Castor-WATER 5.0

Software for analysis, prediction and design of pollutant discharges into diverse water bodies.

User's Manual

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χ Printed on recycled paper.

IMPORTANT. READ ATTENTIVELY

CASTOR-WATER FOR WINDOWS 95

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The CASTOR-WATER software estimates the dispersion of pollutants in the water. These types of numeric simulations are a method to estimate the contamination in an approximate way. Castor Software doesn't guarantee that the results obtained by this program coincide with the real concentrations that we can find in the water. The software, the used algorithms and the manual have been conscientiously examined of the possible existence of errors or omissions. Although we have checked the operation of CASTOR-WATER keeping in mind the results that we can find in the existent scientific literature on the area, Castor Software is not responsible for errors or omissions that we can find in the software, in the used calculation algorithms and in this manual. Castor Software is not responsible for losses or damages caused by the use of this software or of the user's manual. This software has been conscientiously examined of the possible existence of computer virus before its distribution.

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FOREWORD

The numeric algorithms that CASTOR-WATER uses gives us the possibility to study a great quantity of water pollutants that we find in our environment. The numerical method uses a equation that estimates the dispersion of the pollutants in the water.

The software admits meteorological data to establish the form of the polluting plume. The software calculates the pollutant concentration that is produced by each one of the sources and it considers the estates of the pollutant and the state of the water currents. CASTOR-WATER carries out temporary averages (daily, monthly or annual) so that you can calculate the concentration average in each point of the affected area.

The system of simulation of processes of dispersion that CASTOR-WATER has, offers to the beginner and the expert programmer, a quick and practical system to evaluate the dispersion of pollutants in the water. The program is based on the operating system Microsoft WINDOWS where one works intensively with the mouse and the graphic windows. The bars of icons facilitate the realization of the different tasks of the program. We can say, with a certain security that the software CASTOR-WATER is one of the best tools, to carry out numeric simulations of water pollution processes. Without considering the experience that the user possesses in programming languages or in the use of simulation tools, in few minutes he will be able to have the first results.

This manual will describe the use and the possibilities of CASTOR-WATER that we will show with the use of examples. It is not strictly necessary possessing knowledge on the handling of the operating system of Microsoft WINDOWS although it is advisable. Along the user's manual we will simulate some water pollution processes whose development will illustrate the use of the program in the case of complex systems. We will describe the necessary steps for the study of a water pollution process with the software.

Finally, we will say that they exist in the scientific literature a great quantity of models to evaluate the dispersion of pollutants in the water. In this way, we will obtain numeric differences among the results of the program and the results of other numeric models. This is not strange since there are numeric differences among the different models of the scientific literature. The problem is that the dispersion is a complex physical phenomenon (that involves turbulences, non-linear dynamics and thermodynamic of the irreversible processes) and we want to simplify it with a simple equation. On the other hand, we will add that this approach type is the most reasonable that we can think about to evaluate the water pollution.

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1. Introduction

Our planet is fragile and limited as for its potential of generating the resources that the humanity requests and her capacity to absorb the residuals that we emit. The precariousness of the ecological and environmental resistance of the earth can end up threatening the humanity's development. IUICN, PNUMA, WWF and Agenda 21 plead insistently to reach the sustainable development. This admits a growth and an evolution of the carrying capacity of the ecosystems, without committing the necessities of the future generations, by means of the environmental administration of the different places of the Planet.

2. Administration and Environmental Impact

The environmental administration is based on two fundamental tools: the planning and the evaluation of the environmental impact. These two instruments are fundamental to coordinate the human activity and to maintain the quality of the environmental resources. The process of environmental planning combines the characteristics of each place with the possibilities of economic development. We will define administration objectives that will achieve the optimization of the use of the resources minimizing the impact generated on the environment. We will define the environmental impact that suffers a certain region as the difference among the future environmental situation of the place, after the realization of a project, and the environmental state of the area if this project had never taken place. The correct diagnosis of the impact demands to know all the elements implied in the environmental process. A study of environmental impact will also include a planning of the environmental surveillance of the project.

One of the fundamental physical systems for the study of the environmental quality of a region is the water. The water and the ground play a important role in the development of the life. In this software, we will center ourselves in the study and in the administration of the water.

The outfall pipes, which release sewage, are mainly in the sea near the coast, in rivers and in estuaries. CASTOR-WATER Software can simulate both situations. The main pollutants in the water are: organic compounds, heavy metals, organic chemicals, oil slicks and thermal water.

Organic wastes.- It is the main compound of wastewater discharges. The most important discharges with organic compounds are the home sewage and the industrial wastewaters. This type of discharge experiences a very important demand of oxygen (BOD = biochemical oxygen demand). Putting too much sewage into a water body can place too severe an oxygen demand on the water, leading to major pollution problems. Water without pollutants can have a DOB between 1 and 2 mg/L. Raw sewage has a DOB between 300 and 400 mg/L ($1mg/L=1g/m^3$, $1g/m^3=1ppm$, $1L=1dm^3$).

Heavy metals.- Some heavy metals like the Cu and the Zn are not biodegradable and they are deposited in mollusks that filter great quantity of water, as the mussel. These metals are toxic in high concentrations and they can produce a problem for the health when they are ingested.

Organic chemicals.- Some of these compounds like the pesticides and the PCB can cause a great impact in the environment.

Thermal waters.- They are cooling waters from industrial and electric power plants. They may raise the temperature of the receiving water, increasing the rate of decomposition of biodegradable organic wastes.

3. The Water

It is an indispensable element for the life. 97% of the water of the Earth is in the oceans. 70% of the surface of our planet is covered by the water. The water is in seas, rivers, lakes and ice. The water is always moving, from the earth and the oceans to the atmosphere and vice versa. Taking advantage of these movements, the water transports mass and energy. The water dissolves the soluble compounds of the minerals and it transports them until the oceans or it deposits them in far away places. The water transports the nutrients of the plants in its interior. The water absorbs solar energy when it evaporates in the ocean. The energy is liberated when the water condenses. The rain dissolves the present substances in the atmosphere: oxygen, nitrogen, dioxide of carbon, sulphur oxides and nitrogen oxides. In very industrialized areas where big quantities of oxides of sulphur and of nitrogen are emitted to the atmosphere, the degree of acidity of the rain can be between 10 and 100 times superior. This generates big problems in lakes, forests and even constructions.

3.1 Physical characteristics

Colour: It is due to the dissolved minerals and the organic matter.

Turbidity: It is caused by the dissolved matter that disperses and absorbs the light.

Odour: It can be due to the presence of inorganic or organic substances.

Temperature: The disturbance caused by the rise in temperature of the water is called thermal pollution. It has a number of bad effects. Oxygen is less soluble at the higher temperature. If the temperature rises sufficiently, fish may die. The situation is made worse by the speeding up of biochemical processes so the fish respire more rapidly and need more oxygen.

Oxygen concentration in the water	
Temperature (°C)	**Oxygen (g/m^3)**
0	1.42
5	12.4
10	10.9
15	9.8
20	8.8
25	8.1
30	7.5

Density and thermal stratification: The intense heating caused by sunlight results in the formation of a light, warmer layer of water floating on top of a much larger mass of cold, dense water. Where these two bodies of dense water meet there is a zone of rapid change in the water temperature, called the thermocline or pycnocline. Such a thermocline is a permanent feature of both tropical and temperature waters. When the surface water of temperature seas is warmed in the summer a further seasonal thermocline can develop much closer to the surface. This is much stronger feature than the permanent thermocline in temperature waters. This thermocline plays an important role in determining seasonal changes in marine primary production in temperature seas. Thermal stratification represents a physical barrier to the mixing of the water column. There is little or no exchange of nutrient through a thermocline.

Suspended solids: Their size can be of the order of millimeters (for example in waste waters) up to 10^{-9} m. (dissolved solids).

3.2 Chemical characteristics

The chemical characteristics of the water are in function of the dissolved substances.

pH: The mineral waters have a pH value between 6 and 9, the seawater has a value of 8 and the rain of 5.6. Significance: intensity of acid or alkali present.

4. Water pollution

Natural waters contain micro-organism as well as solutes. There is a distinction between 'pure' water, meaning water that is fit to drink and pure water that is a single substance. A water pollutant is a substance that prevents the use of water for a specified purpose. The signs of polluted water are obvious. Poor drinking water tastes and smell bad. Many types of substances which are classified as pollutants are listed.

1. Pathogens, bacteria and viruses
2. Dissolved organic compounds and inorganic compounds
3. Wastes that have a biochemical oxygen demand

4. Nutrients that cause excessive growth of plants
5. Thermal pollution

4.1 Biochemical Oxygen Demand

The Oxygen is used for respiration of animals. Fish require the highest concentration of oxygen. If the dissolved oxygen falls below 5ppm (part per million), fish are the first to suffer and tend to die out. Then, the population of bacteria rises to abnormal levels. The imbalances between species is a sign of water pollution. Substances which use up dissolved oxygen and add to the biochemical oxygen demand are pollutants. Such substances come from the human wastes. The amount of dissolved oxygen used up during oxidation by bacteria of the organic matter in a sample of water is called Biochemical Oxygen Demand (BOD). Water is rated as pure if BOD is 1ppm or less, fairly pure with a BOD of 3ppm and suspect when the BOD reaches 5ppm.

Water	Upper limit of BOD_5 (European Union) (mg/L)
Pure waters	< 1
Polluted rivers (upper limit in European Union)	> 5
Polluted rivers with salmon (upper limit in European Union)	3
Polluted rivers with other fish (upper limit in European Union)	6
Waste waters	150-1000+
Industrial waste waters	thousands

+BOD, not BOD_5
$1mg/L=1g/m^3=1ppm$
BOD is calculated in 20 days. BOD_5 is calculated in 5 days, $BOD=5BOD_5$.

4.2 Eutrophication

In order to grow, plant require about 20 different elements (carbon, hydrogen,…). In normal conditions, water always provides enough elements for plant growth. The rate of growth is limited by the supplies of nitrogen and phosphorous. Lake water may be enriched with nutrients (a process called eutrophication) which encourages plant growth and leads slowly to ageing. Ageing is accelerated when plant nutrients are fed into a lake by human activities (fertilisers, wastewater containing detergent,…). When a lake contains concentrations of nitrates and phosphates higher than the normal, algae flourish and produce a bloom, a green scum which is accompanied by an unpleasant odour in the water. The lowering of oxygen concentration leads to the death of fish. The sources of nitrates and phosphates are sewage and fertilisers. Intensively cultivated land receives generous applications of fertilisers containing nitrates and phosphates.

Nitrates: The World Health Organization recommends that the level of nitrogen in the form of nitrates should not exceed 50ppm. The averaged level in the UK is about 11ppm.

Water	Upper limit (different compounds with nitrogen)
Rivers with water of good quality	1mg/L
Rivers with salmon	1mg NH_3-N/L
Drinking water	0.1mg NO_2-N/L
Rivers with salmon	0.01mg NO_2-N/L
Drinking water	40mg NO_3^-N/L
Rivers with salmon	1mg NO_3-N/L

Phosphates: Phosphates enter water from fertilisers and from detergents. Phosphates are added as builders to improve the cleaning power of synthetic detergents. To inhibit the growth of algae, a phosphate level below 0.5mg/L is the aim. The lakes can become eutrophic if the concentration of phosphates overcomes the 30ug/L ($1ug/L=10^{-6}g/dm^3$). The upper limit in European Union for polluted rivers with salmon is 65ug/L.

4.3 Dissolved organic compounds

Natural organic compounds have been present in the environment for millions of years. Many synthetic chemicals are harmless to living things, but some interfere with biochemical processes. Some of these synthetic chemicals are purposely introduced into the environment to kill insects. Some organic compounds pollute waterways. They are especially dangerous if they are not biodegradable. Some, like DDT, are concentrated by passage through a food chain.

4.4 Acidic pollutants

A source of acidic inorganic pollutants is the drainage of water from mines. Water flowing from underground mines is usually highly acidic. In lakes and rivers, the acids react with carbonate ions to form carbon dioxide. A raised level of carbon dioxide in the water makes it more difficult for animals to respire. Extreme acid pollution kills aquatic plants and animals.

4.5 Cyanides

Cyanides are widely used in industry for cleaning metals. Cyanides enter waterways in effluents from industries. The toxic effect of cyanide is due to the formation of a complex with iron.

4.6 Aluminium

Aluminium ions are present in the water supply because aluminium sulphate is used in water treatment. There is evidence of a correlation between Alzheimer’s disease and the aluminium content of drinking water. The rate of Alzheimer’s disease in districts where the concentration of aluminium in drinking water exceeds 0.11mg/L (1mg=0.001g, $1L=1dm^3$) is higher than the rate in districts where the aluminium concentration is less than 0.01mg/L.

4.7 Cadmium

Pollutant cadmium in water may came from industrial discharges. Heavy metals are serious water pollutants. Cadmium is highly toxic, with a recommended upper limit of only 10ppb (part per billion, 1000ppb=1ppm).

4.8 Lead

Leaded petrol is a source of lead in the atmosphere. Particles of soot and lead compounds from vehicle exhausts can fall on land and contaminate. Lead come from lead pipes and solders, from lead glazes on pottery and glasses. The World Health Organisation recommends that the limit for lead in drinking water should be 50 ug/L.

4.9 Mercury

Mercury compounds are found in nature in low concentrations in rocks and soils. However, we find a variety of uses for mercury which add mercury to the environment. Mercury comes from mercury cathode electrolysis cell, from fungicides, paints, coal and disinfectants. It has accumulated in a number of lakes. Mercury is slowly converted into dimethylmercury and methylmercury which are soluble and can be ingested by animals. Sludge from sewage treatment plants contains about 1ppb of mercury.

4.10 Chromium

Chromium compounds are toxic and irritating. They are present in wastes from electroplating plants and tanneries.

4.11 Nickel

Nickel compounds came from electroplating plants and cause damage to brain.

4.12 Copper

Copper compounds are toxic. If the dose is high enough. It can damage brain and eyes.

4.13 Zinc

Zinc enters the water supply from galvanising plants. It is relatively non-toxic, but large doses cause vomiting.

4.14 Arsenic

Contamination by agricultural pesticides has occasionally been a source of arsenic poisoning. It comes from the combustion of fossil fuels and is concentrated in food chains. The level of arsenic in natural water is 2ppb. Ingestion of 100mg of arsenic by an adult is fatal. The recommended upper limit for drinking water is 50 ppb.

4.15 Thermal pollution

The rise in temperature of the water is called thermal pollution. Water is taking from waterways, used for cooling, and returned to waterways. It decreases the solubility of oxygen, increase the metabolic rate of organism,… If the temperature rises sufficiently, fish may die.

5. Before you begin

Welcome to Castor-WATER - software for analysis, prediction and design of pollutant discharges into diverse water bodies. The CASTOR-WATER software allows you to create robust and useful numeric simulations that fully make use of the graphical user interface. This chapter show you how to sep up CASTOR-WATER on your computer.

We can say, with a certain security that the software CASTOR-WATER are one of the best tools, if not the best and simpler, to carry out numeric simulations of pollutant discharges into the water. It takes just a few minutes to build your first numerical simulation.

Due to the features of the software that allows to simulate the process of pollutant discharges into water immediately, the numeric simulation is carried out with a remarkable speed.

You create the graphical interface for your pollutant discharges by drawing point sources in a graphical way. You create the simulation process by drawing point sources, such as outfall pipelines, on the CASTOR-WATER window. Next, you set properties for the point sourcas and water currents to specify such values as density, concentration,… Finally, the numeric simulation is carrier out.

5.1 CASTOR-WATER Software

Before you attempt to install and use the program, make sure your personal computer meets the hardware and software requirements shown in the following table.

- System requirements: Windows 95, 98, 2000 and XP
- CD-ROM drive
- RAM Memory: 16MB or higher

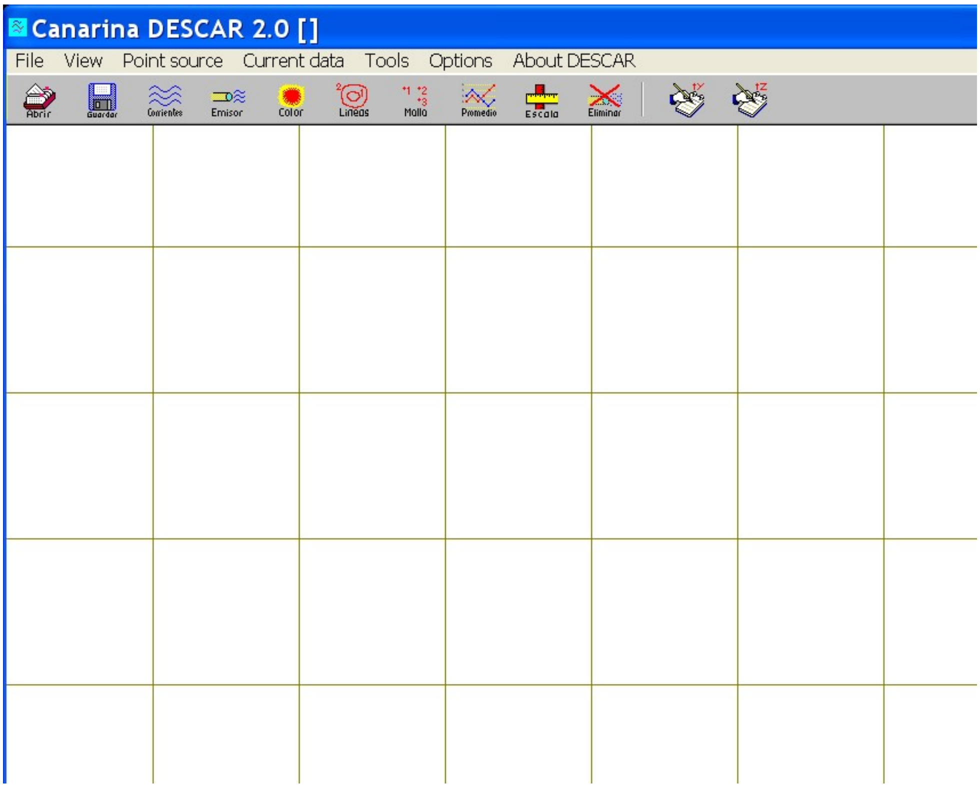
5.2 Installation

- Insert the CD. The CASTOR-WATER CD window appears on your screen.
- Double-click the button labeled **Setup** and follow the instructions on the screen.

If the CASTOR-WATER CD window does not appear, the CD autorun feature might be disabled on your computer. To install CASTOR-WATER, open the CD-ROM drive icon, open the PC directory, and double-click the Installer icon.

5.3 Starting CASTOR-WATER

Click Start, go to Programs, and choose CASTOR-WATER. Here is the program window after startup.



The window has a Menu bar at the top, a Status bar at the bottom and a basic tool bar in the window. The program commands are available through the menus and toolbar buttons. Some commands have associated dialog boxes which you can choose additional options.

6. Understanding the Workplace

The MS Windows bar doesn't appear. In this way, you have more space to draw. However, and if you want, you can modify the properties of the MS Windows bar in the Microsoft Windows system. The program window size is fixed and it cannot modify. The menu bar lists the menus shown above. When you choose one of the menus, the program displays a pull-down list of available commands. The menu bar lists: **File**, **View**, **Point source**, **Current data**, **Tools**, **Options** and **About CASTOR-WATER**…

The program window has a basic tool bar at the top.

In the center of the program window, we will draw and we will calculate the different polluting processes. We can draw using two different planes: parallel to the surface of the water (XY) and perpendicular to the surface of the water (XZ). There is a grid in the XY-plane. The coordinate origin is on the left bottom corner (X=0, Y=0) in XY-planes (parallel to the surface of the water). In addition, the coordinate origin is on the left bottom corner (X=0, Z=0) in XZ-planes (perpendicular to the surface of the water).

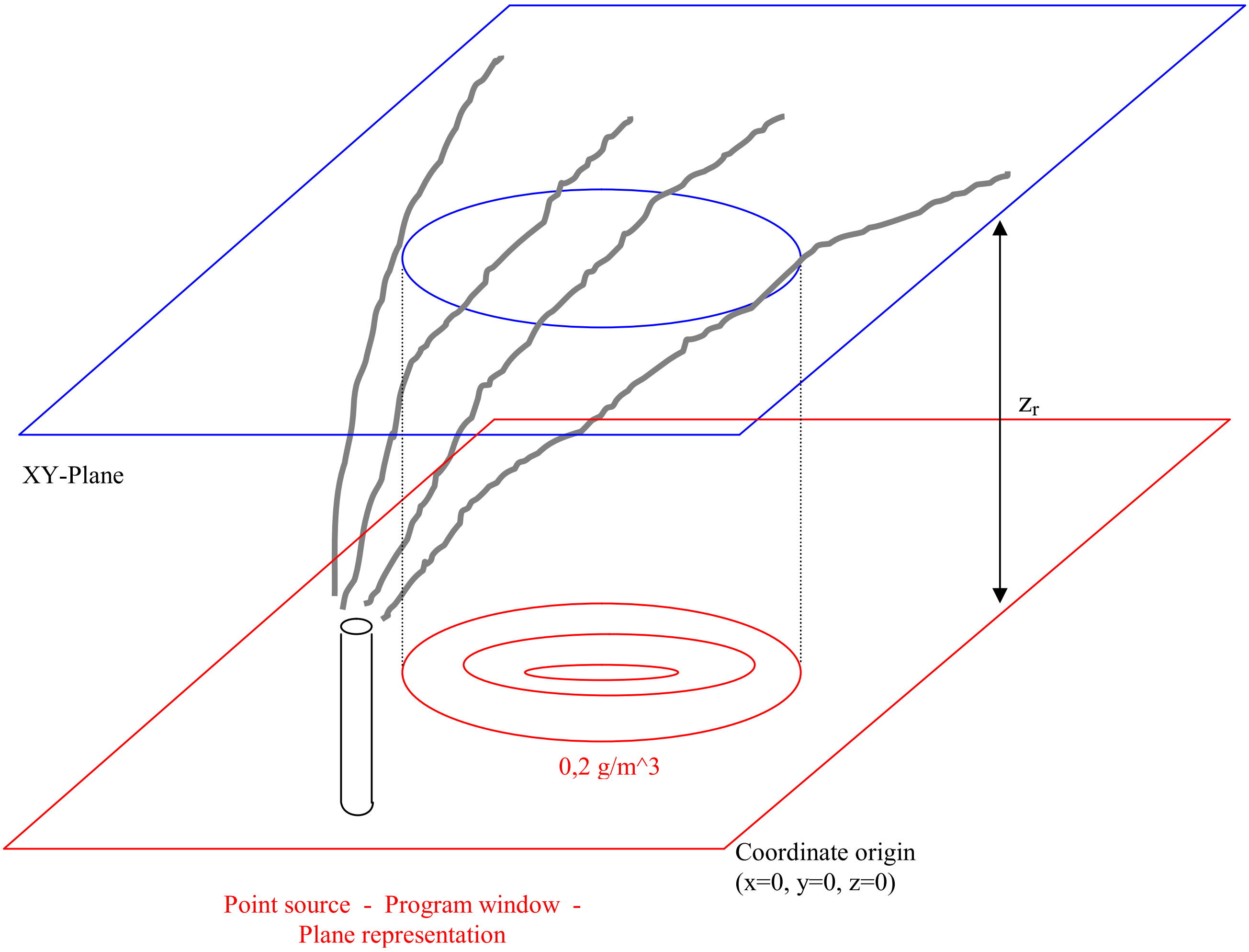
XY-Plane (parallel to water surface):

In such a case, the program window is a XY-plane (parallel to the water surface). A pollutant point source (outfall pipeline) is represented by a small square.

In the Status bar at the bottom, we have X,Y and Z coordinate values in meters and data on our environmental system. Point the mouse where you want in the program window and the X,Y and Z values will be shown in the status bar at the bottom. If you select XY-Plane, a grid appears.

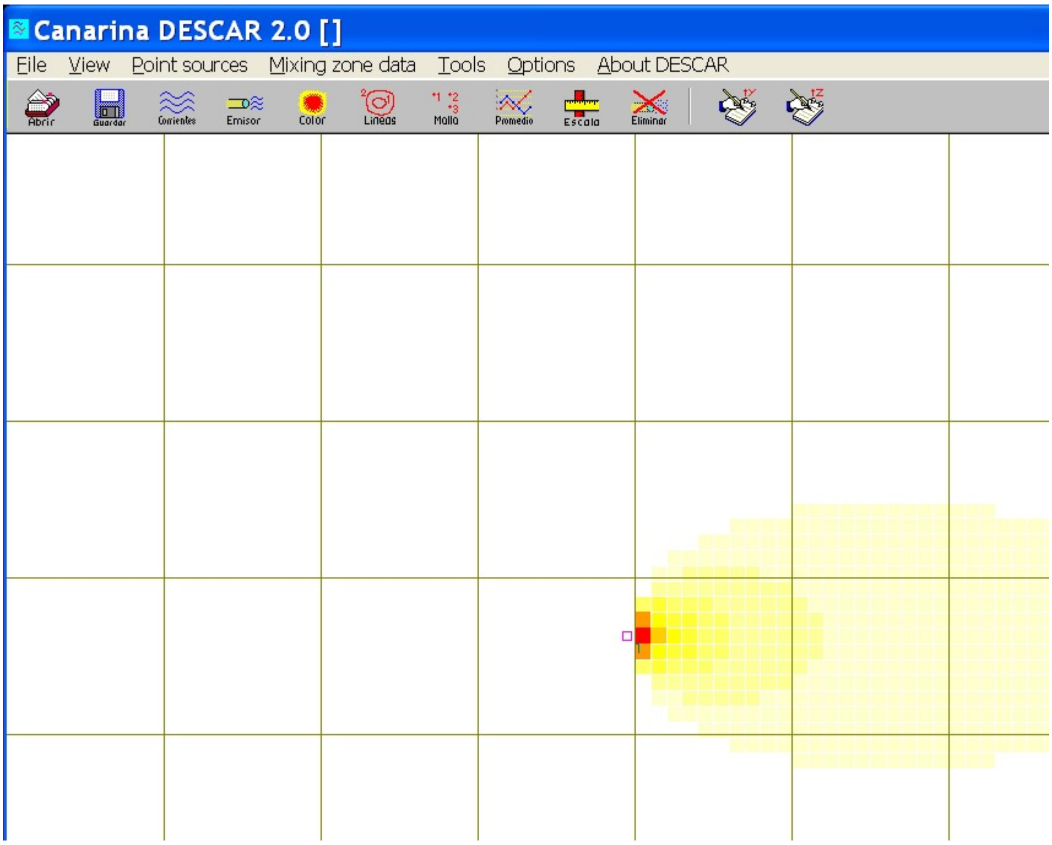
On the left bottom corner, two different text boxes appear: The position of the XY-plane with respect to the water surface (XY-plane height) and the pollutant concentration value (grams per cubic meter, g/m^3). Point the mouse where you want in the program window and the concentration value will be shown in the text box. Remember that $1g/m^3=1mg/L$.

The pollutant concentrations will be calculated in a parallel plane to the water surface (XY-Plane). The plane height will be determined by the user (z_r).



All the points of the XY-plane will be to a z_r height. The z_r value is chosen by the user before the calculation. We will be able to make many calculations considering different plane heights. The different plane heights will be determined by the user (z_r values). In this way, the physical form of the pollutant plume can be studied.

Example: Calculation in the XY-plane, zr=0 (height of the water surface). The red square represents a point source (position of the outfall pipe). The red colour represents high pollutant concentrations.



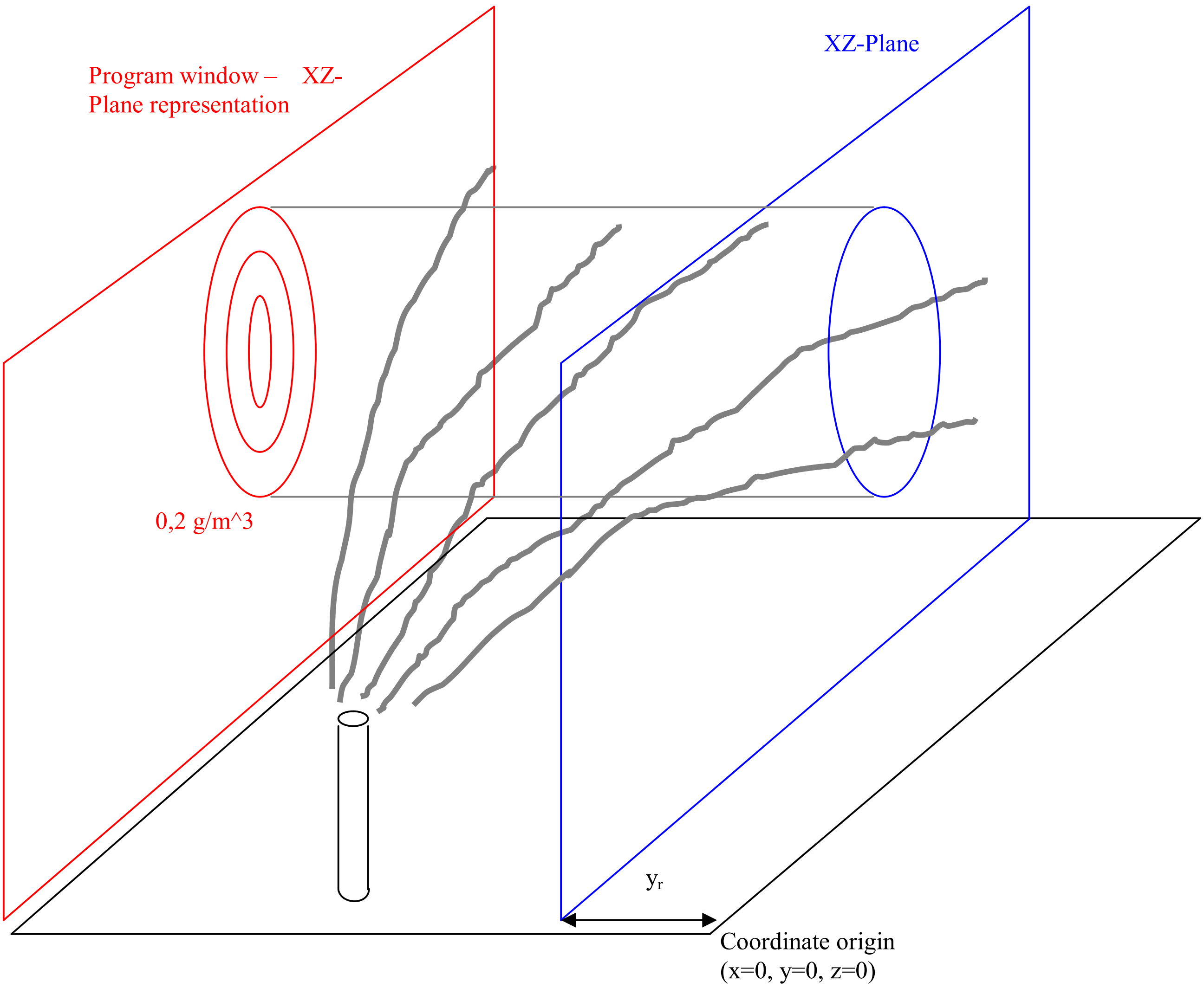
XZ-Plane (perpendicular to water surface):

In such a case, the program window is a XZ-plane (perpendicular to the water surface). A pollutant point source (outfall pipeline) is represented by a small square.

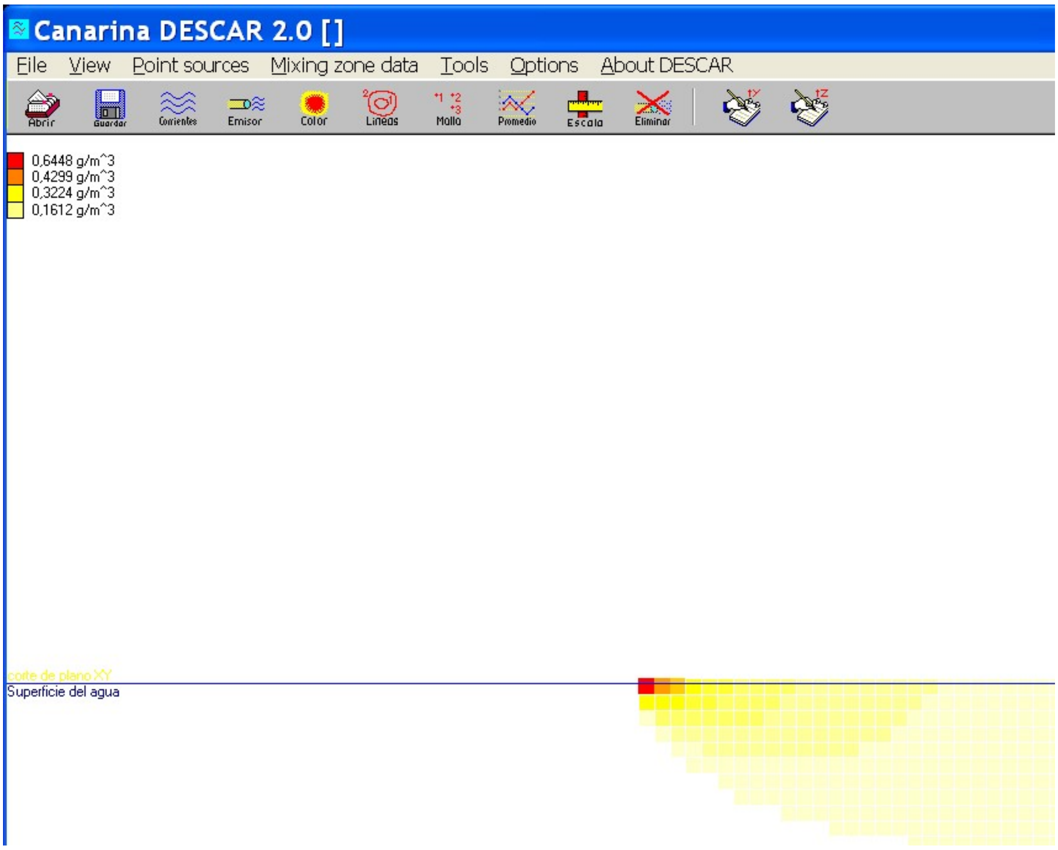
In the Status bar at the bottom, we have X,Y and Z coordinate values in meters and data on our environmental system. Point the mouse where you want in the program window and the X,Y and Z values will be shown in the status bar at the bottom.

On the left bottom corner, a text box appears: the pollutant concentration value (grams per cubic meter, g/m³). Point the mouse where you want in the program window and the concentration value will be shown in the text box. Remember that 1g/m³=1mg/L.

The pollutant concentrations will be calculated in a perpendicular plane to the water surface (XZ-Plane). The plane height will be determined by the user (y_r).



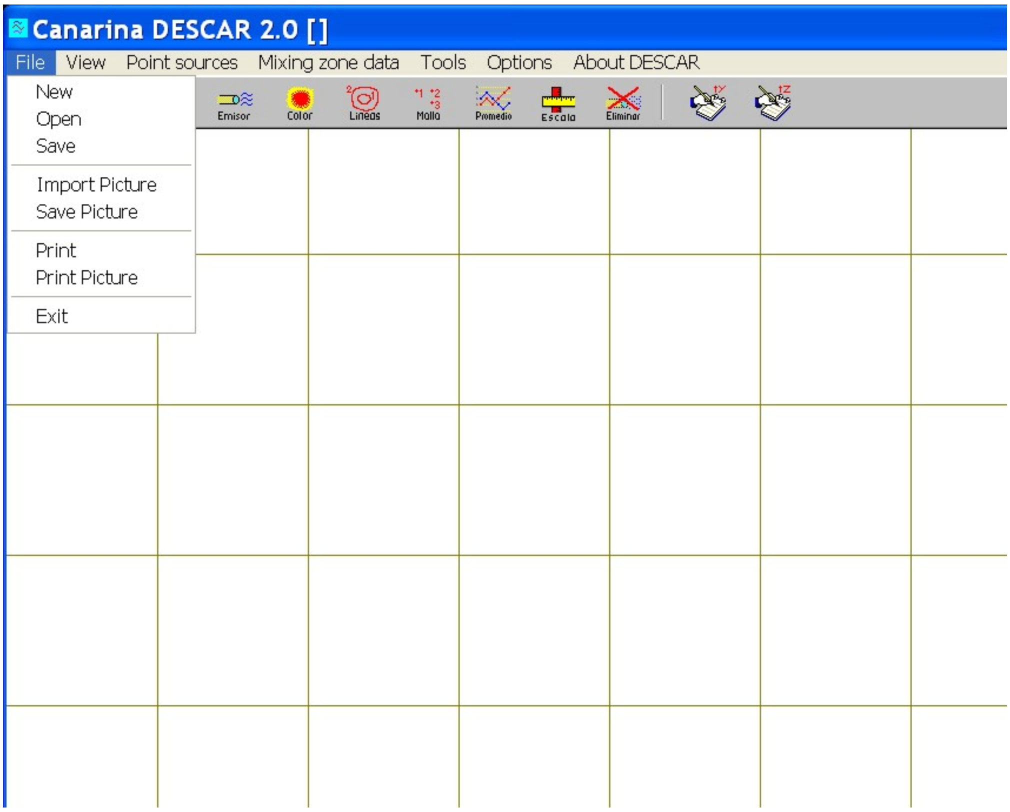
All the points of the XZ-Plane will be to a y_r height. The y_r value is chosen by the user before the calculation. We will be able to make many calculations considering different plane heights. The different plane heights will be determined by the user (y_r values). In this way, the physical form of the pollutant plume can be studied. Example: Calculation in the XZ-plane. The red square represents a point source (position of the outfall pipe). The blue line represents the surface of the water and the green line represents the bottom of the sea. The red colour represents high pollutant concentrations.



6.1 Menu Bar

Display the commands you use to build your simulation. When you choose one of the menus, the program displays a pull-down list of available commands. The program window has a basic tool bar under the Menu bar. The tool bar provides quick access to commonly used commands in the program. You click a button on the toolbar once to carry out the action represented by that button.

For example, when you choose **File** in the Menu bar, the program displays:



6.1.1 File

The File Menu contains the tools you use to open, close and save new and existing files, and import and export graphics. The File Menu lists: **New**, **Open**, **Save**, **Import Picture**, **Export Picture**, **Print**, **Print Picture** and **Exit**.

New.- This command is to begin a new simulation, deleting all that has been made previously.

Save the work with the Save command before clicking the New command. The program doesn't allow to open two files at the same time. This way, we can optimize the available memory and the calculation speed.

Open.- This command is to open an existing file. The program files exist as separate files with **.ems** filename extension.

Save the current work with the Save command before clicking the Open command. The program doesn't allow to open two files at the same time.

Save.- This command is to save an existing result.

The process of saving a file is carried out proportionally to the size in which the elements are drawn in the screen. Then, the saved file will depend on the screen format that we are using (for example, 1280x1024,...). If we try to read a file, saved in another different computer, we will have problems to open it.

Import Picture.- With this command you will be able to import images and pictures (previously saved BMP files). These images will be background pictures and images for your program window. You can display an image by double-clicking the filename of a bitmap (BMP).

Many programs and computer applications (AutoCad, 3d Studio, ArcView,...) export BMP files. You will be able to load pictures and images generated by these programs.

The displayed image size will depend on the size that had when it was saved. If it is necessary, modify the picture size before loading the image (for example, you can use windows Paint, Adobe Photoshop,…). You will be able to load BMP maps generated by AutoCad.

Bitmaps and scanned maps must be loaded into memory and then adapted to the program scale (we will make use of the **Scale** command). The X-Axis width (meters) in the program window can be easily changed to be able to compare both images (simulation results and background maps). Then, the X-Axis width (in meters) of the imported map and the X-Axis width (in meters) of the program window match together. The imported images are not stored physically in the simulation process. Terrain elevations (represented on the imported map) don't interact in the simulation process. We haven't the possibility to zoom an imported map with the **Zoom** command. This command only acts in the calculation process. If it is necessary, zoom the map before loading the image.

Export Picture.- With this command you will be able to export images and pictures (BMP files). These images will contain the background picture and the simulation results.

Many programs, computer applications and word processors (AutoCad, 3d Studio, ArcView, MS Word,...) import BMP files. You will be able to load images generated by CASTOR-WATER.

Print.- The users' printer drivers and printers impact print quality. With this command you can send graphics and text (of the simulation results) to a printer. This command provides the best printing quality across a variety of printers because Windows translate text and graphics from the device-independent drawing space to the Printer object to best match the resolution and abilities of the printer. However, the background pictures cannot be printed.

Print image.- This command send a pixel-by-pixel image of the program window to the printer. To print with **Print image** command, you must first display that information on the program window and then print with this command. This command is by far the easiest way to print from your application.

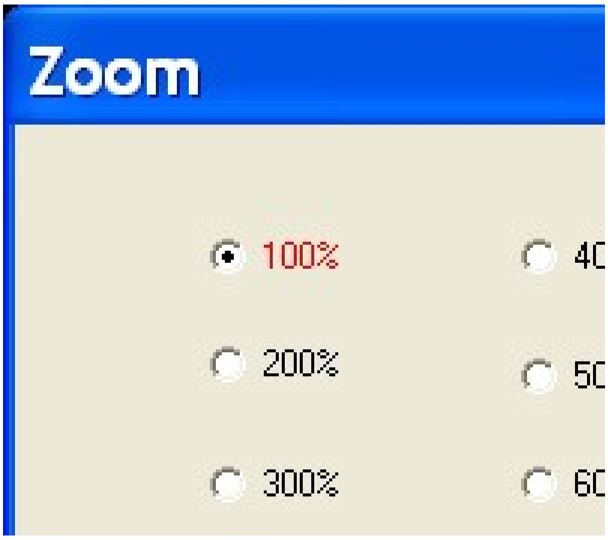
Because it may send information to the printer at the resolution of the user's screen (typically 96 dots per inch), results can be disappointing on printers with much higher resolutions (typically 300 dots per inch for laser printers).

Exit.- The **Exit** command allows you to exit directly from the application.

6.1.2 View

The View Menu contains the tools you use to view your computer screen. The File Menu lists: **Zoom**, **Black background**, **White background**, **Draw grid lines**, **Eliminate grid lines**, **Draw picture**, **Eliminate picture**, **XY View** and **XZ View**.

Zoom.- We have the possibility to zoom a part of the program window with the **Zoom** command. However, we won't be able to enlarge background pictures with this command. If it is necessary, zoom the map before loading the background image. This command only acts in the calculation process. This way, we can place a point source in a side of the computer screen and we can calculate the concentrations in another different detailed region.



To activate the **Zoom** command, eliminate the background picture first.

Black background.- The Black background command allows you to have a black background colour in your screen.

White background.- The White background command allows you to have a white background colour in your screen.

Draw grid lines.- If you select **Draw grid lines** command, the grid appears.

Eliminate grid lines.- If you select **Eliminate grid lines** command, the grid disappears.

Draw picture.- With this command you will be able to see background images and pictures (previously loaded BMP files).

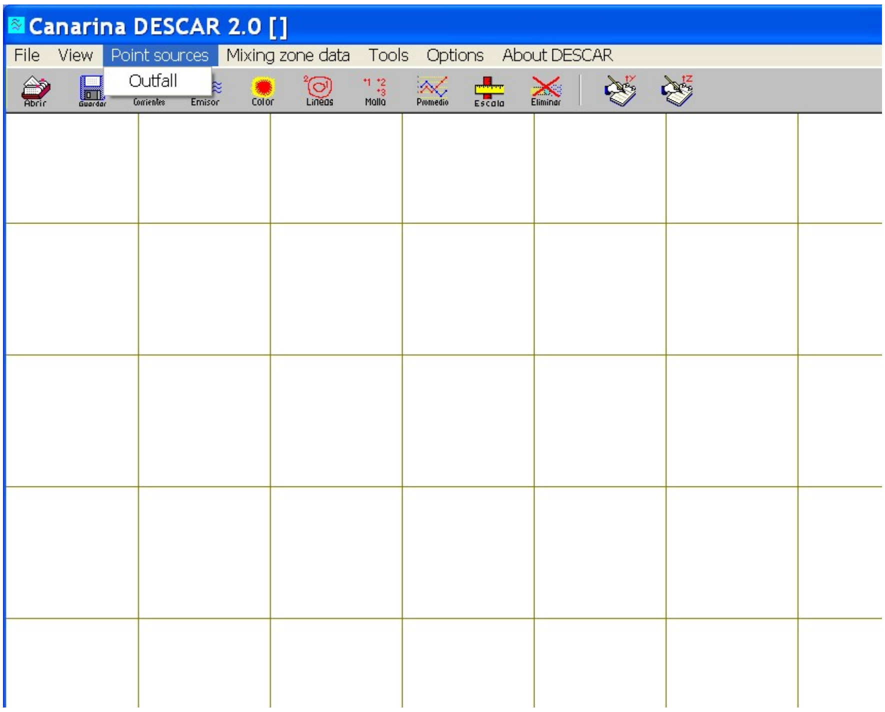
Eliminate picture.- With this command you will eliminate background images and pictures (previously loaded BMP files).

XY View.- With this command, you can draw using a plane that is parallel to the surface of the water (XY).

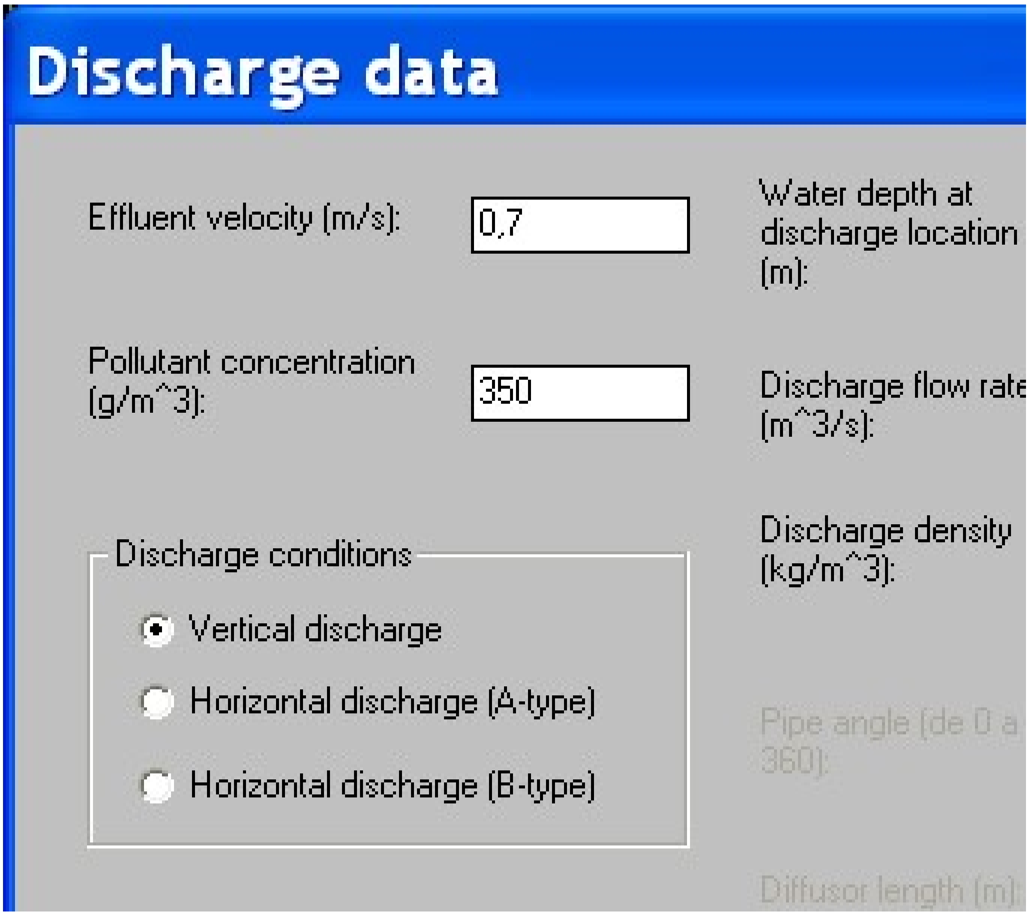
XZ View.- With this command, you can draw using a plane that is perpendicular to the surface of the water (XZ).

6.1.3 Point source

The **Point source** Menu lists the possible pollutant sources: the outfall pipe.



Outfall.- This is a pollutant point source. The outfall is small if we compare it with the size of the area in which we are simulating (point source). If you click this button, the next dialog box is shown:



Depending on the used model, some data of the dialog box can be modified: Buoyant jet model or Stratified model (see calculation models).

Buoyant jet model: The necessary data in the Buoyant jet model is:

Effluent velocity u_a (m/s): The average velocity of the pollutant effluent. It can be around 1 m/s.

Pollutant concentration (g/m^3): The discharge concentration of the material of interest (pollutant or tracer) is defined as the excess concentration above any ambient concentration of that same material. 1g/m^3=1ppm in water.

Water depth at discharge location (m): The actual water depth at the sumerged discharge location. For surface discharges it is the water depth at the channel entry location.

Discharge flow rate (m^3/s): The discharge flow rate and the discharge velocity are related through the port cross-sectional area. (Flow rate)=(area)x(discharge velocity).

Discharge density (kg/m^3): It is the density of the pollutant discharge.

Discharge conditions: There are three options: Vertical discharge, Horizontal discharge (A-type) and Horizontal discharge (B-type). In the vertical discharge, the discharge flow is perpendicular to the water surface. In the horizontal discharges (A and B), the discharge flow is parallel to the water surface. In the horizontal discharge case, we assume that the discharge vector is always perpendicular to current vector. That is to simplify the calculations. In the A-type, the flow vector points the South and the current vector points the East. In the B-type, the flow vector points the North and the current vector points the East.

Stratified model: The necessary data in the Stratified model is:

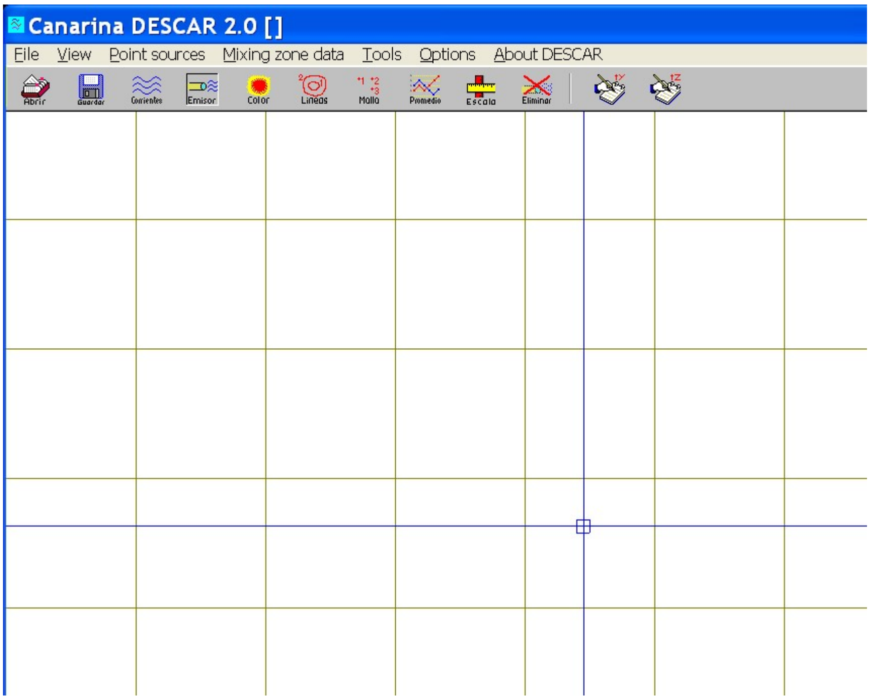
Pipe angle (0 to 360): It is the horizontal angle of discharge measured clockwise from the North (at the window top).

Diffusor length (m): The diffuser length is the distance from the first to the last port or nozzle.

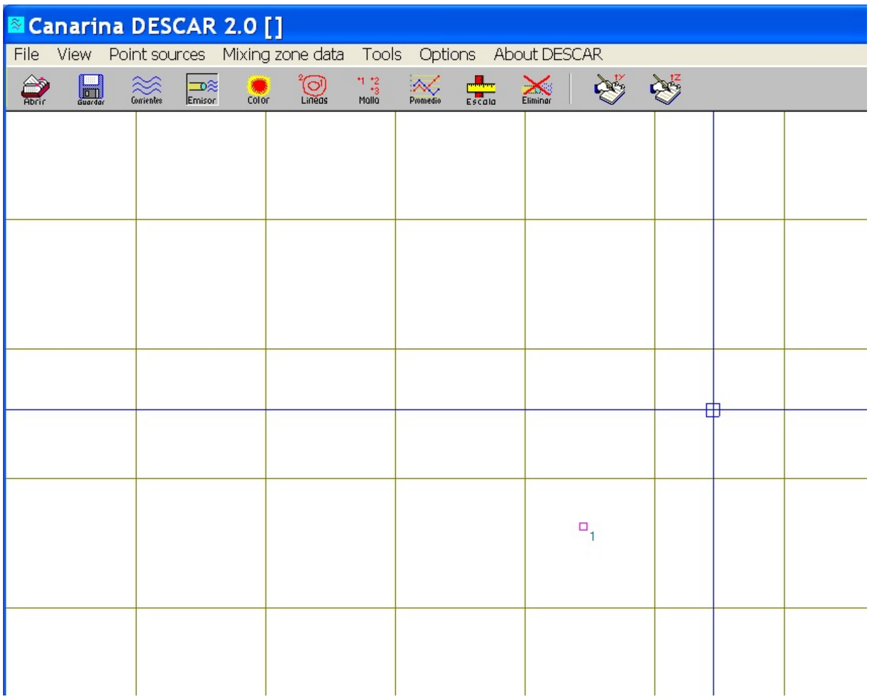
1/T90 (1/seconds): This coefficient considers the half life of the pollutant if this disappears by means of chemical reactions (non-conservative pollutant). This is the T90 for E.Coli. For towns with less than 10,000 inhabitants we can take a T90=2 hours (1/T90=0,5 $hours^{-1}$) in the Mediterranean and T90=3 hours (1/T90=0,33 $hours^{-1}$) in the Atlantic.

Number of openings: CASTOR-WATER allows for different types of discharge geometries. There are three options: Single port, Multiport diffuser and Separated ports. We have a multiport diffuser when the separation among the ports is less than 3% of the depth. We have Separated ports when the separation among the ports is bigger than 20% of the water depth.

If you click the OK button, the next program window is shown



Two blue axis points the place where we can fix the outfall position. After clicking the program window, you draw the outfall.

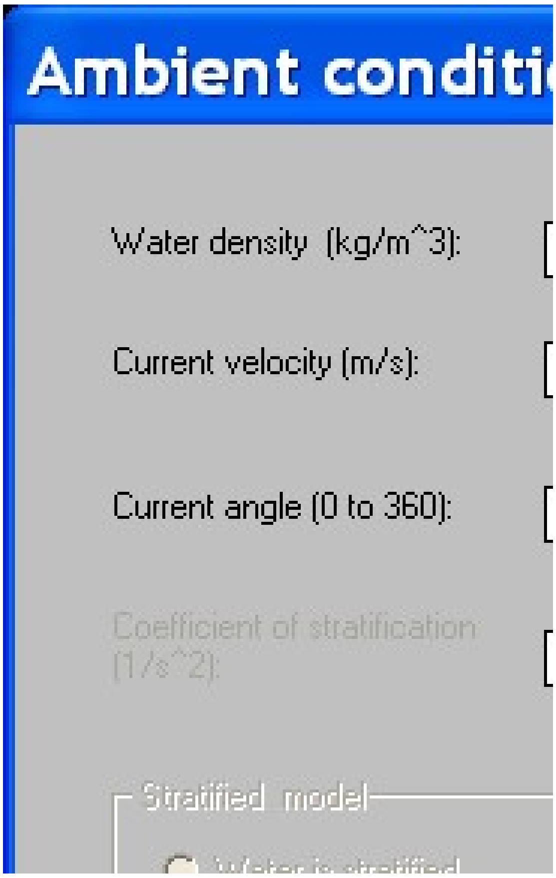


The small red square shows the outfall location. We can draw all the outfalls that we want (up to 1,000). To change the discharge data, we can click the outfall location in the program window. Then, the discharge dialogbox is again displayed. We are not able to put two outfalls in the same location. The older is eliminated automatically.

6.1.4 Current data

Ambient conditions are defined by the hydrographic conditions in the vicinity of the discharge. This Menu lists: **Current**.

Current.- CASTOR-WATER analyses, as all mixing zone evaluations, are usually carried out under the assumption of steady-state ambient conditions. If you click this command, the next dialog box is shown:



Depending on the used model, some data of the dialog box can be modified: Buoyant jet model or Stratified model (see calculation models).

Buoyant jet model: The necessary data in the Buoyant jet model is:

Water density (kg/m^3): It is the density of the ambient water.

Current velocity u_a (m/s): The average velocity of the water current. The admitted minimum velocity is 0,0001 m/s. A typical velocity can be of about 0,015 m/s.

Current angle (0 to 360): It is the horizontal angle of water current measured clockwise from the North (at the window top). For an outfall that is localized near the coast, the vector of the current is usually parallel to the coast.

Stratified model: The necessary data in the Stratified model is:

Coefficient of stratification (s^{-2}): Γ represents the stratification degree in the water

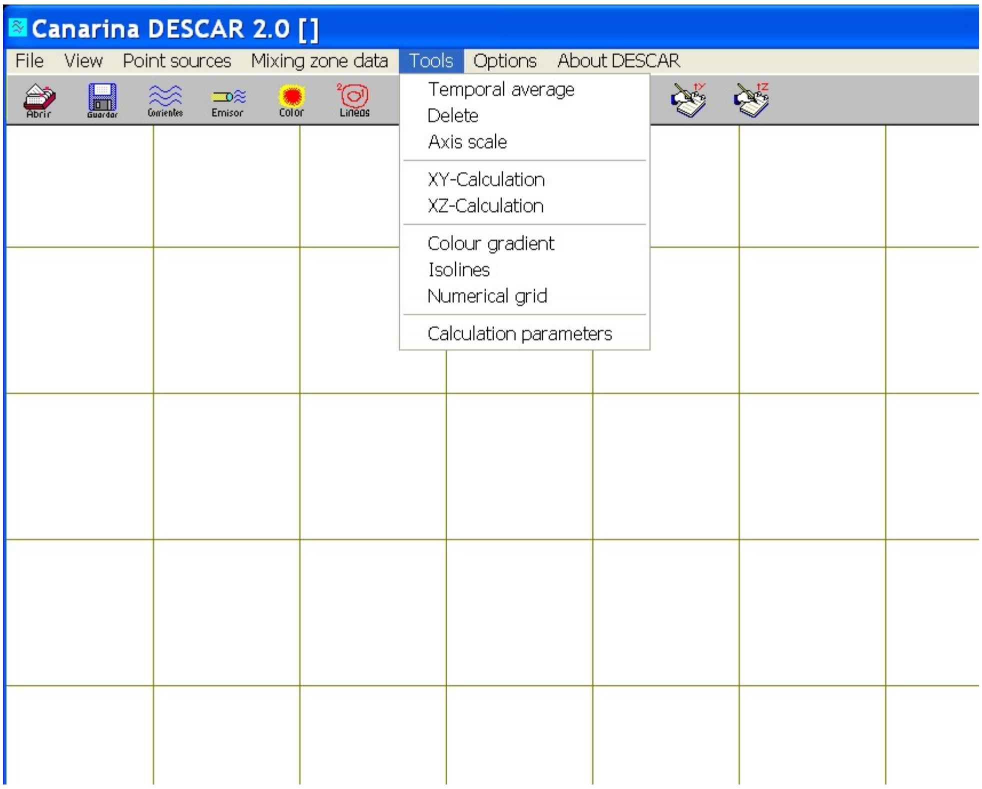
$\Gamma=-(g/\rho_a)(d\rho_a/dh)$,

being g the gravity acceleration, $g=9{,}81 m/s^2$, ρ_a the ambient water density and h the depth. A typical value can be 0,00005 s^{-2} (The density of the seawater increases 5 kg each 1000m).

Stratified model: There are two options: Water is stratified and Water is not stratified. The stratification process usually happens in summer.

6.1.5 Tools

The Tools Menu contains the tools you use to process your data. The File Menu lists: **Temporal average**, **Delete**, **Axis scale**, **XY-Calculation**, **XZ-Calculation**, **Colour gradient**, **Isolines**, **Numerical grid** and **Calculation parameters**. When you choose **Tools** in the Menu bar, the program displays:

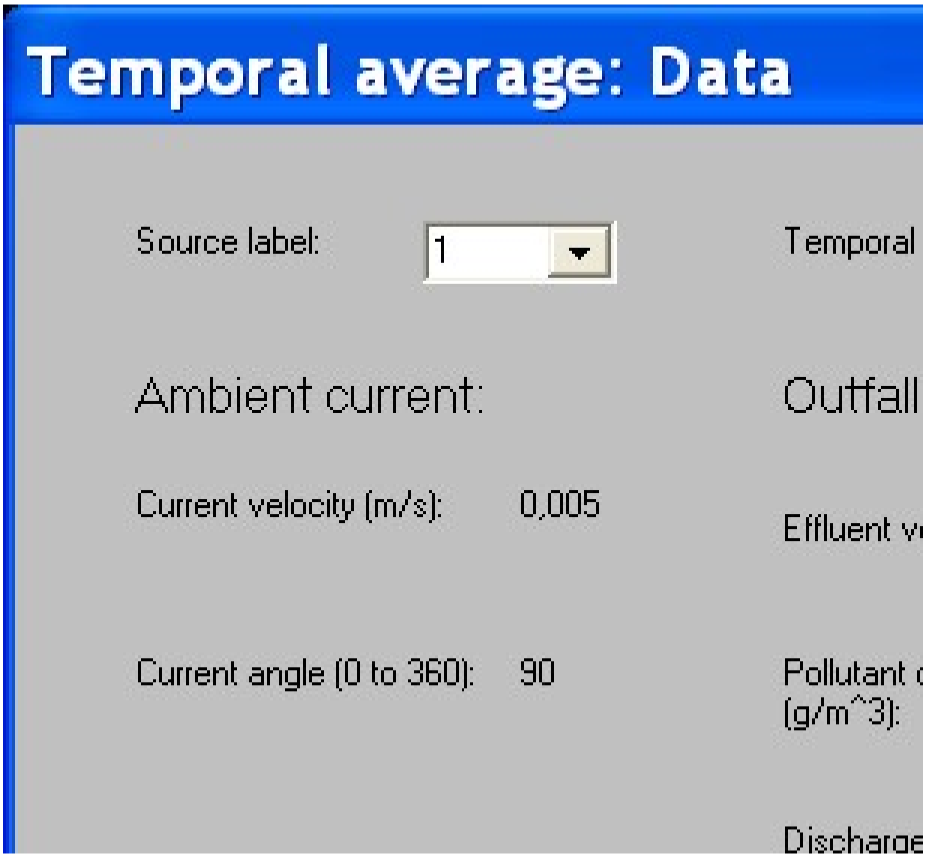


Temporal average.- Some discharge data can vary with time (velocity of the current, pollutant concentration,...). Taking this into account, the program can do temporal averages in the calculation. In the CASTOR-WATER software, these data are allowed to vary with time. If you click this command, the next dialog box is shown:

We can write in the text box the number of temporal points per average. To be able to make an average, we will take more than a temporal point.

The temporary points are elements of an average and we will be able to relate them with any temporary instant. That is to say, if we have data of currents for every hour of one day (a total of 24) and we want to make an average of the pollution in one day, we will be able to make a temporal average with 24 temporal points to calculate the daily average.

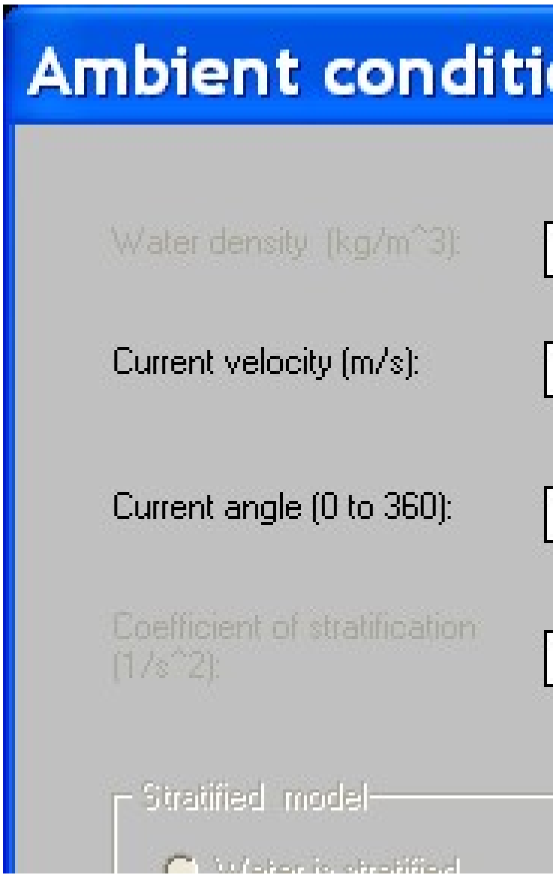
Each temporary point that we average represents the data in a hour of time. If we have monthly data, and we want to make an annual average, we will be able to average with 12 temporary points (the twelve months). Then, and if you click the OK button, the next dialog box is shown:



The window allows to visualize the data to make the average. It also allows to modify the data or to change them. We have two groups of data that can vary in time: Current data (velocity and angle) and Outfall data (velocity, pollutant concentration and flow rate). These are the current and discharge conditions that can vary in time in the numeric simulation.

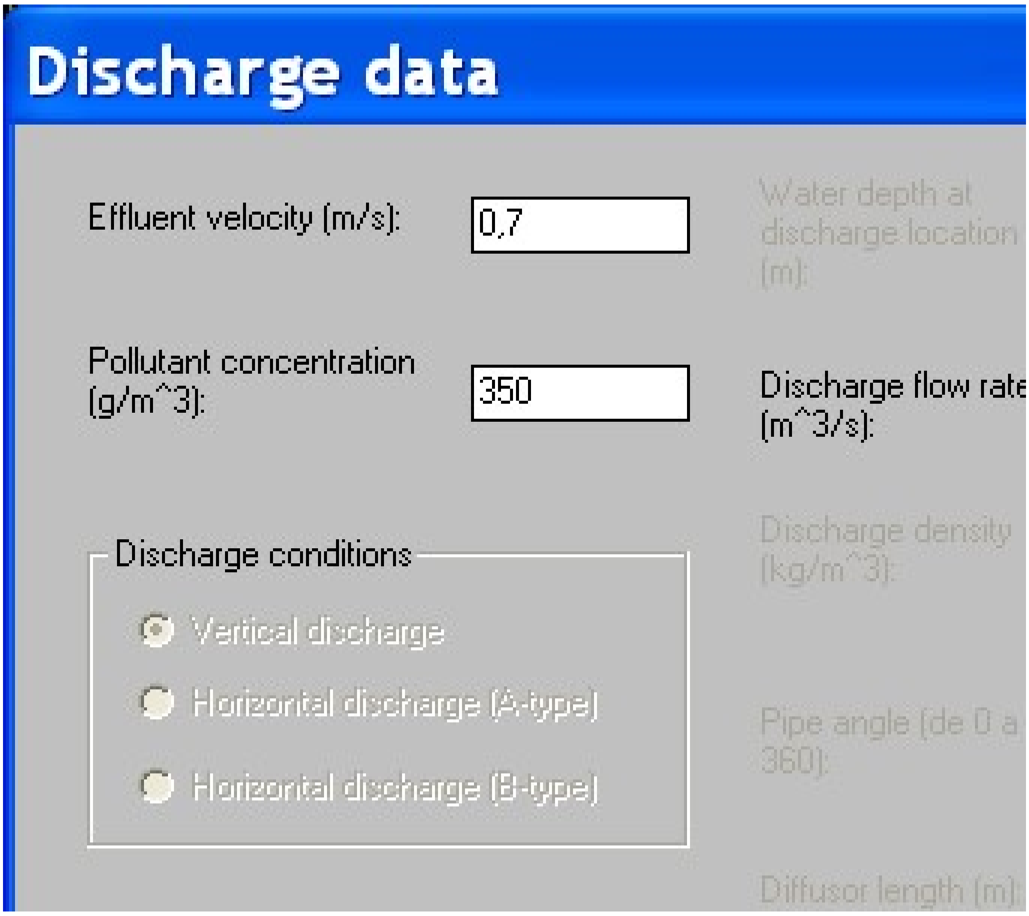
At the top of the dialog box, two different text boxes appear: source label and temporal point label. We can click both arrows to change these values and to visualize the data.

Every time that you enable a new average, the software allocates to all temporal points the same quantities. These quantities coincide with the values that we had in the Current and Outfall dialogboxes before enabling an average. To modify the current and discharge data in the temporal average, we can click **Current** and **Outfall** buttons in the dialogbox. Then, and if you click the **Current** button, the next dialog box is shown:



Where depending on the used model, some data of the dialog box can be modified: Buoyant jet model or Stratified model (see calculation models). The Coefficient of stratification, the water density and the stratified model option can not be modified. There is not interest in varying this data in time. To modify these data, we will have before to disable the temporary average and to open the outfall and current dialogboxes in the Point source Menu and in the Menu of Mixing zone data, respectively. To disable the temporary average, we will have to click the **Temporal average** command and to write **1** in the textbox of the **Number of temporal points**.

If you click the **Outfall** button in the **Temporal average: data** dialogbox, the next dialog box is shown:

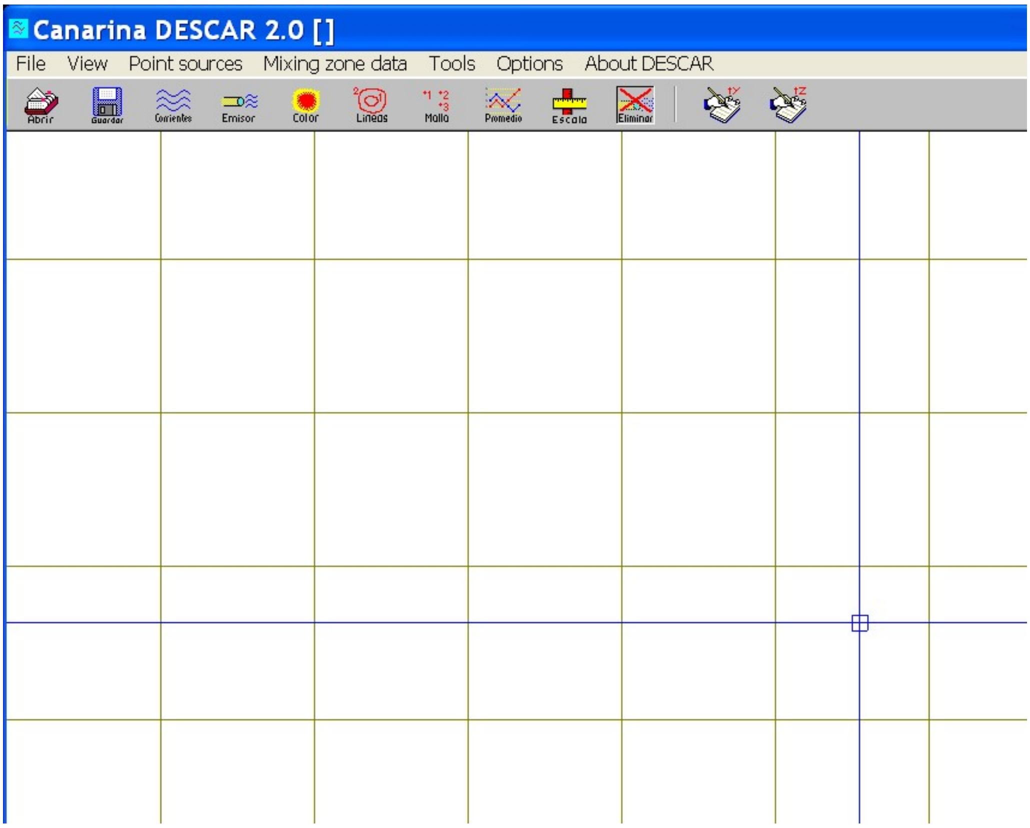


Depending on the used model, some data of the dialog box can be modified: Buoyant jet model or Stratified model (see calculation models). The Water depth, the Discharge density, the Pipe angle, Diffusor length, T90, Discharge conditions option and option of Number of openings can not be modified. There is not interest in varying this data in time. To modify these data, we will have before to disable the temporary average and to open the outfall dialogbox in the Point source Menu. To disable a temporal average, we will have to click the **Temporal average** command and to write **1** in the textbox of the **Number of temporal points**.

Before running the calculation it is convenient to check the data that we have in the average.

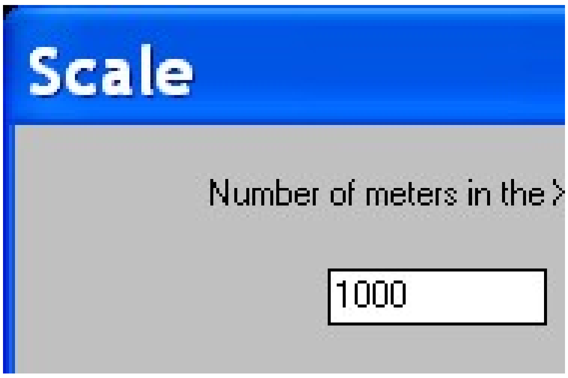
If we enable an average with more than a temporal point, and if later we increase the number of temporal points, it is necessary to be careful since there are data that can have null value. The ideal procedure is to define well, and from the beginning, the number of temporal points before writing the values for the average. If we want to modify an activated average it can be more comfortable to delete the activated average and then to define one new. To delete a temporal average, we will have to click the **Temporal average** command and to write **1** in the textbox of the **Number of temporal points**.

Delete.- This command is used to delete pollutant point sources that we don't want in the simulation. If you click the **Delete** button, the next program window is shown:



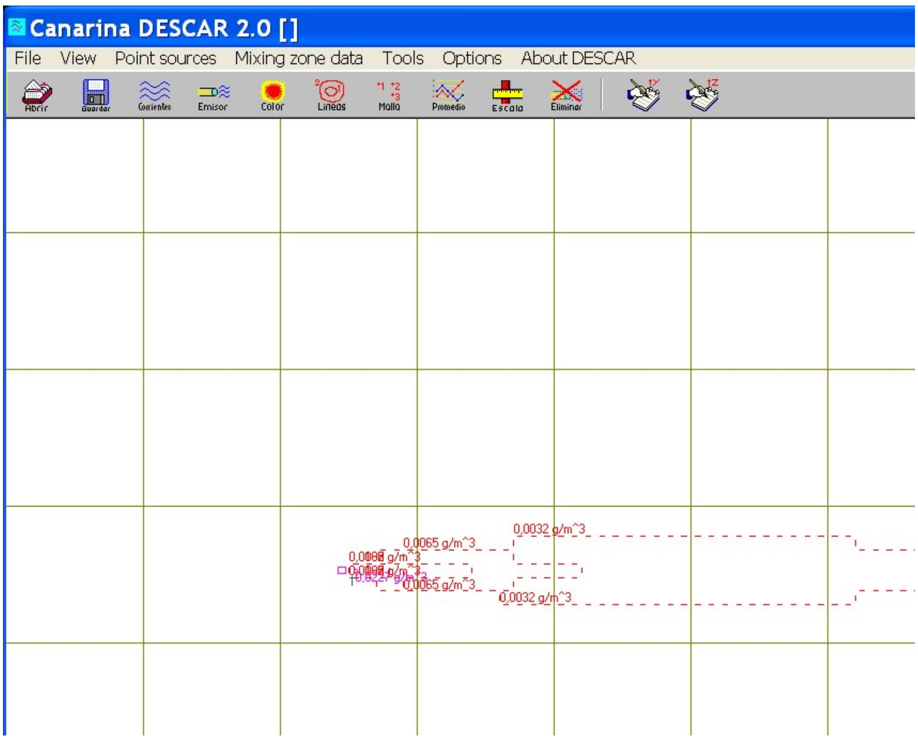
Clicking on these points we will delete them of the screen and of the calculation.

Scale.- With this command, we will decide the work area size in the simulation process. It is an important tool because with their good use we will be able to interpret and to extract interesting data of the numeric simulation. The scale is defined according to the width in meters that we want to associate to the X-Axis of our program window. If you click the **Scale** button, the next program window is shown:

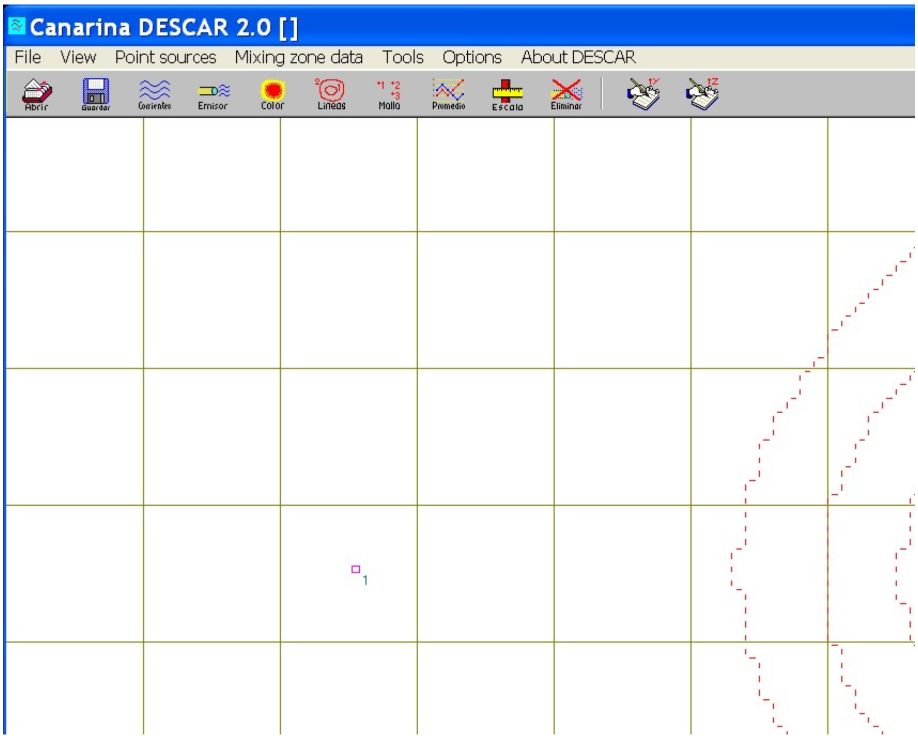


In this window we will be able to choose the number of meters that we want to have in the X-Axis. When we have the value written in the textbox, we will make click with the mouse on Accept button and this value will be modified and the previous window will disappear. If we click the Cancel button it closes the window without modifying the value. This command will be used before using the calculation command, since this parameter should be perfectly defined before making the simulation. When we use this Scale command the program, we clean the whole screen of the computer and we lose all the elements of the simulation placed previously. If we don't want to lose the information obtained until the moment we will use the Save command before executing the Scale command.

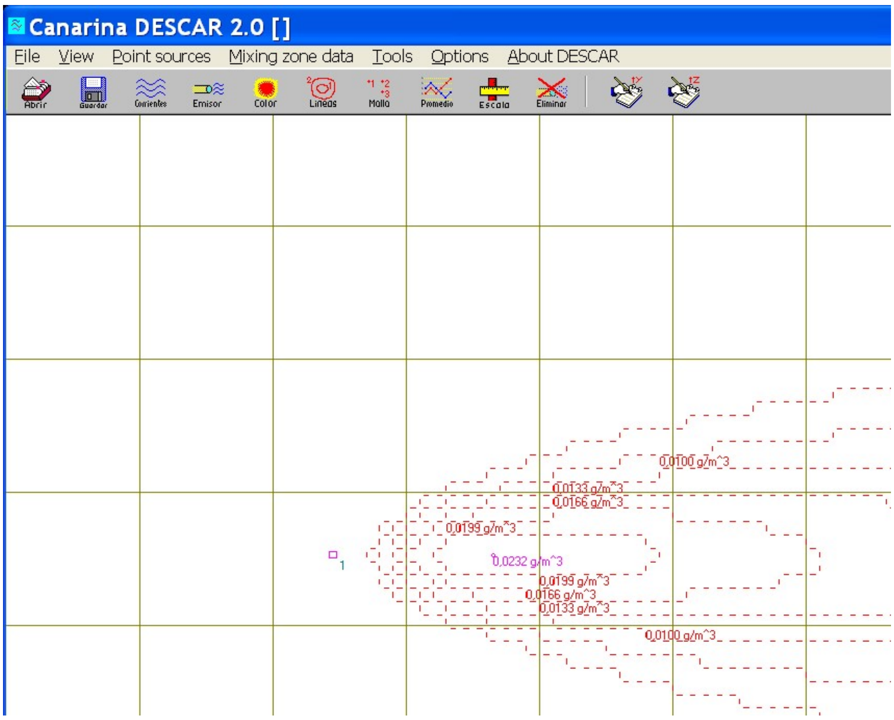
In certain situations, it can be interesting to have a high number of meters in the X-Axis for a better visualization. To illustrate the use of this command, we will carry out the same simulation varying the scale. We will use three different scales. Here, the width of the X-Axis is 100,000 m.



Here, the width of the X-Axis is 1,000 m.

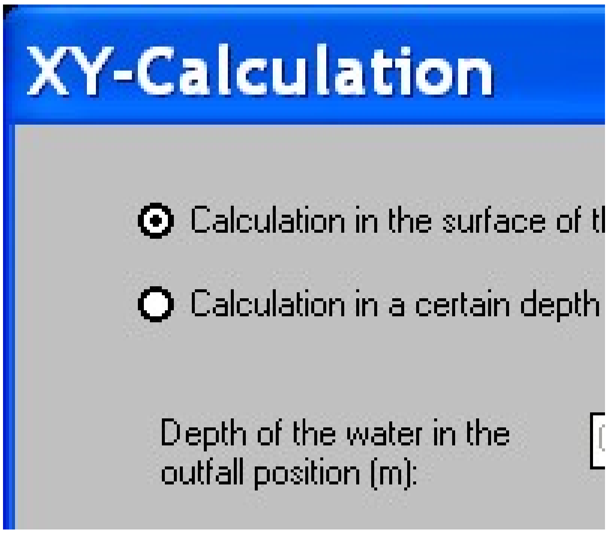


Here, the width of the X-Axis is 10,000 m.



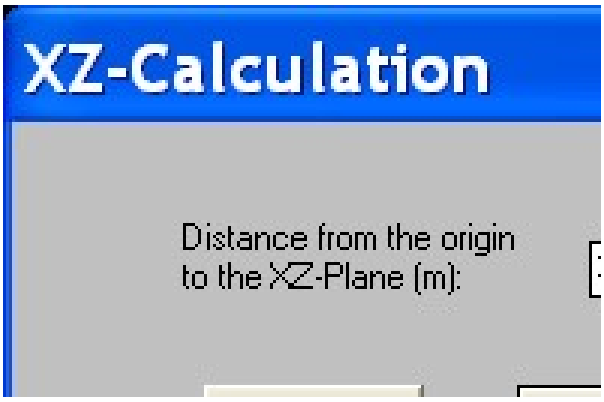
As we can see, when the X-Axis is 10,000 m, it is when we have a clearer representation, where it is shown the value of the maximum point and the concentration lines clearly.

XY-Calculation and XZ-Calculation.- The calculation commands run the necessary algorithms to carry out the numeric simulation. We will run the command after having fixed the necessary data for the simulation, that is to say, the outfalls, the currents, the scale,... If we change any initial data (as the position of the source, velocity of the current,...), we will need to run the command again so that this is reflected in the result. We will be able to choose between XY-Calculation and XZ-Calculation commands to obtain different pollution maps. If we make click on **XY-Calculation** command, we open the following window :



In this window we will be able to choose if we want to carry out the calculation in the surface of the water or to a certain depth (two options). In the first option, the calculation of the pollutant concentrations will be carried out in the surface of the water. If we choose the option for the calculation to a certain depth, we will write in the textbox the plane height in which we will obtain the results (0m for the surface of the sea).

If we make click on **XZ-Calculation** command, we open the following window :



In this window we will be able to write the distance to the origin (inferior left point of the screen) of the XZ-plane that is perpendicular to the surface of the water. On this plane we will carry out the XZ-Calculation.

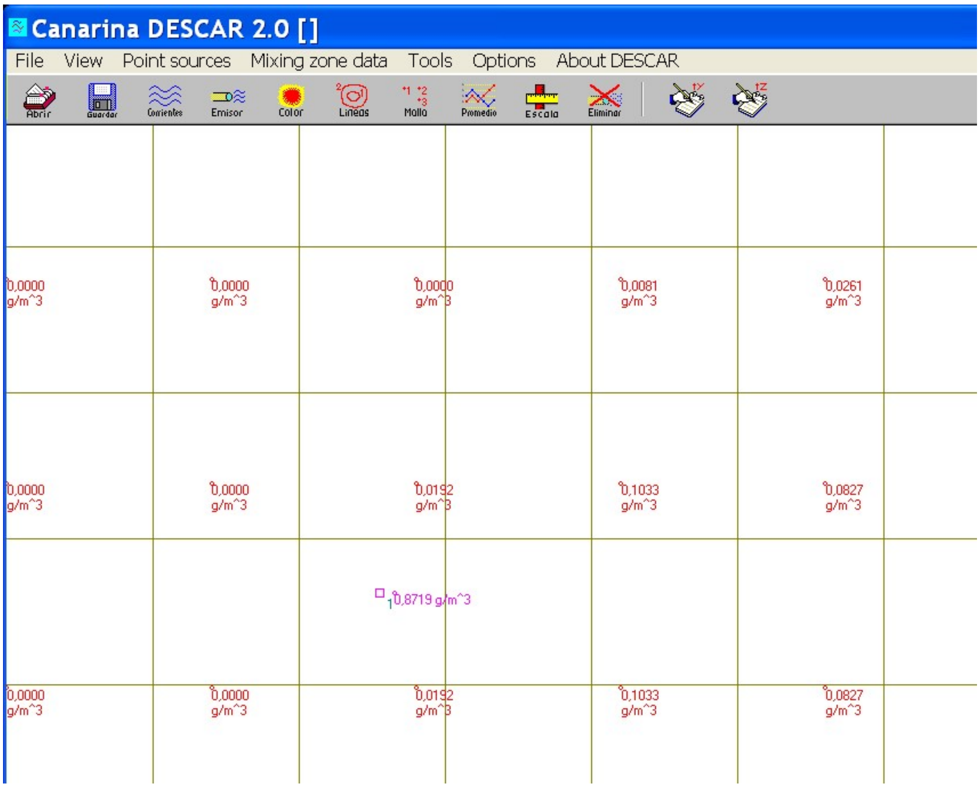
> ***The program works in the following way: while it calculates, the machine centers all the capacity of the CPU in the calculation, stopping the other tasks of Windows. If we want to stop a tedious calculation, we will be able to make it making use of the keys CTRL+ALT+DEL.***

Note about this command.- Near the source, we can find diferences between both XY-calculation and XZ-calculation commads. The application uses a numerical grid for valuing an exponential function. The small differences between adjacent points, when the grid is implemented, can cause different concentration results due to the exponential behaviour near the source. Far away from the source, these differences can be neglected.

Colour gradient.- This command is to draw maps of pollution making use of a colour gradient. It is specially useful when the variation of the concentration of pollutants is very strong in a very short distance. The program takes the maximum value of the concentration and it assigns to the maximum the red colour. Then, the program assigns the different colours to the grade of pollution in a qualitative way. We will be able to obtain the exact values locating the arrow of the mouse on any point and looking at the inferior right textbox of the program.

Isolines.- This command is of effect contrary to the previous one. We will use this command with the purpose of obtaining the isolines again. This way we will be able to change representation easily making use of these last two commands.

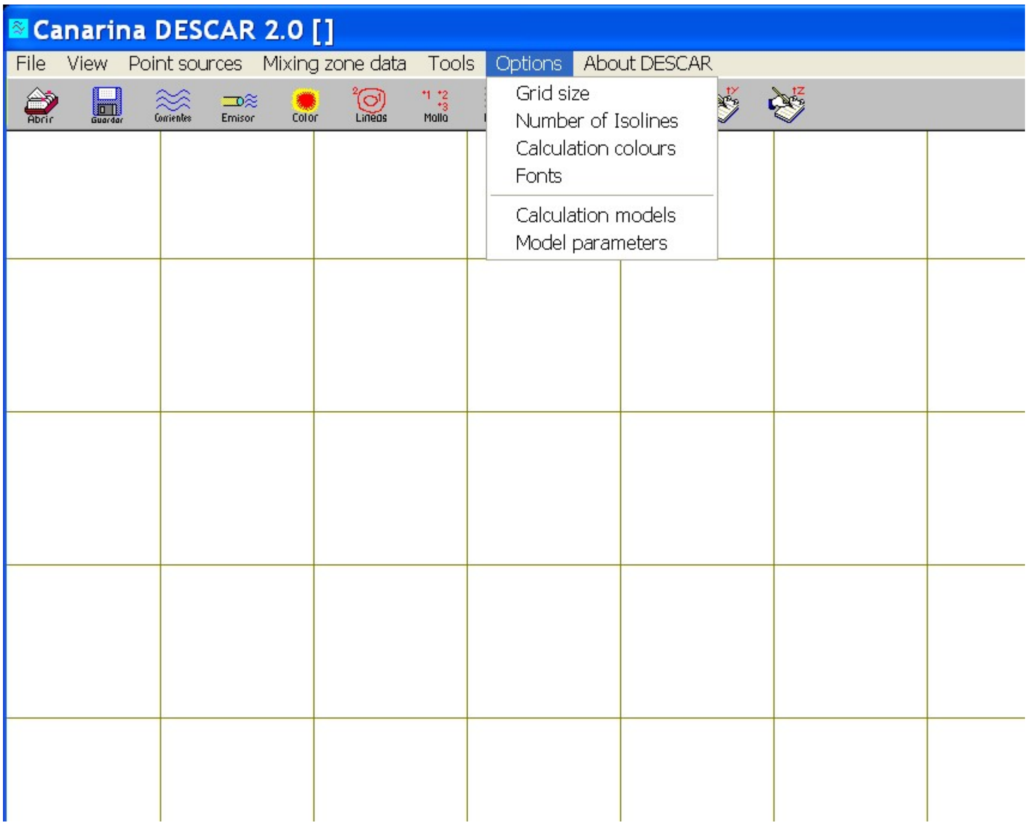
Numerical grid.- This command allows us another alternative representation of the calculated concentrations. It establishes a numerical grid throughout the calculation screen. It is specially useful if we load topographical planes, because with the other representations there are many images in the screen. If you click the **Numerical grid** button, the next program window is shown:



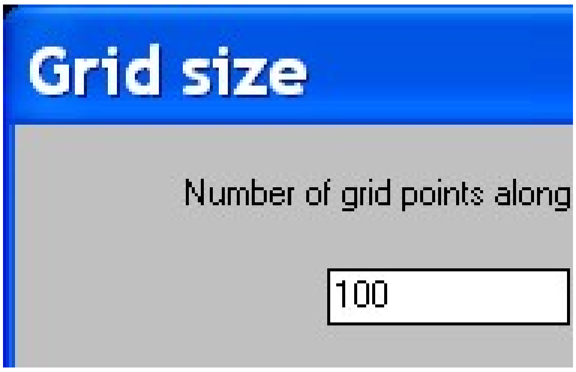
Calculation parameters.- This command will show us the parameters that we have assigned before carrying out the calculation. It is convenient their use with the purpose of verifying that we have written the parameters correctly. Once finish the calculation, the command shows us, also, the value of the maximum concentration and its position.

6.1.6 Options

The Options Menu includes all the elements for the numeric configuration of the simulations. We will use these commands before using the calculation command because these parameters should be perfectly defined before running the simulation. The Options Menu lists: **Grid size**, **Number of Isolines**, **Calculation colours**, **Fonts**, **Calculation models**, **Model parameters**. When you choose **Options** in the Menu bar, the program displays:



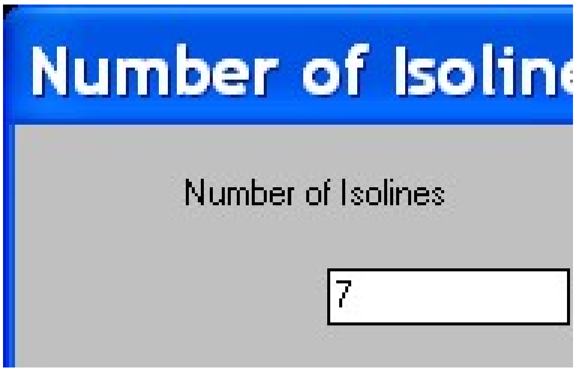
Grid size.- The grid size is an important parameter in the configuration of the system. We will decide the number of calculation points in the grid that we will take to make the simulation. As we increase the number of points, the computer will take much more time in carrying out the calculation but the result will be much more exact. If you click the **Grid size** command, the next program window is shown:



In this window we will be able to choose the number of grid points (calculation points) that we want to have in the X-Axis. The number of points to calculate will increase quadratically with the number of grid points along the X-Axis N, that is to say, it will increase as N^2.

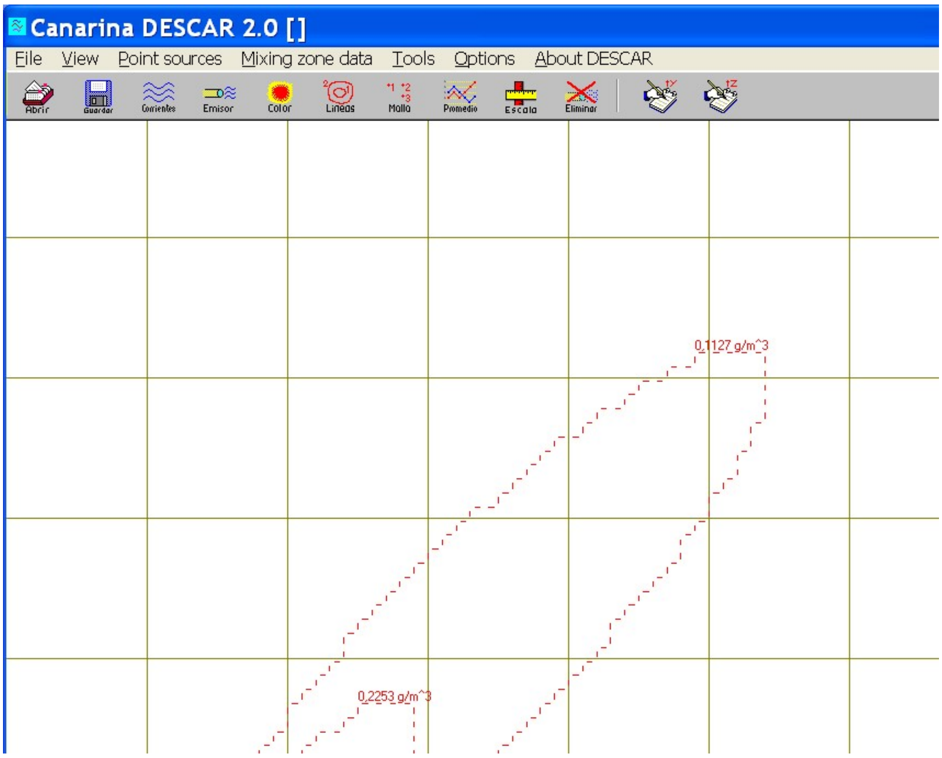
To increase the number of grid points produces that the program needs much more RAM-memory. If we take such a high number of grid points that it overcomes the available memory of the PC, the computer will be blocked.

Number of isolines.- This command is an auxiliary tool for making the maps of pollutant concentration. We will decide the number of isolines in the screen that we will take to make the representation. In certain situations, it can be interesting to have a high number of isolines for a better visualization. We will use this command before using the calculation command because this parameter should be perfectly defined before running the simulation. If you click the **Number of isolines** button, the next program window is shown:

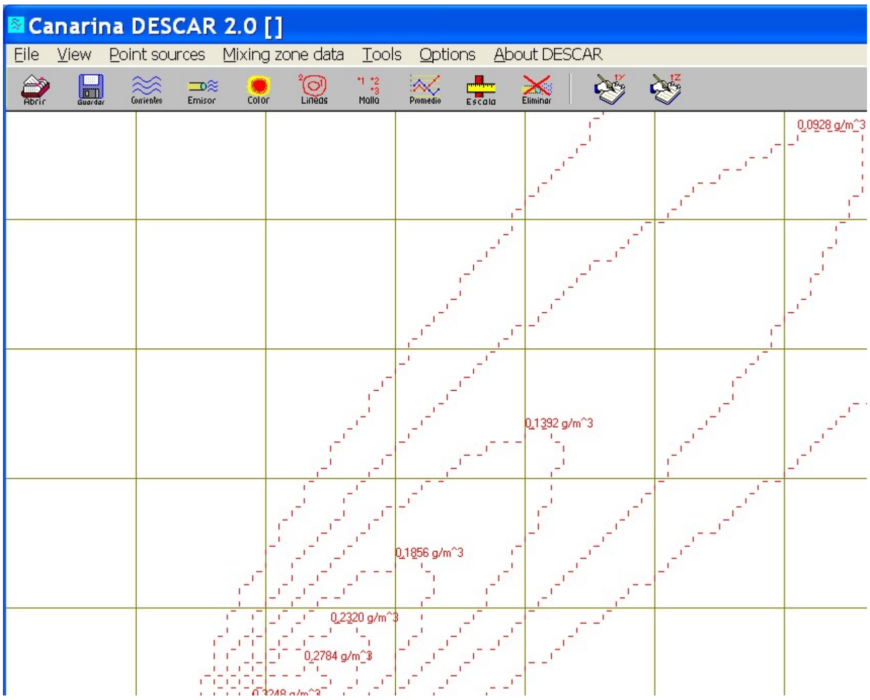


In this window we will be able to choose the number of isolines that we want to have in our computer screen. To calculate the lines, the program also considers to the maximum point as a line.

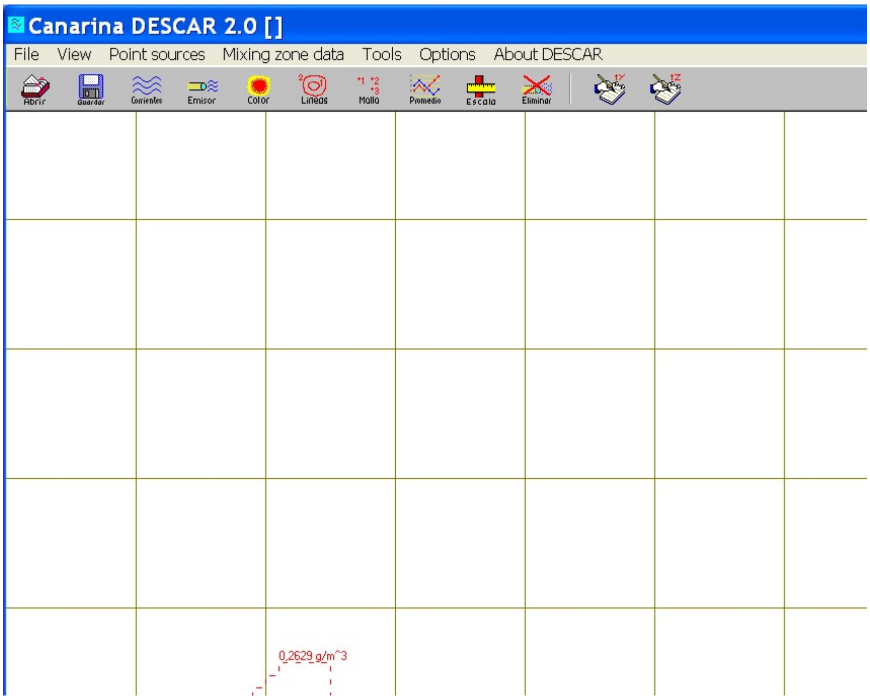
To illustrate the use of this command, we will carry out the same simulation varying the number of isolines. We will use three different number of isolines. Here, the number of isolines is 7.



Here, the number of isolines is 17.

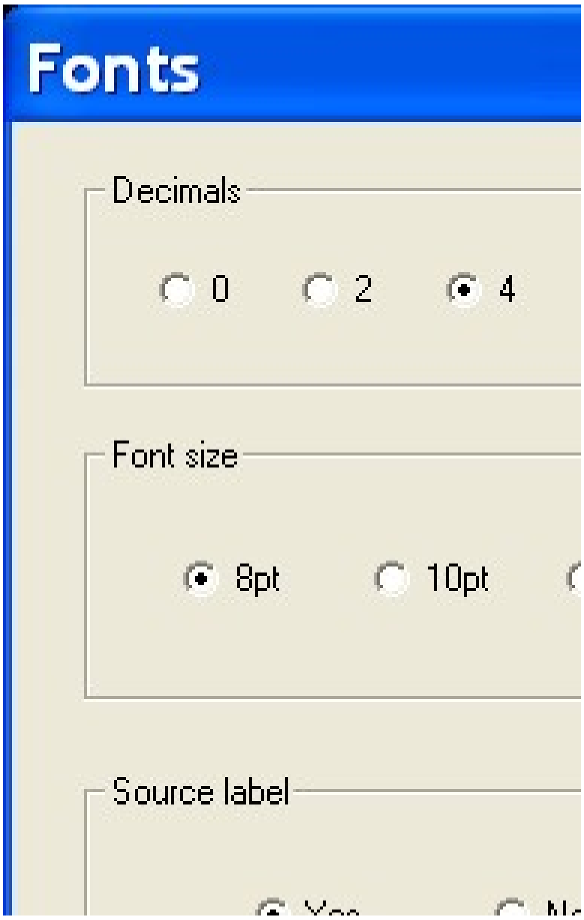


Here, the number of isolines is 3.

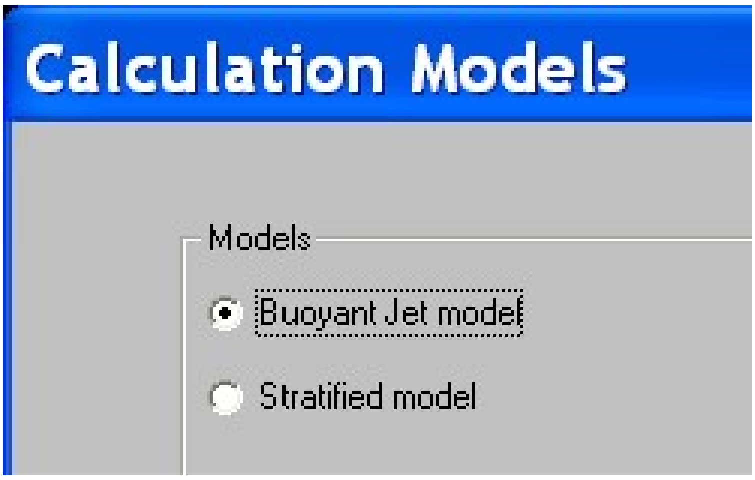


Calculation colours.- By means of this command, we will be able to change the colors of the isolines, of the maximum point and of the point sources.

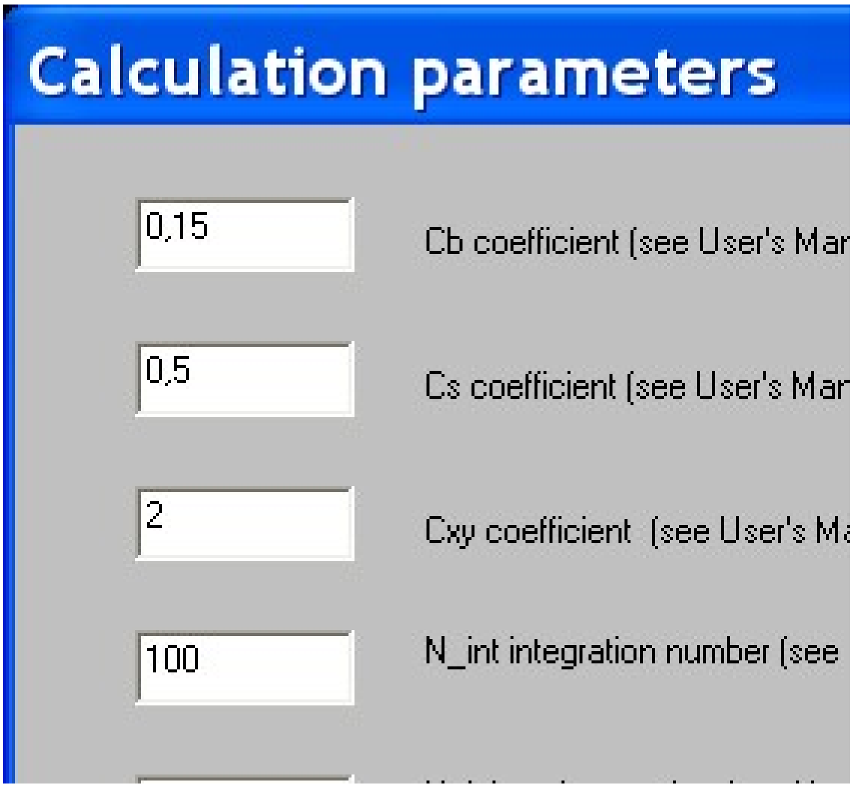
Fonts.- This command is an auxiliary tool for making the maps of pollutant concentration. In this command we have three different options. We can choose: number of decimal places, font size and source label (Yes/No).



Calculation models.- We will be able to choose two different models to carry out the numeric simulation: Buoyant jet model and Stratified model (see **Calculation models**).



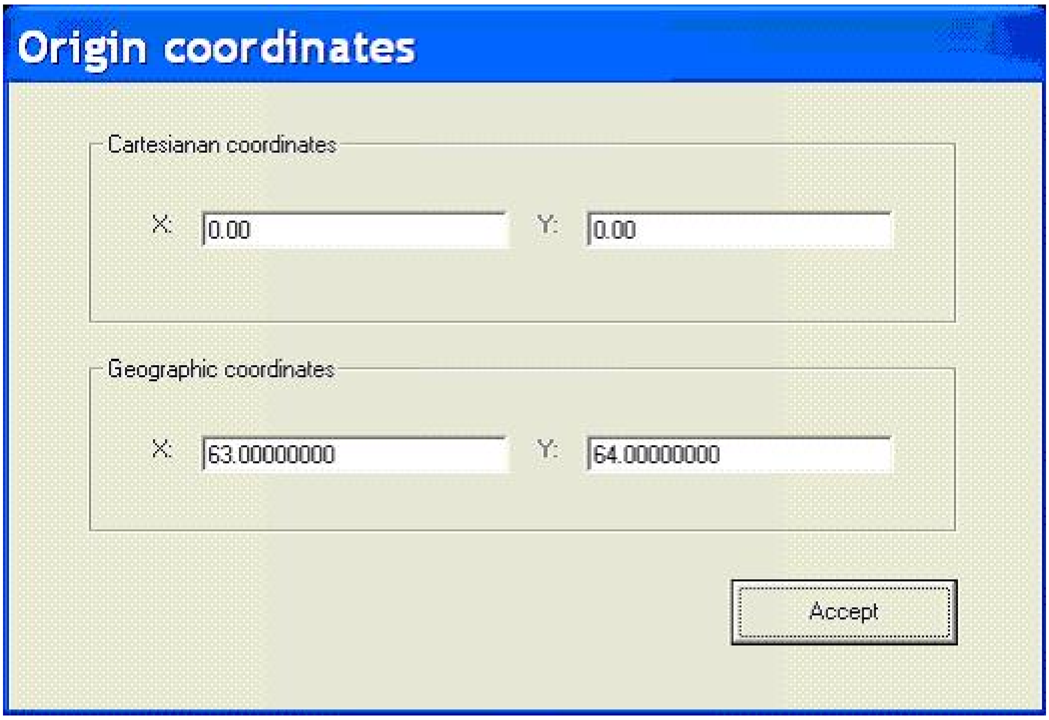
Calculation parameters.- The parameters that you can modify here, are related with necessary algorithms to run the simulations. If it is necessary, we have to modify these values before running the calculation.



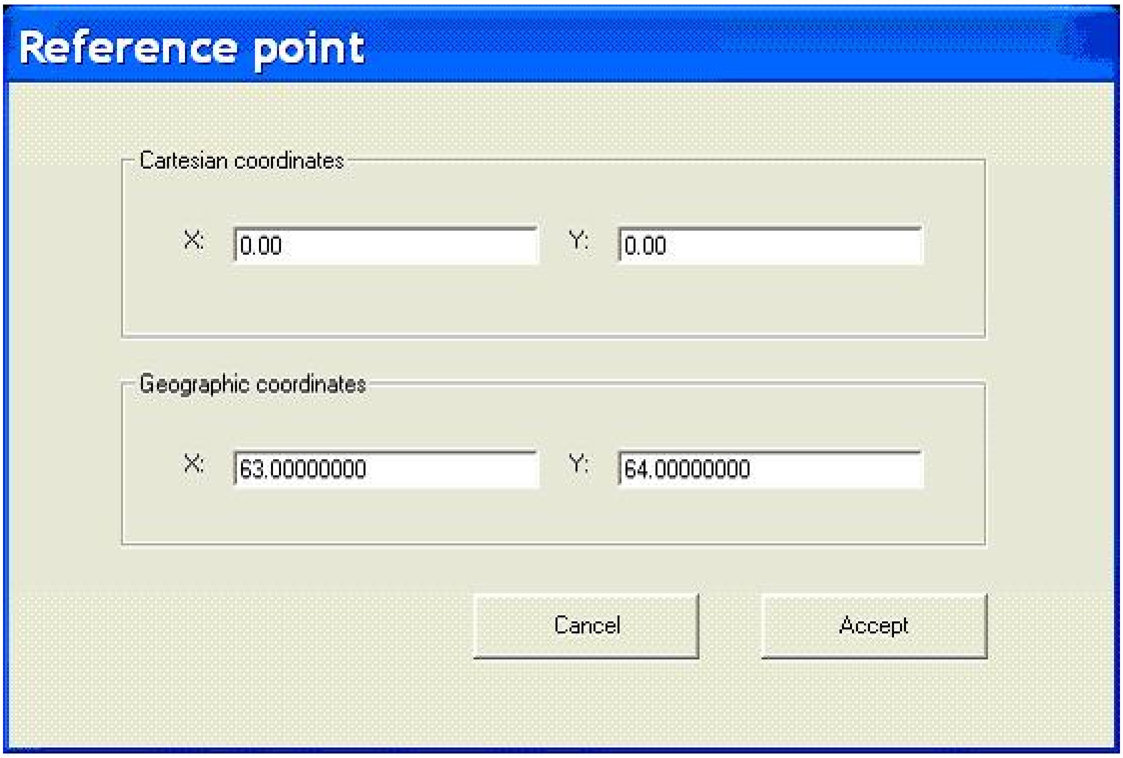
6.1.7 GIS

In this option it can be found all necessary to work with geographical information system.

Coordinates of the origin.- With this command we can choose the value for the origin of coordinates. It is initially in the left bottom corner of the program window. It is possible to work with geographic and Cartesian coordinates.

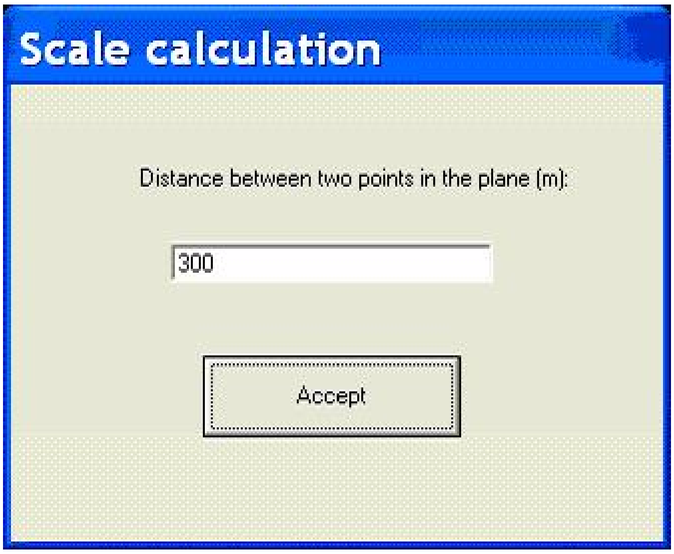


Reference points.- With this command we can decide the coordinate values of a point, that we previously know, in the map in order to have a referenced system. It is possible to work with geographical and Cartesian coordinates. After that, it will be possible to export the results to a GIS system.



Radius of curvature.- By means of this command, you can choose a value for the Earth radius. This radius can be slightly modified to adjust the reference system with the available data. The program considers the Earth as a perfect sphere with an exact radius. We know that this is not exactly true. This option is to correct this kind of effects.

Scale calculation.- With this command it is possible to estimate the map scale that corresponds to a background image, that has trees previously imported by the user. It is necessary to know the distance between to different points in the map. After introducing the distance data, you can click consecutively both points, and the scale will be automatically calculated.



Export maximum, concentrations,….- These are to export the different elements of the programs (isolines, source positions,…) to Microsoft EXCEL csv file. To import without problems with Arcview we have used the english format system for the numbers. For example, one euro and 30 cents is 1.30 euros (NOT 1,30!) in the english format.
If you are using the spanish format, for example, when you open the exported file with EXCEL you obtain "al numbers in the same box". In such a case, the best way is to change your number format in your computer. It is very easy. Just go to WINDOWS >> START >> CONTROL PANEL >> REGIONAL CONFIGURATION and look for english format before opening with your EXCEL program.

6.1.8 3D

The 3D commands are for a qualitative representation, not quantitative. The system generates random points to help you to obtain a 3D view of the pollution process. The pollution concentration value that appears in the screen is an orientative value. In the 3D options you can modify the number of random points and other parameters. The TEMPORAL AVERAGE command doesn't work in 3D hasn't effect on the calculations.

The 3D window is an extension of the 2D XY window. The X coordinate, Y coordinate and concentration value that appear on the bottom of the screen correspond to the XY plane view. The calculated XY data will be deleted after a 3D calculation. The PRINT command only prints the XY view. To print in 3D, you need to use the PRINT IMAGE command. Or you can save a BMP file and print such a file with an another standard program (windows PAINT, ...).

6.2 Icon bar

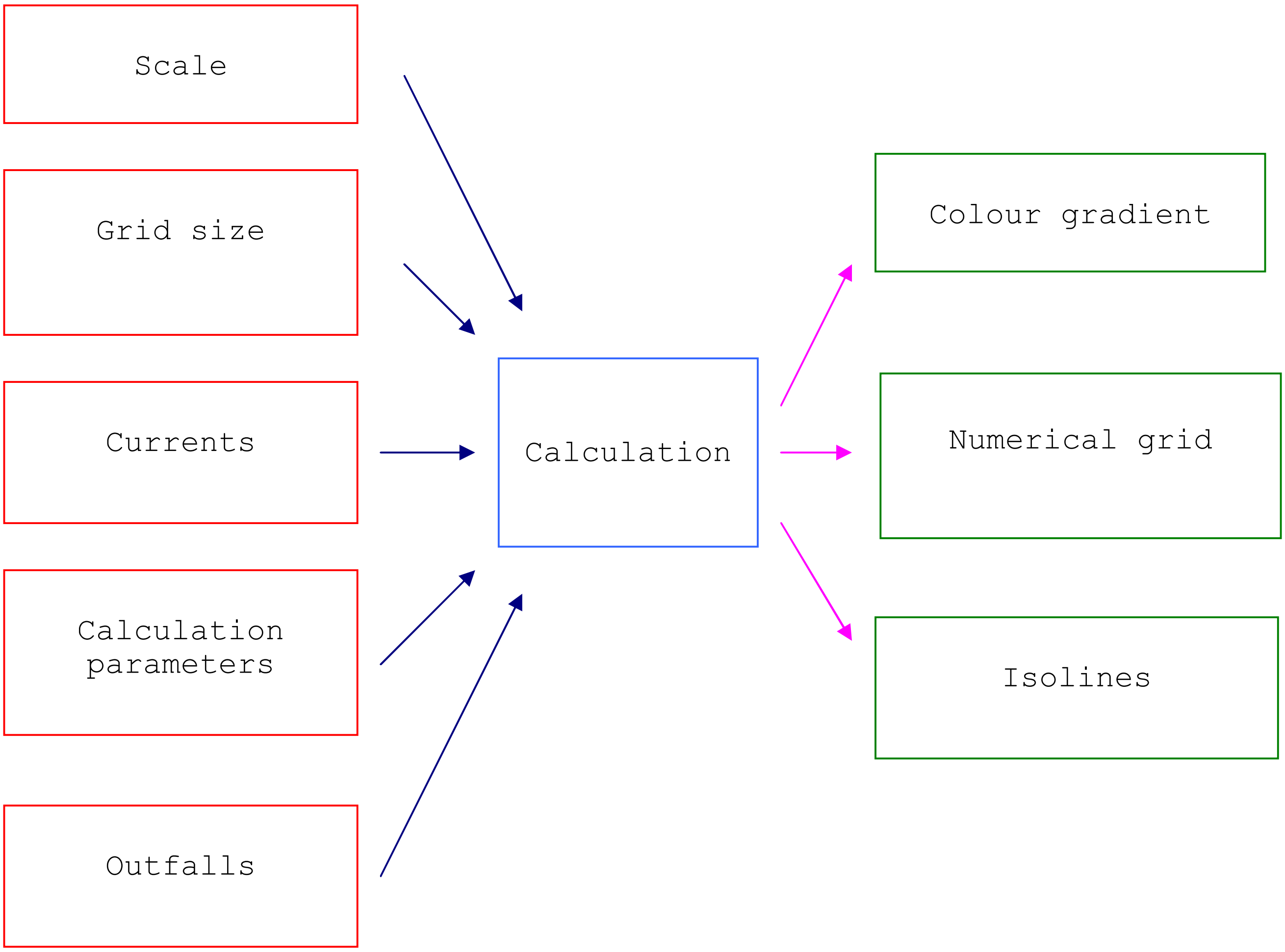
The menu bar display the commands you use to build your simulation. When you choose one of the menus, the program displays a pull-down list of available commands. The program window has a basic icon bar under the Menu bar. The icon bar provides quick access to commonly used commands in the program. You click a button on the icon bar once to carry out the action represented by that button.

7. Application structure

In this section, the general structure of the application will be shown. The Options Menu includes all the elements for the numeric configuration of the simulations. We will use these commands before using the calculation command because these parameters should be perfectly defined before running the simulation.

If we change any initial data (as the position of the source, velocity of the current,...), we will need to run the command again so that this is reflected in the result. We will be able to choose between XY-Calculation and XZ-Calculation commands to obtain different pollution maps.

Colour gradient, Isolines and Numerical grid commands should be applied after running the calculation.



8. Mathematical algorithms

The application uses two different mathematical models: Buoyant jet model or Stratified model. The Buoyant model is ideal for pollutant discharges located in the proximities of the coast and in rivers, (using little depth). This model is based on a time-independent Gaussian equation which simulates the pollutant dispersion in the water. The Stratified model takes into account the formation of the pycnocline in the sea. This model is ideal for outfall discharges in the sea (using a high depth value).

The program calculates the pollutant concentration in each point of the water considering each one of the pollutant sources and the conditions of the water.

8.1 Buoyant Jet model

A type of mathematical model that has been developed for sumerged round buoyant jets is the length-scale model. Discharges flows can be divided into different regimes each dominated by particular flow properties. Within each regime, the flow may be approximated with simple mathematical relations describing the simplified problem. A model that uses asymptotic solutions is refered to as length-scale model because of length scales to delineate the extent of the regimes for which the mathematical expressions are valid.

The pollutant concentration, in a certain instant, and at a distance x (meters) in the X-Axis and at a distance y(meters) in the Y-Axis will be given by:

$$c = c_c \exp[-(r/b)^2] \quad (1)$$

where c is the pollutant concentration, r is the distance from the point (that we are calculating) to the center of the line that forms the polluting plume, c_c is the pollutant concentration in the center of the plume line and b is the plume half-width.

We attempt to link the momentum dominated and buoyanvy dominated regimes into one relationship by using proposed relations for the transition where:

$$z/L_b = 2^{4/3}[(1/2)(x/L_b)^2 + (L_m/L_b)(x/L_b)]^{1/3} \quad (2)$$

$$b/L_b = c_b[(1/2)(x/L_b)^2 + (L_m/L_b)(x/L_b)]^{1/3} \quad (3)$$

$$S = c_s(u_o/u_a)[(1/2)(L_b/L_m)(x/L_m)^2 + (x/L_m)]^{1/3} \quad (4)$$

L_b=plume-to-crossflow length scale
L_m=jet-to-crossflow length scale
x=horizontal downstream coordinate in global coordinate system
y=horizontal coordinate in coordinate system perpendicular to ambient crossflow
z=vertical coordinate
u_a=ambient velocity
u_o=discharge velocity
S=dilution along the plume centerline C/C_0 being C the centerline pollutant concentration and the C_0 initial pollutant concentration at the discharge.
c_b=constant of proportionality that can be modified by the user (can be determined experimentally)
c_s=constant of proportionality that can be modified by the user (can be determined experimentally)
c_{xy}=constant of proportionality that can be modified by the user (can be determined experimentally)

We obtain solutions for a vertical buoyant jet in a crossflow
And buoyant jets discharged horizontally perpendiculat to crossflow.

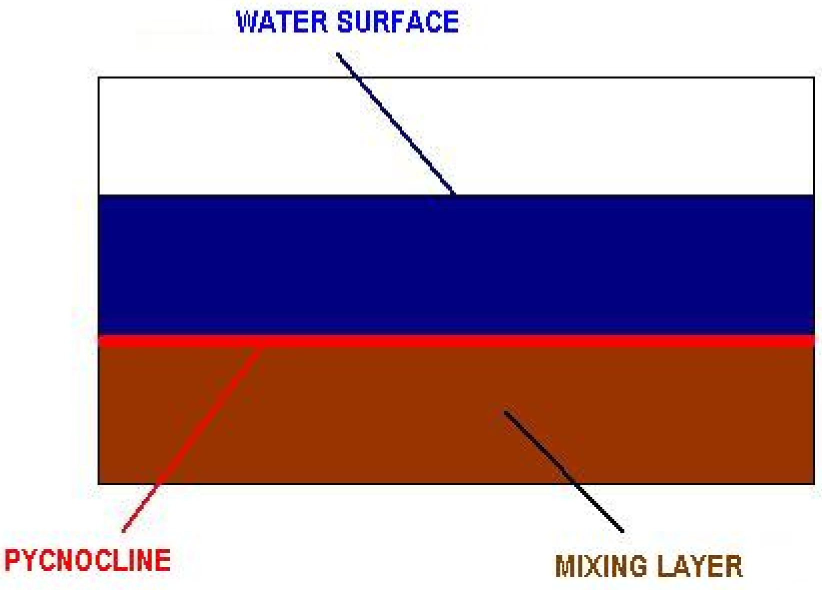
$$z/L_b = c_{xy}(x/L_m)^{1/3} \quad (5)$$

This model performs satisfactorily for simple flows with no shoreline interaction or attachment. Strong crosscurrents or limited depths causing attachment with the downstrean bank or strong initial buoyancy render this model invalid. In addition, they are incapable of simulating any far-field processes that occur after a certain distance. If the z-coordinate of the plume centerline z_cl is higher than then water surface z_ws, the algorithm takes z_cl=z_ws.

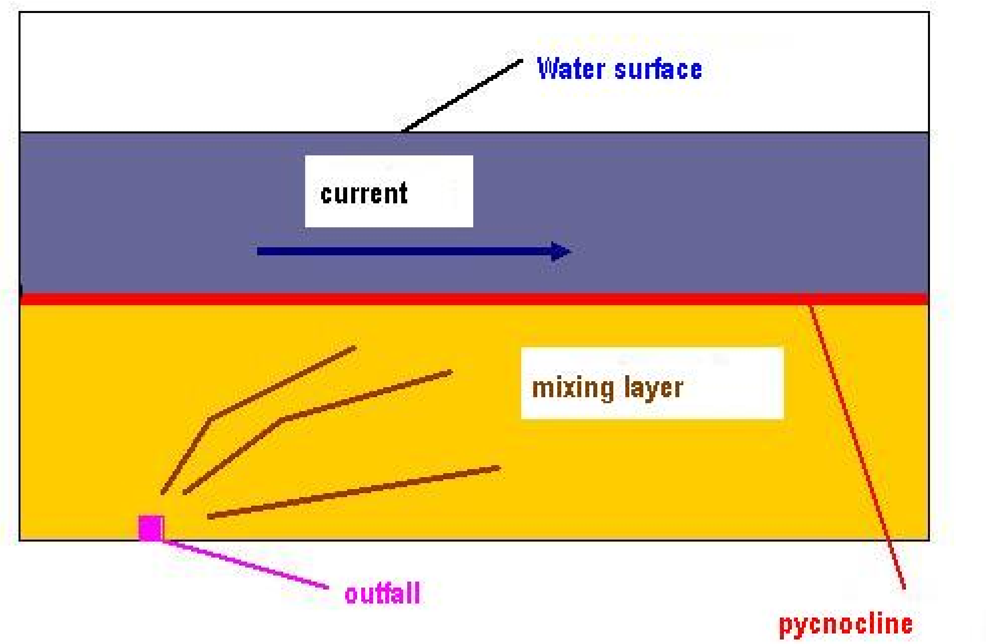
8.2 Stratified model

This model is official in Spain and it follows *Orden del 13 de Julio de 1993 del Ministerio de Obras Públicas y Transportes del Reino de España, B.O.E. Martes 27 de Julio de 1993, página 22861, I. Disposiciones generales. Proyecto de conducciones de vertidos desde tierra al mar.*

Density and thermal stratification: The intense heating caused by sunlight results in the formation of a light, warmer layer of water floating on top of a much larger mass of cold, dense water. Where these two bodies of dense water meet there is a zone of rapid change in the water temperature, called the thermocline or pycnocline. Such a thermocline is a permanent feature of both tropical and temperature waters. When the surface water of temperature seas is warmed in the summer a further seasonal thermocline can develop much closer to the surface. This is much stronger feature than the permanent thermocline in temperature waters. This thermocline plays an important role in determining seasonal changes in marine primary production in temperature seas. Thermal stratification represents a physical barrier to the mixing of the water column. There is little or no exchange of nutrient through a thermocline.



The stratification phenomena is the existence of two homogeneous water layers and separated by a thin thermocline layer. In such a case, we can say that the water is stratified. There is no exchange of pollutants through this pycnocline layer.



In case we suppose that a pycnocline layer exists, we will be able to check the stability by means of the application of the following equation:

$$[u_0^2 B + U_a^2 H]/[(u_0 B g')^{2/3} H] < 0.54$$

u_0=effluent velocity (m/s)
H=water depth at discharge position (m)
g'=reduced gravity acceleration (m/s^2), $g'=g(\rho_a - \rho_0)/\rho_0$
g=9,81m/s^2 (gravity acceleration)
ρ_a=water density (Kg/m^3)
ρ_0=effluent density (Kg/m^3)

Typical values (pollutants):
Organic matter as DBO5 - 350g/m3
Suspended matter - 600g/m3
E. Coli - 10^{12} /m3
N2 (total) - 30 gN/m3
Effluent velocity - entre 0.6 y 0.8 m/s
Port diameter - 6cm

Dispersion coefficients:

Horizontal dispersion: $K_y (m^2/s)=3x10^{-5}\ B^{4/3}$.
B=initial plume width(m)

Vertical dispersion: $K_z (m^2/s)=4x10^{-3}\ U_a\ e$
e= thickness of the mixing layer
U_a=horizontal ambient velocity (m/s)

8.2.1 Water is not stratified

8.2.1.1 Multiport diffuser.- We have three different cases:

Case I:

$\theta >= 65°$ $F<=0.1$ ó
$\theta < 65°$ $F<=0.36$
θ=angle between U_a vector and diffuser.
F=Fraude number $F=Ua^3\ (g'q)^{-1}$
q=Unitary flor rate in the diffuser $q=QL_t^{-1}$ (m^2/s)
Q=Discharge flow rate (m^3/s)
L_t=Diffuser length (m)
S=initial dilution

In such a case, we have the next relationships

$$S=0.27\ U_a\ H\ q^{-1}\ F^{-1/3}$$
$$e=0.29H$$
$$B=SQ/eU_a$$

Case II:

$25° =< \theta < 65°$ $F>0,36$ (*)

In such a case, we have the next relationships

$$S=0.38\ U_a\ H\ q^{-1}$$
$$B=\max[L_t \sin\theta;\ 0.93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

Case III:

$\theta < 25°$ $0,36<F=<20$

In such a case, we have the next relationships

$$S=0.294\ U_a\ H\ q^{-1}\ F^{-1/4}$$
$$B=\max[L_t \sin\theta;\ 0.93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

Case IV:

θ <25° F>20

In such a case, we have the next relationships

$$S=0.139\ U_a\ H\ q^{-1}$$
$$B=\max[L_t \sin\theta;\ 0.93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

Case V:

θ >65° F>0,1

In such a case, we have the next relationships

$$S=0.58\ U_a\ H\ q^{-1}$$
$$B=\max[L_t \sin\theta;\ 0{,}93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

From Case II to Case V, and if e>H, we take e=H and S= U_aBH/Q.

8.2.1.2 Separated ports.- We will solve this case by means of a iterative mathematical method

$$B=\max[L_t \sin\theta;\ 0{,}93L_t\ F^{-1/3}]$$
$$S=0.089\ g'^{1/3}\ (H-e)^{5/3}\ Q_b^{-2/3}$$
$$e=SQ/BU_a$$

Q_b= flow rate at each single port(m^3/s).

The number of iterations can modify by means of the parameter N_it of the function **Calculation parameters** of the program. Increasing N_it value, we increase the numeric convergence but we will need more time of calculation. We should look for an optimized value of N_it.

Single port.- In such a case, we have the next relationships

$$e=0.15H$$
$$S=0.089\ g'^{1/3}\ (H-e)^{5/3}\ Q^{-2/3}$$
$$B=SQ/eU_a\ (*)$$

However, at high velocity values and if B<=0.3H, the approximation is not correct .

8.2.2 Water is stratified

In this case, the pycnocline or thermocline has been formed. We will distinguish the following cases:

8.2.2.1 Multiport diffuser.- In such a case, we have the next equations

$$y_{max}=2,84\ (g'q)^{1/3}\ \Gamma^{-1/2}$$
$$S=0,31\ g'^{1/3}\ y_{max}\ q^{-2/3}$$
$$B=max[L_t sin\ \theta;\ 0,93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

where $\Gamma=-(g/\rho)d\rho_a/dy$ is the stratification coefficient (s^{-2}) and y_{max} is the thickness of the mixing layer (m).

8.2.2.2 Separated ports.- In such a case, we have the next equations

$$y_{max}=3,98\ (g'Q_b)^{1/4}\ \Gamma^{-3/8}$$
$$S=0,071\ g'^{1/3}\ y^{5/3}{}_{max}\ Q_b^{-2/3}$$
$$B=max[L_t sin\ \theta;\ 0,93L_t\ F^{-1/3}]$$
$$e=SQ/BU_a$$

8.2.2.3 Single port.-

$$y_{max}=3,98\ (g'Q)^{1/4}\ \Gamma^{-3/8}$$
$$S=0,071\ g'^{1/3}\ y^{5/3}{}_{max}\ Q^{-2/3}$$
$$e=0,13\ y_{max}$$
$$B=SQ/eU_a$$

For a profile of velocities different from the previous ones, it will be required a more complex method of numeric integration to solve the problem.

8.2.3 Near mixing zone and distant mixing zone

We need to know the place where the plume centerline crosses the water surface or pycnocline layer. To calculate this point we will use U_a and the vertical velocity

Multiport diffuser.- $W=1,66(g'q)^{1/3}$ being W the vertical velocity of the effluent (m/s).

Separated ports.- $W=6,3(g'Q_b/H)^{1/3}$.

Single port.- $W=6,3(g'Q/H)^{1/3}$.

In the last two cases, H will be replaced by ymax when the water is stratified. The point localization with regard to the place where the plume centerline crosses the surface, gives us the near and distant mixing zone definitions.

8.2.4 Concentration calculations

The concentration value in a plume point is determined by the X,Y,Z coordinates and is given by the equation:

$$C(X,Y,Z)=(C_0/S)\ F_0(t)F_1(t)F_2(Y,t)F_3(Z,t)$$

C_0=pollutant concentration in the effluent
S=initial dilution

being $t=X/U_a$. $F_0(t)$ takes into account non-conservative pollutants and is equal to:

$$F_0(t)=10^{-t/T90}$$

The F_0, F_1, F_2 and F_3 functions depend on being in near or distant mixing zone.

(a) Near mixing zone:
In such a case, the equations are

$$F_1(t)=1$$
$$F_2(Y,t)=(1/2)[erf[(B/2+Y)/(\sigma_y 2^{1/2})]+ erf[(B/2-Y)/(\sigma_y 2^{1/2})]]$$
$$F_3(Z,t)=(1/2)[erf[(e+Z)/(\sigma_z 2^{1/2})]+ erf[(e-Z)/(\sigma_z 2^{1/2})]]$$

being $\sigma_y=(2K_y t)^{1/2}$ and $\sigma_z=(2K_z t)^{1/2}$. The program calculats erf function by numerical integration. The the precision of integration method depends on the parameter N_int. Increasing N_int value, we increase the numeric convergence but we will need more time of calculation. We should look for an optimized value of N_int.

(b) Distant mixing zone:
In such a case, we approach

$$F_1(t)=(2\pi)^{-1/2}B\ \sigma_y^{-1/2}$$
$$F_2(Y,t)=\exp[(-Y^2/2\sigma_y^2)]$$
$$F_3(Z,t)=e/H_h$$

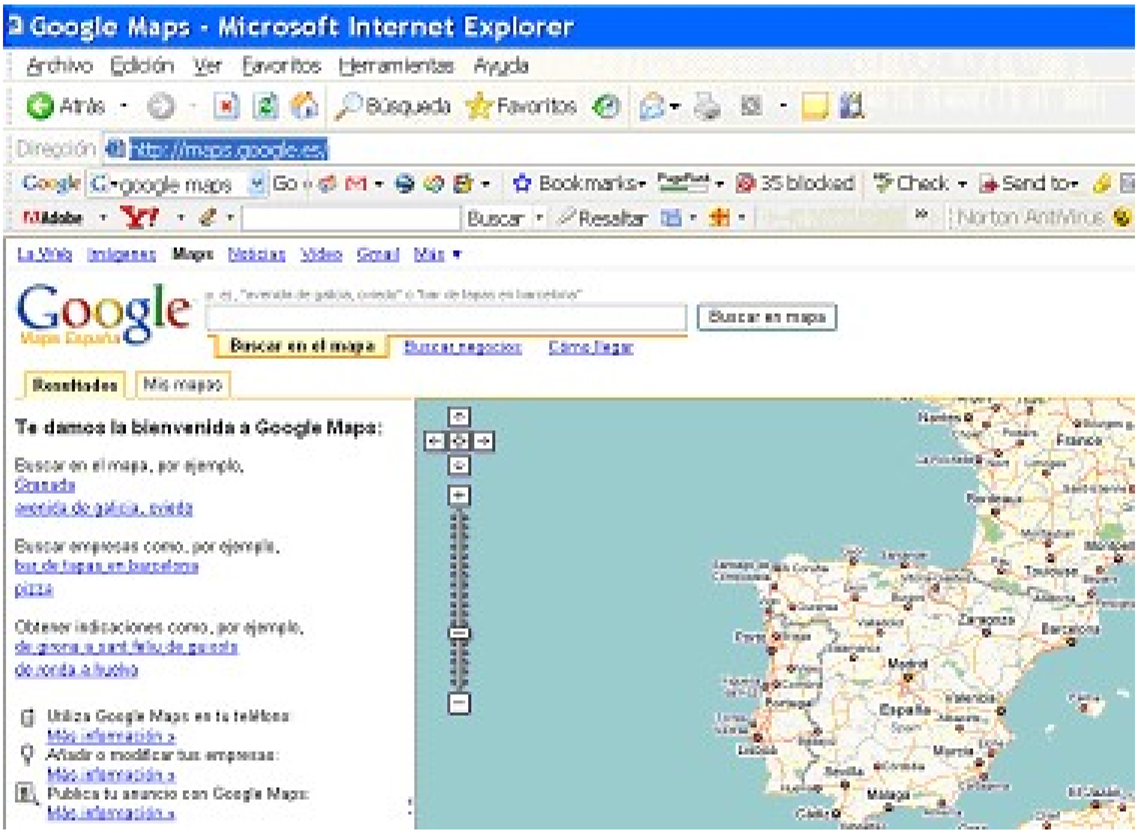
being $\sigma_y=(B^2/16+2K_yt)^{1/}2$. Here, we suppose that the plume was homogenized vertically when the water depth was H_h, that is the depth in the point where the thickness of the plume begins to occupy the whole layer of water. The program calculates considering the bottom of the sea like a flat surface. Then, H_h is the water depth at the location of the deepest outfall. If you want to consider a higher water thickness than outfall depth, you can draw a deeper outfall whose pollutant concentration is null. In asuch a case, the water depth is the depth of the deepest outfall. The calculation will not be affected by the null concentration of the deepest outfall.

(*)We have found, in our opinion, typographic errors in *Orden del 13 de Julio de 1993 del Ministerio de Obras Públicas y Transportes del Reino de España, B.O.E. Martes 27 de Julio de 1993, página 22861* that we have corrected considering mathematical consistency. The software assumes the present corrections in the calculation.

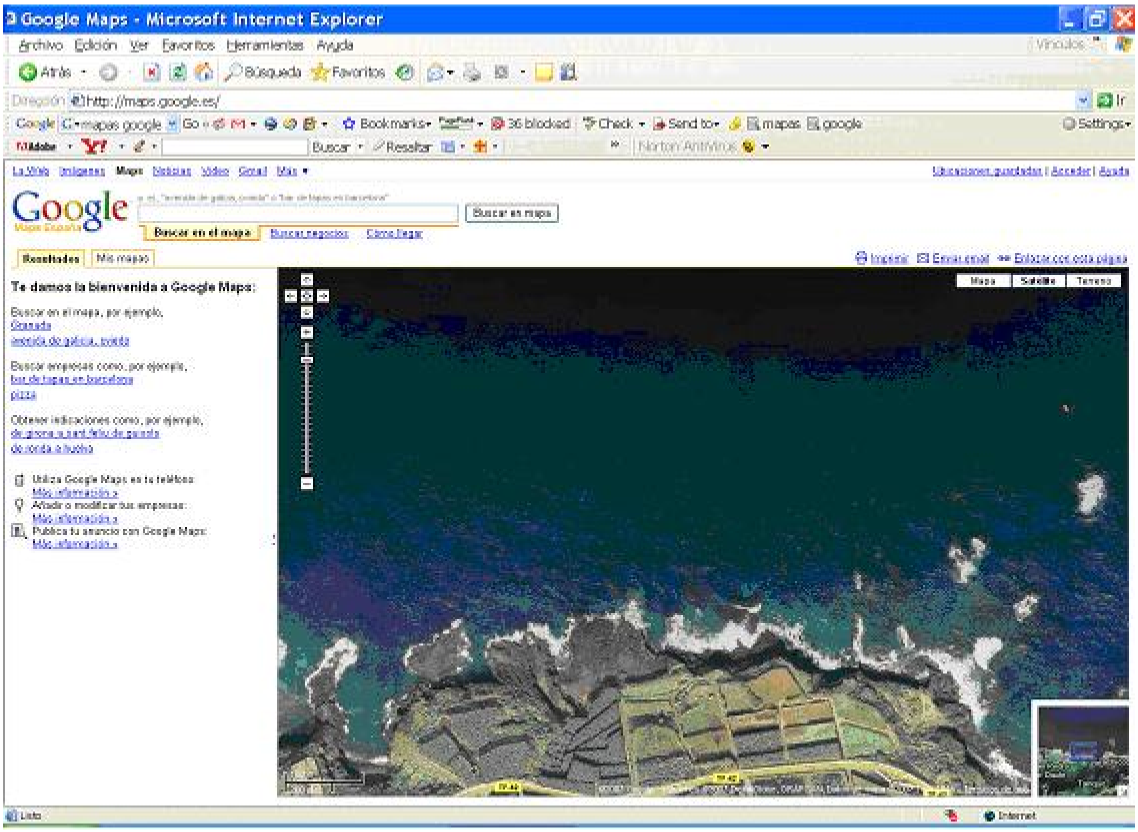
9. Working with Google maps

1. Firstly you can can navigate to Google maps web.

http://maps.google.com/

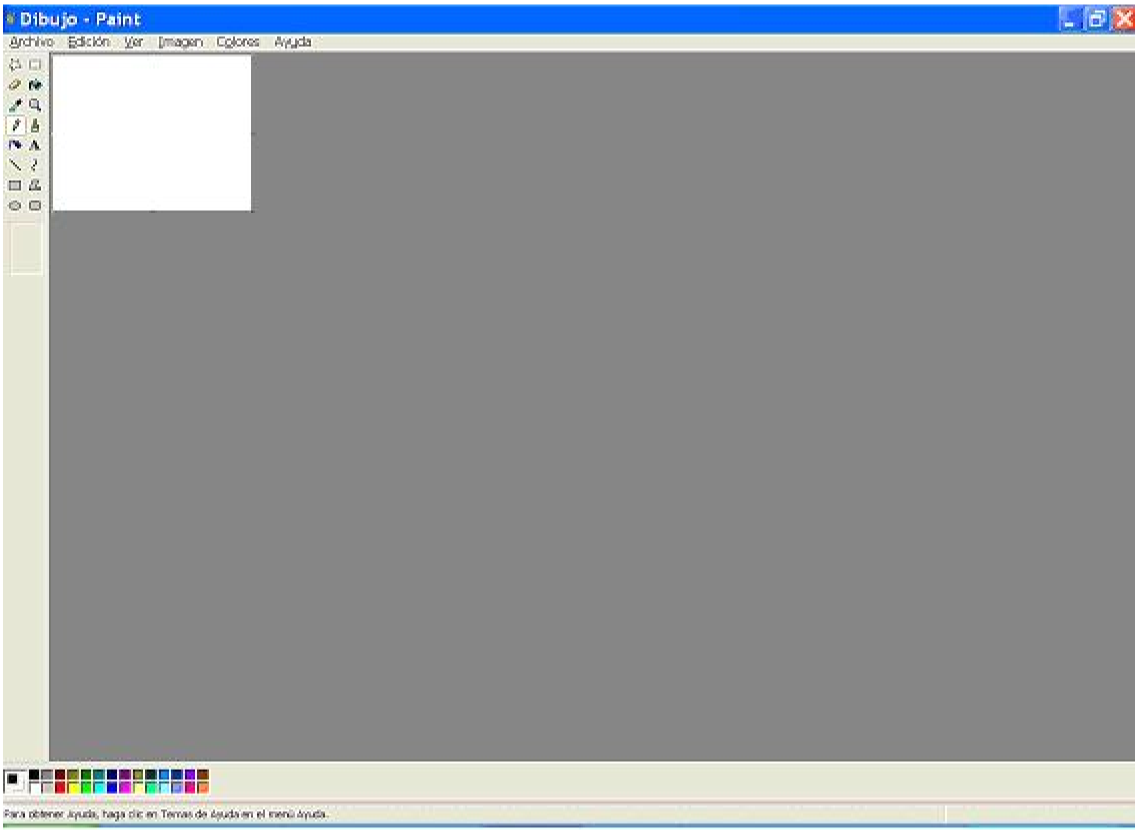


2. Using the screen arrows move to the map area that you want to watch. For example, we can watch Garachico coast in Tenerife North.

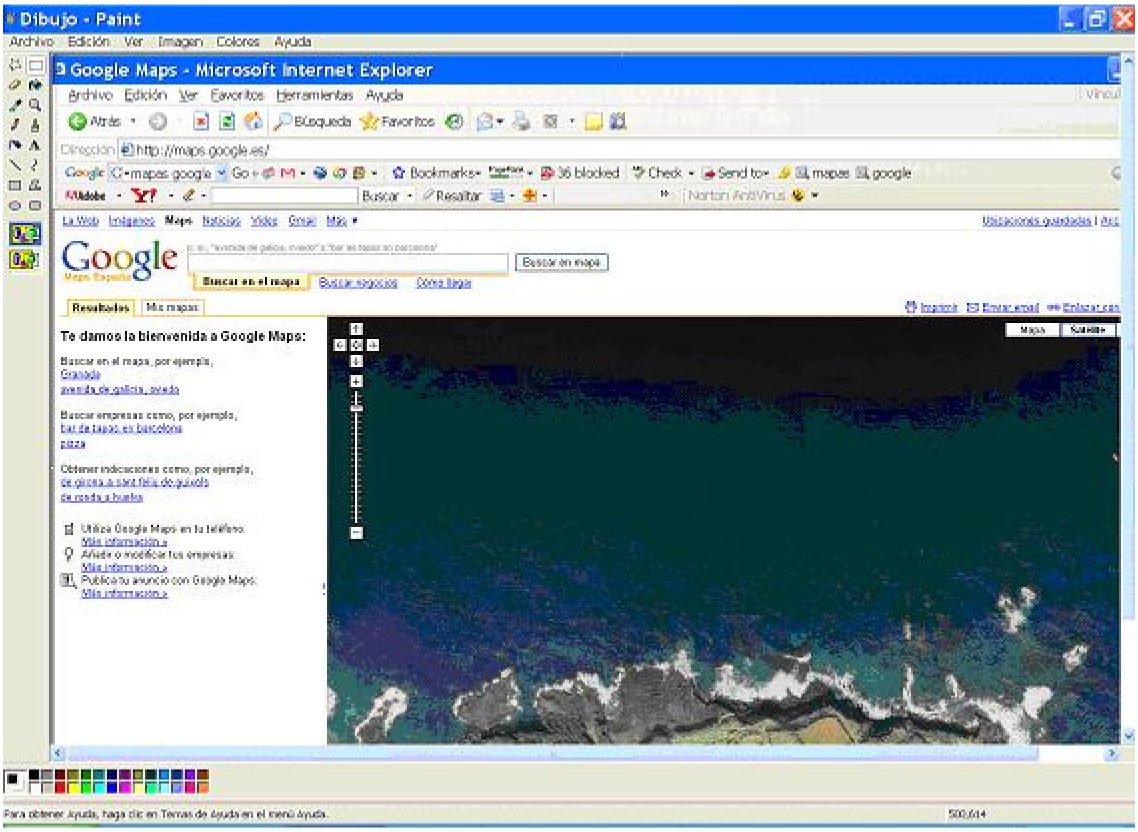


3. For the image capture, it is possible to use in the keyboard Ctrl+Alt+PrtSc). In the keyboard you can push at the same time (Ctrl+Alt+PrtSc). In that way, the screen image is copied by the computer memory.

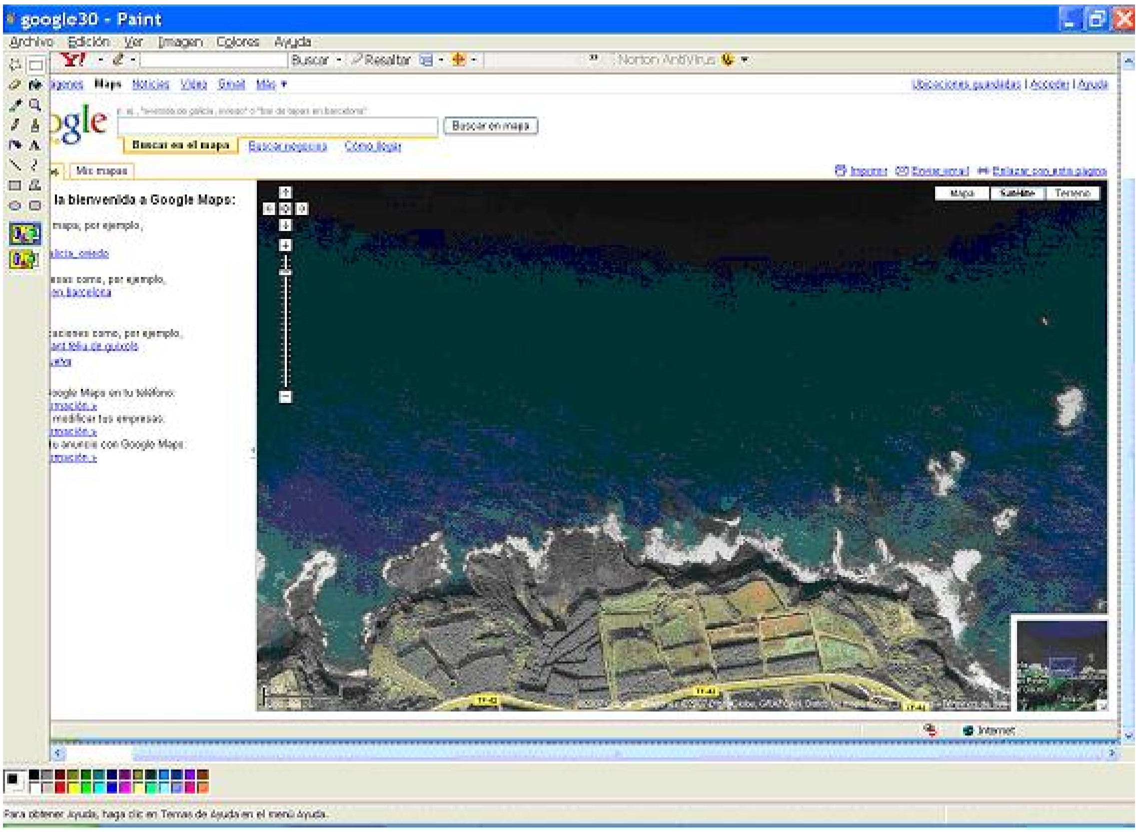
4. Open the windows PAINT program (Windows >> Start>> Programs>> Accessories >> PAINT).



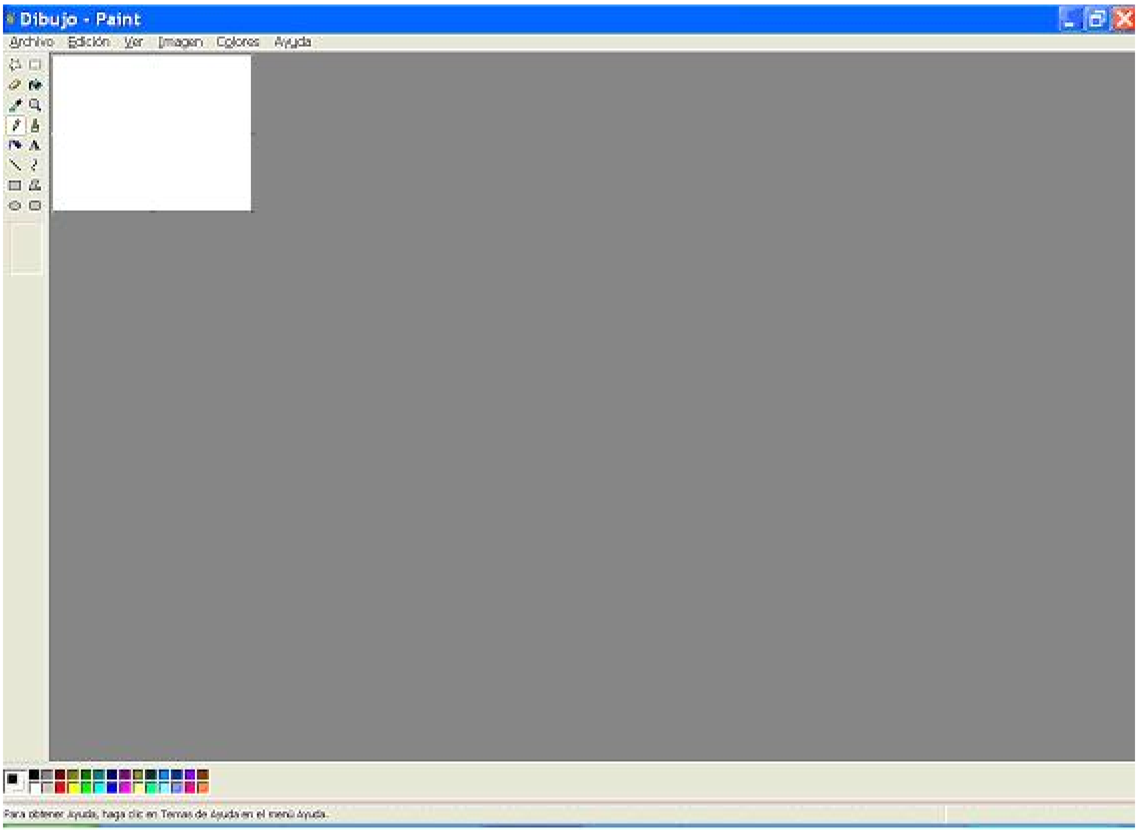
5. To paste the image that has been previously copied in the computer memory, you can use the commands (Edit >> Paste in the PAINT program) or (Ctrl+V). You can watch now the copied image from the Google maps web page.



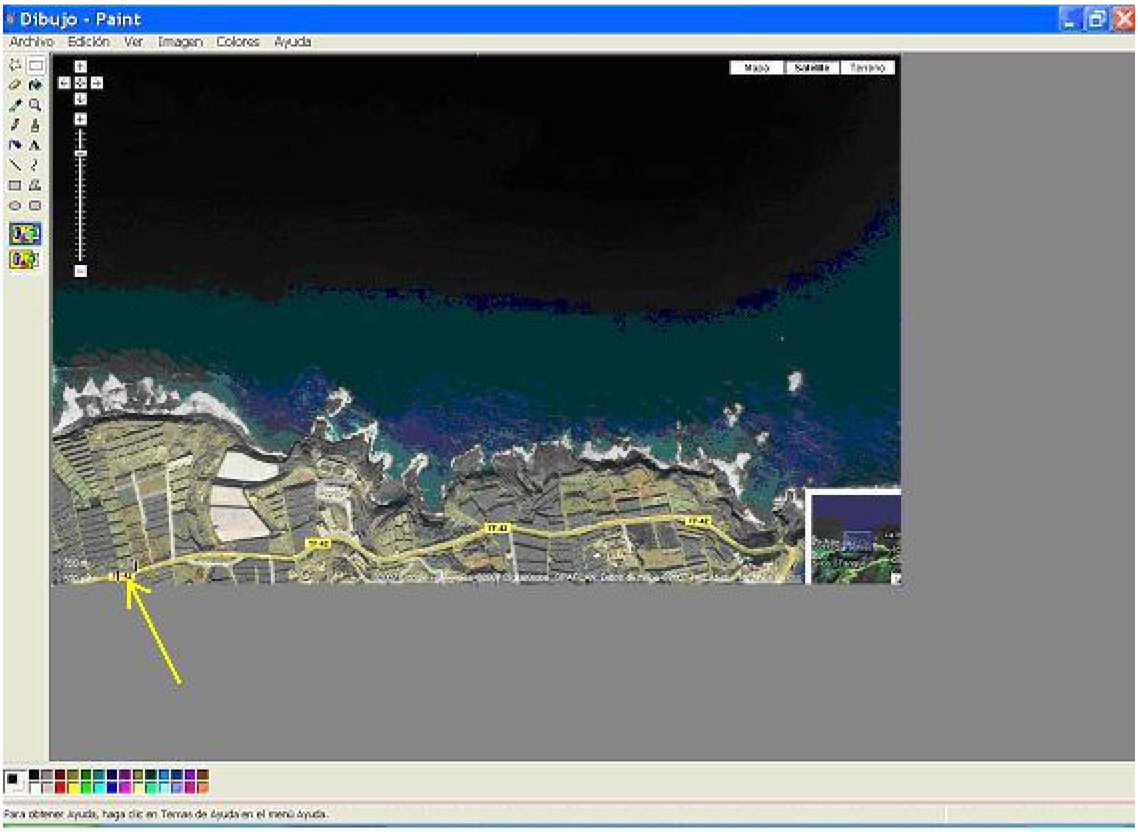
6. It is obvious that you don't want to watch the navigator bars that appears in the screen. Use the arrows of the PAINT program to center the image, that you are interested for, in your computer screen. In the toolbar of PAINT, you can use the icon SELECT (it is on top of the toolbar and at the right in the last picture). Drag the mouse arrow selecting the screen area that you are interested for. For our case, it is the rectangle where the picture of the terrain appears.



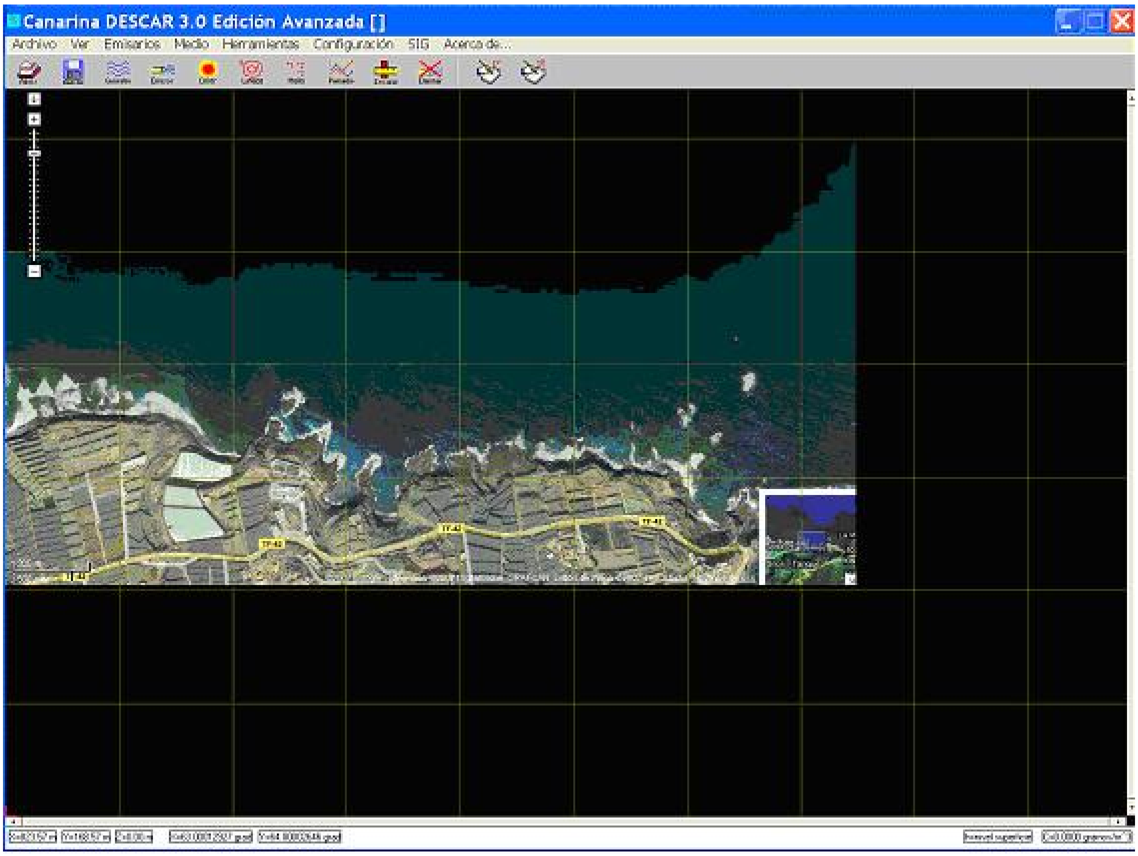
7. Copy now the selected area by the rectangle in the last image using (*Ctrl+C*) or the command (*PAINT Edit>>Copy*) in the PAINT program. Then, you can use the command (*File>>New*) in the PAINT to have a new and clear screen



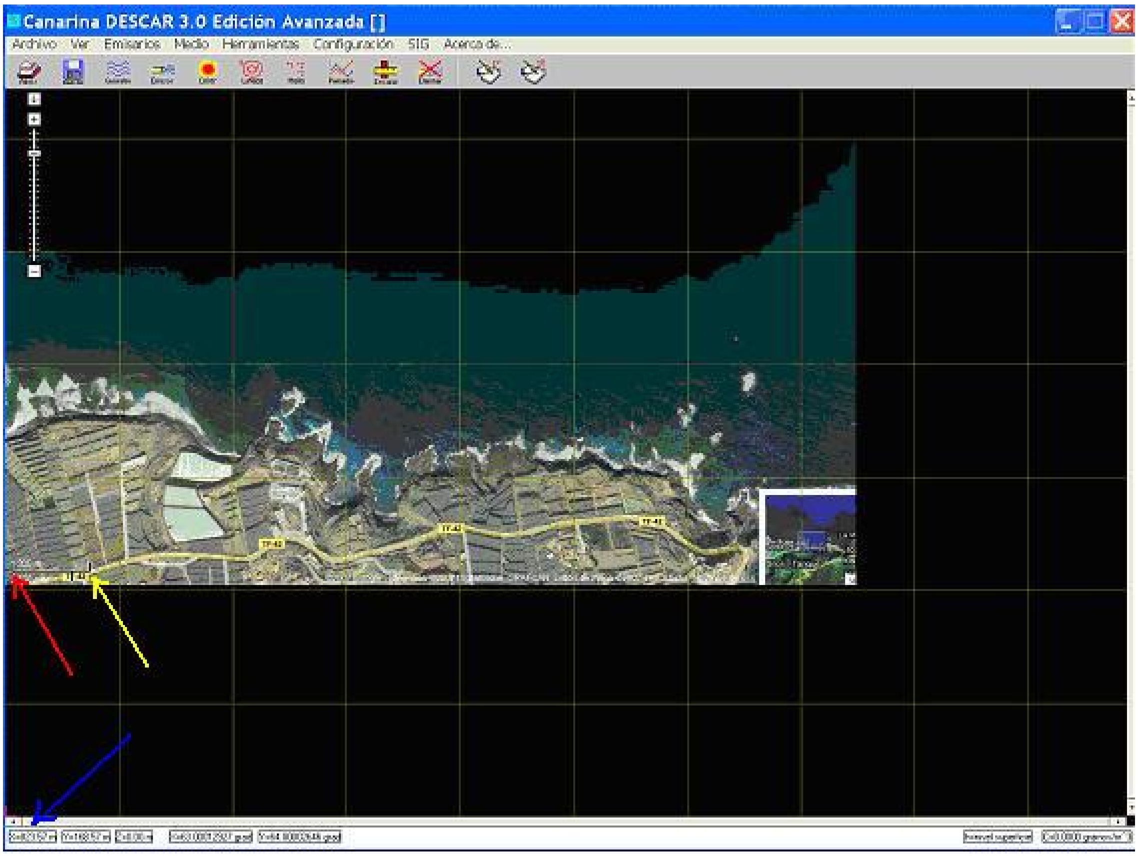
8. Use (*Ctlr+V*) command in the keyboard, or (*Edit>>Copy*) in the PAINT program to paste the selected retangle. The copy of the image appears now in the PAINT screen. The scale of the map imported from Google maps appears now in our screen (marked by a yellow arrow). This will be of great interest in a near future. It is important to have this scale in the image that you have selected.



9. Save the file using BMP format using the commands of the PAINT program (*File>> Save as. . .*). Then, you can open the previously saved BMP file using the Castor Software program.



10. To work in the correct scale, we need to check the scale bar width in the Google map. The Google scale bar is between the red and yellow arrows (in the next picture). The Google bar width is in meters. When we put the mouse pointer in the point of the red arrow we can see the X-Coordinate value in the box marked by a blue arrow. If we put now the mouse pointer in the point of the yellow arrow, we will obtain a new value for the X-coordinate. The difference between both values in meters must be the same that the original Google bar width in meters to be in the correct scale.



When we put the mouse pointer in the point of red arrow, it is found 7 m in the X-Coordinate box (marked with a blue arrow). If we do the same with the yellow arrow, we obtain 75 m in the box marked with a blue arrow. Then, and in our actual scale, the bar width have 75 m -7m = 68m. However, the correct value in the original Google scale is 100 m. The correcting ratio is

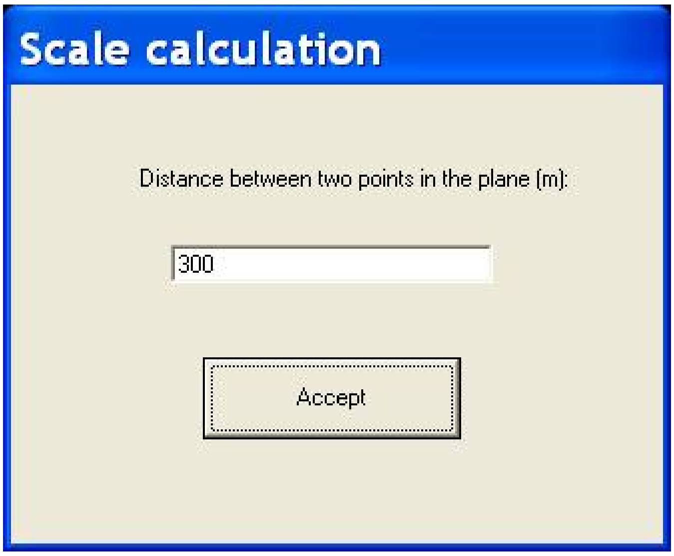
P = 100/68 = (real value)/ (our value).

P=100/68=1.47

11. To work in the correct scale, we have two methods:

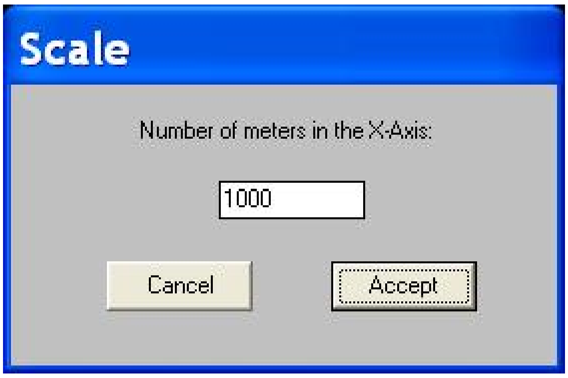
<u>METHOD A:</u>

We go now to Castor Software *program>> GIS >> Scale calculation* in the program and we get



We replace the 300m value that appears in the last picture by 100m (the original Google bar width in meters) and 'click' *ACCEPT*. Then we click firstly in the left extreme of the original Google scale bar and secondly, we click again in the right extreme of the original Google scale bar (both points in the screen were market with red and yellow arrows in the last step 10). The imported Google map is now in the correct sale and we can check it. When we put the mouse pointer in the red arrow, we get an X-Coordinate value equal to 10 m (in the box market with a blue arrow). We can also get 110 m for the position market with the point of the yellow arrow. The difference is now 110 in -10m = 100 m. Such a value coincides with the original value of the Google map bar. So, the program scale is correct now.

<u>METHOD B:</u>
We go now to *Castor Software program>> Tools >> Scale* in the program and we get

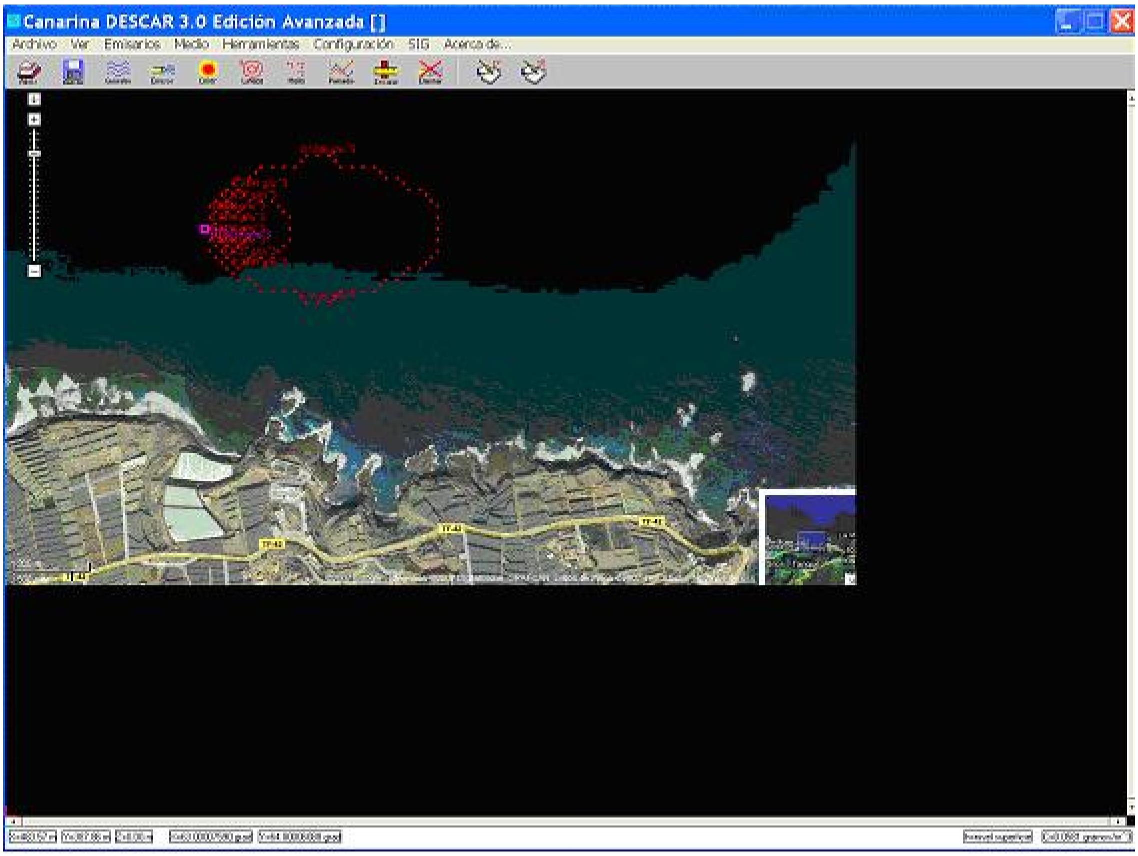


Now we multiply (our actual X-Axis width) by P to get the correct X-axis width, (correct X-Axis width)=Px(X-Axis width)

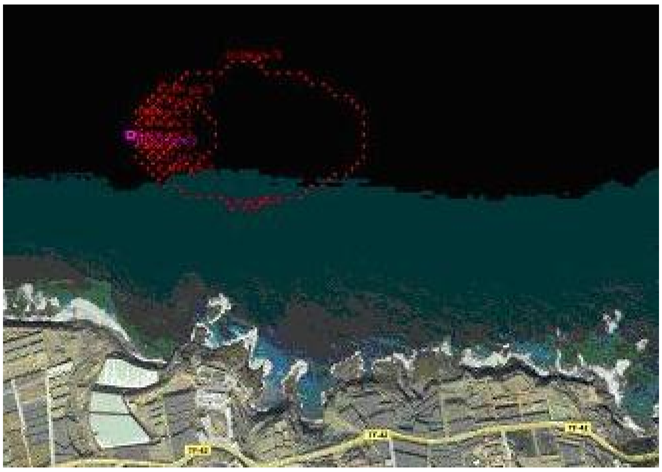
(correct X-Axis width)=1.47x1000=1470m

And we introduce the new X-Axis width and click *ACCEPT* in the last window. The imported Google map is now in the correct scale and we can check it. When we put the mouse pointer in the red arrow, we get an X-Coordinate value equal to 10 m (in the box market with a blue arrow). We can also get 110 m for the position market with the point of the yellow arrow. The difference is now 110 in -10m = 100 m. Such a value coincides with the original value of the Google map bar. So, the program scale is correct now.

12. Now we introduce a pollutant source and we make the simulation. The result can be exported to a BMP file using the Castor Software.



13. We can repeat the 6-7-8 steps 'in order to eliminate not necessary parts in the picture. At the end we have a clean image with both the Google map and the simulation process results.



10. References

- Orden del 13 de Julio de 1993 del Ministerio de Obras Públicas y Transportes del Reino de España, B.O.E. Martes 27 de Julio de 1993, página 22861, I. Disposiciones generales. Proyecto de conducciones de vertidos desde tierra al mar.

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