adverse health effects. In addition, we will estimate the economic consequences.

Prior to starting our analysis, we will briefly review all of the steps in the analysis – exposure estimation, calculating adverse health effects and valuing them – and the data required for each. We will then separately consider each of the steps in detail.

As part of this more detailed description, we will describe the data that we could locate and how we processed it for use in BenMAP. The data we gathered are not perfect. With additional time and resources, we would have been able to generate a more comprehensive set of data. Nevertheless the data represent a starting point, as well as a foundation that we can build upon in future analyses. In addition, we will discuss the strengths and limitations of the data, as it is important to understand where the greatest uncertainties might exist, in order to avoid misinterpreting the results of the analysis.

To provide an understanding of how BenMAP itself works, we will include detailed problem sets related to the particular step in the analytical process.

Components of a BenMAP Analysis

BenMAP analyses have three basic components:

- Estimating exposure to air pollution, and how this exposure has changed, or will change, due to policies, population change and other factors;

- Estimating the change in adverse health impacts potentially associated with this change in exposure; and
- Estimating the economic value of the health impacts. This component is optional.

Each component is discussed in detail below.

Calculating the Change in Pollution Exposure

In estimating the change in pollution exposure, we will begin with a discussion of the available particulate matter monitoring data for Mumbai. We will then describe how you can load the monitoring data into BenMAP. Finally, we will describe how we then use the loaded data to estimate how air pollution exposure has changed over time.

Available Air Pollution Monitor Data in Mumbai

In the case of Mumbai, since we are interested in the change in ambient PM10 levels over time, we need to first examine the available PM10 monitoring data. We were able to gather monitoring data from 1995 to 2004, from over 20 monitors located throughout the city. However, we could only gather a very limited amount of data from some monitors, requiring us to drop them from our analysis. Moreover, some monitors provided data for only certain years.

Several different monitoring networks exist in the city, using somewhat different collection methods and measuring different sizes of particulate matter. Some monitors have measured PM10 and others have measured total suspended particulate matter (SPM). Measurement of SPM is not as desirable as PM10, because the most serious adverse health impacts are associated with fine particle matter.

Ideally we would focus on monitors that measure only particles less than 2.5 microns (PM2.5), as it appears that the most serious adverse health effects are linked to PM2.5. This is not possible, however, as we only have PM10 and SPM data. The next best choice would be to focus on monitors that measure only PM10, since PM10 is more closely related to adverse health impacts than SPM. Unfortunately, the available monitoring data for PM10 is fairly limited, with no more than three monitors operating continuously from 1995 to 2004, and with the location of one of these monitors changing between 2000 and 2001 (Figure 1).

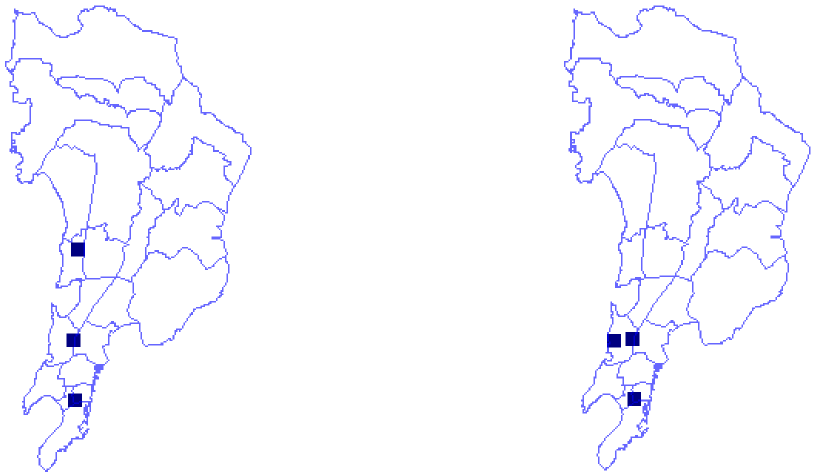
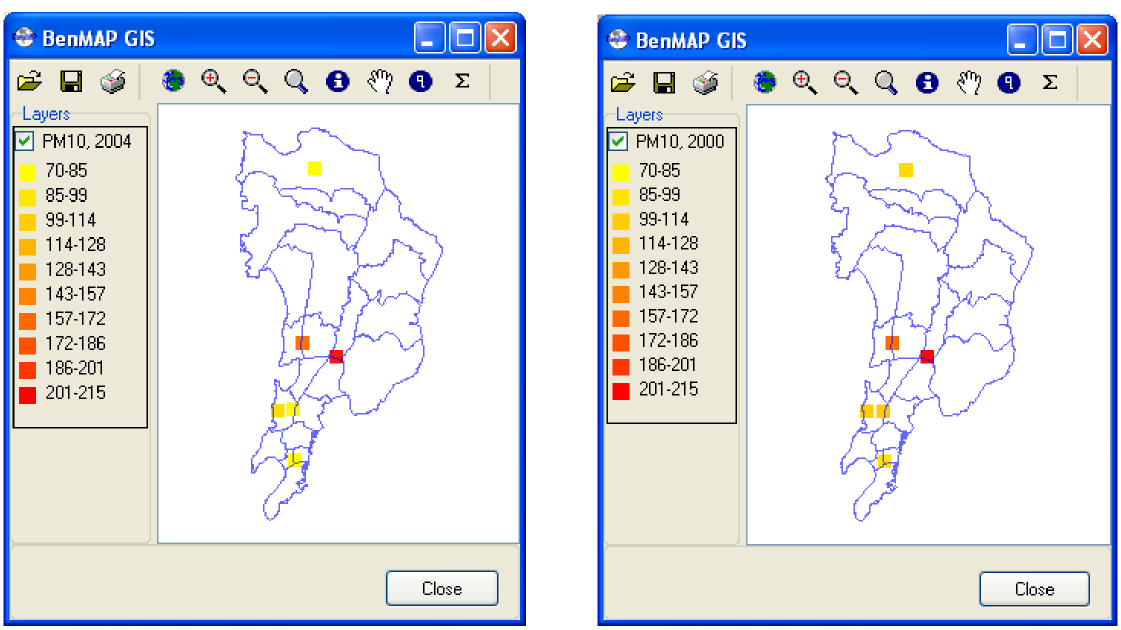


Figure 1. PM10 Monitor Locations in Mumbai: 1995-2000 (left map) and 2001-2004 (right map)

Because of the limited amount of PM10 monitoring data (only two monitors with data in both 2000 and 2004), we decided to include SPM monitor data. Since SPM is not directly comparable with PM10 monitoring data, we assumed a fixed fraction (50 percent) of SPM is comprised of PM10. The fixed fraction is based on an estimate that is on average roughly correct, though in any particular month it may be incorrect.

Figure 2. PM10 & SPM-Estimated PM10 Monitor Data for Mumbai in 2000 (left map) and 2004 (right map)



By adding the adjusted SPM we have increased the numbers of monitors from two to six, but this comes at the cost of using estimated PM10 for four of these monitors. More effort examining the PM10/SPM ratio is beyond the scope of this work, so it is difficult to say the impact that this might have on the analysis. Given additional time, we would want to include alternative assumptions about this fraction, in order to see how much impact this might have on the conclusions of our study.

This use of alternative assumptions at key points is sometimes referred to as a "sensitivity analysis." It is difficult to determine in advance which assumptions are going to be most important or influential in the study's conclusions, so it is important to keep track of our assumptions and to include as many as we can in a sensitivity analysis. However, time and resources are not always available to conduct a thorough sensitivity analysis. At the very least, we need to clearly report the assumptions that we are making, so subsequent researchers may evaluate which may be most important in determining our results.

Loading Monitor Data into BenMAP

The PM10 monitor data are in the file *Mumbai PM10-TSP Monitors.xls,* which is included in the *Sample data*. We have already formatted these data, following the instructions in the *Data Requirements* appendix at the end of this document. To load these data into BenMAP, you need to first create a *Setup*.

A BenMAP *Setup* is a collection of all the different types of data necessary to conduct analyses for a particular geographic region. A *Setup* typically contains grid definitions (electronic maps), air pollution data, population data, health impact functions, and more. BenMAP *Setups* (and subsets of *Setups*) can be imported and exported to facilitate the sharing of data. This saves users from having to enter the data in BenMAP, a fairly complicated process, more than once. Note that a *Setup* is different from a *Configuration*, which is specific to each model run. You can run BenMAP hundreds of times with different configurations using the same *Setup.*

Y For practice loading grid definitions, pollutant definitions, and air pollution monitoring data, try working through the tasks in *Problem Set 1. Setup Manager - Loading Grids, Pollutants & Monitor Data.*

Creating PM10 Exposure Estimates for Mumbai

With the monitor data loaded into BenMAP, we want to now estimate exposure in the city. In BenMAP, this is the process of creating an *Air Quality Grid*, which is a collection of PM10 measurements at each area in the city. The user can specify the size

of the areas via the selected grid definition. We will use the *Ward* grid definition, and estimate air quality at the center of each of the 20 or so wards in Mumbai.
By using the *Ward* grid definition, we assume that estimating PM10 levels at the center of each ward is a reasonably good estimate of exposure throughout the ward. We do this because (as seen later) our population data is available only at the ward-level, and because wards are a commonly used geographic reference. Later, if desired, we can change this assumption. For example, assuming that the center is representative of the whole might not be a good assumption in larger wards, and it might be desirable to use a smaller grid definition instead. For example, using the uniformly shaped *Mumbai Grid* would give us several estimates of air quality in different parts of large wards.

Monitors only estimate PM10 air pollution at a single point, and most wards do not have a PM10 monitor, so to estimate exposure we will use an average of nearby monitors. This averaging process is also called "interpolation." BenMAP supports a number of options for interpolation, but we will initially just use one to generate maps for our comparison of PM10 levels in 2000 and 2004.

We will use an approach called Voronoi Neighbor Averaging (VNA), which identifies the monitors that are near the center of each ward and then uses inverse distance weighting to combine these monitors. The VNA process is somewhat complicated; please refer to the BenMAP User's Manual for a full explanation.

Y For practice creating and comparing air quality grids for 2000 and 2004, try working through the tasks in *Problem Set 2. Creating & Mapping Air Quality Grids.*

Figure 3 presents the exposure estimates that we have initially generated for 2000 and 2004. Values in the wards range from about 70 to 175 ug/m3, with somewhat higher values in 2000 (map on left) compared with 2004. The scales on each map are identical, so we may interpret the somewhat darker shades in 2000 as higher PM10 levels relative to 2004.

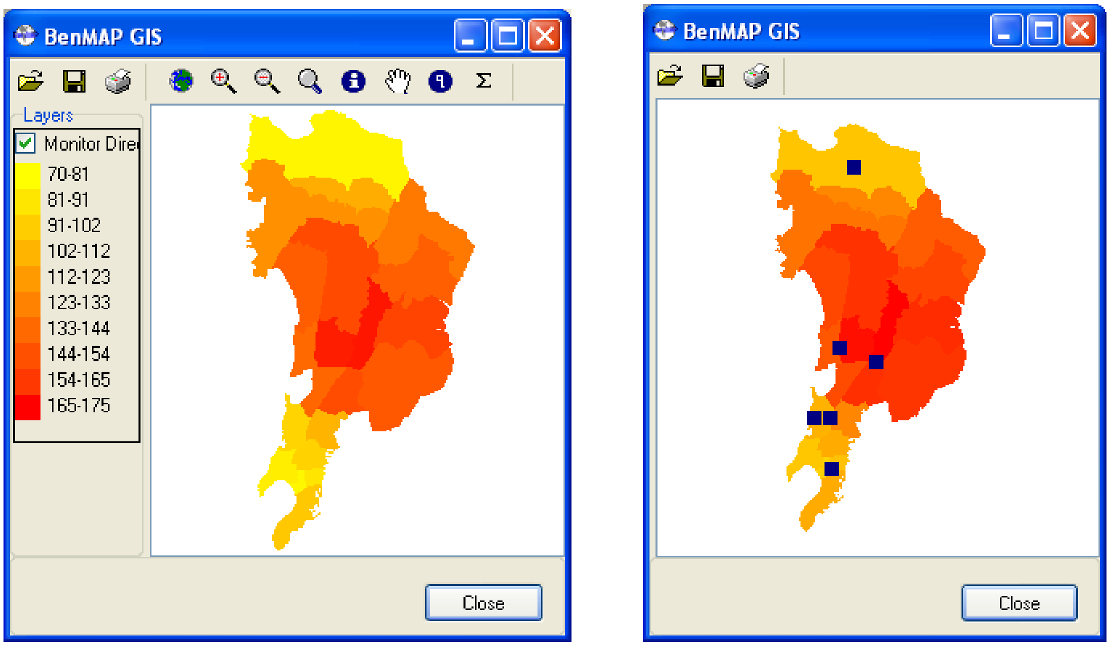


Figure 3. Exposure Estimates for Mumbai in 2000 (left map) and 2004 (right map)

In addition, the map on the left in Figure 3 identifies the locations of the monitors used in the interpolation. (The locations are the same in both 2000 and 2004, so they are included as blue squares only on the 2000 map.) In certain parts of Mumbai, particularly the northern portion, the monitor coverage is less dense, so the distance between the ward center and the neighboring monitors is generally greater in the northern half of Mumbai.

Increased distance will tend to make the monitor-based estimates less accurate, so we may want to consider whether to exclude monitors from the PM10 calculation if they are beyond a certain distance of a ward center. BenMAP allows you to specify whatever maximum distance you might want to choose. The choice of the maximum distance is going to depend on your beliefs about how uniformly PM10 levels are distributed, among other things, with greater uniformity suggesting a greater maximum distance.

Monitors outside of the chosen maximum distance are dropped. If no monitors are located within the maximum distance of a ward center, then BenMAP will not estimate a PM10 level. As a result, the map of exposure estimates may have blank spaces.

In addition, or as an alternative to specifying a maximum distance, you can choose to place a greater weight on nearby monitors by choosing inverse-distance-squared weighting. The default approach in BenMAP is inverse-distance weighting.

Y To better understand the various interpolation approaches that we have mentioned, try working through the tasks in *Problem Set 3. Analyzing Trends in PM10 Levels & Interpolation Methods.*

Based on the results from *Problem Set 3*, it appears that setting a maximum distance can have a significant effect on our results, by potentially limiting the included population. However, by setting a maximum distance, we tend to increase the accuracy of our exposure estimate.

Setting a maximum distance of five kilometers seems to be a reasonable approach. It captures a reasonably large fraction of the total population (roughly 7 million out of 12 million) while still placing fairly strict limits on the interpolation distance. We will not use the other interpolation variables (maximum relative distance and inverse distance squared), as they do not appear to make a significant difference beyond that made by setting a maximum distance of five kilometers.

When examining the different interpolation approaches to calculate population exposure, we considered the type of grid definition that we wanted to use. That is, we are calculating population exposure for different areas throughout the city. We considered two possibilities, one based on the wards in Mumbai, and the other a simple uniform grid. The *Ward* definition is somewhat irregular and some of the wards are relatively large, so our calculated exposure estimate for some of the wards may be less accurate than using a uniform grid with smaller grid cells. As a result, the uniform *Mumbai Grid* would appear to be a better approach when calculating population exposure.

However, another factor to keep in mind is the population data. Our population data have been collected at the ward-level, so when using the *Mumbai Grid* to calculate health impacts, we need to estimate the population in each square grid cell from the ward-level population. BenMAP does this by assuming that the population is uniformly distributed in each ward, and then assigns population to each uniform grid cell based on the fraction of the ward it covers. If a particular grid cell covers 25 percent of a ward, then 25 percent of the ward population is assumed to be in this grid cell. To the extent the population is *not* uniformly distributed in the wards, then our approach to estimating the population in each uniform grid will tend to be inaccurate.

Here again we have a tradeoff. The *Ward* grid definition provides an accurate population estimate, at the expense of its exposure estimate, which tends to be less accurate the less uniform the distribution of pollution levels throughout the city. The *Mumbai Grid* definition provides a relatively detailed estimate of exposure, because there are more uniform grid cells than there are wards. However, the population estimate tends to be less accurate the less uniformly the population is distributed in the wards. Neither grid definition is clearly better than the other. To test the sensitivity of our results to the grid definition, we will use both grid definitions when calculating health impacts.

Calculating Health Impacts

The health impacts of air pollution can be severe, and include premature mortality, hospital admissions, asthma, and other respiratory symptoms. To calculate these adverse health effects, BenMAP uses health impact functions, which quantify the relationship between a change in a health effect and a change in the pollution level.

A typical health impact function requires an effect estimate, a change in air pollution, a baseline health effect incidence rate, and population data. The basic form is the same for different types of health effects. Taking mortality as an example, the form of the health impact function is as follows:

*Mortality Reduction = Pollution Change * Effect Estimate * Incidence Rate * Population*

where:

Pollution Change = annual change in PM10 in micrograms per meter cubed (ug/m3).
Effect Estimate = percent change in mortality per ug/m3 of PM10.
Incidence Rate = baseline number of deaths per person per year (probability of death).
Population = number of persons in a specific age group.

In this case study, the pollution change will be the change over time in PM10 levels in Mumbai. The other parts of the health impact function (effect estimate, incidence rate, and population) need to be developed.

Choosing Studies and Generating Health Impact Functions

In developing effect estimates, which quantify the percent change in a health effect per unit of pollution, we turn to epidemiological studies. Epidemiological studies quantify the relationship between air pollution and health. A number of studies throughout the world have found that even daily changes in air pollution can have severe health consequences. Providing a review of the literature is well beyond the scope of this case study. Instead, we will present the results of our review of the literature, particularly studies involving India and other countries in Asia.

Table 1 lists the health effects and the studies that we will use when examining the health impacts of PM10. We discuss each category of health effect in more detail below, including the data sources for incidence rates and population levels.

Table 1. Health Impacts and Studies Used in Analysis of Mumbai

Health Effect	Source	Description
Premature Mortality	Health Effects Institute (2004, Table 2)	Summary of studies in Asia
	Cropper et al (1997)	Analysis conducted in New Delhi
	Ostro (2004, p. 9)	Based on a variety of developing and developed countries
Cardiovascular Hospital Admissions	Environment Protection Training & Research Institute (2005, p. 341)	Estimate appears to be based on U.S. studies
Cough	Kumar (undated)	Punjab, India
Lower & Upper Respiratory Symptoms	Vichit-Vadakan (2001, Table 3)	Bangkok, Thailand
Minor Restricted Activity Days	Ostro & Rothschild (1989)	United States

Premature Mortality

We used several studies to develop effect estimates for premature mortality, because there was not a single study that seemed clearly superior. The study by Cropper et al (1997) is desirable because it was conducted in New Delhi, India – one of the few studies in India that have been completed thus far.[1] However, it uses a relatively coarse measure of particulate matter (SPM).

We decided to include additional studies to capture some of the uncertainty surrounding the relationship between PM10 and premature mortality, so we included two summaries of epidemiological studies. One by the Health Effects Institute (2004) is an analysis of all of the available studies conducted in Asia between 1980 and 2003. The other is a recent report by Ostro (2004), commissioned by the World Health Organization.

Note that while we have three studies in our analysis, this does not necessarily mean that we have adequately captured the uncertainty in the relationship between PM10 and premature mortality. We have only used time-series studies, which examine daily fluctuations in air pollution and mortality. Other types of studies designed to capture more long-term effects of air pollution are not yet available for Asia. For example, a cohort study by Pope et al (2002) found effects associated with air pollution significantly greater than that found in time-series studies. However, we decided not to use this study because the effect estimate is so much larger, and it is not clear that this estimate accurately captures the long-term effects of PM10 in Mumbai.[2]

In addition to the effect estimate, we need an estimate of the baseline mortality rate in Mumbai, as well as population data. To estimate the baseline mortality rate, we used a

[1] The Health Effects Institute is currently conducting epidemiological studies in several Indian cities focusing on premature mortality and hospital admissions associated with air pollution.
[2] A great deal has been written on the relationship between mortality and air pollution. A number of the recent regulatory impact assessments (e.g., Clean Air Interstate Rule) by the USEPA have discussed this issue.

recent work by Kumar (2002, p. 138), which in turn gathered mortality statistics from the Bombay Municipal Corporation. To estimate population levels, we used ward-level data gathered in 2001 census that has three age groups: under 18, 18-64, and over 64 years of age.

Hospital Admissions

Studies in different parts of the world have linked air pollution to hospital admission for cardiovascular- and respiratory-related causes. No studies were found from India that examined this issue, so we turned to an analysis of pollution control options conducted in Hyderabad Environment Protection Training & Research Institute (2005, p. 341). It appears that this study based their effect estimate on studies from the United States.

Using a study from the United States, particularly a hospital admission study, for an analysis of Mumbai raises issues that could cause a biased estimate. Perhaps most importantly, the hospital system in Mumbai is quite different from that in the United States. It is not unlikely that a number of persons in Mumbai will generally not use a hospital and will instead care for themselves in other ways. It is unclear how this might affect the effect estimate, which captures the percent change in hospital use per unit of PM10. As a result, we should treat this estimate with some caution.

To complete the health impact function, we also need an incidence rate and population data. The population data can again be taken from the Indian census. The incidence rate is somewhat difficult to calculate. We did not find good estimates of the hospital admission rate in Mumbai, so we used the Environment Protection Training & Research Institute (2005, p. 338) study, which calculated the incidence rate for hospital admissions in Hyderabad. We assume that this rate is a reasonably good estimate for Mumbai. Clearly, however, this may be inaccurate, and thus is another source of uncertainty in our estimate of hospital admissions associated with PM10.

Cough

There are few Asian epidemiological studies that have examined the relationship between ambient air pollution and various types of respiratory symptoms. We were able to identify only a single, unpublished study from India that we could use in our analysis. This study by Kumar (undated) quantified the relationship between particulate matter levels and cough.

The study is not published, so it is not clear what type of peer-review process it received. However, the study appears to have been carefully conducted, and it is the only study of its kind, so we decided to include it. We developed the effect estimate from the results of the logistic regression that Kumar conducted (in Problem Set 4, below, we go into the details of this calculation). To complete the health impact function, we used the incidence rate reported by Kumar in our health impact function, and we used population data from the 2001 Indian census for persons over 17 years of age.

Lower & Upper Respiratory Symptoms

Air pollution has been linked with a range of both lower and upper respiratory symptoms, including asthma, itchy eyes, cough, phlegm, and sinusitis. Since cough is only a subset of these effects, we decided to include one of the only other Asian studies that we found that examine this issue. The study by Vichit-Vadakan (2001, Table 3) examined the relationship between air pollution and both lower and upper respiratory symptoms in Bangkok, Thailand.

Using this study raises the issue of counting the same health effects twice, because we have an estimate of cough (based on the study by Kumar) and we have an estimate of lower and upper respiratory symptoms (based on the study by Vichit-Vadakan). When interpreting the results of these studies, it is important to note this possibility of double-counting. Nevertheless, we decided to include this study because of the relative paucity of studies from Asia, and because it is desirable to have more than one estimate of a particular type of adverse health effect. Again, to complete the health impact function, we used the incidence rate reported by Vichit-Vadakan (2001, Table 1) and population data from the 2001 Indian census.

Minor Restricted Activity Days

Finally, we included a study of minor restricted activity days (MRADs) by Ostro and Rothschild (1989). This examined the relationship between fine particulate matter and MRADs, which include virtually any kind of minor symptom. Using this study again raises the possibility of counting health effects more than once, because of the overlap between MRADs, cough, and lower and upper respiratory symptoms. Also, the baseline incidence rate used is the one reported in the study, which introduces another source of uncertainty, since the baseline rates would presumably be different in the United State and Mumbai. Nevertheless, we included this study because it is included in many analyses of the benefits of reducing air pollution, and thus provides a point of comparison between different sets of results.

Y To examine the development of health effect estimates, try working through the tasks in *Problem Set 4. Deriving Health Effect Estimates.*

Preparing Database of Health Effect Estimates, Incidence, and Population Data

After choosing the health impact functions to consider for the analysis, the next step is to develop databases that we can then load into BenMAP. For this particular case study we will develop two databases.

One database is simply referred to as the "health impact function" database. This has the health effect estimates, the incidence rates, and various kinds of descriptors needed to define the health impact function, such as the age group to be considered for each health impact function.[3] The data are in the file *Mumbai Health Impact Functions.xls*, and have already been formatted, following the instructions in the *Data Requirements* appendix.

A second database has the actual population data that is referenced by the health impact function database. These ward-level population data were collected during the 2001 Indian census, and are in the file: *Mumbai Ward Population for BenMAP.xls*. As with the health impact function database, this database has been formatted following the instructions in the *Data Requirements* appendix.

Y To examine the loading of health impact functions and population databases into BenMAP try working through the tasks in *Problem Set 5. Setup Manger - Loading Population & CR Functions.*

Calculating Health Impacts

We now have everything in place – health impact functions, baseline and control air quality grids, population data, and baseline incidence rates – to estimate the health impacts avoided by the improvements in air quality which have occurred between 2000 and 2004 in Mumbai. In BenMAP, this step involves creating and running a *Configuration*. A *Configuration* is a reusable file which stores the choices involved in estimating health impacts – the air quality grids, the selected health impact functions, the population data, choices about uncertainty characterization, etc.

Once a *Configuration* is created, it can be used many times to generate health impact estimates that are directly comparable – across scenarios within an analysis (e.g. 5km maximum interpolation distance vs. no maximum interpolation distance) or across analyses. They can thus be shared to create a standard way of measuring the health impacts of various changes in pollution levels.

[3] It is possible to have a separate database with incidence rates, but we have used a simpler approach and simply included the incidence rate with the effect estimate.

Y To examine the calculation of health impacts in BenMAP, try working through the tasks in *Problem Set 6. Creating and Running Configurations.*

Aggregation and Pooling

As a final step in estimating health impacts, you may wish to combine your results in various ways. We have already seen, in creating tabular reports, that BenMAP can *aggregate* our results from one grid definition (e.g. *Mumbai Grid*) to another (e.g. *Metropolitan Area*). In BenMAP, then, *aggregation* refers to translating values from one grid definition to another. Typically, this process involves going from a fine resolution to a coarser one – this can be useful for reporting citywide impacts, for example.

In addition to aggregating results when generating reports, BenMAP also supports aggregation as one of the steps in running an *Aggregation, Pooling, and Valuation Configuration*, or *APV Configuration*.

The second part of an *APV Configuration*, *Pooling*, refers to the mathematical combination of results in the same location. BenMAP supports various methods of combining results, but the basic idea behind each is to combine multiple distributions of results into a single combined distribution. This single combined distribution can represent the sum of its components (when adding results up for different age ranges, for example), the difference of its components (when subtracting one health effect from a result representing a group of health effects, for example), or the weighted average of its components (when combining several estimates of the same health effect into a single estimate).

Y To examine the aggregation and pooling of health impacts in BenMAP, try working through the tasks in *Problem Set 7. Aggregation and Pooling.*

Valuing Health Impacts

Estimating the economic value of health impacts can be useful as an additional measure of the impacts of air pollution, as a tool for finding cost-effective strategies for reducing air pollution, and to allow comparing the benefits of strategies for reducing air pollution with the costs. The process of estimating the economic value of health impacts typically involves calculating the total number of cases of various health effects, and then multiplying each by a corresponding *unit value*, which estimates the cost of a single case of that health effect (or, correspondingly, the benefit of avoiding a single case).

In the ideal case, each *unit value* would be the sum of three components – (a) the value of medical and other resources used to treat the health effect, (b) or the value of time lost because of the health effect (or *opportunity cost*), and (c) the value of avoiding the pain and suffering caused by the health effect. For many endpoints, estimated unit values will consist of only the first two components, and will therefore typically underestimate the true unit value. For example, the unit value for a hospitalization might include the average cost of a hospital visit and the average wages lost due to a hospital visit.

Unit values for premature mortality, on the other hand, typically do not include the first two components at all and are instead estimates of the amount of money *society* is willing to pay to avoid one death. It is important to note that unit values for premature mortality do not say anything about the value of a particular individual's life – rather, they are simply indications of the value placed by society on the risk of premature death in general.

There are various methods for arriving at these values, including *hedonic* methods (wage-risk studies, for example, which look at the correlation between wages and job-related risk of death), averting behavior methods, and survey methods. A discussion of these various methods is beyond the scope of this case study, but it is important to note that benefits analysts do not typically do primary research to collect data for valuation, but instead use the research others have conducted and made available.

Loading Variables and Valuation Functions

The final databases to be loaded are the valuation functions database and a variables database.

The valuation functions database is in the file *Mumbai Valuation Functions.xls*, and has already been formatted, following the instructions in the *Data Requirements* appendix. It contains unit values for each of the health effects we have investigated, along with various descriptors, etc.

The variables database is in the file *Mumbai Variables.xls*, and has also already been formatted, following the instructions in the *Data Requirements* appendix. Variable databases allow you to load any geographically variable value of interest and use it in either health impact or valuation functions.

Y To examine the loading of variables and valuation functions into BenMAP, try working through the tasks in *Problem Set 8. Setup Manager - Variables & Valuation Functions.*

Aggregation, Pooling, and Valuation Configurations

The final part of an *Aggregation, Pooling, and Valuation Configuration* (*APV Configuration*) is *Valuation*. In BenMAP, this consists of selecting valuation functions for the various pooled and aggregated health effect estimates we have generated. The valuation estimates generated by these functions can themselves then be aggregated and pooled.

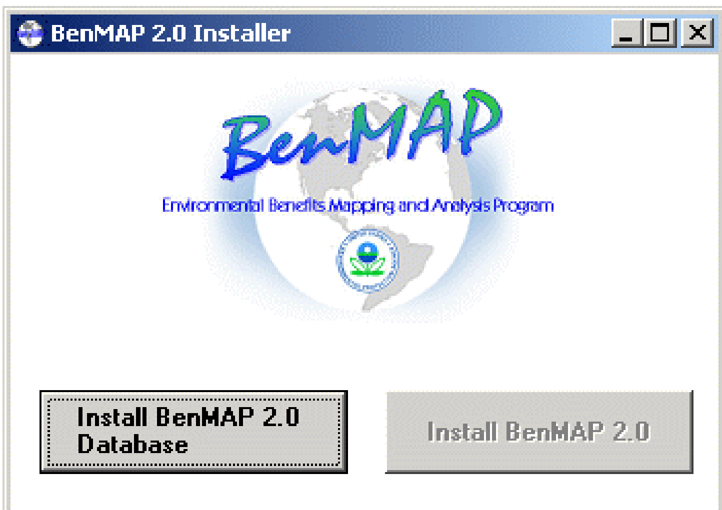
Y To examine the valuation of health impacts in BenMAP, try working through the tasks in *Problem Set 9. Valuation.*

Installing BenMAP

BenMAP 2.2 uses the Microsoft SQL Server Desktop Edition (MSDE) as its underlying database technology. As such, the installation process for BenMAP 2.2 has two steps - installing MSDE, and installing BenMAP 2.2.

Installing MSDE

Get started by double clicking *Setup.exe* in the BenMAP Installer directory on your CD. This will bring up the following dialog:

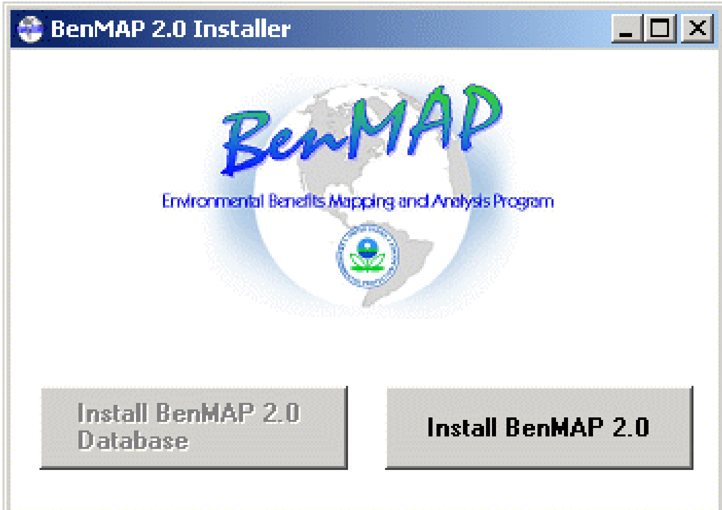


Click on the *Install BenMAP 2.0 Database* button. This will bring up the MSDE installer. Normally this installer will complete its work without any input from you. In certain cases, however, it may require you to reboot your computer after it is finished. If this occurs, simply reboot your computer and then return to the BenMAP 2.2 installation process by double-clicking *Setup.exe* in your installation directory again.

Additionally, there are two known issues with the MSDE installer. If you have trouble with this installer, see the additional notes below.

Installing BenMAP

Once MSDE is installed, the installation dialog will return, with the second button enabled.



Click on the *Install BenMAP 2.0* button. A progress bar will appear as the BenMAP 2.2 database is built in the installed instance of MSDE. When this process is complete, the BenMAP 2.2 installer will come up. Follow its directions to install BenMAP 2.2.

Uninstalling BenMAP

To uninstall BenMAP, go to *Control Panel*, *Add/Remove Programs* and remove both *Microsoft SQL Server Desktop Edition (BenMAP)*, and *BenMAP 2.2*.

MSDE Installation Issues

If you have trouble installing MSDE, the most likely problems are that:

(1) You don't have File and Print Sharing for Microsoft Networks enabled, or
(2) You have disabled unsigned driver installation.

For more information on how to fix these issues to enable a successful installation of MSDE, see section 3.2, *Installation Prerequisites*, in the file *ReadmeMSDE2000A.htm* in the MSDE directory within your installation directory.

Problem Set 1. Setup Manager (1)- Loading Grids, Pollutants & Monitor Data

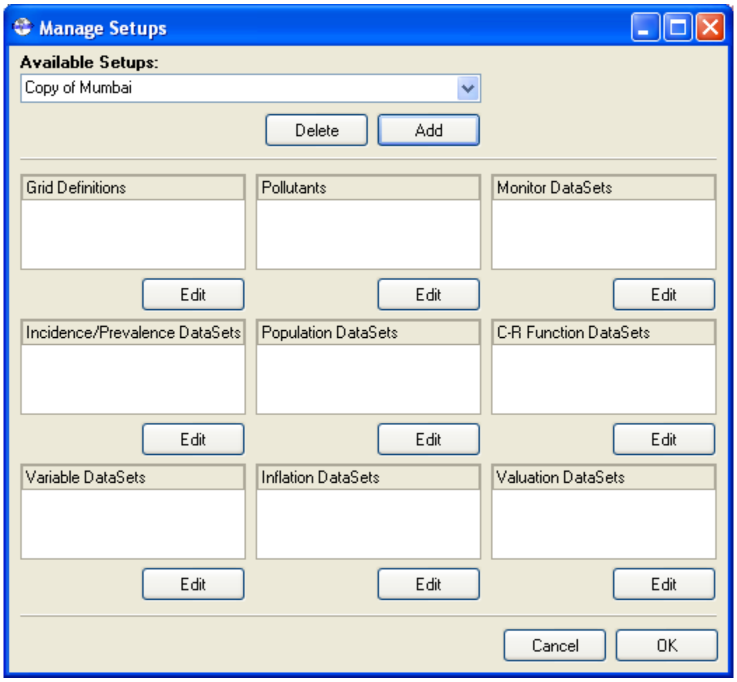
The first step in any BenMAP analysis is to load all of the data needed to estimate exposure levels. The data, including grid definitions (electronic maps), air pollution data, and population data are loaded into a *Setup*, which is saved for future use and can be even be shared with other users. Once you have created a *Setup*, you can use it to perform multiple model runs with different configurations. This saves users from having to enter the data in BenMAP, a fairly complicated process, more than once. *Setups* also contain health impact and valuation information, which will be explained in *Problem Sets 5* and *8*.

In the tasks below, we are going to practice creating *Setups* by creating a copy of the *Setup* named *Mumbai* that already exists. We will do this by adding a *Setup* named *Copy of Mumbai* to which we will then add grid definitions, pollutants of interest, and air pollution monitoring data. All of the data you need for this task and the tasks in all of the other problem sets is installed automatically when you install BenMAP. The default location is C:\Program Files\Abt Associates Inc\BenMAP 2.2\Sample Data\Mumbai. In the following tasks, when we refer to the *Sample Data*, we are referring to the data located there.

Task 1: Add a Setup

- Start BenMAP.
- Click *Tools,* then *Modify Setup*. This will bring up the *Manage Setups* window.
- Click the *Add* button under the *Available Setups* list.
- Name the new setup *Copy of Mumbai* and click the *OK* button.

Your screen should now look like this:



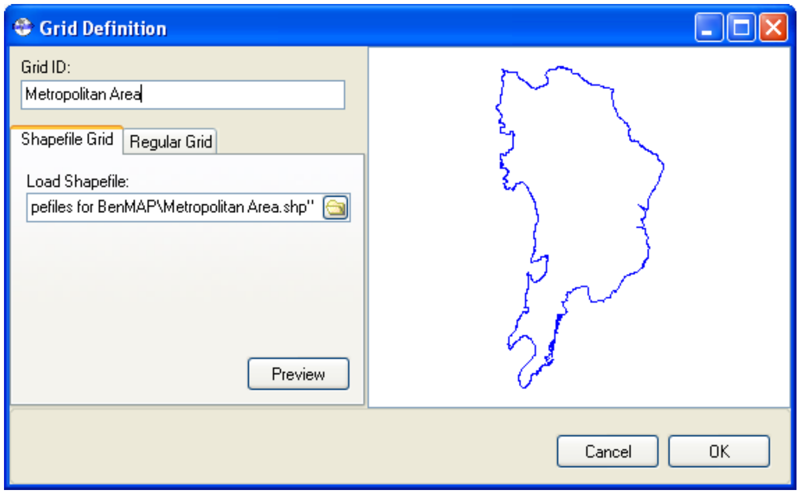
Task 2: Create Two Shapefile Grid Definitions

Grid definitions are used to break a geographic region into areas of interest (grid cells). There are two types of grid definitions: shapefile grid definitions are created by loading in an existing shapefile, and regular grid definitions, which are created by specifying a regularly shaped grid pattern. Typically, shapefile grid definitions are used when the areas of interest are political boundaries with irregularly shaped borders, like cities, while regular grid definitions are used with air quality modeling data.

In this task, we will create two shapefile grid definitions, one that shows the outline of the Mumbai metropolitan area, and one that shows the Wards for the city. Both new definitions will use shapefiles provided in the *Sample Data*.

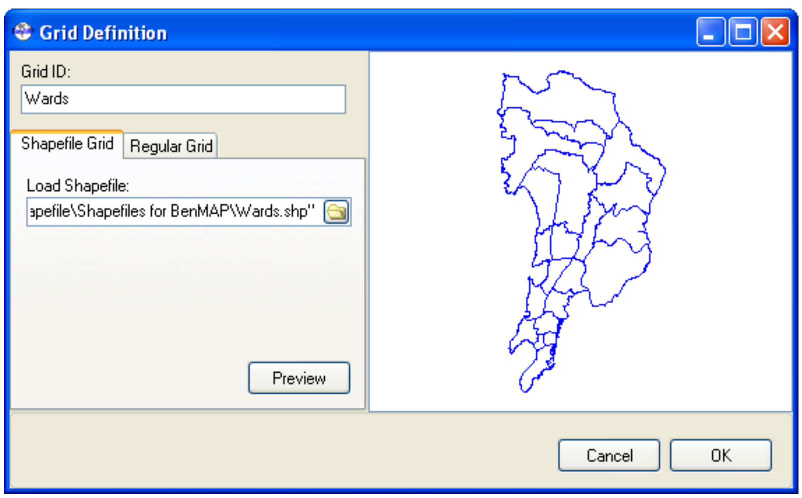
- Click the *Edit* button under the *Grid Definitions* list. This will bring up the *Manage Grid Definitions* window.
- Click the *Add* button under the *Available Grid Definitions* list to add a new Grid Definition. This will bring up the *Grid Definition* window.
- Click the *Shapefile Grid* tab.
- Click the  icon in the *Load Shapefile* box to browse for a shapefile.
- Locate the *Metropolitan Area.shp* shapefile and click the *Open* button.
- In the *Grid ID* box, type *Metropolitan Area*. This will be the name of the new Grid Definition.
- Click the *Preview* button to see what the new grid definition looks like.

Your screen should now look like this:



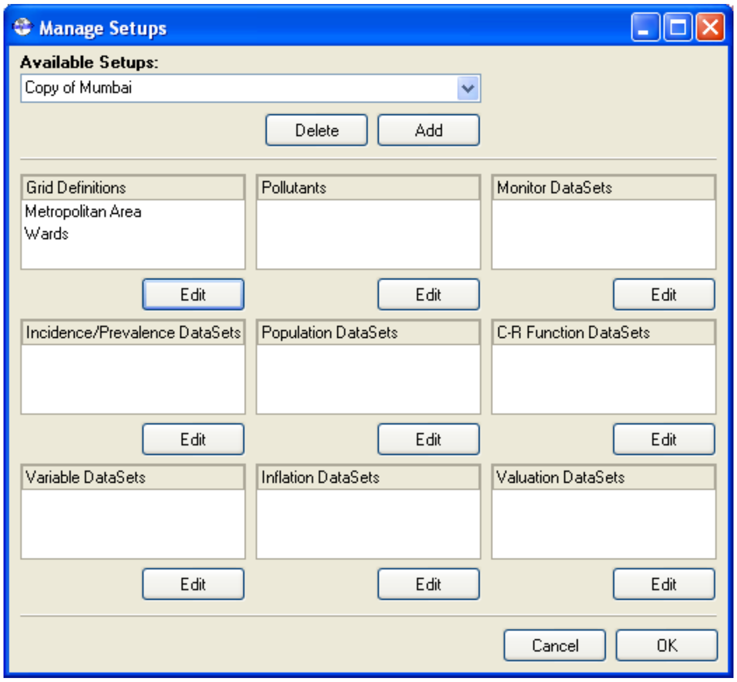
- Click the *OK* button to return to the *Manage Grid Definitions* window.
- Repeat this process for the file *Wards.shp*, naming the Grid Definition *Wards*.

Your screen should now look like this:



- When you are done, click the *OK* button to return to the *Manage Setups* window.

Your screen should now look like this:



Task 3: Create One Regular Grid Definition

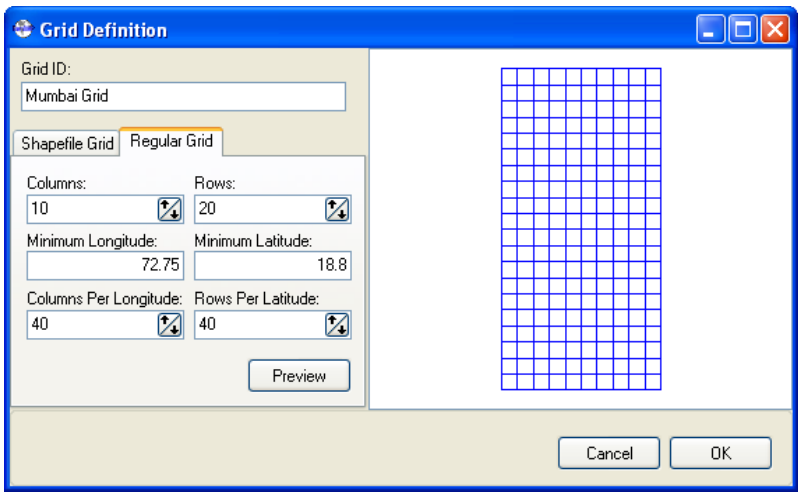
Regular grid definitions are defined by a lower left corner (specified as decimal degree latitude and longitude, with West and South having negative values and East and North having positive values), a total number of columns and rows, a number of columns per degree longitude, and a number of rows per degree latitude. Individual cells within the resultant grid are numbered in sequential order (columns from left to right, rows from bottom to top) starting at (1, 1). These field values will be used to link the regular grid definition with other sources of data.

In this task we will create a new regular grid definition called *Mumbai Grid*, that will be used in *Problem Set 3* as an alternative to the *Wards* grid. This new grid corresponds to the domain of the Mumbai air quality modeling data. Although modeling data is not used in this case study, it is available in the *Sample Data* installed with BenMAP.

- Click the *Edit* button under the *Grid Definitions* list. This will bring up the *Manage Grid Definitions* window.
- Click the *Add* button under the *Available Grid Definitions* list to add a new Grid Definition. This will bring up the *Grid Definition* window.
- Click the *Regular Grid* tab.
- In the *Columns* box, enter *10*.
- In the *Rows* box, enter *20*.
- In the *Minimum Longitude* box, enter *72.75*.
- In the *Minimum Latitude* box, enter *18.8*.

- In the *Columns Per Longitude* box, enter 40.
- In the *Rows Per Latitude* box, enter 40.
- In the *Grid ID* box, type *Mumbai Grid.* This will be the name of the new grid definition.
- Click the *Preview* button to see what the new grid definition looks like.

Your screen should now look like:



- Click the *OK* button to return to the *Manage Grid Definitions* window.
- Click the *OK* button to return to the *Manage Setups* window.

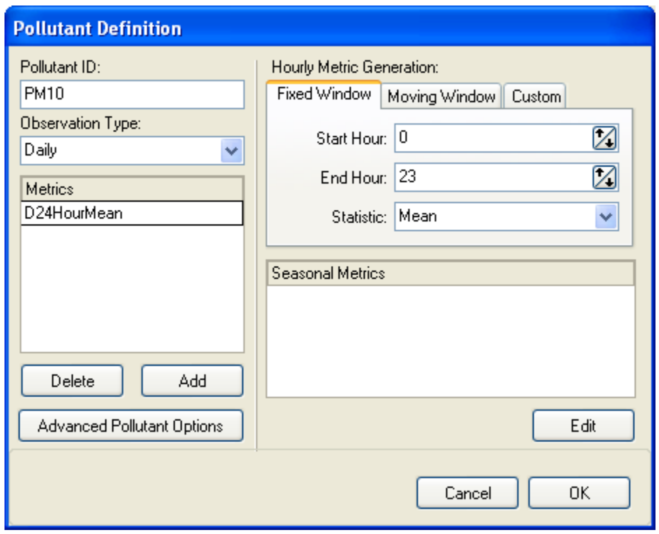
Task 4: Add a Pollutant with Daily Observations

Air pollution data in BenMAP is of two types - monitoring data from point sources, and modeling data based on grid definitions. For both types, the data must be associated with a particular pollutant. In the following steps, we will add a new pollutant, PM10, and then define its observations and metrics. The *Observation Type* identifies whether a pollutant is measured hourly or daily, while the *Metric* defines the daily values calculated directly from daily observations, or through various mathematical manipulations of hourly observations. We will also add 12 *Seasonal Metrics*, each of which calculates a monthly mean value.

- Click the *Edit* button under the *Pollutants* list. This will bring up the *Manage Pollutants* window.
- Click the *Add* button under the *Available Pollutants* list to add a new Pollutant. This will bring up the *Pollutant Definition* window.

- In the *Pollutant ID* box, type *PM10*. This will be the name of the new Pollutant. (**Note:** It is very important that this name be spelled properly, as the name of the Pollutant is used to link it to Health Impact functions, Monitors, etc.)
- In the *Observation Type* list, select *Daily*.
- Click the *Add* button under the *Metrics* list. This will add a Metric to the Pollutant named *Metric 0*. Rename this Metric by clicking where it says *Metric 0* and typing *D24HourMean*.

Your screen should look something like this:



- Click the *Edit* button under the *Seasonal Metrics* list. This will bring up the *Manage Seasonal Metrics* window.
- Click the *Add* button under the *Seasonal Metrics* list. This will add a Seasonal Metric to the Metric named *Seasonal Metric 0*. Rename this Seasonal Metric by clicking where it says *Seasonal Metric 0* and typing *MonthlyMean*.

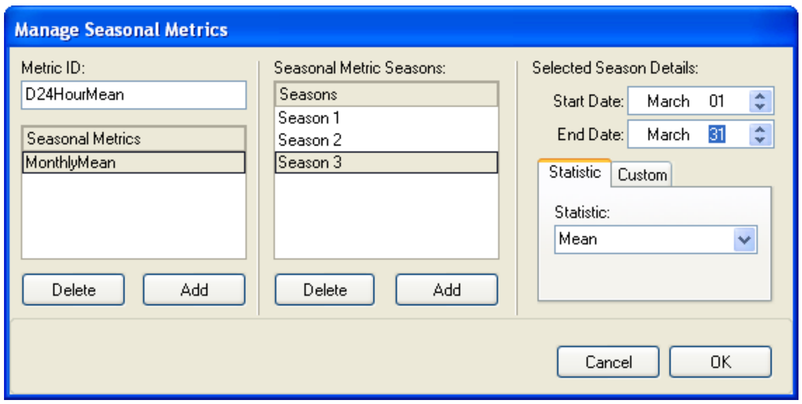
> Λ **Note:** It is very important that pollutant and metric names be spelled properly, as the names are used to link the pollutants and metrics to Health Impact functions, Monitors, etc.

- Click the *Add* button under the *Seasonal Metric Seasons* list. This will add a season to the Seasonal Metric. Change the *End Date* value to *January 31*. To change the date, highlight either the month or the day and use the up and down arrows to increase or decrease the highlighted value. Leave the *Start Date* at its current value, *January 1*; and leave the *Statistic* at its current value, *Mean*.

- Click the *Add* button under the *Seasonal Metric Seasons* list again. This will add a second season to the Seasonal Metric. Note that the *Start Date* value is automatically set to one day after the previous seasons *End Date* value. Change the *End Date* value for this second season to *February 28*.

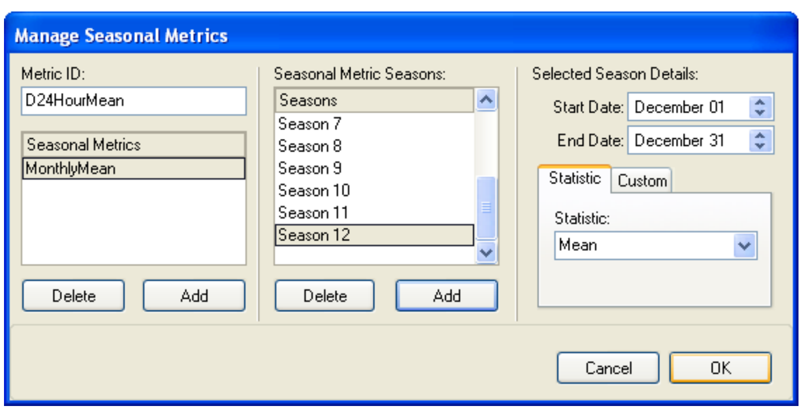
- Click the *Add* button under the *Seasonal Metric Seasons* list again, and change the *End Date* value for this third season to *March 31*.

At this point your screen should look something like this:



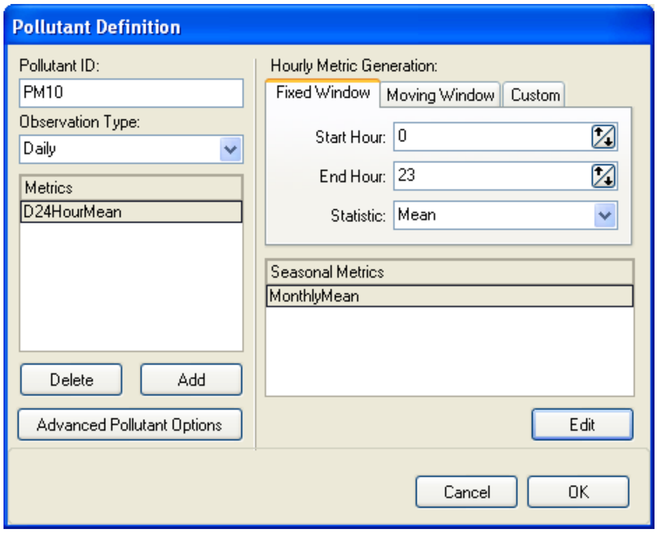
- Continue adding seasons until you have 12 seasons (for each month in the year). When you get to the 12^{th} and final season, there is no need to modify any values.

After adding the final season, your screen should look something like this:



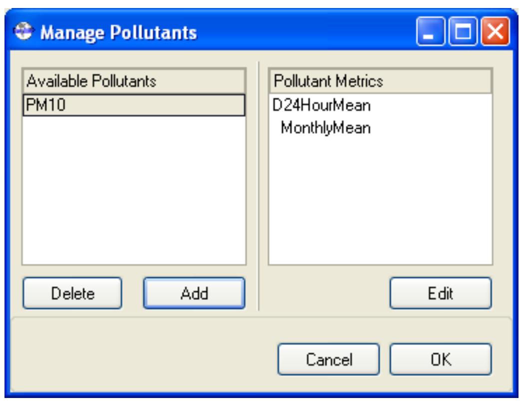
- Click the *OK* button to return to the *Pollutant Definition* window.

Your screen should now look like this:



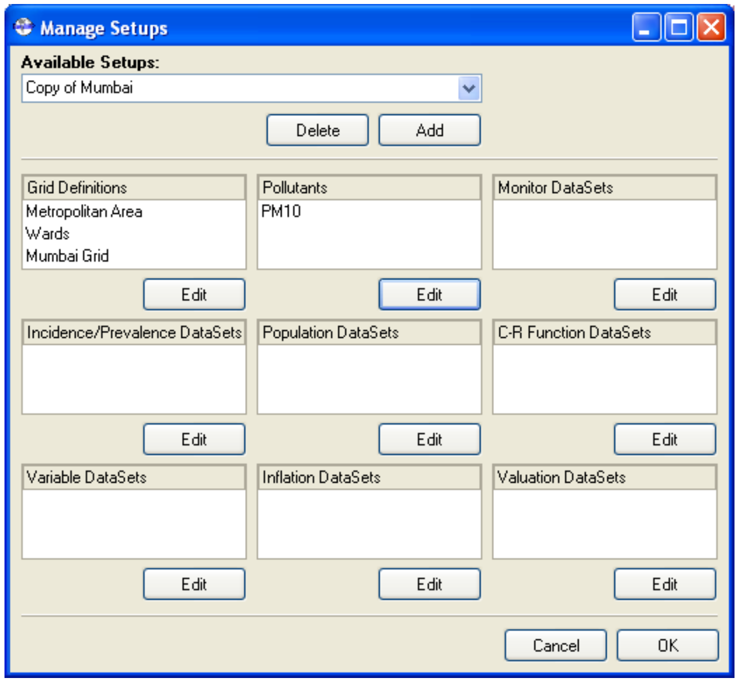
➢ Click the *OK* button to return to the *Manage Pollutants* window.

Your screen should now look like this:



➢ Click the *OK* button one final time to return to the *Manage Setups* window.

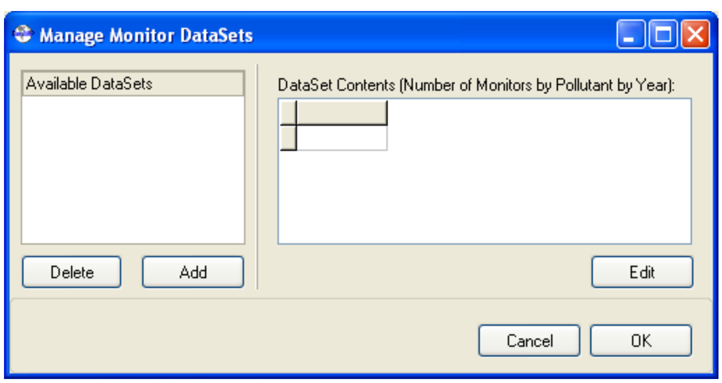
Your screen should look something like this:



Task 5: Add Monitors

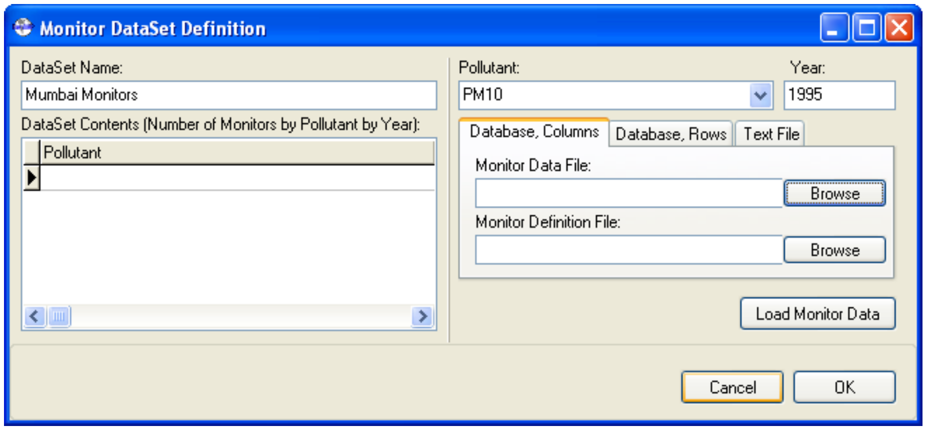
In this task, we will add monthly PM10 monitoring data for Mumbai, for the years 2000 and 2004. The data is provided in the BenMAP *Sample Data*.

- Click the *Edit* button under the *Monitor DataSets* list. This will bring up the *Manage Monitor DataSets* window.

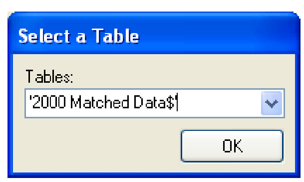


- Click the *Add* button under the *Available DataSets* list to add a new Monitor DataSet. This will bring up the *Monitor DataSet Definition* window.
- In the *DataSet Name* box, type *Mumbai Monitors*. You will be adding monthly PM10 data from 2000 first, and then, in a separate step, data from 2004.
- In the *Pollutant* list, select *PM10*.

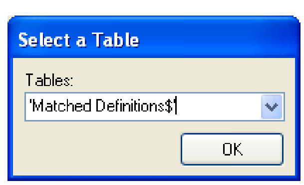
- In the *Year* box, type *2000*.



- In the *Database, Columns* tab, click the *Browse* button next to the *Monitor Data File* box.
- Locate the *Mumbai PM10-TSP Monitors.xls* file and click *Open*. (**Note:** Make sure that the *Files of Type* is set to Excel Files.)
- The *Select a Table* window will appear. In the drop-down list choose the year *2000 Matched Data* and click *OK*.
-

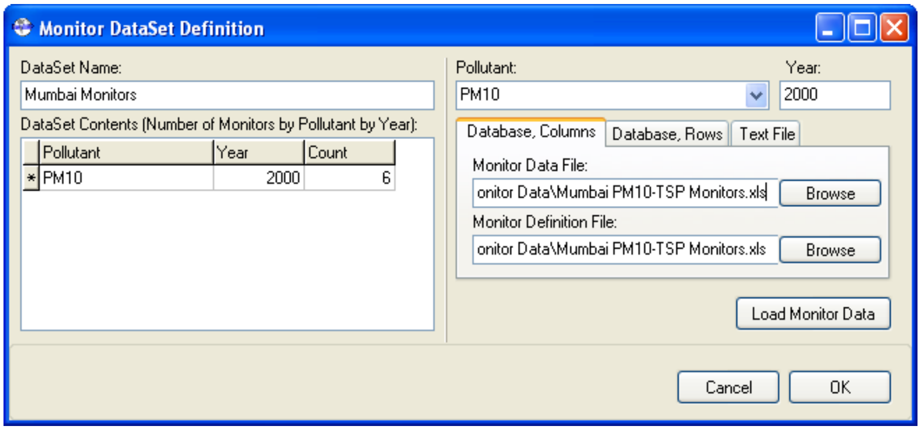


- In the *Database, Columns* tab, click the *Browse* button next to the *Monitor Definition File* box.
- Locate the *Mumbai PM10-TSP Monitors.xls* file and click *Open*.
- The *Select a Table* window will appear. In the drop-down list choose *Matched Definitions* and click *OK*.



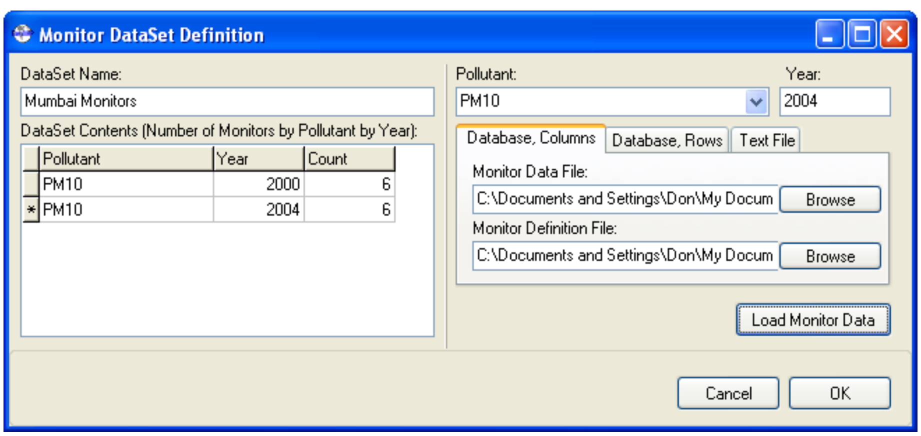
- Click the *Load Monitor Data* button.

Your screen should now look something like this:



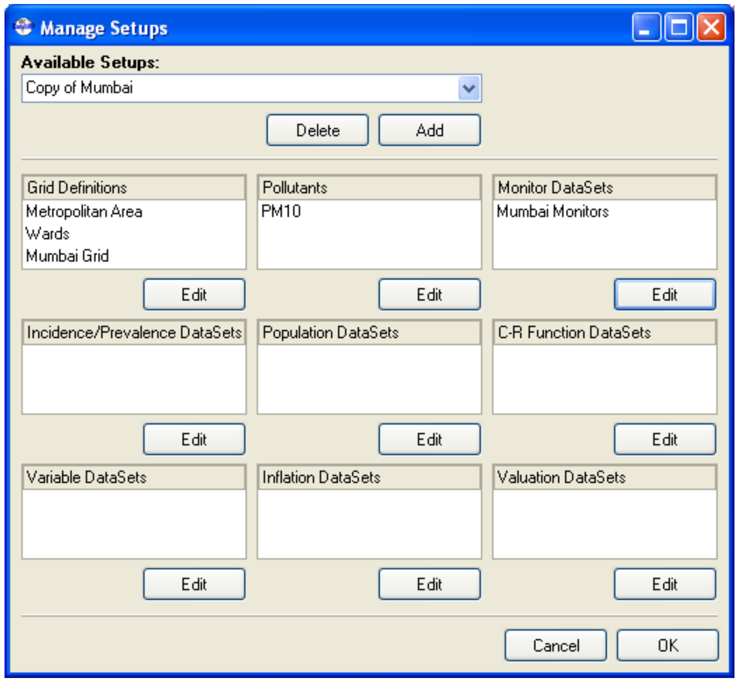
- ➢ Following the same steps, now load the data for 2004. (**Note:** To load data for 2004 you must again select the *Monitor Data File [Mumbai PM10-TSP Monitors.xls]* by clicking on *Browse* next to the *Monitor Data File* box then selecting *OK*. The *Select a Table* window will appear and you will then need to select from the drop-down list the year you would like to load.)

After you have finished loading the data, your screen should look something like this:



- ➢ Click the *OK* button to return to the *Manage Monitor DataSets* window.
- ➢ Click the *OK* button to return to the *Manage Setups* window.

Your screen should now look like this:



- Click the *OK* button to return to the main BenMAP window.

In this problem set you have created a *Setup* for all of the data related to the Mumbai case study, loaded into it grid definitions and monitoring data, and defined the pollutant of interest.

In the next problem set, you will use the grid definitions and monitoring data in the setup to create air quality grids, which contain air pollution exposure estimates. In *Problem Set 5*, you will return to the *Setup* and load in population data and concentration-response (C-R) functions.

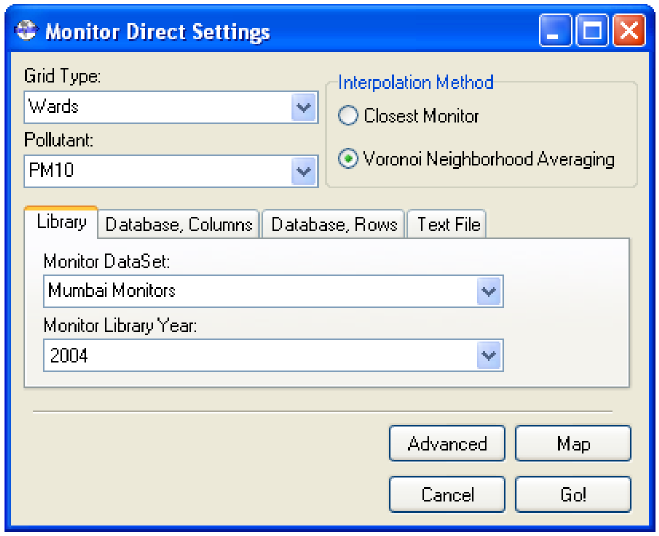
Problem Set 2. Creating & Mapping Air Quality Grids

In *Problem Set 1*, you created a *Setup* for all the data on Mumbai. In Tasks 2 and 3 you created grid definitions, and in Task 5, you loaded the PM10 monitoring data into the *Setup*. In this problem set, we are going to combine the grid definitions with the monitor data to generate air quality grids containing air pollution exposure estimates. We are then going to map these grids and compare them. And to finish, we will create an *Audit Trail*, which allows you to track all of the assumptions that you have made when generating your air quality grids. (And as you will see later, you can generate an *Audit Trail* from almost any of the files that you create with BenMAP. This is particularly useful when analyses are complex.)

Task 1: Generate Two Monitor Direct Air Quality Grids

In this task, we will use the PM10 air quality monitoring data loaded into the *Copy of Mumbai Setup* to generate two air quality grids: one for 2000 and one for 2004.

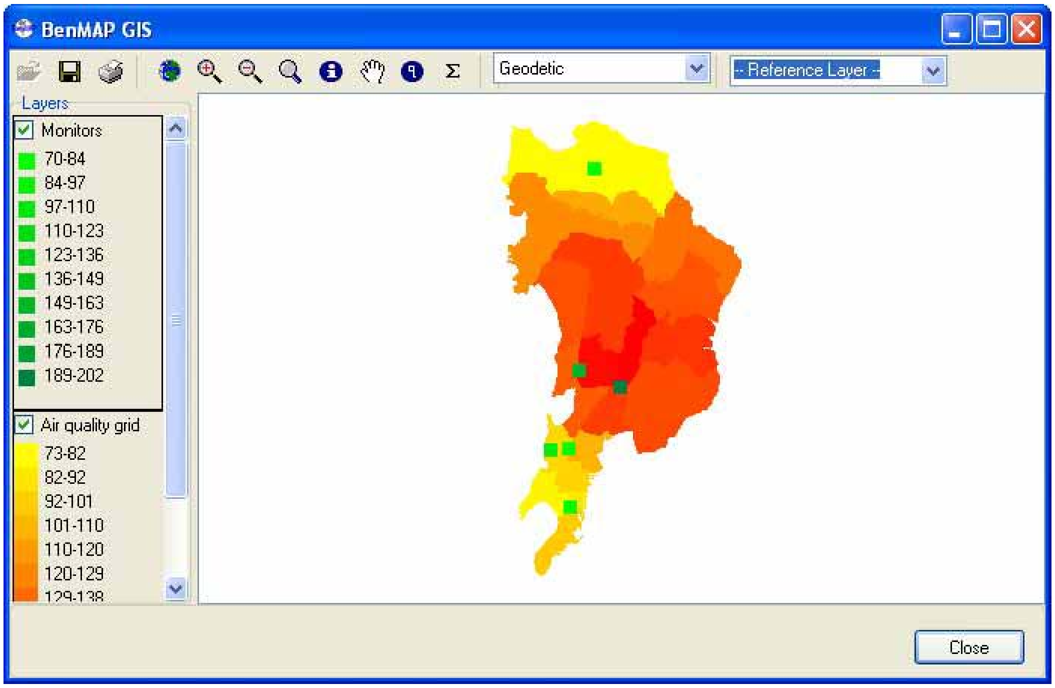
- Click the *Create Air Quality Grid* button. This will bring up the *Air Quality Grid Creation Method* window.
- Select *Monitor Direct* and click the *Go!* button. This will bring up the *Monitor Direct Settings* window.
- Select *Wards* in the *Grid Type* list (this was a grid created in Problem Set 1).
- Select *PM10* in the *Pollutant* list.
- Select *Voronoi Neighborhood Averaging* in the *Interpolation Method* list.
- Make sure that the *Library* tab is selected, and select *Mumbai Monitors* in the *Monitor DataSet* list (this is the name of the monitor data loaded in *Problem Set 1*).
- Select *2000* in the *Monitor Library Year* list.



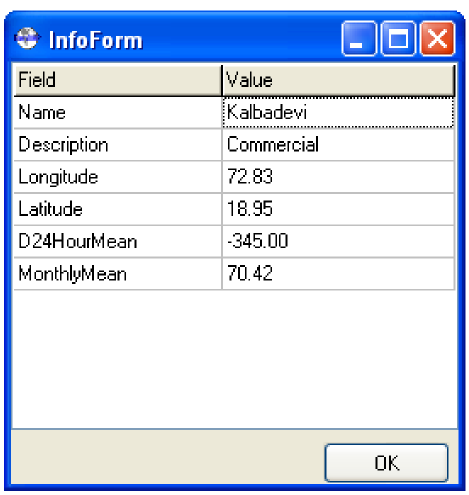
- Click the *Map* button. This will create the Air Quality Grid and bring up the *BenMAP GIS* window.
- Double click the text *Air Quality Grid* in the *Layers* list on the left side of the window. This will bring up the *Display Options* window.
- Select *MonthlyMean* in the *Variable* list.
- Uncheck the *Grid Outline* box.
- Click the *OK* button to return to the *BenMAP GIS* window.
- Double click the text *Monitors* in the *Layers* list on the left side of the window. This will bring up a slightly different *Display Options* window.
- Select *MonthlyMean* in the *Variable* list.
- Select a new *Start Color* and *End Color* – in the below example we have selected a light and a dark shade of green.
- Set *Decimal Digits* to 0.
- Click the *OK* button to return to the *BenMAP GIS* window.

Note: To change the size of the points displayed for the monitors, return to the *Display Options* window (by double clicking on the text *Monitors*) and modify the *Start Size* and *End Size* values. The sizes of the displayed monitors will progress from *Start Size* to *End Size* as they move from *Min Value* to *Max Value*. *Default Size* will be used for values outside this range.

Your screen should now look like this:

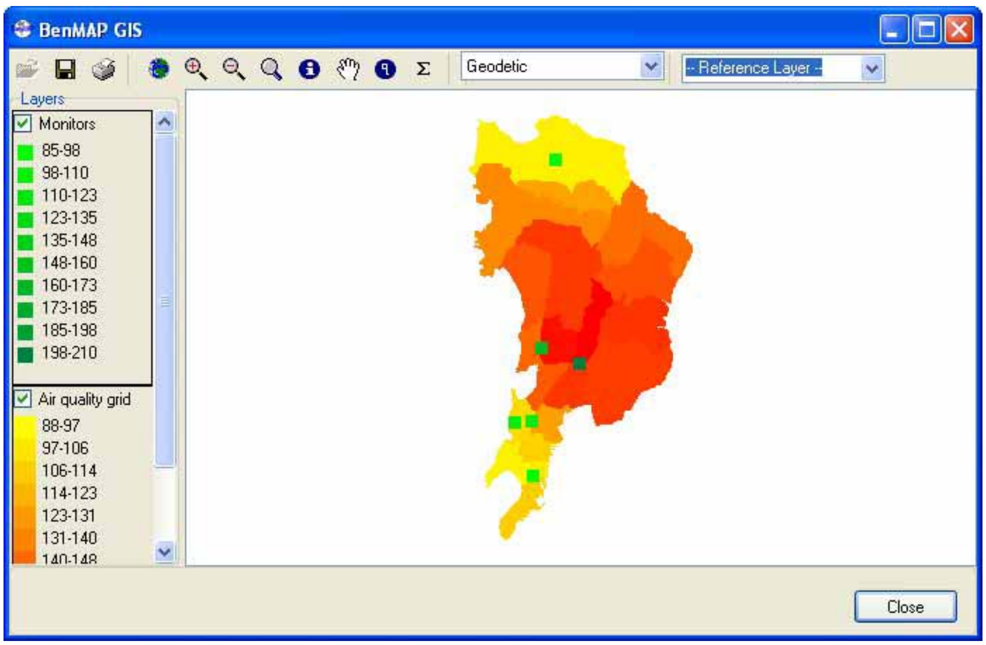


- In the toolbar above the map, place your cursor on top of each button and read the descriptions that appear.
- Click on the "i" button (*Click to display info for the cell under the mouse*) to activate it. This will allow you to get information about the active layer in the map, in this case the *Monitors*.
- Click on each monitor (Kalbadevi, Parel, Worli, Marivali, Khar and Borivali). This will bring up the *InfoForm* window. The Kalbadevi *InfoForm* should look something like this:



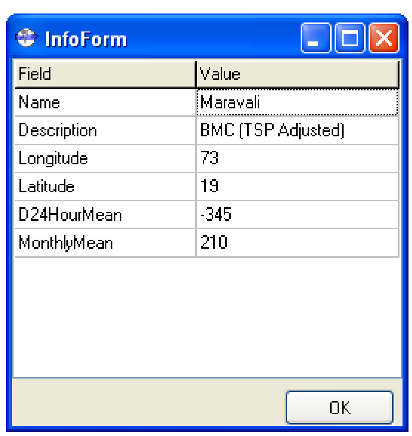
Note that a value of "-345" stands for missing data. The *D24HourMean* is missing because (as you will see later) we only loaded in monthly values for the monitor data.

- Click the *OK* button to return to the *BenMAP GIS* window, and the *Close* button to return to the *Monitor Direct Settings* window.
- Click the *Go!* button to save the Air Quality Grid to file.
  - Save the Air Quality Grid as *Monitor Direct PM10 VNA 2000 Wards.aqg*.
  - BenMAP will automatically return to the main BenMAP window when done.
- Repeat the above steps for year 2004 monitors, with the appropriate substitutions:
  - Select *2004* in the *Monitor Library Year* list.
  - Save the Air Quality Grid as *Monitor Direct PM10 VNA 2004 Wards.aqg*.



When you map this new Air Quality Grid for 2000, your screen should look like this:

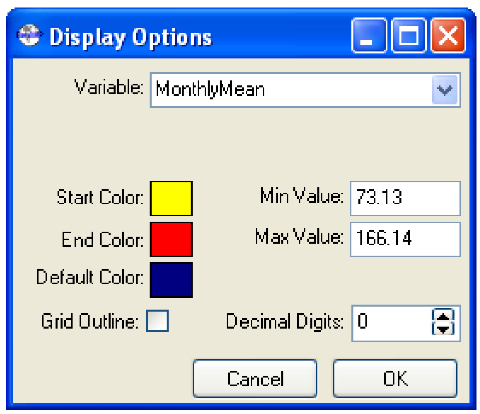
Note that the PM10 values in 2000 are higher than the values in 2004. Why? Note also that the values in Maravali are significantly higher than the other monitors. Why might that be the case?



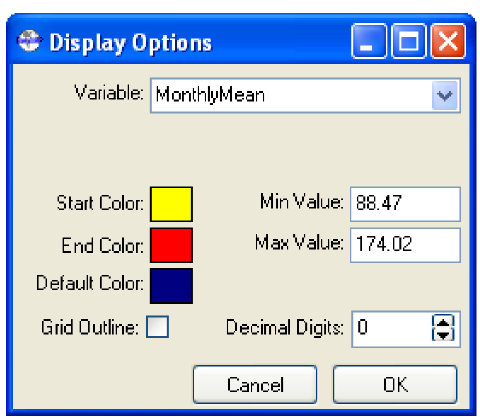
Task 2: Map Monitor Direct Grids with Same Scale

In this task we will continue examining maps of the air quality grids created in Task 1. To introduce the use of the *Display Options*, we will change the minimum and maximum display values.

- Open up the *BenMAP GIS* window by clicking *Tools* and then *GIS / Mapping* from the main *BenMAP 2.0* window.
- Click on the icon and select *Air Quality Grid (*.aqg)*. Locate the file called *Monitor Direct PM10 VNA 2004.aqg* that you created in Task 1 and click *Open*.
-



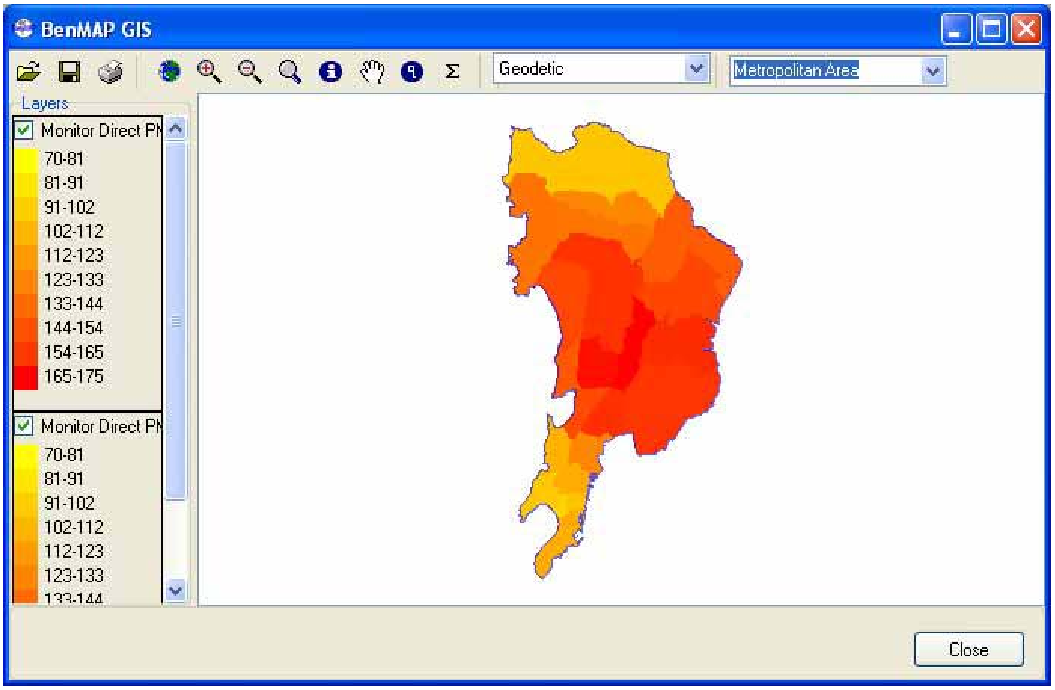
- Double click the text *Monitor Direct PM10 VNA 2004.aqg* in the *Layers* list, and then identify the *Min Value* and the *Max Value* in the *Display Options* window.
- Repeat these steps with the other file you created in Task 1, *Monitor Direct PM10 VNA 2000.aqg*.



- Choose the lowest of the *Min Values* and the highest of the *Max Values* to ensure that you have covered the entire range. The air quality grids span a range from 73.13 to 174.02.

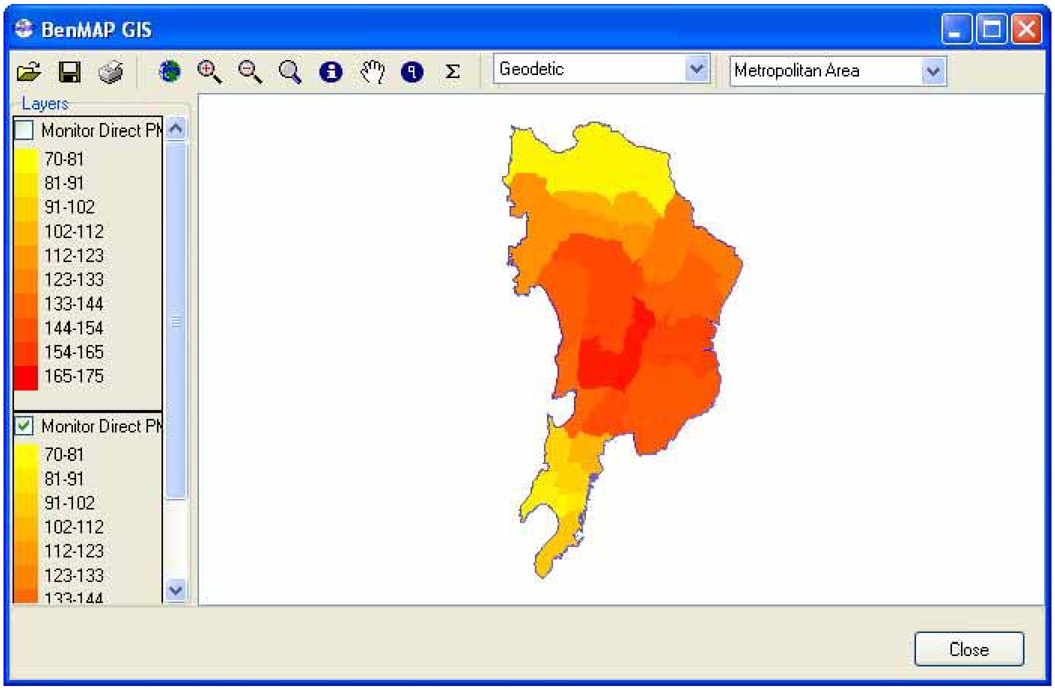
- For each of the maps change the *Min Value* to "70" and the *Max Value* to "175."
- Finally, select *Metropolitan Area* in the *Reference Layer* list.

Your screen should now look like this:



- The *BenMAP GIS* window cannot display both of the Air Quality Grid layers at the same time. To hide the *Monitor Direct PM10 VNA 2000.aqg* layer, uncheck the box next to the text *Monitor Direct PM10 VNA 2000.aqg* in the *Layers* list.

Your screen should now look like this:



- Try checking and then unchecking this box to visualize the change from the *Monitor Direct PM10 VNA 2000* grid to the *Monitor Direct PM10 VNA 2004* grid. Recall that it is the difference between two air quality grids that will drive the estimate of health impacts later on in the BenMAP analysis process.

Task 3: Check Audit Trail

Audit Trail Reports provide summaries of the assumptions underlying each of five types of files generated by BenMAP: Air Quality Grid (".aqg"), Configuration (".cfg"), Configuration Results (".cfgr"), Aggregation, Pooling, and Valuation (".apv"), and Aggregation, Pooling, and Valuation Results (".apvr"). These reports can be viewed within BenMAP in an expandable tree structure, or can be exported as tab-delimited text files.

In this task, you will generate an Audit Trail for the air quality grids that you have just created. If you are ever in doubt about the assumptions that you have used in generating an air quality grid, you can use an audit trail to find out!

- Click the *Create Reports* button. This will bring up the *Select Report Type* window.
- Select *Audit Trail Reports*, and click the *OK* button.
- Locate the PM10 Monitor Direct grids that you have created. (They should be in the Air Quality Grids folder.) Choose one and click *Open*.

- This will bring up an *Audit Trail Report*. Browse through the report and confirm that it contains the choices you made for the monitoring year, interpolation type, and grid definition.

Task 4: Additional Practice

Want additional practice?

- Investigate the impact of the various *Monitor Direct* grid creation options within the *Monitor Direct Settings* window (from the main BenMAP window, click *Create Air Quality Grids*, select *Monitor Direct*, and click *Go!*). Options include:
  - Grid Type.
  - Interpolation Method.
  - Maximum Neighbor Distance (via the *Advanced* button).
  - Maximum Relative Neighbor Distance (only when Interpolation Method = VNA).
  - Inverse Distance Squared weights (only when Interpolation Method = VNA).
- Select your options, click the *Map* button, and view the results.

In this problem set you have gained a familiarity with the process of grid creation. In the next problem set, you will create grids based on different interpolation methods, and learn more about the different options BenMAP offers.

Problem Set 3. Analyzing Trends in PM10 Levels & Interpolation Methods

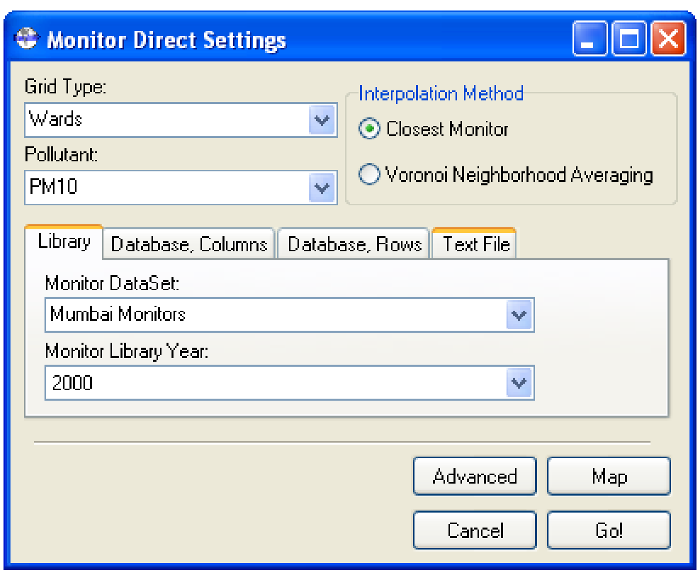
In this problem set, we are going to analyze the PM10 monitoring data from the years 2000 and 2004 that we loaded into BenMAP. In addition, we are going to consider the impact of alternative interpolation approaches, and the use of a maximum distance when interpolating.

Task 1: Compare Monitors & Grids

In this task we will take a closer look at an air quality grid that uses the Closest Monitor interpolation method. We create an air quality grid using Monitor Direct data just as we did in Task 1 of *Problem Set 2*; you can refer to that section if you have questions.

- At the main BenMAP window click on the *Create Air Quality Grids* button, and then choose *Monitor Direct* at the *Air Quality Grid Creation Method* window.
- Create a grid for PM10 using the *Wards* grid type, the *Closest Monitor* interpolation method, and the *Monitor Library Year* 2000.

Your screen should look like this:

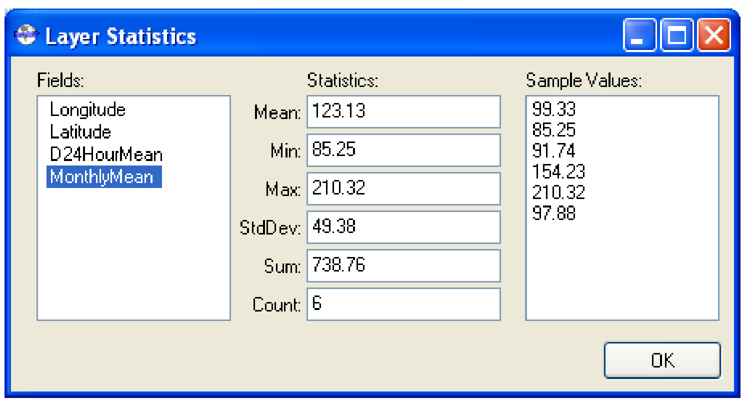


- Click the *Map* button. This will bring up the *BenMAP GIS* window.
- Double click the text *Air quality grid* in the *Layers* panel on the left side of the window. This will bring up the *Display Options* window.
- Set the *Display Options* as we did previously to *MonthlyMean*, and click *OK*.

- Similarly, double click the text *Monitors*, set the *Display Options*, and click *OK*.

> Λ **Note:** to move a layer either up or down on the left side of the *BenMAP GIS* window, right click on the layer that you want to move and select *Move Up* or *Move Down*.

- Consider the following questions.
  - Does the placement of the monitors make sense?
  - What parts of Mumbai have the highest PM10 levels?
- To get a quick summary of the active layer, click the "Σ" button (*View statistics for the active layer*), in the panel at the top of the window. This will bring up the *Layer Statistics* window. With monitors as the active window, your screen should look something like this:



- Compare the mean PM10 levels among the *Monitors* and the *Air quality grid.*
- Click the *OK* button to return to the *BenMAP GIS* window.
- When finished click the *Close* button in the *BenMAP GIS* window. This will take you back to the *Monitor Direct Settings* window.
- Click the *Go!* button and save the file as: *Monitor Direct PM10 Closest Monitor 2000 Wards.aqg*

Task 2: Analyzing Trends and Comparing VNA & Closest Monitor Interpolation

In this task, we will compare air quality grids using *Closest Monitor* and *VNA* interpolation.

- Create air quality grids with different selections for *Interpolation Method* and *Monitor Library Year*. In particular, create the following air quality grids (**Note:** some of these air quality grids may have already been created in an earlier section

of the tutorial. To confirm this look in the *Air Quality Grids* folder on your computer.):
- o *Monitor Direct PM10 Closest Monitor 2004 Wards.aqg*
- o *Monitor Direct PM10 VNA 2004 Wards.aqg*
- o *Monitor Direct PM10 Closest Monitor 2000 Wards.aqg*
- o *Monitor Direct PM10 VNA 2000 Wards.aqg*

➢ In the *Tools* menu on the main BenMAP screen, choose *GIS / Mapping* and load each of the above air quality grids, as well as the monitor data for the years 2000 and 2004.
- o Examine the values for the monitors. How do they compare with the values for the air quality grids?
- o What differences do you notice between grids using VNA and Closest Monitor interpolation?
- o How have PM10 levels changed over time?

➢ Compare your results with those in the following Table.
- o Are you able to reproduce these results?
- o What sorts of trends do you notice?

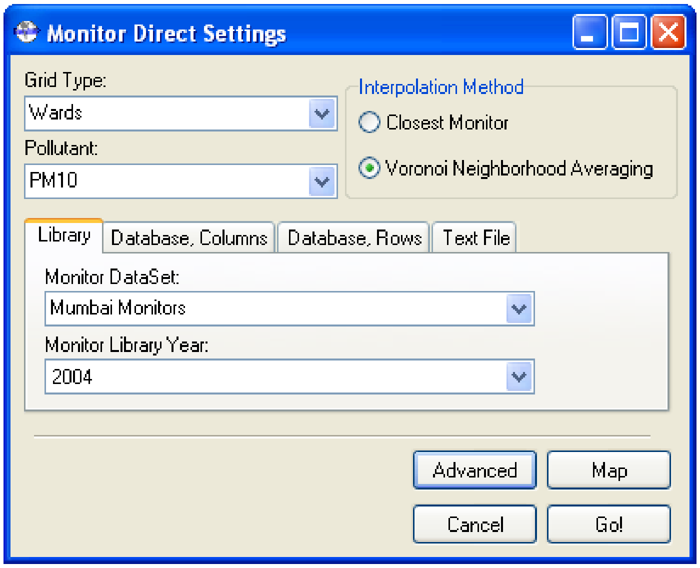
Table 1. Comparing Interpolation Approaches: Statistics for PM10 Air Quality Grids

Year	Active Layer	Grid	Interpolation	PM_{10} Levels (ug/m^3) *Mean*	*Min*	*Max*
2004	Monitors	--	--	110	70	202
	Air quality grids	Wards	Closest Monitor	122	70	202
			VNA	117	73	166
2000	Monitors	--	--	123	85	210
	Air quality grids	Wards	Closest Monitor	134	85	210
			VNA	130	88	174

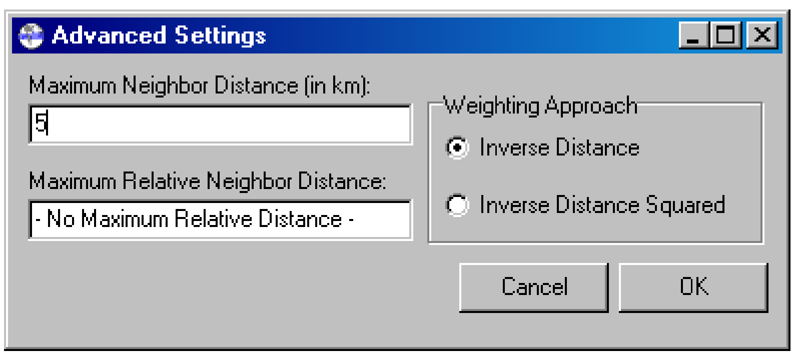
Task 3: Using Maximum Distance for Interpolation

In this task, we will generate PM10 air quality grids using a *Maximum Neighbor Distance* when interpolating monitors. The *Maximum Neighbor Distance* is a filter used by BenMAP, which will not include monitors when the interpolation distance is beyond the specified distance. Setting a *Maximum Neighbor Distance* is useful when you think that interpolating monitors a great distance is prone to significant error, such as when there is a mountain range between a monitor and a grid cell to which it would be interpolated.

- In the *Monitor Direct Settings* window, click the *Advanced* button.



- This will bring up the *Advanced Settings* window.

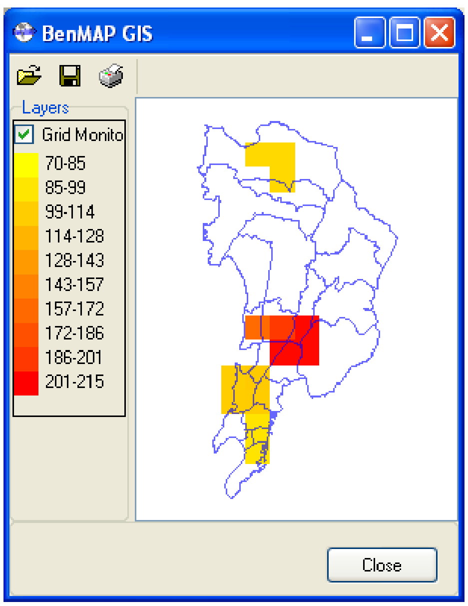


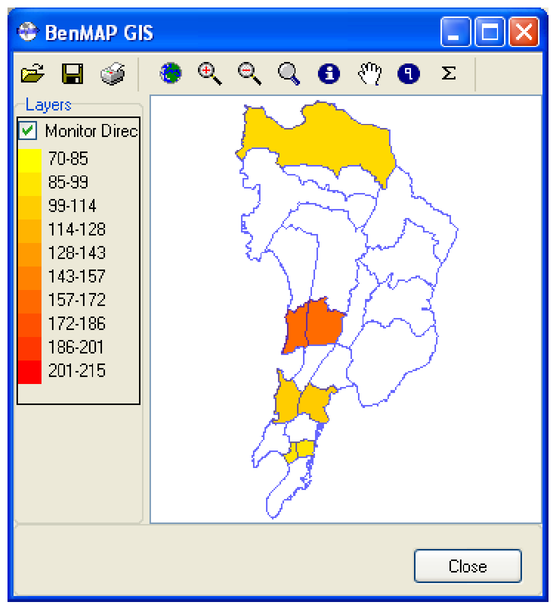
- In the box for *Maximum Neighbor Distance (in km)* type "5" and click *OK*.
- Click the *Map* button and examine the resulting air quality grid. You may wish to use the *Wards* reference layer to see which wards are included in the grid.
- When done examining the resulting air quality grid, save it as *Monitor Direct PM10 VNA 2004 Wards 5km Max.aqg*.
- Follow the same sorts of steps as above, and map and save air quality grids with different distances for the *Maximum Neighbor Distance (in km)*, as in Table 2 below.
    - How do the number of wards included in the interpolation process change with the *Maximum Neighbor Distance*?
    - What distance seems most appropriate for Mumbai? Why?
    - Compare your results with the following maps.
    - Consider the table with total population included within grids that have monitors within the specified maximum distances.

Table 2. Total Population by Maximum Distance

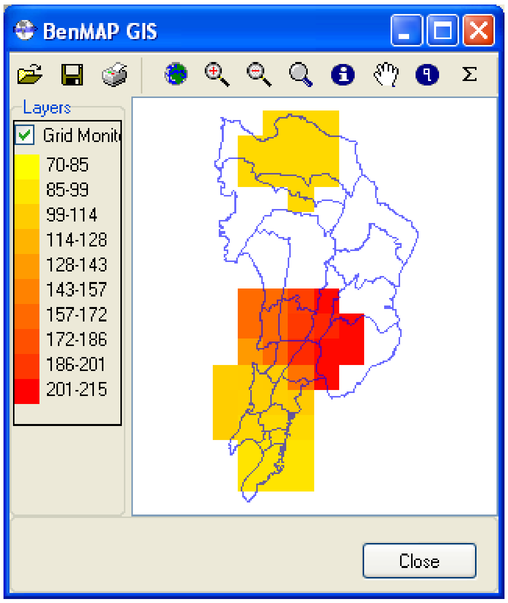
Grid	Interpolation	Maximum Distance (km)	Ward Grid Population (million people)	Mumbai Grid Population (million people)
Wards	VNA	1.5	1.7	1.2
		2.5	3.1	3.7
		5	7.6	7.0
		7.5	9.6	9.0
		10	10.9	11.2
		12.5	11.9	11.8
		15	11.9	11.9
		No Max	11.9	11.9

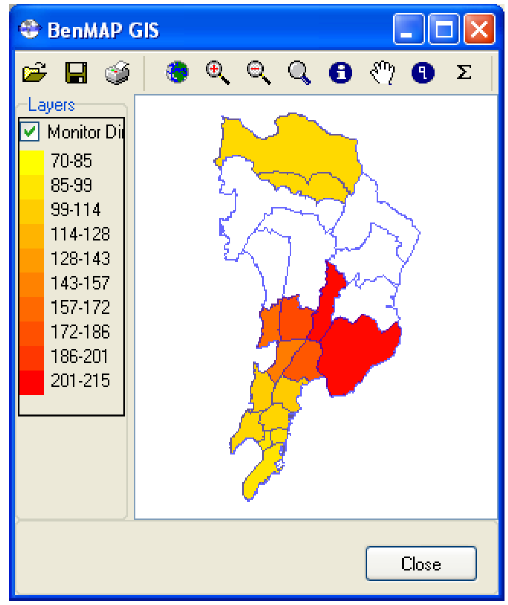
2.5 Kilometer Maximum Distance for Interpolation by Grid (2004 Monitors)



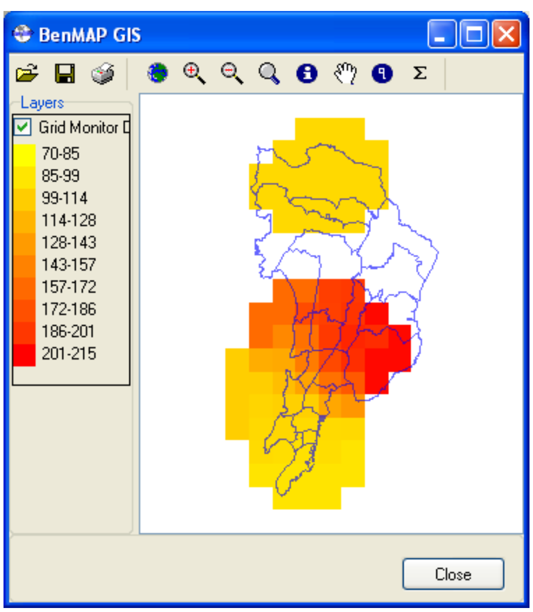


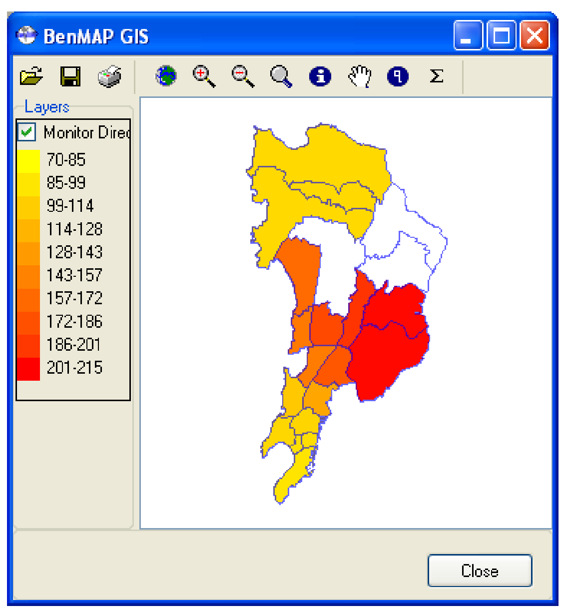
5 Kilometer Maximum Distance for Interpolation by Grid (2000 Monitors)



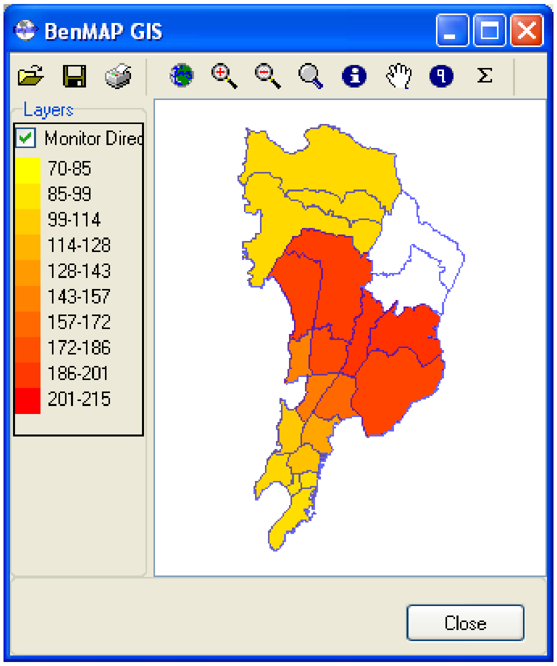


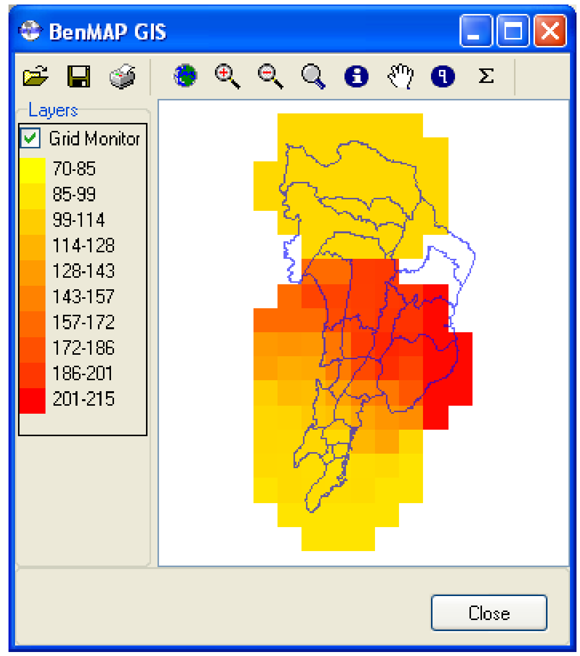
7.5 Kilometer Maximum Distance for Interpolation by Grid (2000 Monitors)



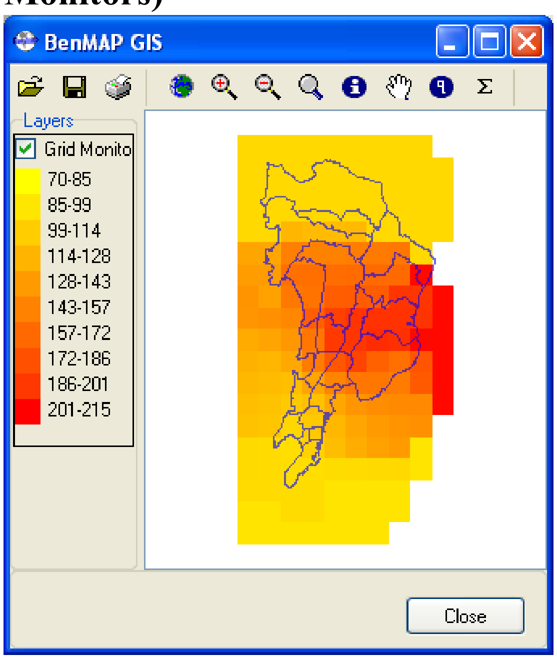


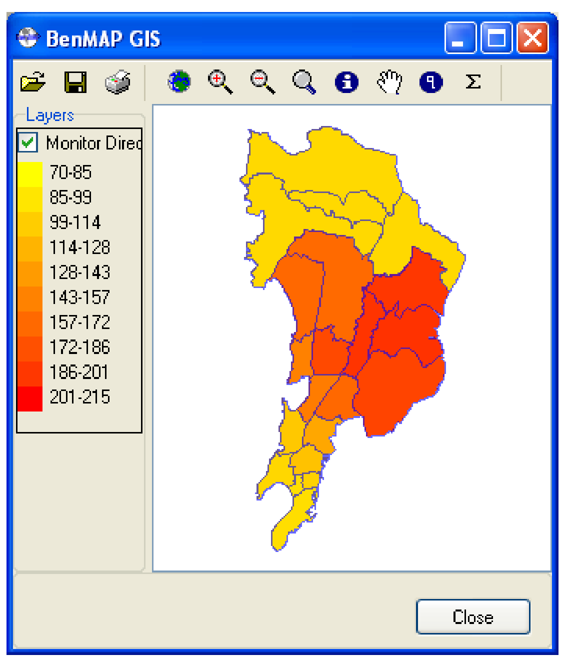
10 Kilometer Maximum Distance for Interpolation by Grid (2000 Monitors)





12.5 Kilometer Maximum Distance for Interpolation by Grid (2000 Monitors)





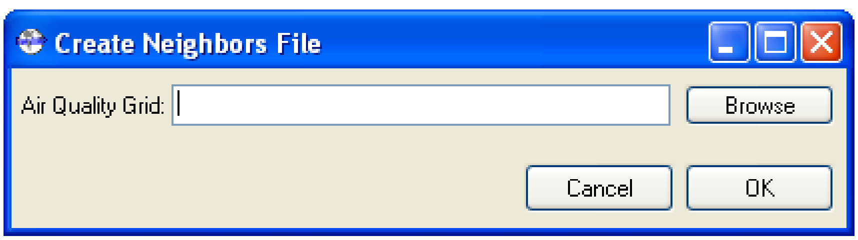
Task 4: Analyzing Weights Used in Voronoi Neighbor Averaging

BenMAP includes two interpolation methods. The *Closest Monitor* method simply uses the monitor closest to a grid cell's center as its representative value. The *Voronoi Neighbor Averaging* method takes an inverse-distance weighted average of a set of the monitors surrounding a grid cell's center as its representative value.

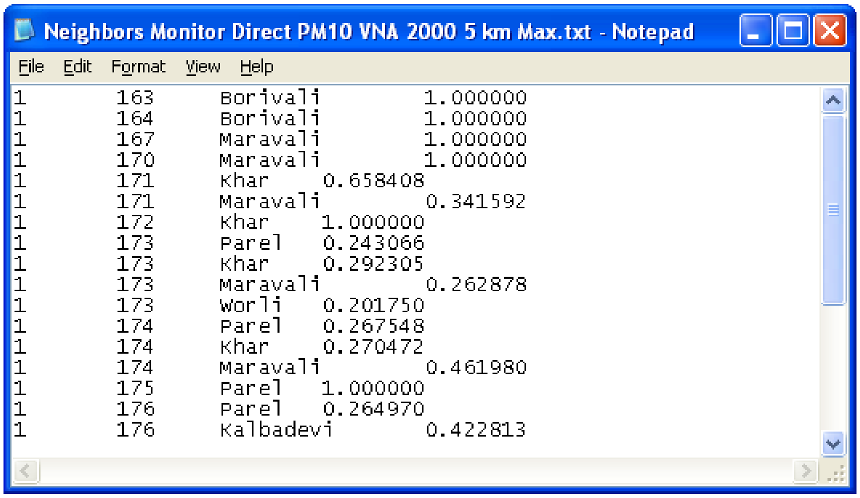
In this task, we will examine the weights used in the Voronoi Neighbor Averaging (VNA) process.

- Create an air quality grid based on year 2000 monitor data for PM10.
    - Choose a 5 kilometer *Maximum Neighbor Distance*.
    - Make sure that VNA is chosen as the *Interpolation Method.*
    - Save the file with a name like *Monitor Direct PM10 VNA 2000 Wards 5 km Max.aqg*.

- In the *Tools* menu on the main BenMAP screen, choose *Neighbor File Creator*. This will bring up the *Create Neighbors File* window:



- Click the *Browse* button, and locate the air quality grid that you created, and then click *Open*. Click *OK* in the *Create Neighbors File* window. This will bring up the *Reports* window. Save the neighbors file with a name like *Neighbors Monitor Direct PM10 VNA 2000 5 km Max.txt*.
- Open the file in Notepad or a similar text reader. The file should look something like this:

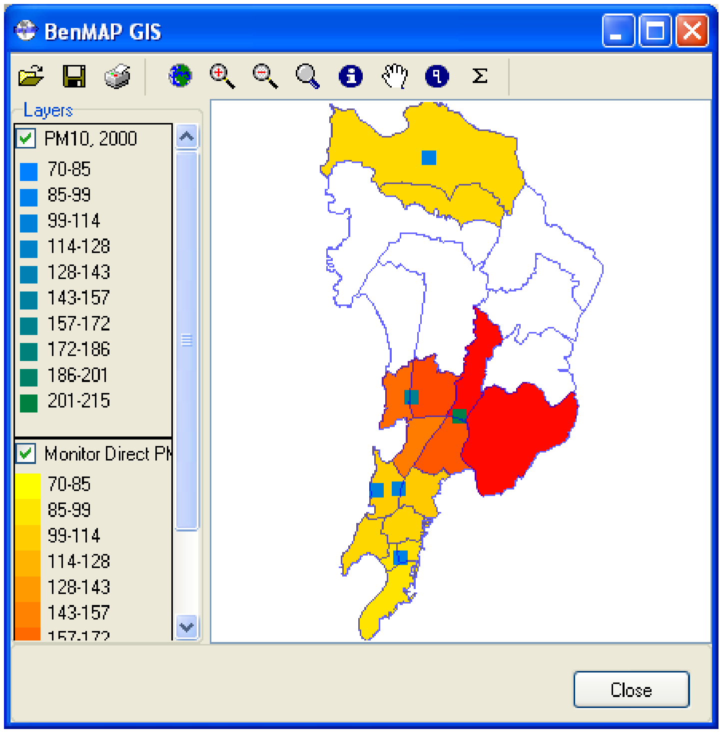


1	163	Borivali	1.000000
1	164	Borivali	1.000000
1	167	Maravali	1.000000
1	170	Maravali	1.000000
1	171	Khar	0.658408
1	171	Maravali	0.341592
1	172	Khar	1.000000
1	173	Parel	0.243066
1	173	Khar	0.292305
1	173	Maravali	0.262878
1	173	Worli	0.201750
1	174	Parel	0.267548
1	174	Khar	0.270472
1	174	Maravali	0.461980
1	175	Parel	1.000000
1	176	Parel	0.264970
1	176	Kalbadevi	0.422813

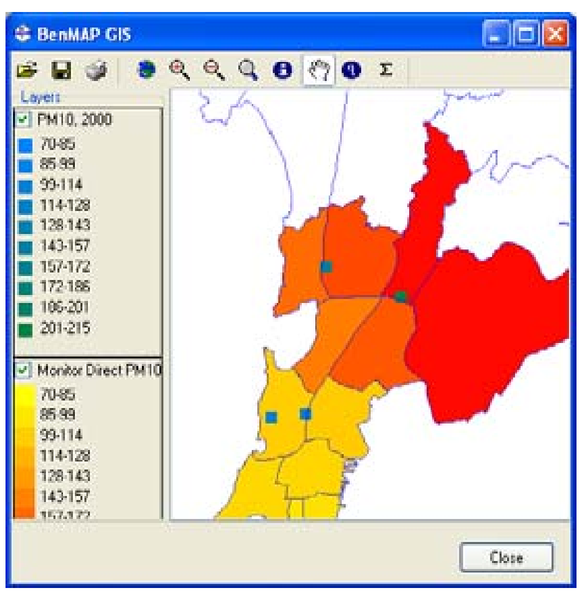
- The second column gives the numerical identifier of a particular Ward (e.g., “171”). The third column lists the monitors that are used to estimate PM10 levels at that Ward (e.g., Khar, Maravali). Finally, the fourth column gives the weights used in the interpolation process:
  - In the case of Ward 171, the PM10 level equals approximately 0.66 times the PM10 value at the Khar monitor PLUS 0.34 times the PM10 value at the Maravali monitor.

Plausibility Check Using a Map

- In the *Tools* menu on the main BenMAP screen, choose *GIS / Mapping*. This will bring up the *BenMAP GIS* window.
- Click on the *Open a file* button in the top panel. Load the air quality grid that you just created, and the PM10 monitors for 2000.
- Choose Display Options that allow you to clearly see the monitors.
- Set the *Reference Layer* to *Wards*. Your screen should look something like this:



- Use the *Increase Zoom* and the *Drag Mode* buttons, at the top of the panel in the *BenMAP GIS* window, to zoom to the Wards with PM10 data.
- Make the *Monitor Direct* grid that you created the active layer by right clicking the text and choosing *Move Up*.
- Identify the Ward with the numerical identifier of "171."
  - **Note:** you will need to use the "i" button (*Click to display info for the cell under the mouse*). Also, the Ward numerical identifier equals the row value when you click to display info for a particular Ward.

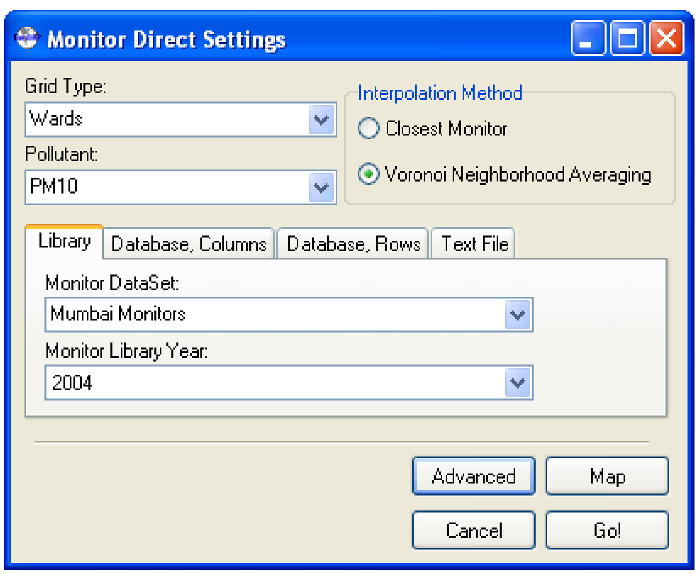


- After you have identified Ward 171, then move the monitor layer (*PM10, 2000*) to the top of the left panel so that it is active.
- Find the Khar and Maravali monitors, and then examine the weights used with them to estimate PM10 levels at Ward 171.
  - Recall the weights from the Neighbor File Creator are: Khar = 0.66; Maravali = 0.34.
  - Do these weights seem reasonable?
- Identify a few more Wards and check if their weights seem plausible.
  - Does VNA seem like a good interpolation approach?
  - Alternatively, would it be better to use Closest Monitor to estimate PM10 levels at each Ward?

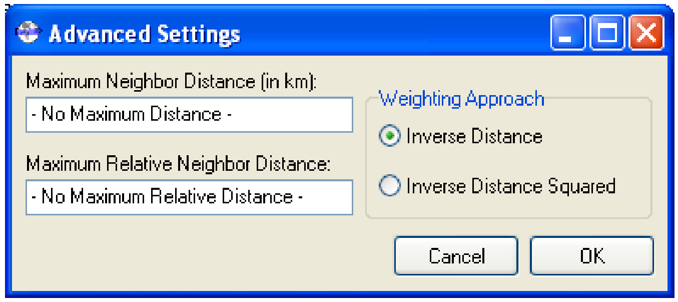
Task 5: Comparing Inverse Distance & Inverse Distance Squared Interpolation

In this task, we will compare PM10 air quality grids using different approaches to weighting distance when interpolating monitors. Throughout, we assume a *Maximum Neighbor Distance* of 5 kilometers.

- In the *Monitor Direct Settings* window, click the *Advanced* button.



- This will bring up the *Advanced Settings* window.



- Choose either Inverse Distance or *Inverse Distance Squared* option in the *Weighting Approach* panel. Set *Maximum Neighbor Distance (in km)* to 5 kilometers. (For now, ignore the option for *Maximum Relative Neighbor Distance*.) Click *OK*.

> Λ **Note:** the default *Weighting Approach* is *Inverse Distance*, so there is no need to specify *Inverse Distance* if this is the *Weighting Approach* that you would like to use.

- Follow the same sorts of steps as in prior tasks, and map air quality grids with different selections for *Weighting Approach*.
  - What differences do you notice between grids using the *Inverse Distance* and *Inverse Distance Squared* approaches?
  - The choice of *Weighting Approach* is only an option for *VNA* interpolation (and not *Closest Monitor* interpolation). Why?
- Compare your results with those in the following Table.
  - Are you able to reproduce these results?
  - What sorts of trends do you notice?

Note that inverse distance squared weighting has more of an effect with no maximum distance compared with a maximum distance of five kilometers. This happens because fewer monitors are involved in the weighting process with a five kilometer maximum distance. In some instances, only a single monitor is involved in the interpolation (the rest of the monitors are more than five kilometers away). With just a single monitor, the two weighting approaches are identical.

Table 3. Comparing Weighting Approaches: Statistics for PM10 Air Quality Grids (No Maximum Distance)

Year	Active Layer	Grid	Interpolation	Weighting Approach	PM_{10} Levels (ug/m^3) Mean	Min	Max
2004	Monitors	--	--	--	110	70	202
	Air quality grids	Wards	VNA	Inverse Distance	117	73	166
				Inverse Distance Squared	118	71	178
		Grid	VNA	Inverse Distance	112	76	171
				Inverse Distance Squared	109	72	192
2000	Monitors	--	--	--	123	85	210
	Air quality grids	Wards	VNA	Inverse Distance	130	88	174
				Inverse Distance Squared	131	86	185
		Grid	VNA	Inverse Distance	125	89	179
				Inverse Distance Squared	123	87	201

Table 4. Comparing Weighting Approaches: Statistics for PM10 Air Quality Grids (5 km Maximum Distance)

Year	Active Layer	Grid	Interpolation	Weighting Approach	PM_{10} Levels (ug/m^3) Mean	Min	Max
2004	Monitors	--	--	--	110	70	202
	Air quality grids	Wards	VNA	Inverse Distance	112	70	202
				Inverse Distance Squared	112	70	202
		Grid	VNA	Inverse Distance	109	70	202
				Inverse Distance Squared	109	70	202
2000	Monitors	--	--	--	123	85	210
	Air quality grids	Wards	VNA	Inverse Distance	126	85	210
				Inverse Distance Squared	126	85	210
		Grid	VNA	Inverse Distance	123	85	210
				Inverse Distance Squared	123	85	210

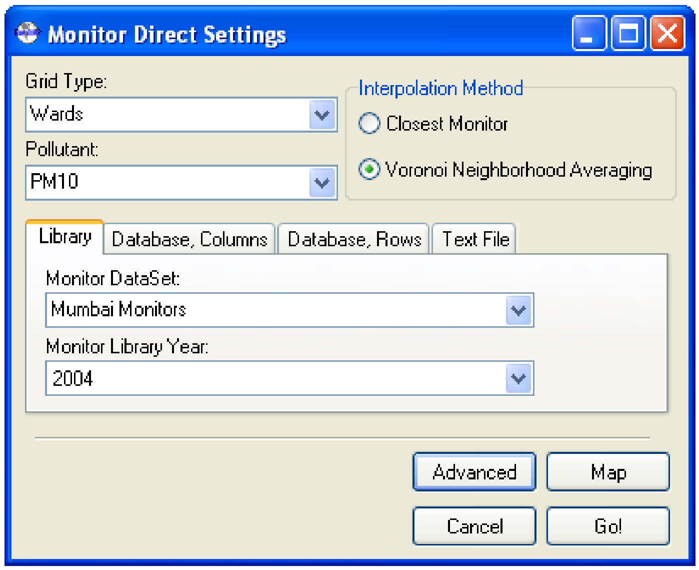
Task 6: Using Maximum Relative Distance for Interpolation

In this task, we will generate PM10 air quality grids using a *Maximum Relative Neighbor Distance* when interpolating monitors. Setting a *Maximum Relative Neighbor Distance* is useful when you would prefer to avoid using monitors in the interpolation process which are much further away from a grid cell than its other neighboring monitors.

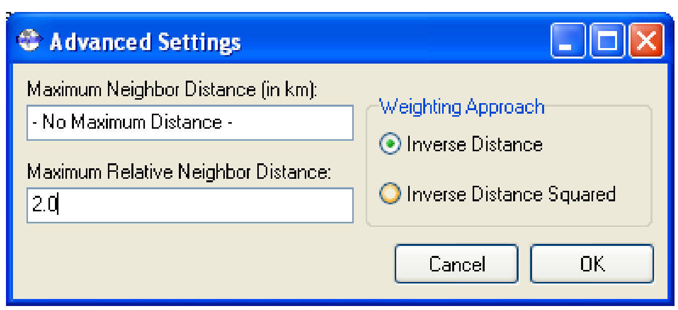
Note that a *Maximum Relative Neighbor Distance* can be used along with a *Maximum Neighbor Distance*. In such a situation BenMAP drops monitors that are relatively far away compared to their neighbors AND drops all monitors that are beyond a given distance.

Λ **Note:** *Maximum Relative Neighbor Distance* and *Maximum Neighbor Distance* help determine the monitors that BenMAP will use in the interpolation process. The *Weighting Approach* determines how to weight the remaining monitors.

- In the *Monitor Direct Settings* window, click the *Advanced* button.



- This will bring up the *Advanced Settings* window.



- In the box for *Maximum Relative Neighbor Distance* type "2.0" and click *OK*.
- Follow the same sorts of steps as in prior tasks, and map air quality grids with lower values for the *Maximum Relative Neighbor Distance*.
    - Do the number of wards included in the interpolation process change with the *Maximum Relative Neighbor Distance*?
    - What distance seems most appropriate for Mumbai? Why?
- Compare your results with those in the following Table.
    - Are you able to reproduce these results?
    - What sorts of trends do you notice?

Table 5. Maximum Relative Distance: Statistics for PM10 Air Quality Grids

				PM_{10} Levels (ug/m^3)		
Year	**Active Layer**	**Interpolation**	**Maximum Relative Distance**	*Mean*	*Min*	*Max*
2004	Monitors	--	--	110	70	202
	Air quality grids	VNA	1	122	70	202
			1.5	121	70	202
			2	118	70	202
				116	70	180
			No Max	117	73	166
2000	Monitors	--	--	123	85	210
	Air quality grids	VNA	1	134	85	210
			1.5	133	85	210
			2	131	85	210
			3	129	85	186
			No Max	130	88	174

Note that when the *Maximum Relative Neighbor Distance* is set to "1," this is equivalent to using *Closest Monitor* interpolation. Unless the monitors are an identical distance away, there will always be a closest monitor, so when setting the relative distance to "1" we are saying that all monitors have to be at least as close as this closest monitor.

Now that you are familiar with creating grids and analyzing air pollution levels, we will move on to the next component of BenMAP: estimating the change in health impacts. The next problem set provides examples of how health effect estimates are derived. *Problem Set 5* then describes how to load population and concentration-response (C-R) functions into a *Setup*.

Problem Set 4. Deriving Health Effect Estimates

Task 1: Derive PM_{10} Mortality Health Effect Estimate

In this task, you will derive a health impact coefficient and its associated standard error using the result from a recent analysis of by the Health Effects Institute (2004).[4] This study included all epidemiological studies published up through 2003 from Asian cities such as Taipei, Hong Kong, Seoul, and others.

This is the same kind of exercise performed to create the effect estimates (betas) used in BenMAP. The effect estimates and standard errors are included in the C-R functions that you load into the *Setup Manager*.

Answers are provided at the end of this problem set.

- Using a random-effects statistical approach, Health Effects Institute (2004, Table 2) reported that a 10 microgram per meter cubed (ug/m^3) increase of daily mean level of PM10 was found to be associated with 0.49% increase of additional daily mortality (Relative Risk (RR) = 1.0049, 95% Confidence Interval (CI) = 1.0023-1.0076).

- The health impact estimate (or "Beta") can be calculated by taking the log of the relative risk and dividing by the change in air pollution associated with this relative risk. Calculate the value of Beta.

  Beta =

.

- The standard error can be calculated by assuming that Beta is normally distributed, and using the fact that there are 3.92 standard errors between the 2.5th percentile and the 97.5th percentile.

- Start by calculating the Beta associated with the 2.5th and 97.5th percentiles of the relative risk. Calculate the difference between the two, and then divide by 3.92.

---

[4] Health Effects Institute. 2004. Health effects of outdoor air pollution in developing countries of Asia: A literature review. Special Report 15. Boston, MA. April.

$Beta_{5th} =$

$Beta_{95th} =$

$Beta\ Std\ Error =$

Task 2: Derive PM_{10} Mortality Health Impact Function

In this task, you will derive a health impact coefficient (Beta) and its associated standard error using the result from a recent analysis by Kumar (undated).[5] Using logistic regression, this study examined the relationship between air pollution and cough in adults in the State of Punjab, India.

Kumar reported an odds ratio of 1.59 (95 percent confidence interval: 1.21 – 2.21) associated with a pollution SPM level of 291.3 ug/m^3 in the less polluted city and 890.3 ug/m^3 in the more polluted city (a difference of 599 ug/m^3). Calculate the SPM coefficient.

Next, calculate the PM10 coefficient, assuming a PM10/SPM ratio of 0.50. To estimate the PM10 coefficient, use the following equation:

$Beta_{PM10} = (1/0.5) * Beta_{SPM}$

[5] Manoj Kumar (undated) "An Epidemiological Study on Effects of Air Pollutants on Respiratory Morbidity among Adults." Power point presentation available on internet.

Task 3: Additional Practice

Want additional practice?

- Derive a health impact coefficient and its associated standard error using the result from Cropper et al (1997).[6] This study examined the relationship between premature mortality and SPM in Delhi, India.

- Cropper et al (1997) reported a relative risk of 1.023 (t statistic: 2.28) associated with a change in the SPM level of 100 ug/m^3. Calculate the SPM coefficient. Then calculate the PM10 coefficient, assuming a PM10/SPM ratio of 0.50.

- Note that the t-statistic equals the coefficient divided by the standard error. Once you have calculated the coefficient, use the t-statistic to calculate the standard error.

[6] Cropper, M. L., N. B. Simon, A. Alberini, S. Arora and P. K. Sharma. 1997. The health benefits of air pollution control in Delhi. American Journal of Agricultural Economics. Vol. 79 (5 SI): 1625-1629.

Answers:

<u>Task 1</u>
PM_{10} Beta = ln(1.0049) / 10 = 0.00049
PM_{10} $Beta_{2.5th}$ = ln(1.0023) / 10 = 0.00023
PM_{10} $Beta_{97.5th}$ = ln(1.0076) / 10 = 0.00076
PM_{10} Std Err = ($Beta_{97.5th}$ – $Beta_{2.5th}$) / 3.92 = 0.000135

<u>Task 2</u>
SPM Beta = ln(1.59)/ 599 = .00077
PM_{10} Beta = .00077 * 0.50 = .00039

<u>Task 3</u>
SPM Beta = ln(1.023)/ 100 = .00023
SPM Std Err = .00023/ 2.28 = .00010
PM_{10} Beta = .00023 * 0.50 = .00011
PM_{10} Std Err = .00011/ 2.28 = .00005

Problem Set 5. Setup Manager (2)– Loading Population & C-R Functions

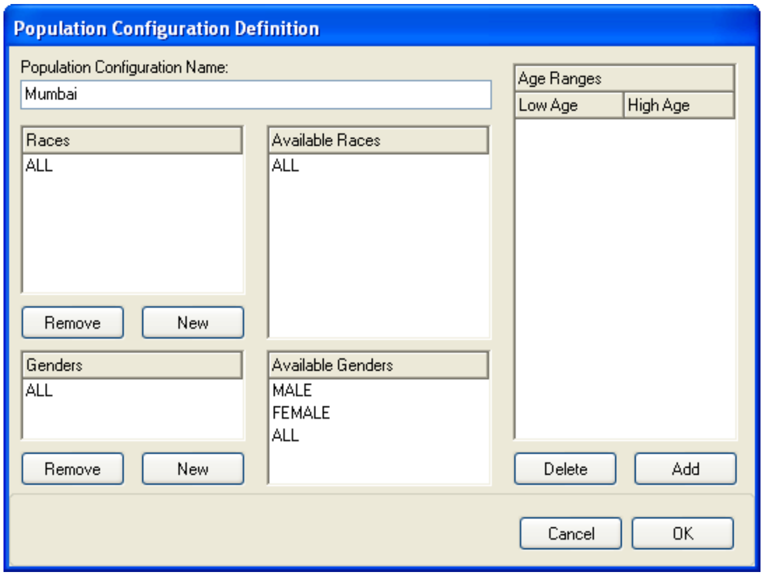
In this problem set, we will return to the *Setup* that we created in *Problem Set 1*. In that problem set, we loaded the pollutant information and monitoring data into the Mumbai *Setup*. Now we will load the population data and the concentration response (C-R) functions.

Task 1: Add Population Data

In this task, we will define the population data and then load it into BenMAP. The population data is provided in the *Sample data*.

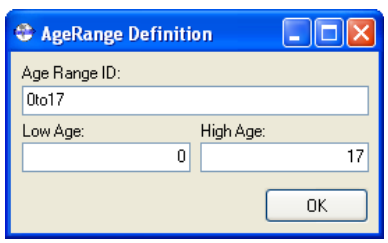
- Click *Tools* and then *Modify Setup*. This will bring up the *Manage Setups* window.
- Make sure that *Copy of Mumbai* is selected in the *Available Setups* list.
- Click the *Edit* button under the *Population DataSets* list. This will bring up the *Manage Population DataSets* window.
- Click the *Add* button under the *Available DataSets* list to add a new Population DataSet. This will bring up the *Load Population DataSet* window.
- In the *Population DataSet Name* box, type *Mumbai Ward Population*. This will be the name of the new Population DataSet.
- Click the *Add* button. This will bring up the *Population Configuration Definition* window.
- In the box for the *Population Configuration Name* type “Mumbai.”
- Drag “ALL” from *Available Races* panel to the *Races* panel.
- Drag “ALL” from the *Available Genders* panel to the *Genders* panel.

Your screen should now look like this:



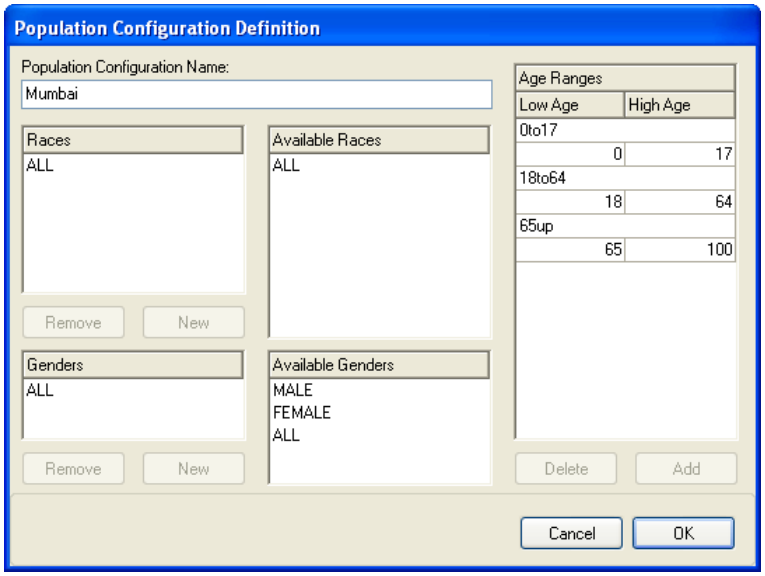
- The next step is to add the age groups to your Population Configuration. Click the *Add* button. This will bring up the *AgeRange Definition* window.
- Type "0to17" in the *Age Range ID* box and "17" in the *High Age* box.

Your screen should now look like this:



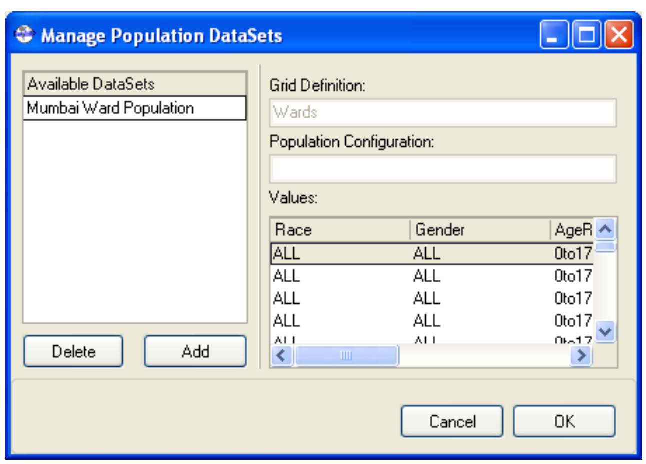
- **Note:** be very careful to spell the *Age Range ID* values correctly, as BenMAP uses these to load values from the external population database you will be loading in the next step.
- Click *OK*. This will take you back to *Population Configuration Definition* window.
- Click *Add* to define the next age group. This will bring up the *AgeRange Definition* window. Type "18to64" in the *Age Range ID* box and "64" in the *High Age* box.
- Click OK. Repeat this process for the "65up."
- Note: for the age group "65up", type "100" in the *High Age* box.

Your screen should now look like this:



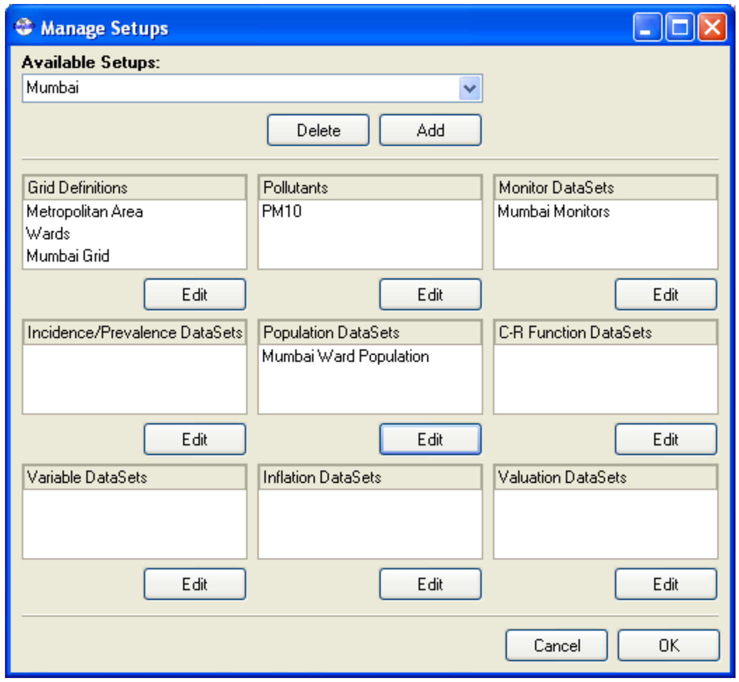
- Click the OK button to return to the *Load Population Dataset* window.
- Select *Wards* in the *Grid Definition* list.
- Click the *Browse* button next to the *Database* box.
- Locate the *Mumbai Ward Population for BenMAP.xls* file and click *Open*.
- Click the *OK* button to load the Population DataSet and return to the *Manage Population DataSets* window. This may take some time.

Your screen should now look like this:



- Click the *OK* button to return to the *Manage Setups* window.

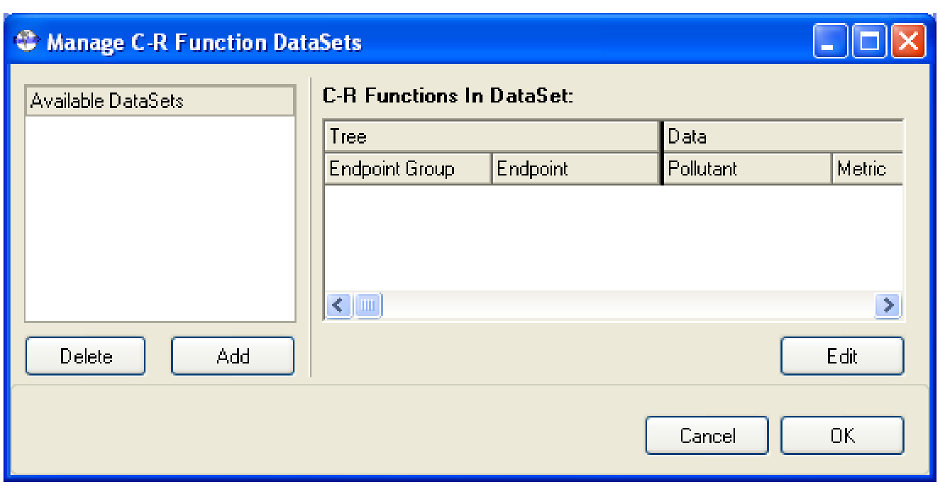
Your screen should look like this:



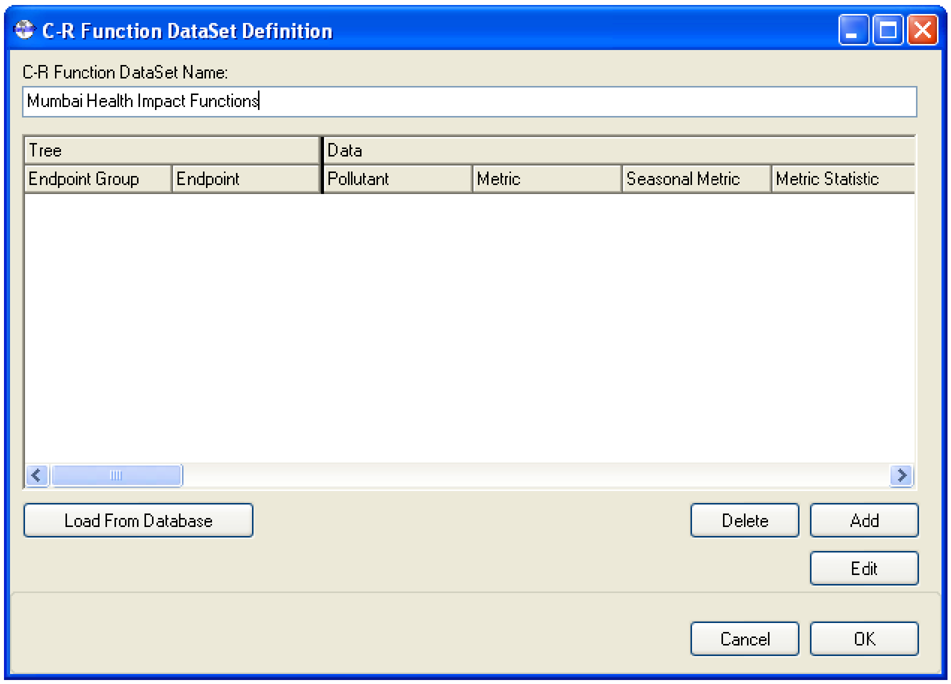
Task 2: Add Health Impact Functions

In this task we will add the health impact functions that describe the change in health impact (such as mortality or hospital admissions) associated with changes in air pollution levels. Health impact functions for Mumbai are provided in the *Sample Data.* This task will load all of the available functions; in *Problem Set 6* we will select specific functions to include in a configuration.

- Click the *Edit* button under the *C-R Function DataSets* list. This will bring up the *Manage C-R Function DataSets* window:

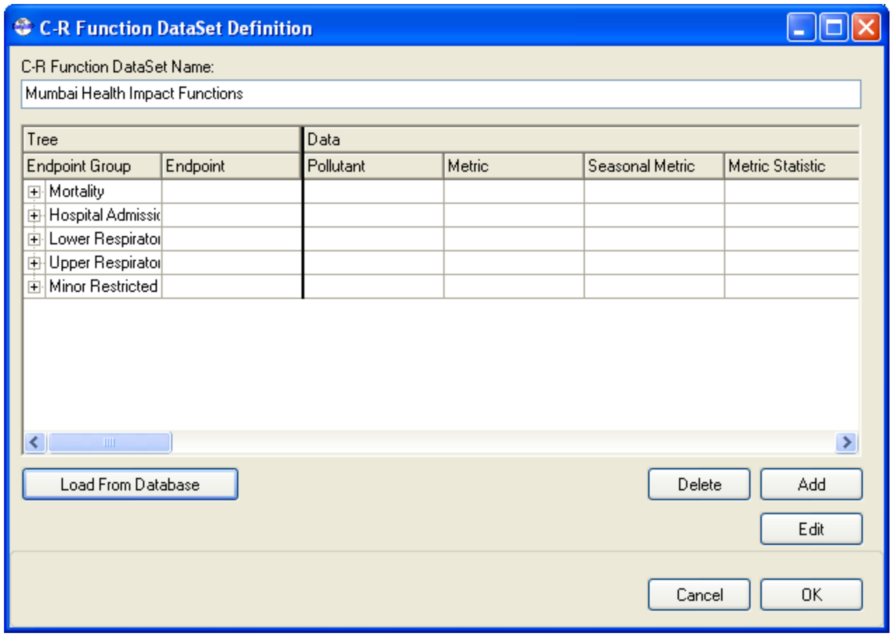


- Click the *Add* button under the *Available DataSets* list to add a new C-R Function DataSet. This will bring up the *C-R Function DataSetDefinition* window.
- In the *C-R Function DataSet Name* box type *Mumbai Health Impact Functions*. This will be the name of the new C-R Function DataSet.



- Click the *Load From Database* button. This will bring up the *Load a C-R Function Database* window.
- Locate the *Mumbai Health Impact Functions.xls*. file. (Make sure that *File of Type* located at the bottom of the window is set to Excel Files.) After locating the file (by default in \Program Files\Abt Associates Inc\BenMAP 2.2\Sample Data\Mumbai\Population), click *Open*. This will bring up the *Select a Table* window.
- In the drop-down list, select the "*Health Functions BenMAP*" table.
- Click *OK*. This will bring you back to the *C-R Function DataSet Definition* window.

Your screen should now look like this:



- Click the *OK* button to return to the *Manage Setups* window.
- Click *OK* to get back to the main BenMAP window.

Now your *Setup* is complete, and can be used over and over to run many different configurations, as described in the next problem set. In *Problem Set 8*, you will return to the *Setup* to add optional information on variables and valuation.

Problem Set 6. Creating and Running Configurations

A configuration is a reusable file that specifies the air quality grids, health impact functions, population data, and other parameters necessary for a health impact analysis. The same *Setup* is used for many different configurations, each containing a different set of choices, but based on the same general data contained in the *Setup*.

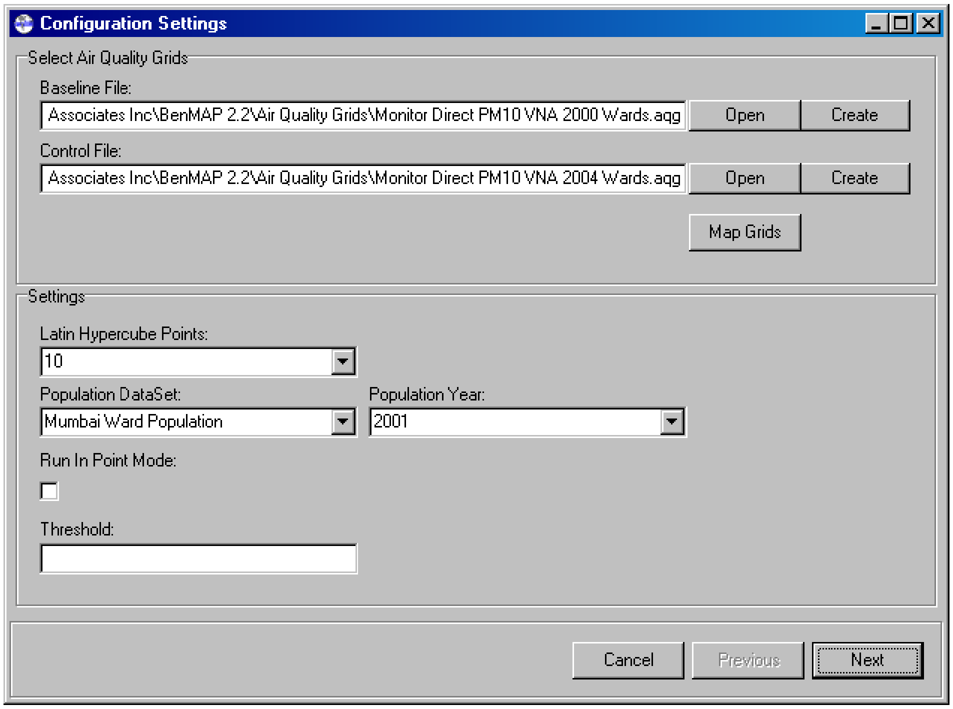
This problem set will take you through the steps of creating a configuration, running it, creating an audit trail, and exploring the results.

Task 1: Create a PM_{10} Configuration

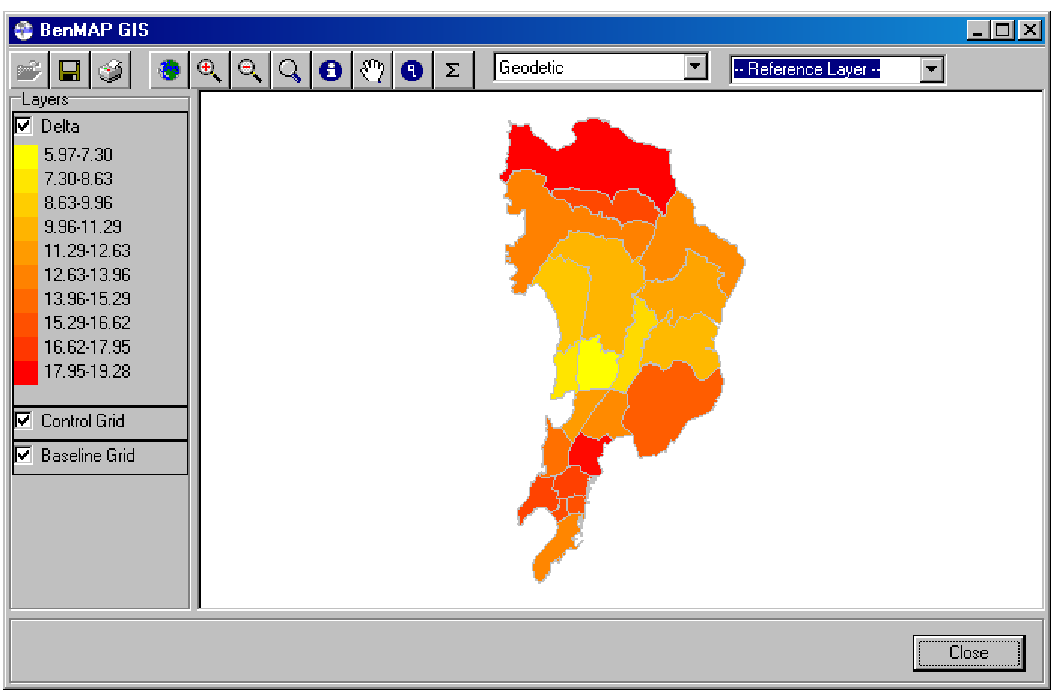
In this task, we will create a configuration for an analysis of the effect of PM10 on premature mortality, cardiovascular hospital admissions, and other health effects. This configuration will be saved and can be re-used in the future.

- Make sure *Mumbai* is selected as the *Active Setup*.
- Click the *Create and Run Configuration* button. This will bring up the *Configuration Creation Method* window.
- Select *Create New Configuration* and click the *Go!* button. This will bring up the *Configuration Settings* window.
- Click the *Open* button next to the *Baseline File* box, locate the previously created *Monitor Direct PM10 VNA 2000 Wards.aqg* file, and click *Open*.
- Click the *Open* button next to the *Control File* box, locate the previously created *Monitor Direct PM10 VNA 2004.aqg* file, and click *Open*.
- Select the value *10* in the *Latin Hypercube Points* list.
- Select the value *Mumbai Ward Population* in the *Population DataSet* list.
- Select the value *2001* in the *Population Year* list.

Your screen should now look like this:

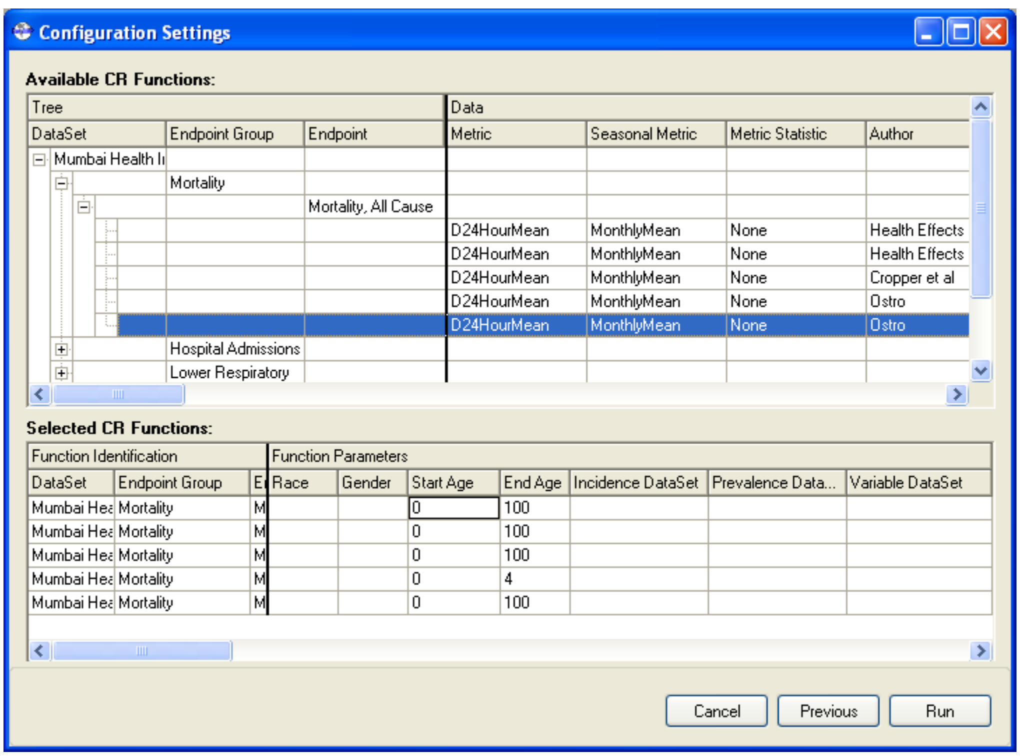


- ➢ Click the *Map Grids* button. This will bring up the *BenMAP GIS* window.
- ➢ Double click the *Delta* in the *Layers* panel, which will open the *Display Options* window. Select *MonthlyMean* in the Variable drop-down box. This will allow you to view the change between the *Baseline* and *Control* modeled scenarios. Your screen should look something like this:



Note: Examining maps of the *Delta*, *Baseline*, and *Control* allows you to better understand your analysis, particularly where large changes may be occurring between the Baseline and Control scenarios. (Also, viewing these maps can be useful to determine why you might be getting strange results!)

- Click the *Close* after you have examined the maps. This will take you back to the *Configuration Settings* window.
- Click the *Next* button to move on to selecting health impact (C-R) functions. This may take a moment as BenMAP loads the appropriate functions.
- Expand the *Mumbai Health Impact Functions* node by clicking on the + symbol next to it. Then expand the *Mortality* and *Mortality, All Cause* nodes.
- Click on each of the *Mortality* functions, and drag it to the *Selected C-R Functions* panel. When you have selected all of the mortality functions, your screen should look something like this:



Note: you can narrow and widen the various columns by dragging their right edges. Alternatively, if you double click the right edge of a column it will automatically size itself to the longest value present.

- Repeat this process with the rest of the available C-R functions.
    - You can save time by dragging a node, rather than individual functions (a node can represent multiple functions if their leftmost variables are the same). Highlight the node and drag it into the *Selected CR Functions* panel.
    - If you accidentally drag the same function twice, highlight the duplicate in the *Selected CR Functions* panel, and hit *Delete* on your keyboard.

Task 2. Run the Configuration

This task shows you how to save and run your configurations. Once a configuration is saved, it can be re-opened and run at any time in the future.

- Click the *Run* button. This will bring up the *Save Configuration* window.
- Click the *Save* button to save the Configuration to file – this will store the various choices you just made: the baseline and control air quality grids, the number of Latin hypercube points, the population dataset and year, and the selected CR functions. Name the configuration *Mumbai PM10 Configuration* and click *Save*.
- Click the *OK* button to save the Configuration Results to file – this will store the health impact estimates generated by the various choices we just made. Name the configuration results *Monitor Direct PM10 VNA 2000-2004 Wards Results* and click *Save*. This may take some time, as BenMAP loads all of the relevant data and then runs each of the health impact functions for each cell in the analysis.

When BenMAP is done generating results, you will be returned to the main BenMAP window.

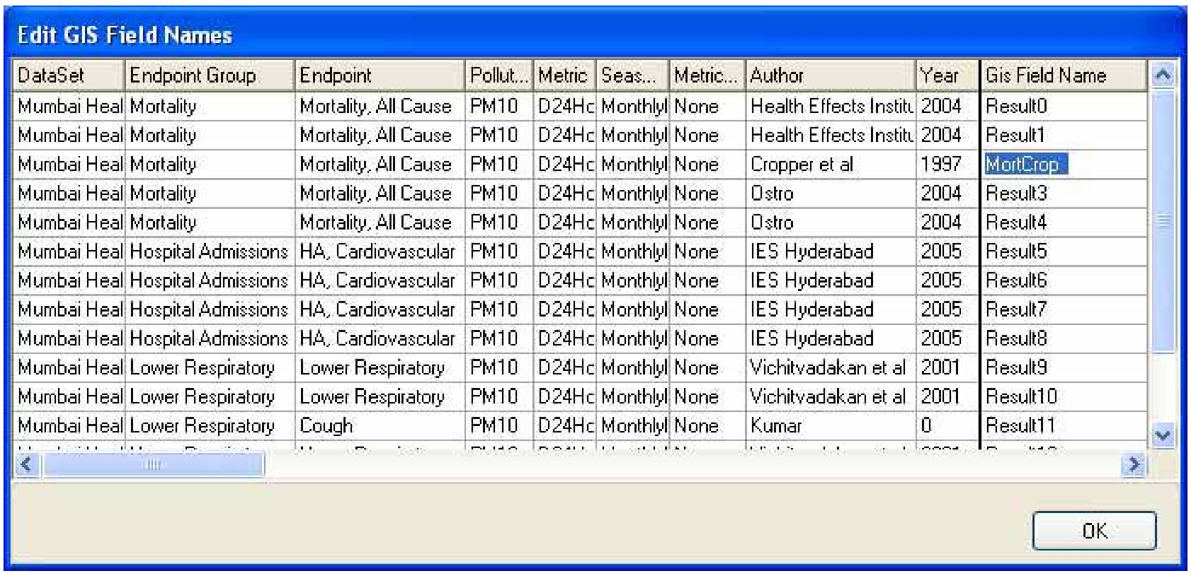
Task 3: Map Your Results

Now you can map the results of your model run. You can use the mapping tools described in this task at any time, for any previously-run configuration.

- Go to the *BenMAP GIS* window by clicking *Tools* and then *GIS / Mapping*.
- Click on the  icon and select *Configuration Results (*.cfgr)*. Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Wards Results.cfgr* and click *Open*. This will bring up the *Edit GIS Field Names* window.

- Select easy to remember names – no longer than 10 characters – for each of the estimated health impact changes that you wish to map. BenMAP assigns them default names of the form *ResultX*, which may not be easy to remember.
- For example, rename *Result2* as *MortCrop* (short for premature mortality based on the Cropper et al [1997] function).

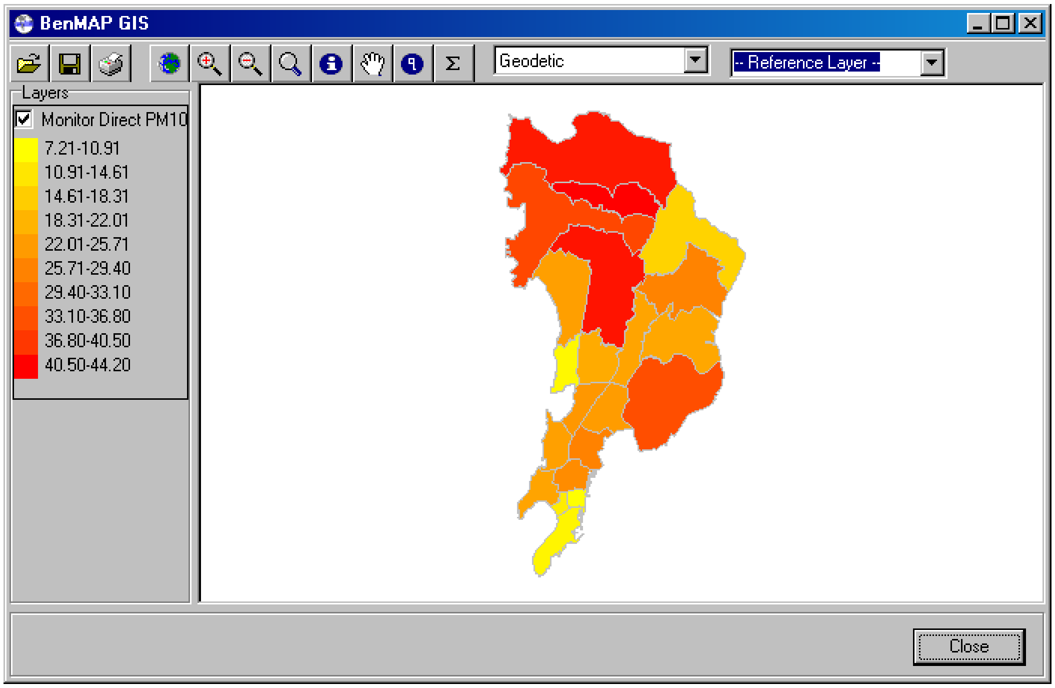
Your screen should look something like this:


Edit GIS Field Names

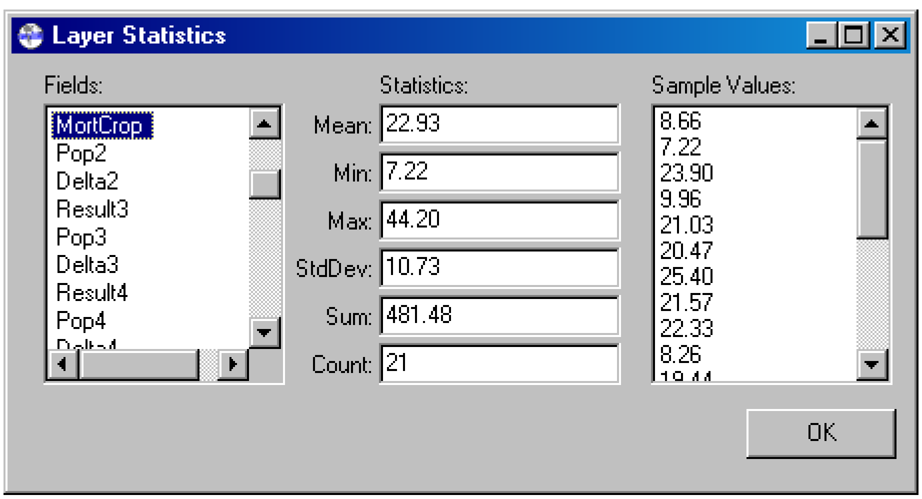
DataSet	Endpoint Group	Endpoint	Pollut...	Metric	Seas...	Metric...	Author	Year	Gis Field Name
Mumbai Heal	Mortality	Mortality, All Cause	PM10	D24Hc	Monthlyl	None	Health Effects Institu	2004	Result0
Mumbai Heal	Mortality	Mortality, All Cause	PM10	D24Hc	Monthlyl	None	Health Effects Institu	2004	Result1
Mumbai Heal	Mortality	Mortality, All Cause	PM10	D24Hc	Monthlyl	None	Cropper et al	1997	MortCrop
Mumbai Heal	Mortality	Mortality, All Cause	PM10	D24Hc	Monthlyl	None	Ostro	2004	Result3
Mumbai Heal	Mortality	Mortality, All Cause	PM10	D24Hc	Monthlyl	None	Ostro	2004	Result4
Mumbai Heal	Hospital Admissions	HA, Cardiovascular	PM10	D24Hc	Monthlyl	None	IES Hyderabad	2005	Result5
Mumbai Heal	Hospital Admissions	HA, Cardiovascular	PM10	D24Hc	Monthlyl	None	IES Hyderabad	2005	Result6
Mumbai Heal	Hospital Admissions	HA, Cardiovascular	PM10	D24Hc	Monthlyl	None	IES Hyderabad	2005	Result7
Mumbai Heal	Hospital Admissions	HA, Cardiovascular	PM10	D24Hc	Monthlyl	None	IES Hyderabad	2005	Result8
Mumbai Heal	Lower Respiratory	Lower Respiratory	PM10	D24Hc	Monthlyl	None	Vichitvadakan et al	2001	Result9
Mumbai Heal	Lower Respiratory	Lower Respiratory	PM10	D24Hc	Monthlyl	None	Vichitvadakan et al	2001	Result10
Mumbai Heal	Lower Respiratory	Cough	PM10	D24Hc	Monthlyl	None	Kumar	0	Result11

- ➢ When you have finished renaming the variable, click the *OK* button. This will bring up the *BenMAP GIS* window.
- ➢ Double click the text *Monitor Direct PM10 VNA 2000-2004 Wards Results.cfgr*. This will bring up the *Display Options* window.
- ➢ Select *MortCrop* from the *Variable* list.
- ➢ Click the *OK* button to return to the *BenMAP GIS* window.

Your screen should now look like this:



- For the Cropper et al (1997) results, click on the click the "Σ" button (*View statistics for the active layer*), in the panel at the top of the window. To quickly determine the total number of premature deaths in Mumbai, look at the *Sum*.



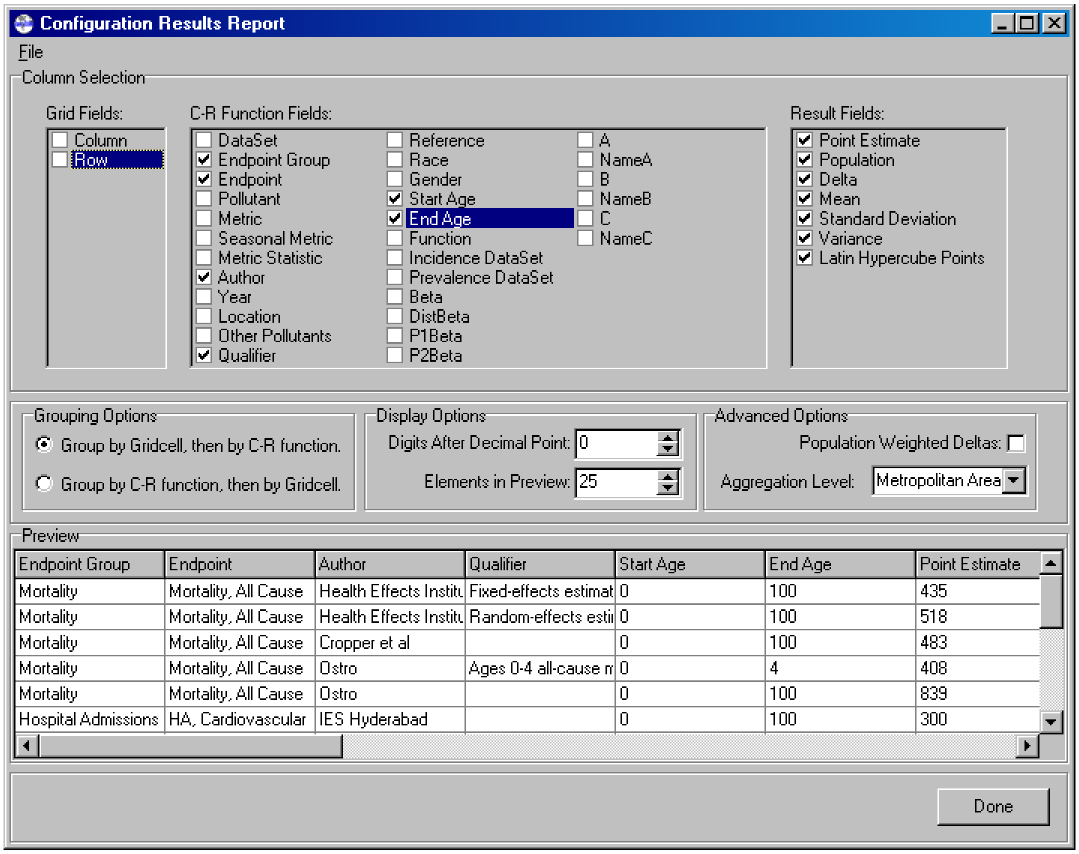
- Explore your results for a while. Note that in the *Fields* window, which contains the *Variable* list you also have the population used to calculate each result in the *PopX* variables, and the air quality change used to calculate each result in the *DeltaX* variables.
- When done, click the *Close* button to return to the main BenMAP window.

Task 4: Generate a Tabular Report From Configuration Results

In this task we will create a report in Excel format containing the raw incidence results from the run performed in Task 2. You can also generate reports that include aggregated incidence, pooled incidence, valuation, aggregated valuation, or pooled valuation results; this will be explained in *Problem Set 9*.

- Click the *Create Reports* button. This will bring up the *Select Report Type* window.
- Select *Raw Incidence Results. (Created from *.cfgr files)* option and click *OK*.
- Locate the file *Monitor Direct PM10 VNA 2000-2004 Wards Results.cfg*, that you created in Task 2, and click *Open*. This will bring up the *Configuration Results Report* window.
- Select *Metropolitan Area* from the *Aggregation Level* list.
- Set *Digits After Decimal Point* to "0."
- Check the *Endpoint Group*, *Endpoint*, *Author*, *Qualifier, Start Age* and *End Age* boxes in the *C-R Function Fields* panel – these fields should uniquely identify the various studies.
- Uncheck the *Column* and *Row* boxes in the *Grid Fields* panel.

Your screen should now look something like this:



- Look at all of the results.
  - Do the numbers seem plausible?
  - If not, what do you think the problem might be?
- Try out the various options – *Grouping Options*, *Display Options*, and *Advanced Options*.
- Include any additional fields you wish to be displayed.
- When ready, press *Ctrl+S*, or click *File* then *Save*. Save the report as *Monitor Direct PM10 VNA 2000-2004 Wards Results*.
- Locate the file in which you saved your report and open it up in Microsoft Excel.
  - Note that all of the information that was used in the calculation appears in the Excel file!
- Create a second report. This time leave checked *Column* and *Row* (these are the identifiers for each of the squares in the Mumbai Grid). In addition, leave the *Aggregation Level* blank (this will keep the results at the grid square level).

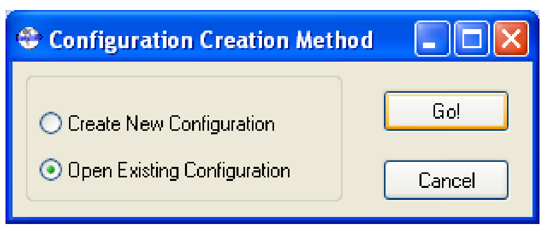
Task 5: Audit Trail

- Generate and examine an audit trail for one of the air quality grids used in this analysis.
- Generate and examine audit trails for the configuration result files *Monitor Direct PM10 VNA 2000-2004 Wards Results.cfgr* .
- What additional information does an audit trail from a .cfgr file have compared to an audit trail of an air quality grid?

Task 6: Reuse PM10 Configuration

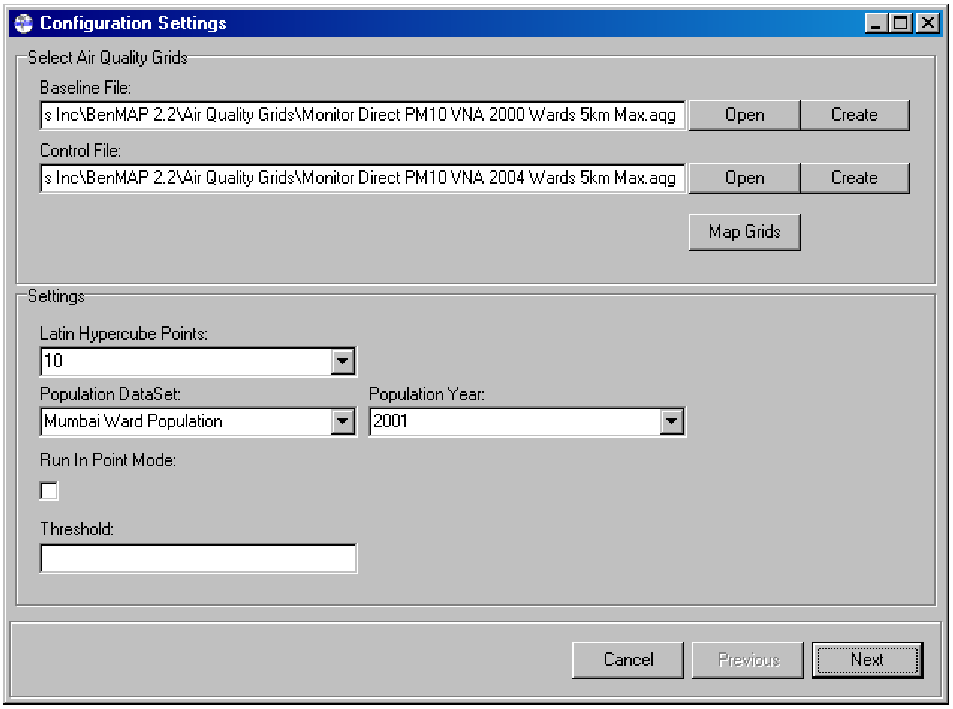
In this task, you will reuse the configuration you created in Task 1 in combination with the 5km maximum distance air quality grids you created in *Problem Set 3*.

- In the main BenMAP window, click the *Create and Run Configuration* button. This will bring up the *Choose Configuration Method* window.
- Choose *Open Existing Configuration* and click *GO!*



- Locate and open the *Mumbai PM10 Configuration.cfg* file, which you created in Task 1.
- Click the *Open* button for the *Baseline File* and select the file *Monitor Direct PM10 VNA 2000 Wards 5km Max.aqg*. (You should have created this air quality grid in *Case Study Work 3* – if you did not, create it now by clicking the *Create* button)
- Click the *Open* button for the *Control File* and select the file *Monitor Direct PM10 VNA 2004 Wards 5km Max.aqg*. (You should have created this air quality grid in *Case Study Work 3* – if you did not, create it now by clicking the *Create* button)

Your screen should look something like this:



- Click the *Next* button. You should see all of the functions chosen for this configuration in Task 1.
- Click the *Run* button. This will bring up the *Save Configuration* window.
- There is no need to re-save the configuration, so simply click the *OK* button to generate and save configuration results. Save the results as *Monitor Direct PM10 VNA 2000-2004 Wards 5km Max Results*.
- Repeat this procedure for these additional pairs of air quality grids:

Baseline Air Quality Grid	**Control Air Quality Grid**
Monitor Direct PM10 VNA 2000 Grid.aqg	*Monitor Direct PM10 VNA 2004 Grid.aqg*
Monitor Direct PM10 VNA 2000 Grid 5km Max.aqg	*Monitor Direct PM10 VNA 2004 Grid 5km Max.aqg*

Task 7: Explore Your Results

Generate reports from your various configuration results files and compare them with the following table:

Health Effect	Source	Wards	Wards, 5km Max	Grid	Grid, 5km Max
Premature Mortality	HEI, Fixed Effects	435	299	431	271
	HEI, Random Effects	518	356	514	322
	Cropper et al.	483	331	478	300
	Ostro, All Ages	839	576	832	521
Cardiovascular Hospital Admissions, All Ages	IES Hyderabad	300	203	298	184
Lower Respiratory Symptoms, All Ages	Vichit-Vadakan	70,800,000	47,300,000	70,100,000	42,800,000
Cough	Kumar	4,100,000	2,800,000	4,100,000	2,550,000
Upper Respiratory Symptoms, All Ages	Vichit-Vadakan	78,000,000	51,000,000	77,000,000	46,000,000
Minor Restricted Activity Days	Ostro & Rothschild	2,345,000	1,564,000	2,326,000	1,412,000

In this problem set you have learned how to create and run configurations, and how to save and explore your results. These results were exclusively the raw incidence results; in the next problem set, you will become familiar with how BenMAP allows you to pool, aggregate and include valuation in your results.

Problem Set 7. Aggregation and Pooling

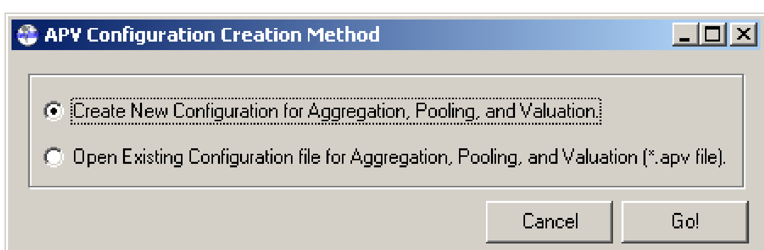
An *Aggregation, Pooling and Valuation Configuration* (*APV Configuration*) is a reusable file that records the aggregation, pooling, and valuation choices for an analysis. Aggregation refers to spatial aggregation – typically summing results up from smaller areas (e.g. Mumbai grid cells) to larger ones (e.g. Mumbai wards).[7] Pooling refers to the mathematical combination of two or more results – through addition, subtraction, or weighted averaging. Finally, valuation refers to applying unit values to health effect estimates results to get monetized benefits.

It is important to remember than an APV configuration is different from the configuration that we created and ran in *Problem Set 6*. The APV configuration uses the raw incidence results that are created when you run a configuration, and aggregates, pools, and/or provides valuation. The first step in creating a new APV configuration is selecting the results file that you have previously created.

Task 1: Create and Run a PM10 APV Configuration

In this task, we will aggregate health effect estimates from the *Mumbai Grid* level to the *Wards* level. We will also investigate various methods of pooling our health effect estimates. We will not do any valuation at this time, but in Problem Set 8, we will add valuation to the *APV Configuration* which we create in this example.

- **Create APV Configuration.** Click the *Aggregation, Pooling, and Valuation* button. This will bring up the *APV Configuration Creation Method* window.



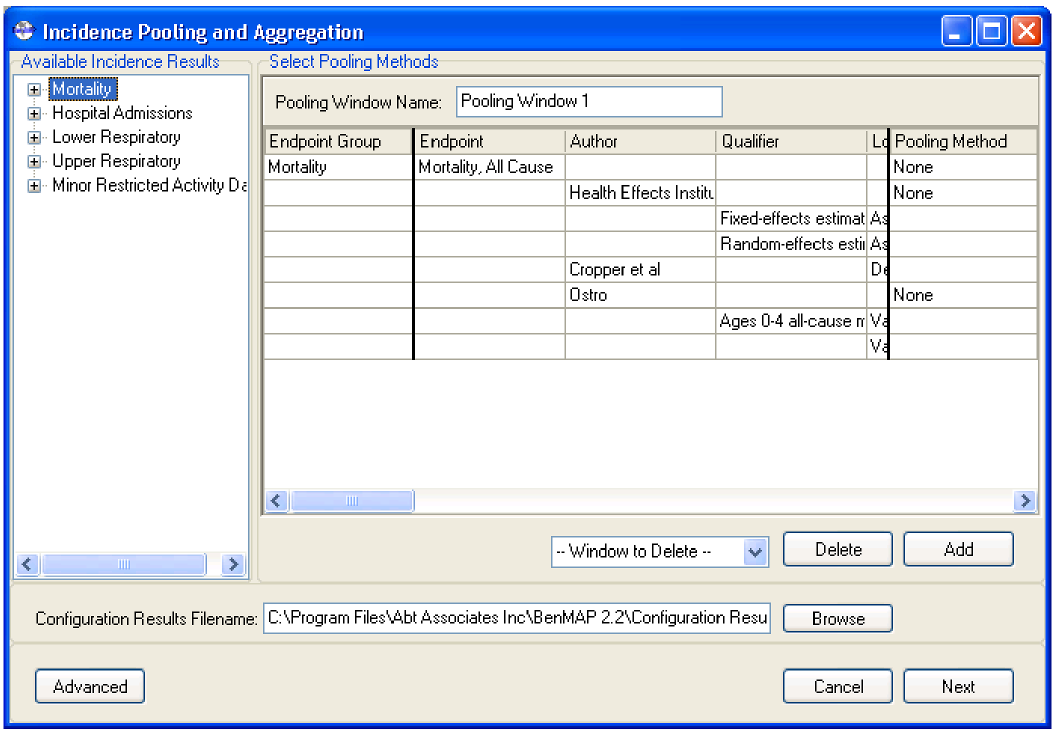
- Select *Create New Configuration for Aggregation, Pooling, and Valuation* and click the *Go!* button. Locate the previously generated *Monitor Direct PM10 VNA*

[7] Another example would be aggregating Mumbai wards to the Metropolitan Area. Or if doing a national analysis of India with results at the District level, you might rather aggregate these District results and present them at the State level.

2000-2004 Grid Results.cfgr file, and click *Open*. This will bring up the *Incidence Pooling and Aggregation* window.

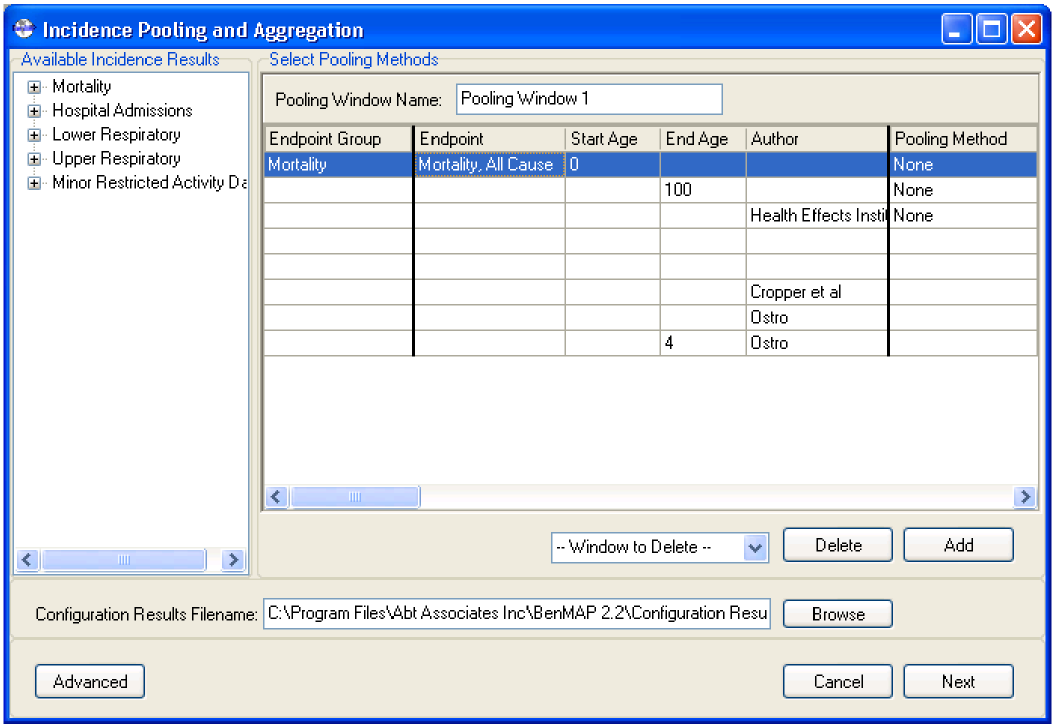
- **Pooling Mortality.** Click the text *Mortality* in the *Available Incidence Results* tree on the left side of the window. Drag this node to the *Pooling Window 1*, on the right side of the window, and release it.

Your screen should now look like this:



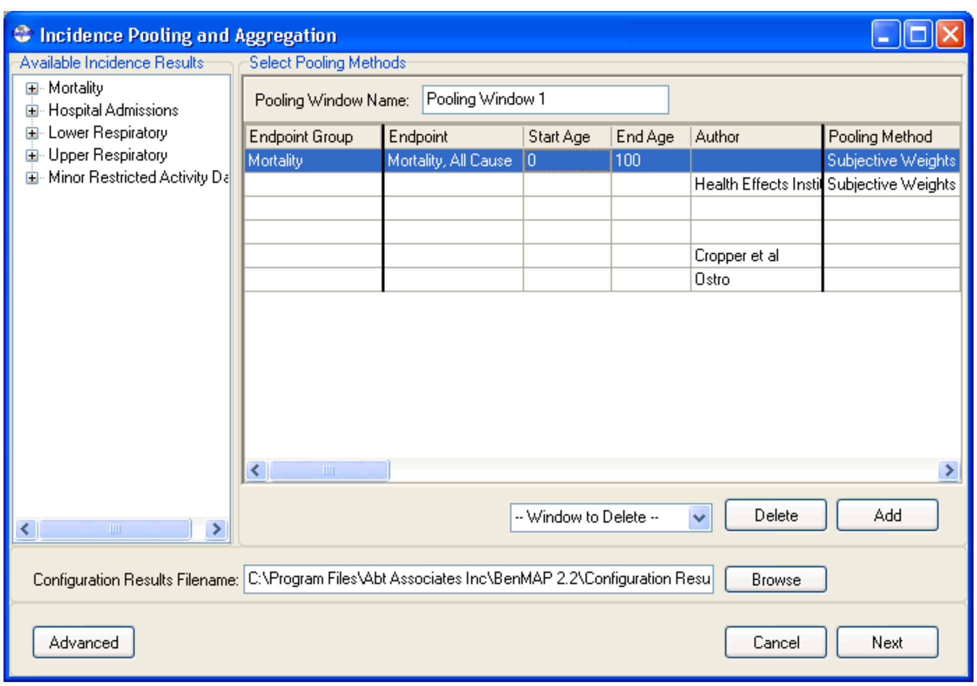
- The pooling tree needs to be sorted by *Endpoint*, *Start Age*, *End Age*, and finally by *Author*.
  - Locate the *Start Age* column and drag it to the right of the *Endpoint* column.
  - Locate the *End Age* column and drag it to the position immediately after *Start Age*.
  - Locate the *Author* column and drag it to the position immediately after *End Age*.

Your screen should now look something like this:



- ➢ We will not be using the *Ostro* study on *0-4* year olds – highlight this result and use the *Delete* button on your keyboard to delete it.
- ➢ Select the *Subjective Weights* option in the *Pooling Method* column in both locations where you see the text *None*.

Your screen should now look something like this:



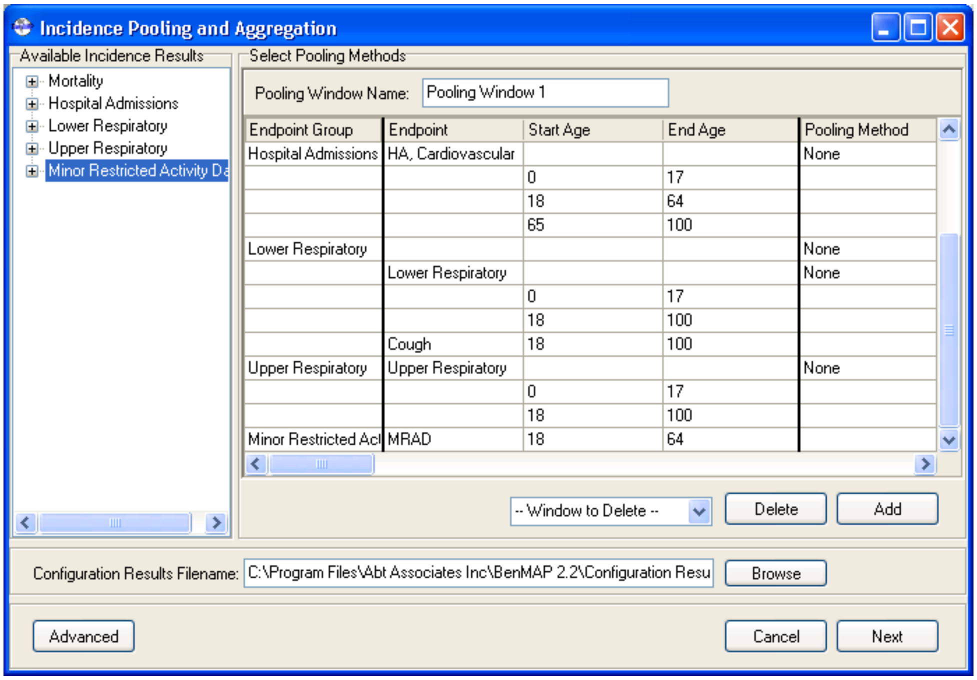
The *Subjective Weights* pooling method calculates a "weighted-average" composite distribution of two or more input distributions. The procedure for doing this involves a Monte Carlo simulation that works as follows: for each of *n* iterations, choose one of the input distributions with probabilities corresponding to their weights, and then choose a random value from that input distribution. The resulting collection of *n* values is the new, composite distribution.

The *Fixed Effects* pooling method uses the same Monte Carlo procedure, but with weights automatically generated using the inverse of the variance of each input distribution. The *Random/Fixed Effects* pooling method also uses the same Monte Carlo procedure, but with weights generated in a more complicated fashion that does not assume that the input distributions are estimates of the same underlying uncertain variable. For a full discussion of this pooling method, see the BenMAP user manual.

BenMAP actually by default uses a simplified version of the Monte Carlo simulation procedure described above, taking advantage of the latin hypercube structure used for uncertainty characterization. A full discussion of this topic is beyond the scope of this case study, but the BenMAP user manual contains full details.

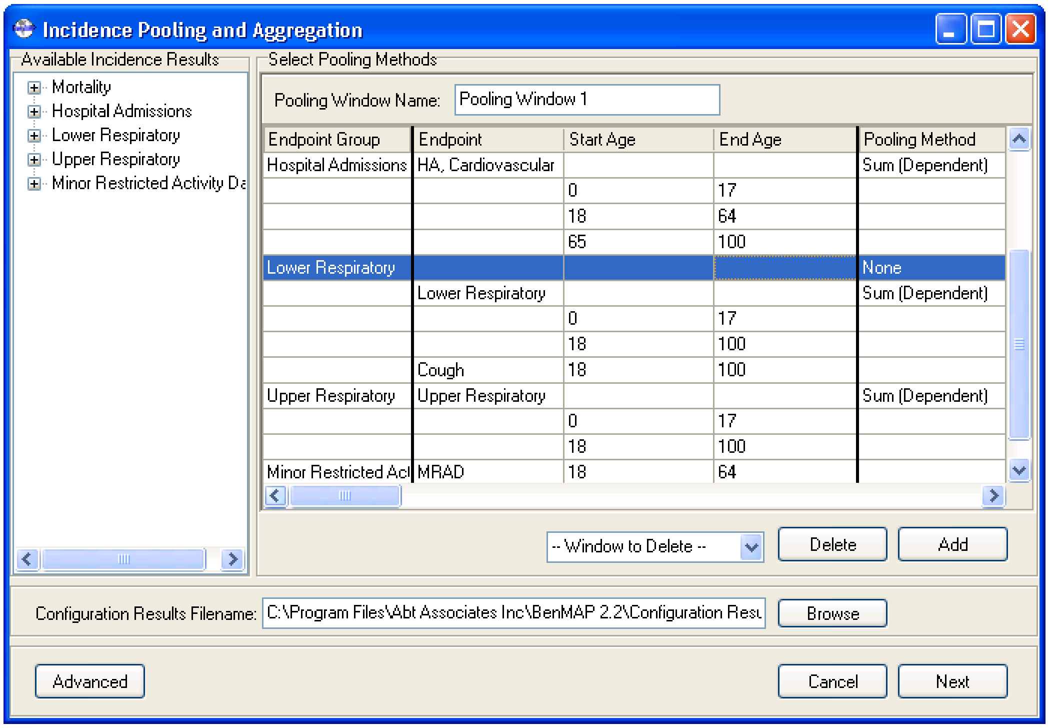
- **Summing Hospital Admissions and Respiratory Symptoms.** Drag the *Hospital Admissions*, *Lower Respiratory*, *Upper Respiratory*, and *Minor Restricted Activity Day* nodes into *Pooling Window 1*, as you did with the *Mortality* node.

Your screen should now look something like this:



- Delete the *IES Hyderabad Hospital Admissions* study on *0-100* year olds, keeping the studies on *0-17* year olds, *18-64* year olds, and *65-100* year olds.
  - We have separate incidence rates for these age groups, so it makes sense to use them.
- Select the *Sum (Dependent)* option in the *Pooling Method* column next to the *HA, Cardiovascular*, *Lower Respiratory*, and *Upper Respiratory* Endpoint nodes. Note that you should leave *None* selected next to the *Lower Respiratory* Endpoint Group node, as we do not want to add the *Cough* results to the general *Lower Respiratory* results – this would involve double counting!

Your screen should now look something like this:



- **Aggregating From Mumbai Grid to Wards.** Click the *Advanced* button. This will bring up the *APV Configuration Advanced Settings* window.
- Select *Wards* from the *Incidence Aggregation* list. This tells BenMAP to spatially aggregate the incidence estimates from the *Mumbai Grid* level to the *Wards* level before pooling them.
- Click *OK* to return to the *Incidence Pooling and Aggregation* window.

- **Saving & Running APV Configuration.** Click the *Next* button. This will bring up the *Select Subjective Weights* window.
- Leave the default weights in place (the default behavior is to use equal weights) and click the *OK* button. This will bring up the *Select Valuation Methods, Pooling, and Aggregation* window.
- We will be valuing our results later. For now, select *Mumbai Variables* in the *Variable DataSet* list, and click *Run*. This will bring up the *Save Aggregation, Pooling, and Valuation Configuration* window.
- Click the *Save* button to save the APV Configuration to file – this will store the various choices we just made: the pooling options, and the county aggregation. Name the APV Configuration *Mumbai PM10 APV Configuration.apv* and click *Save*.
- Click the *OK* button to save the APV Configuration Results to file – this will store the aggregated and pooled health impact estimates generated by the various

choices we just made. Name the configuration results *Monitor Direct PM10 VNA 2000-2004 Grid Results.apvr* and click *Save*.

- When BenMAP is done pooling and aggregating results, you will be returned to the main BenMAP window.

Task 2: Map Your Results

Just like the raw incidence results, APV results can also be mapped. This task shows you how use the GIS tools to view your pooled incidence results.

- Go to the *BenMAP GIS* window by clicking *Tools* and then *GIS / Mapping*.
- Click on the  icon and select *APV Configuration Results (*.apvr)*, and then *Pooled Incidence Results*. Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Grid Results.apvr* file and click *Open*. This will bring up the *Edit GIS Field Names* window.
    - Select easy to remember names for each of the pooled health impact changes that you wish to map. BenMAP assigns them default names of the form *ResultX*, which may not be easy to remember.
    - For example, rename *Result0* as *Mortality*.
    - When ready, click the *OK* button. This will bring up the *BenMAP GIS* window.
- Double click the text *Monitor Direct PM10 VNA 2000-2004 Grid Results.apvr*. This will bring up the *Display Options* window.
- Select *Mortality* from the *Variable* list.
- Uncheck the *Grid Outline* box.
- Click the *OK* button to return to the *BenMAP GIS* window.
- Select *Metropolitan Area* from the *Reference Layer* list.

Your screen should now look like this:

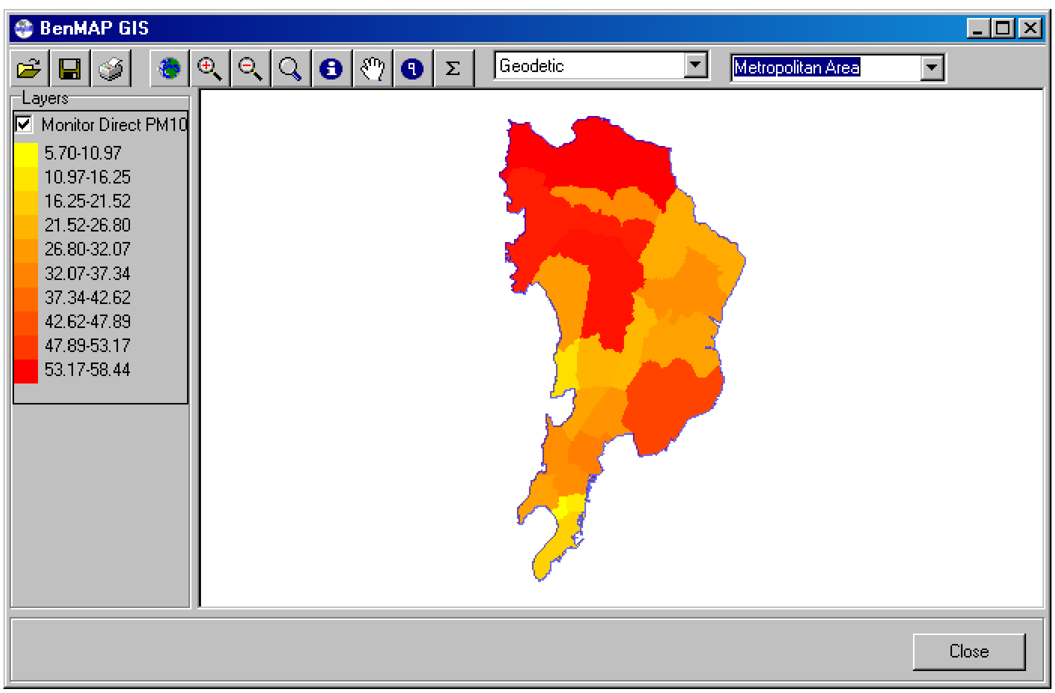
- Explore your results for a while.
- When done, click the *Close* button to return to the main BenMAP window.

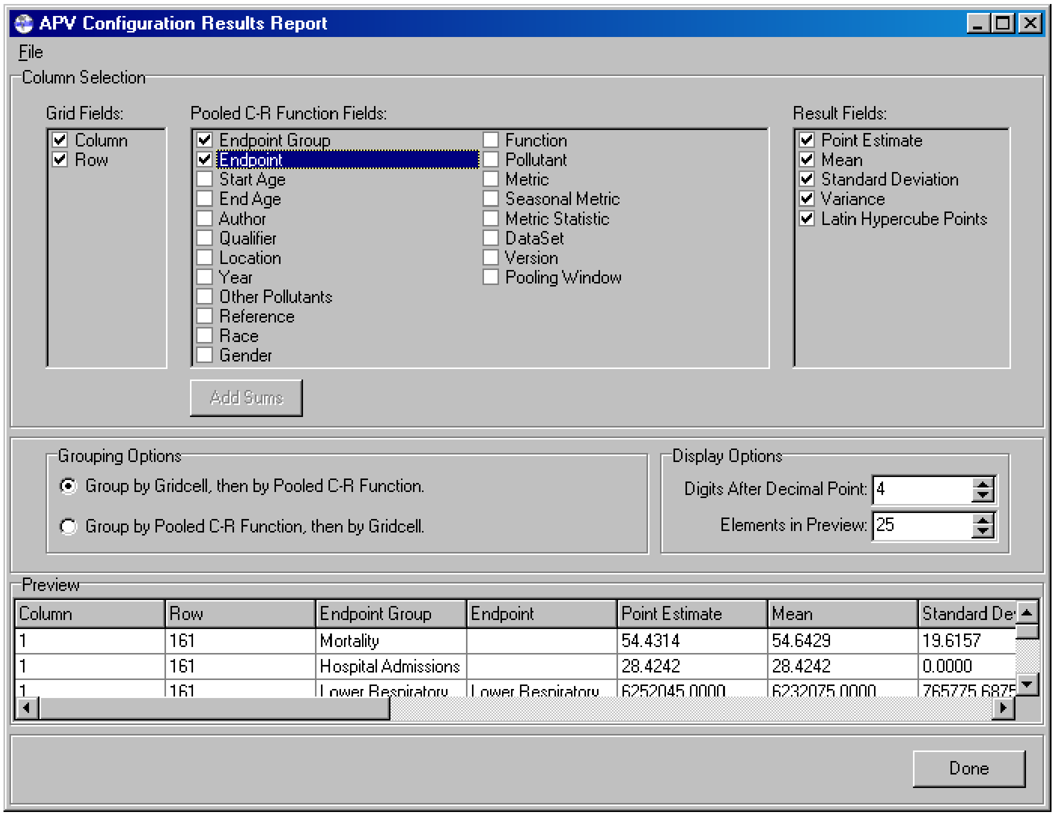
Task 3: Generate a Tabular Report From APV Configuration Results

In this task, you will create a report based on the new APV configuration that you ran in Task 1.

- Click the *Create Reports* button. This will bring up the *Select Report Type* window.
- Select *Incidence and Valuation Results: Raw, Aggregated, and Pooled (Created from *.apvr files)* and click *OK*.
- Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Grid Results.apvr* file and click *Open*.
- Select *Pooled Incidence Results* and click *OK*.
- Check the *Endpoint Group* and *Endpoint* boxes in the *Pooled C-R Function Fields* panel.

Your screen should now look something like this:



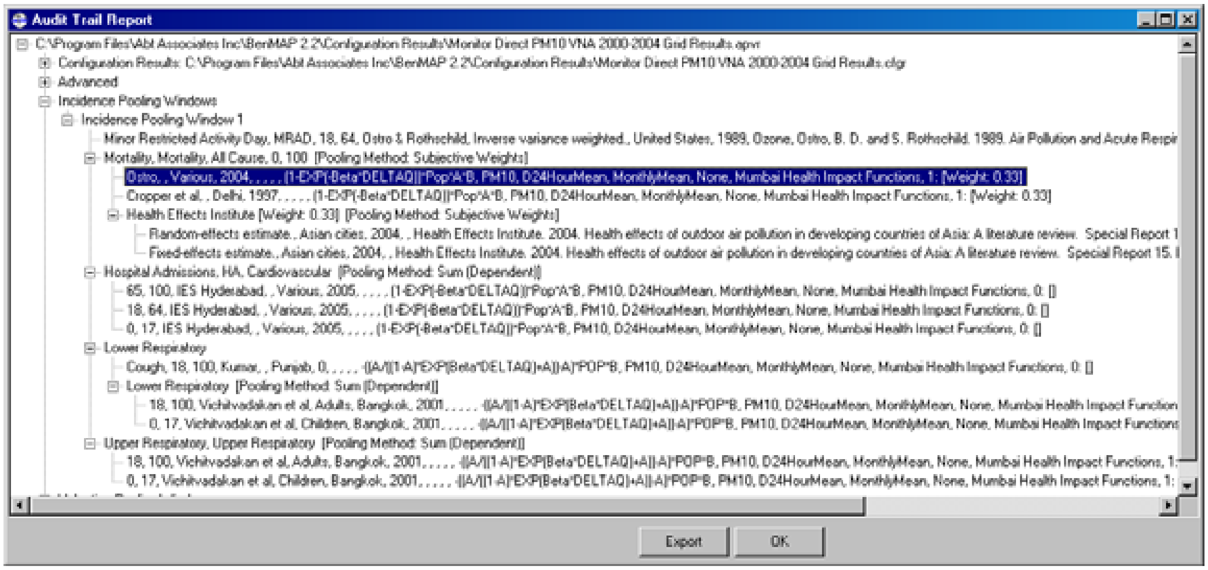


- Try out the various options – *Grouping Options*, and *Display Options*.
- When ready, press *Ctrl+S*, or click *File* then *Save*. Save the report as *Monitor Direct PM10 VNA 2000-2004 Grid Results – Pooled Incidence*.
- Locate the file in which you saved your report and open it up in Microsoft Excel.

Task 4: Generate an Audit Trail Report

- Click the *Create Reports* button. This will bring up the *Select Report Type* window.
- Select *Audit Trail Reports (Created from *.aqg, *.cfg, *.cfgr, *.apv, or *.apvr files)* and click *OK*.
- Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Grid Results.apvr* file and click *Open*.
- Expand the root node by clicking on the + symbol.
- Expand all nodes under the text *Incidence Pooling Windows*. Note especially the weights which are listed – the weights (which are specified by you for subjective weights pooling, or automatically generated by BenMAP for fixed effects and random/fixed effects pooling) are listed in the audit trail of **.apvr* files.

Your screen should now look like this:



- Explore the audit trail for a while by expanding and collapsing the various nodes.
- When done, click the *OK* button to return to the main BenMAP window.

In this task, you have learned about APV configurations and practiced pooling results. In the next problem set you will learn about how BenMAP includes valuation, and in *Problem Set 9*, add valuation to your APV configuration.

Problem Set 8. Setup Manager (3)– Variables & Valuation Functions

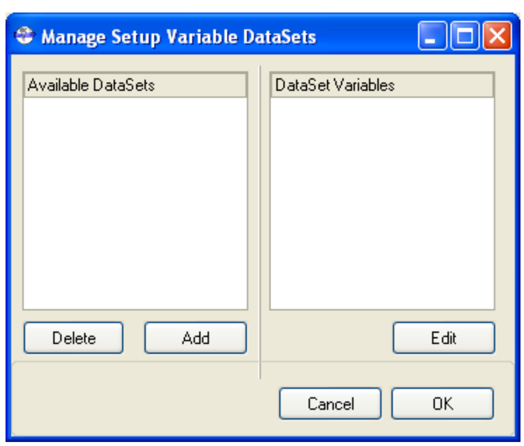
This problem set returns to the *Setup Manager* that we used in *Problem Sets 1* and *5*. Valuation is an optional step, so the loading of the valuation data is not necessary for configurations to be run. However, it must be loaded before APV configurations can be used to generate valuation data. Below, we will first add the variables that are used in the valuation functions, and then add the functions themselves.

Task 1: Add Variable Data

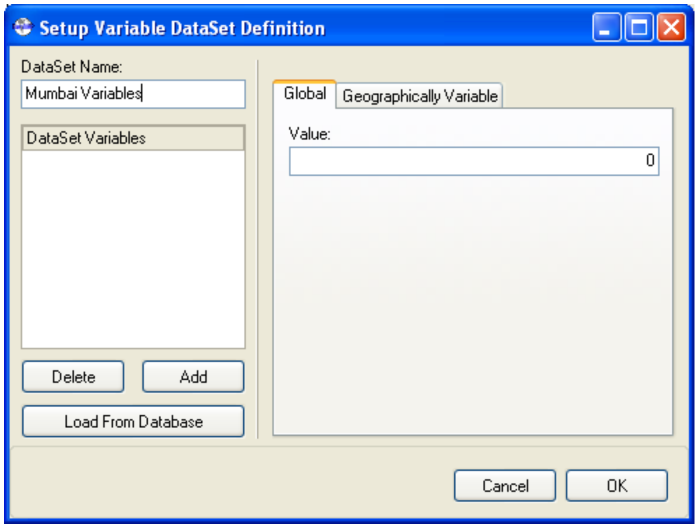
Valuation functions (and health impact functions) may sometimes need to refer to variables other than those for which BenMAP automatically calculates values. For example, some valuation functions may need to reference the median income within each area of analysis. To facilitate this, BenMAP allows you to load datasets of variables, which may either be global values or may vary geographically (meaning they are associated with a grid definition).

In this task you will load an existing set of variables from the *Sample Data* provided with the CD.

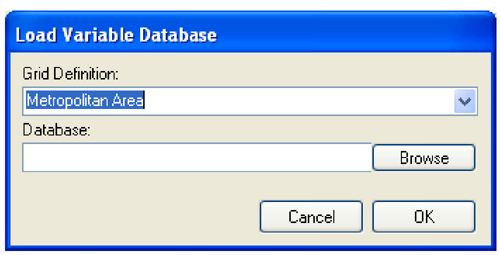
- Click *Tools* and then *Modify Setup*. This will bring up the *Manage Setups* window.
- Make sure that *Copy of Mumbai* is selected in the *Available Setups* list.
- Click the *Edit* button under the *Variable DataSets* list. This will bring up the *Manage Setup Variable DataSets* window:



- Click the *Add* button under the *Available DataSets* list to add a new DataSet. This will bring up the *Setup Variable DataSet Definition* window.
- In the *DataSet Name* box, type *Mumbai Variables*. This will be the name of the new Variable DataSet.

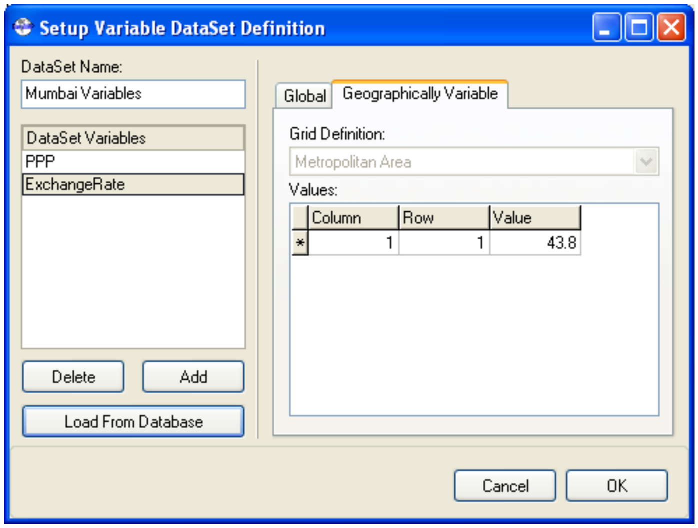


- Click the *Load From Database* button under the *DataSet Variables* window. This will bring up the *Load Variable Database* window.
- Select *Metropolitan Area* in the *Grid Definition* list.

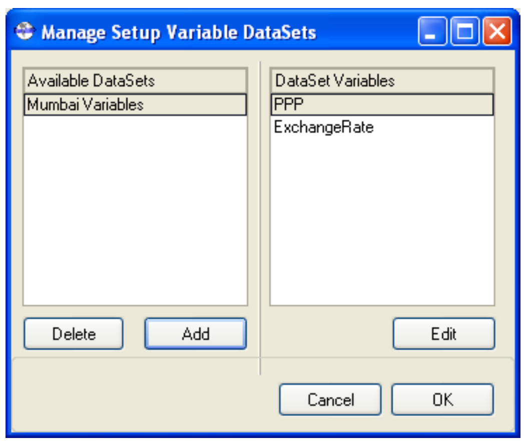


- Click the *Browse* button next to the *Database* box.
- Locate the *Mumbai Variables.xls* file and click *Open*. *Note:* Make sure to select *Excel Files* in the *Files of Type* list.

Your screen should now look like this:



➢ Click the *OK* button to return to the *Manage Setup Variable DataSets* window.

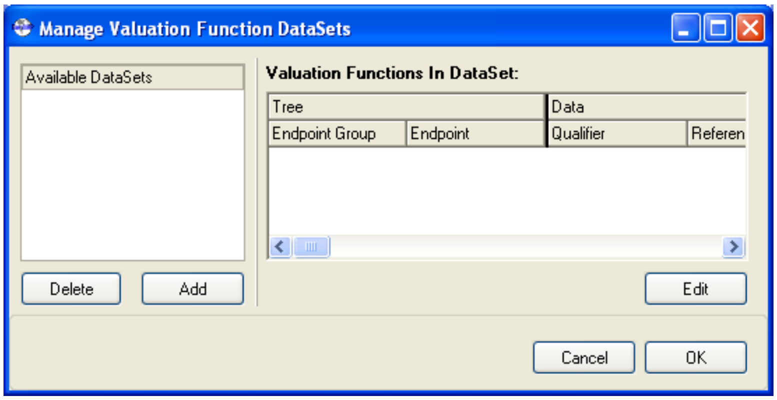


➢ Click the *OK* button to return to the *Manage Setups* window.

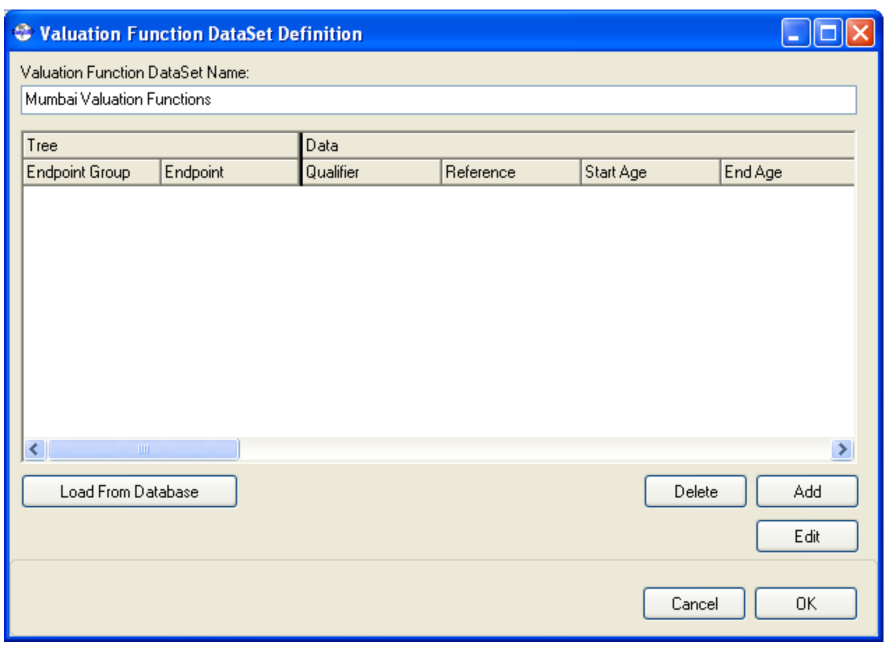
Task 2: Add Valuation Functions

This task will load into the S*etup* all of the valuation functions related to Mumbai.

- Click the *Edit* button under the *Valuation DataSets* list. This will bring up the *Manage Valuation Function DataSets* window.

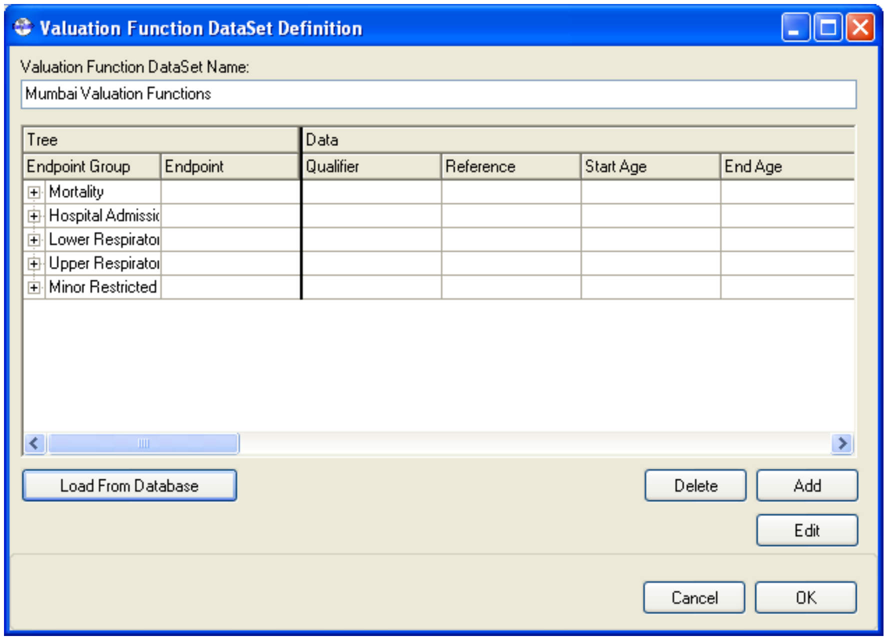


- Click the *Add* button under the *Available DataSets* list to add a new DataSet. This will bring up the *Valuation Function DataSet Definition* window.
- In the *Valuation Function DataSet Name* box, type *Mumbai Valuation Functions*. This will be the name of the new Valuation Function DataSet.



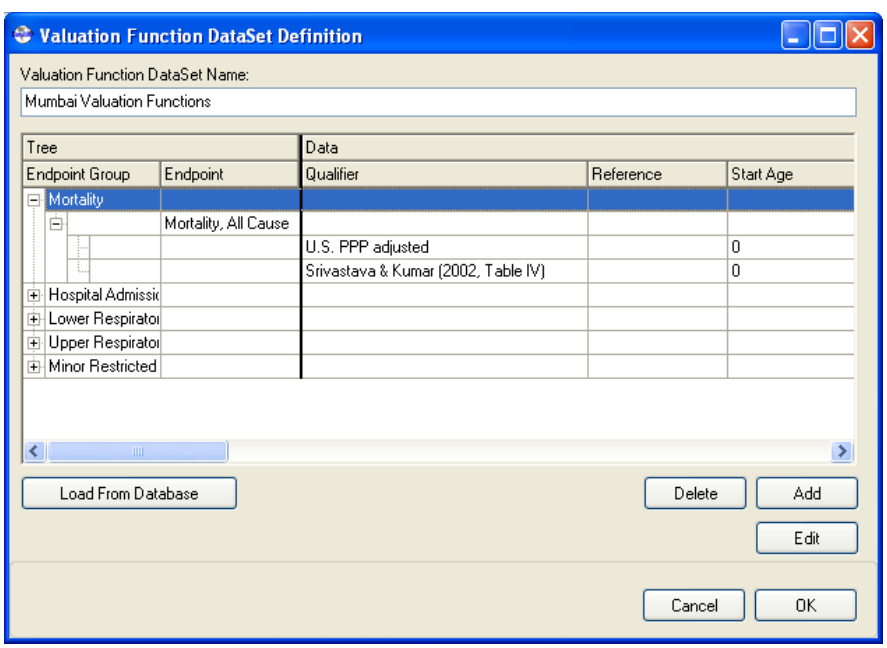
- Click the *Load From Database* button, locate the *Mumbai Valuation Functions.xls* file, and click *Open*.

Your screen should now look like this:



- ➢ Click on the + next to *Mortality*.
- ➢ Click on the + next to the newly exposed *Mortality, All Cause* (under the line you just clicked on).

Your screen should now look something like this:



- Explore the Function Display window for a while – try dragging the field headers around between the *Tree* and *Data* sides of the window, expanding the various *Tree* nodes, etc.
- When you are done, click the *OK* button to return to the *Manage Valuation Function DataSets* window.
- Click the *OK* button to return to the *Manage Setups* window.

In this problem set you have added all the valuation data to the existing Mumbai Setup. In the next problem set will select valuation functions to add to an APV configuration.

Problem Set 9. Valuation

In this problem set, we will include valuation in the APV configuration created in Problem Set 7, and explore the resulting maps and tables.

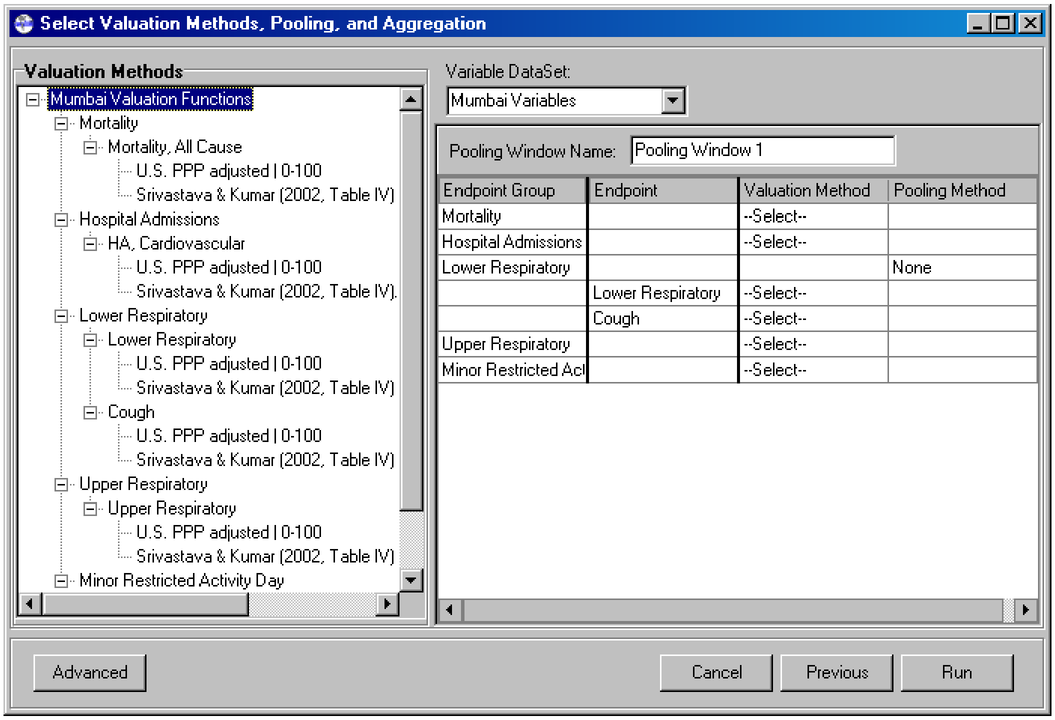
Task 1: Add Valuation to Your APV Configuration

In this task, we will be opening the previously generated APV configuration and revising it. In particular, we will add valuation functions and pool their results.

- **Open APV Configuration.** Click the *Aggregation, Pooling, and Valuation* button. This will bring up the *APV Configuration Creation Method* window.
- Select *Open Existing file for Aggregation, Pooling, and Valuation (*.apv file)* and click *Go!*. Locate the previously generated *Mumbai PM10 APV Configuration.apv* file and click *Open*. This will bring up the *Incidence Pooling and Aggregation* window.
- Click the *Next* button. This will bring up the *Select Valuation Methods, Pooling, and Aggregation* window.

- **View Valuation Functions.** Click the + symbol next to the text *Mumbai Valuation Functions* in the *Valuation Methods* tree on the left side of the window. The tree nodes here represent Valuation Functions, and are sorted by the individual Valuation Functions' *Endpoint Groups*, and *Endpoint* fields. The values displayed are the *Qualifier*, *Start Age*, and *End Age* values of the individual Valuation Functions.
- Expand each node in the *Valuation Methods* tree by clicking on the + symbols.

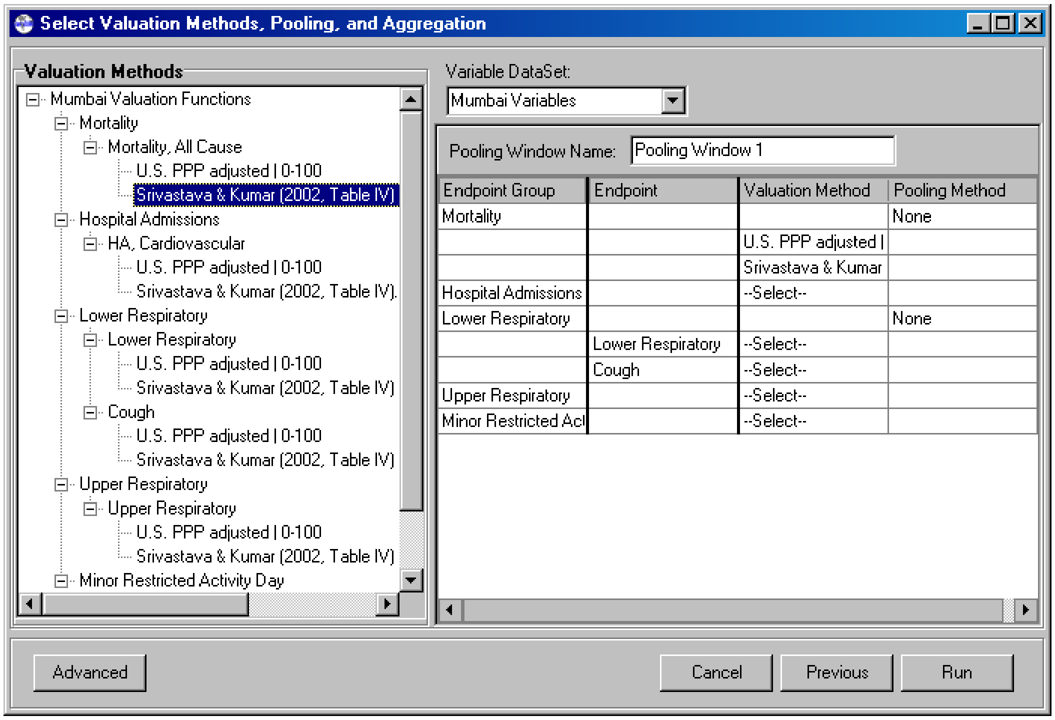
Your screen should now look something like this:



To apply a valuation function to a health impact estimate, simply drag it from the *Valuation Methods* list to the appropriate *Pooling Window* and release it on top of the appropriate node in the tree.

- **Add Valuation Functions and Pool Valuation Results.** Click on the *Mortality*; *Mortality, all Cause* Valuation Function *U.S. PPP adjusted | 0-100* and drag it on top of the *Mortality* entry in *Pooling Window 1*. Release it there.
- Repeat this procedure with the *Mortality*; *Mortality, All Cause* Valuation Function *Srivastava & Kumar (2002, Table IV)*.

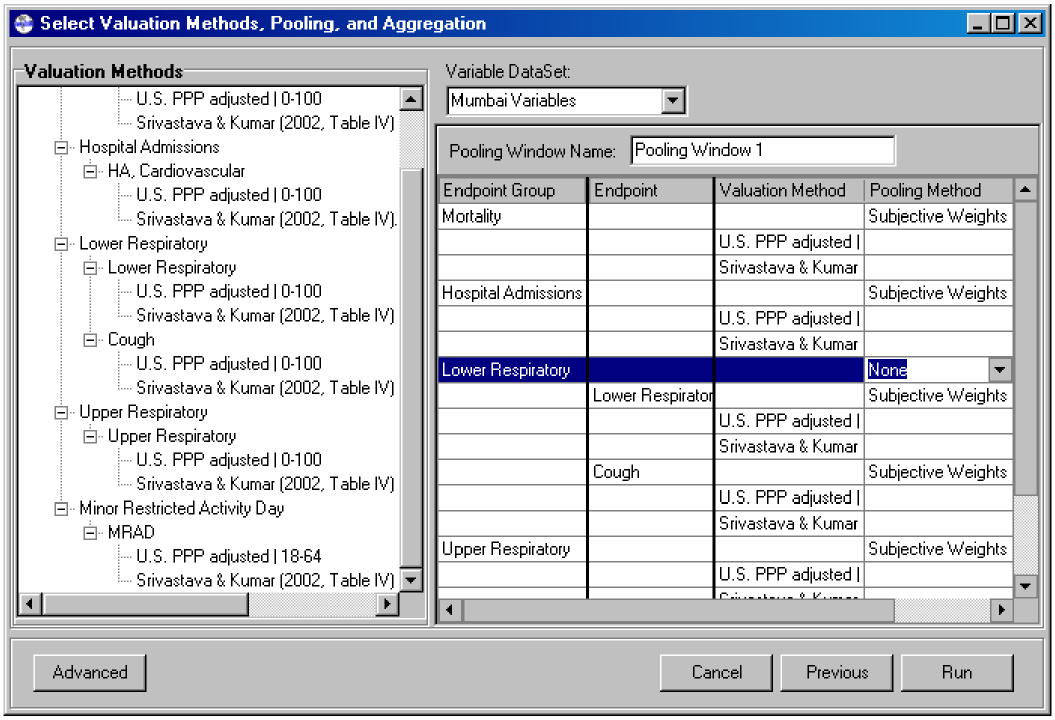
Your screen should now look something like this:



Note that a *None* has appeared in the *Pooling Method* column next to the *Mortality* node. This is because we now have two valuation results that can be pooled together, just as our incidence results were pooled together in the *Incidence Pooling and Aggregation* window.

- Pool the two *Mortality* valuation results together using the *Subjective Weights* method, leaving the weights at *0.50* each.
- Repeat this process for each of the remaining nodes where you see the text --*Select—*in the *Valuation Method* column, using the two valuation methods for the corresponding *Endpoint Group* and *Endpoint* (if relevant) and pooling each of the pairs of results using the *Subjective Weights* pooling method.
- Note that we still do not want to pool the *Lower Respiratory* and *Cough* endpoints together, to avoid double counting.

When you are done, your screen should look something like this:



- **Add Valuation Aggregation.** Click the *Advanced* button. This will bring up the *APV Configuration Advanced Settings* window.
- Select *Metropolitan Area* from the *Valuation Aggregation* list. This tells BenMAP to spatially aggregate the valuation estimates from the *Wards* level to the *Metropolitan Area* level before pooling them.
- Click the *OK* button to return to the *Select Valuation Methods, Pooling, and Aggregation* window.

- **Subjective Weights**. Click the *Run* button. The *Select Subjective Weights* window will appear with default weights assigning equal weight to each valuation study.
- Click *OK*. This will bring up the *Save Aggregation, Pooling, and Valuation Configuration* window.

- **Save & Run Revised APV Configuration.** Click the *Save* button and save the APV Configuration as *Mumbai PM10 APV Configuration with Valuation*.
- Click the *Run* button and save the APV Configuration Results as *Monitor Direct PM10 VNA 2000-2004 Grid Results with Valuation*.
- When BenMAP is done generating results, you will be returned to the main BenMAP window.

Task 2: Map Your Results

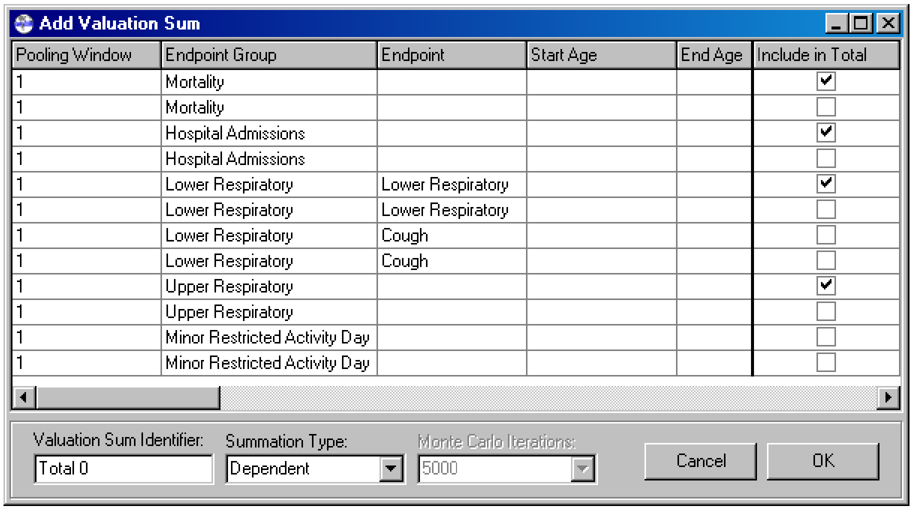
In this task, we will be mapping the PM10 results that we have previously generated. This will involve loading the results file, renaming variables, and then adjusting map parameters. In addition, we will be using a useful mapping feature that allows us to sum the values of different variables in order to get a total cost.

- **Load Results.** Go to the *BenMAP GIS* window by clicking *Tools* and then *GIS / Mapping*.
- Click on the  icon and select *APV Configuration Results (*.apvr)*, and then *Valuation Results* (remember – our *Pooled Valuation Results* are aggregated to the *Metropolitan Area*, and are thus pretty uninteresting to map!). Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Grid Results with Valuation.apvr* file and click *Open*. This will bring up the *Edit GIS Field Names* window.

- **Rename Variables.** Edit the default names in the *Edit GIS Field Names* window:
    - Select easy to remember names for each of the pooled health impact changes that you wish to map. BenMAP assigns them default names of the form *ResultX*, which may not be easy to remember.
    - For example, rename *Result0* as *MortUSPPP* (short for Mortality, U.S. PPP Adjusted).
    - When ready, click the *OK* button. This will bring up the *Valuation Sums Layer* window.

- **Sum Variables.** Click the *Add Sum* button. This will bring up the *Add Valuation Sum* window.
- We will be adding a *Dependent Sum* of the *Mortality*, *Hospital Admissions*, *Lower Respiratory*, and *Upper Respiratory* estimates which use the *U.S. PPP Adjusted* valuation method (leaving out the *Cough* and *Minor Restricted Activity Day* estimates). To do this, check the boxes in the *Include in Total* column for the appropriate rows.

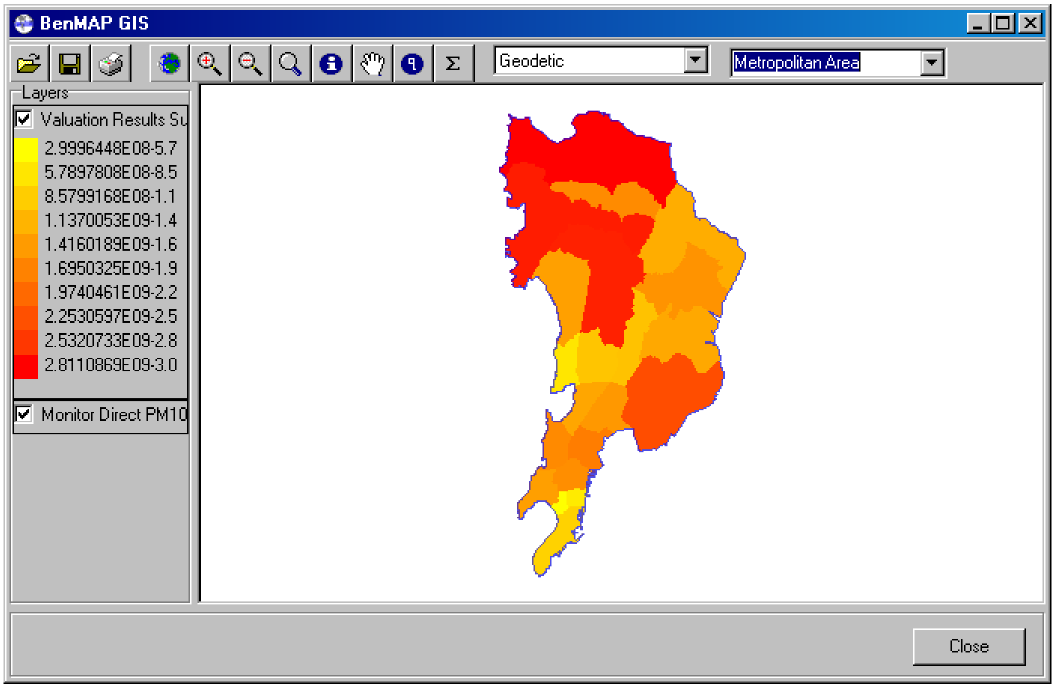
When you are done, your screen should look like this:



- Type a name for the sum in the *Valuation Sum Identifier* box – for example, *U.S. PPP Adjusted Sum*.
- Finally, click *OK* to return to the *Valuation Sum Layer* window.
- Type an easier to remember *GIS Field Name* for your new sum – BenMAP defaults to field names of the form *TotalX*. For example, replace *Total0* with *USPPPAdj* for the *U.S. PPP Adjusted* sum.
- Click the *Add Sum* button again and add a second sum for the same *Endpoint*s, but for the estimates that used the *Srivastava & Kumar (2002, Table IV)* valuation method. (**Note:** remember to replace the *GIS Field Name* for this *Valuation Sum Identifier* like you did above for *U.S. PPP Adjusted Sum*.)
- Click the *OK* button. This will bring up the *BenMAP GIS* window.

- **Adjust Map Parameters**. Double click the text *Valuation Results Sums*. This will bring up the *Display Options* window.
- Select *USPPPAdj* from the *Variable* list.
- Uncheck the *Grid Outline* box.
- Click the *OK* button to return to the *BenMAP GIS* window.
- Select *Metropolitan Area* from the *Reference Layer* list.

Your screen should now look like this:



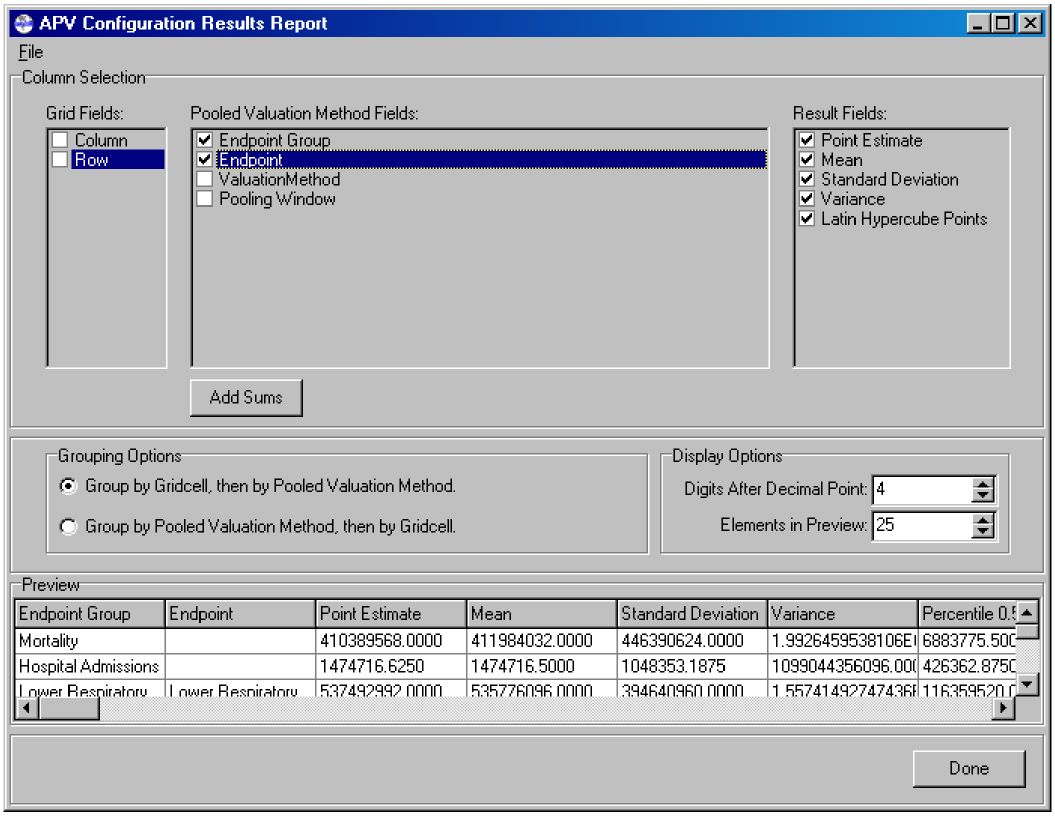
- Explore your results for a while.
- When done, click the *Close* button to return to the main BenMAP window.

Task 3: Generate a Tabular Report From APV Configuration Results

This task will create a report of your pooled valuation results, using the file created in Task 1.

- Click the *Create Reports* button. This will bring up the *Select Report Type* window.
- Select *Incidence and Valuation Results: Raw, Aggregated, and Pooled (Created from *.apvr files)* and click *OK*.
- Locate the previously generated *Monitor Direct PM10 VNA 2000-2004 Grid Results with Valuation.apvr* file and click *Open*.
- Select *Pooled Valuation Results* and click *OK*.
- Uncheck the *Column* and *Row* boxes in the *Grid Fields* panel.
- Check the *Endpoint Group* and *Endpoint* boxes in the *Pooled Valuation Method Fields* panel.

Your screen should now look something like this:



➢ Try out the *Add Sums* button, which will bring up the same *Add Valuation Sum* window we saw earlier when adding sums to the map of our valuation results.

➢ Examine your results, try out the various options, and save your results to a file for viewing in Microsoft Excel.

Task 4: Generate Valuation Results for Rollback Scenarios

Now that you have created and saved an APV Configuration, you can reuse it over and over again with new configuration results files. Generate valuation results for each of your rollback configuration results (*.cfgr) files and compare the pooled valuation results with the following table:

Health Effect	Wards	Wards, 5km Max	Grid	Grid, 5km Max
Premature Mortality	4,540,000,000	3,120,000,000	4,500,000,000	2,820,000,000
Cardiovascular Hospital Admissions, All Ages	16,500,000	11,200,000	16,300,000	10,100,000
Lower Respiratory Symptoms, All Ages	6,070,000,000	4,070,000,000	6,030,000,000	3,680,000,000
Cough	352,000,000	252,000,000	349,000,000	219,000,000
Upper Respiratory Symptoms, All Ages	6,680,000,000	4,410,000,000	6,640,000,000	3,980,000,000
Minor Restricted Activity Days	217,000,000	145,000,000	216,000,000	131,000,000

Congratulations! You have completed an analysis with BenMAP – you have estimated population exposure to air pollution, estimated the health impacts of pollution reductions from 2000 to 2004, and finally aggregated, pooled, and valued these health impacts. Along the way, hopefully you have learned how to use BenMAP for additional analyses of Mumbai or whatever city, region, or nation interests you.

Appendix: Data Requirements