Surface Analysis and Interpolation Methods

The creation of surfaces that indicate the distribution of different chemical parameters in targeted disposal areas well as, others with similar activities, in order to obtain an idea of the possible diffusion of the chemical parameters and the degree of risk in the vicinity of the waste disposal areas is the goal of this process. We need to map those variables (chemical parameters) with respect to the depth (and date) and study the temporal variations of their spatial distribution and the diffusion of them in the subsurface.

The Inverse Distance Weighted (IDW) interpolation method produces the most satisfying results, and that is the method we used for the interpolation process. IDW calculates cell values by averaging the values of sampling points in the vicinity of each cell based on distance.

$$z_j = k_j \sum_{i=1}^{n} \frac{1}{d_{ij}^{\alpha}} z_i$$

It has to be mentioned that surfaces could only be interpolated for more than 4 known values. In cases where the measured values were less than 4 it was not possible to interpolate surfaces and therefore no results were produced.

Existing Tools

There are several tools and techniques in order to present the interpolated surfaces via an understandable and easy to use interface. We need to present these interpolated surfaces (i.e. images actually) inside the website of **Prosodol**, so at the end a web based application must be implemented to be used and handled by the public (in the partners area). This fact pushes us to integrate the entire interpolation process results into a Map API such as Google API, or Google Earth API, flash maps techniques

(Flash Builder software), so that a user can view the interpolated surface area images simultaneously above a topographic/satellite map provided by those APIs. After consideration of the time based functionality, which a user can view the chemical parameters diffusion in a subsurface over time, testing and using several of the above techniques, **Google Earth API** was the most appropriate to use, which handles this possibility by integrating time tagged images via EXtensible Markup Language (XML), a language designed to transport and store information data.

What about though of the interpolation process? We chose ArcGIS Desktop for creating the interpolated surface maps using the **ArcGIS ModelBuilder**[1] Tool. ModelBuilder is an application in which you create, edit, and manage models. In the next section we are going to cover the whole process for creating the interpolated surface maps in order to provide them as input in the end, to the Google Earth API of the final web based application.

ArcGIS ModelBuilder

In order to create the interpolated surfaces we have to study carefully the several steps, processes needed, from the beginning. The way to build a model is by building and connecting processes. A process is simply a tool plus its variables. A variable is either a data variable that references our data (layers, shape files of measurements information), or a value variable, which is anything else, such as numbers and text strings. Variables are connected to tool parameters. The ArcToolbox provides all the necessary tools that our model needs. The following figure shows how such a process works.

Figure 1

The **Input data** for the Model we need are stored as a shape file and presented as a layer in the ArcMap application as in the following figure.

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[1] An overview of ModelBuilder

Figure 2

The **Derived Data** are going to be the XML files that contain the interpolated surface maps with time variation tags, in order to be given as input to the Google Earth web application. As previously said, the **Tool** of Figure 1, is a process, actually a group of several processes that have to take place in order to export out interpolated surfaces to XML files. In the following, these tools are going to be described step by step. The Model for the interpolation of the surfaces for one measurement variable (chemical parameter) is presented below.
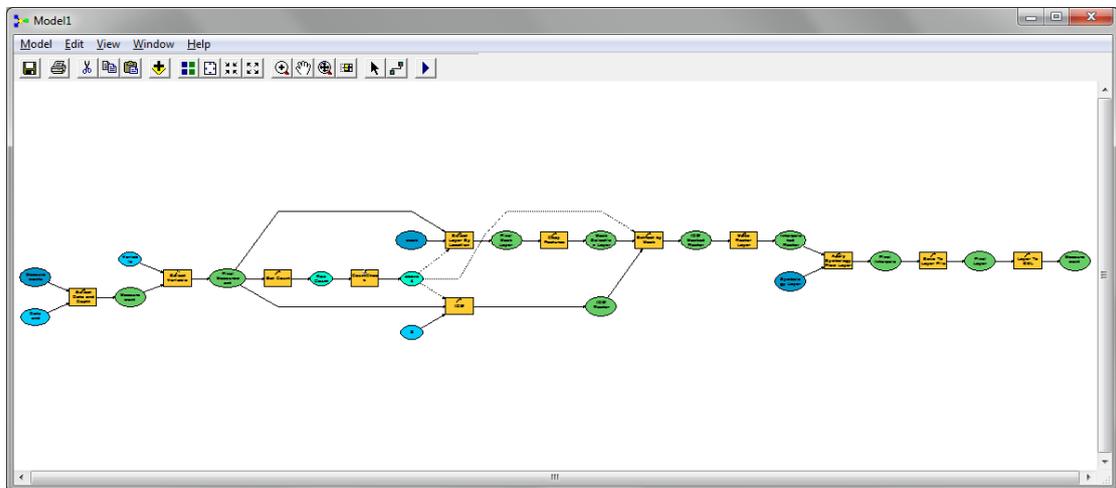

Figure 3

At this point we are going to analyze the entire methodology for building a model for interpolating surfaces of measurements (provided as point shape files) according to the fact that the derived output must be an XML file, with a proper schema to be used from the Google Earth API application.

Several tools (processes) that need to be performed in order to achieve the expected result are shown in Figure 3. The first step for the whole interpolation process is to define the date and depth of a measurement for the interpolated output map file. So, the first tool that has to take place is a **Selection** tool, which selects the date, depth and the variable (chemical parameter) from the input measurements shape file, as shown in Figure 4 below.
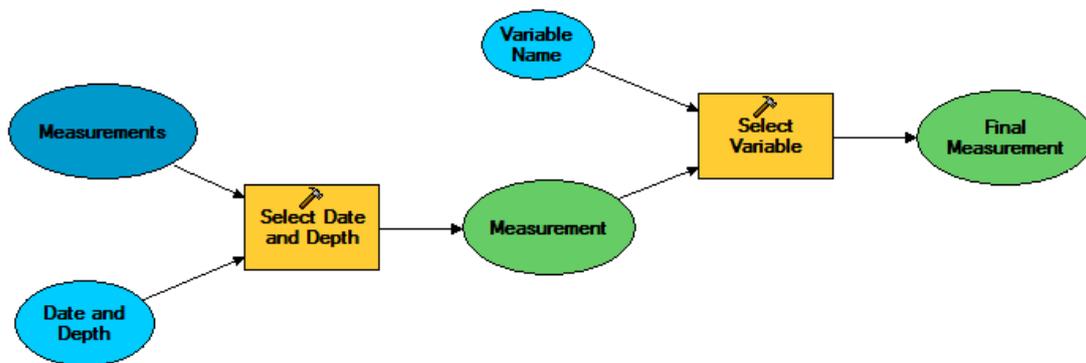

Figure 4

The next step, which is the most important one, is where the interpolation process takes place. We must note at this point that the interpolation of a surface, in other words, the diffusion of a chemical parameter in an area, has no meaning above a radius, or a long distance from the measurement points. For this reason we need to provide a **Mask** in order to determine the interpolated area bounds as shown in the figure below. The mask is actually a polygon that surrounds the measurements area and inside this polygon the interpolation of the surface is only going to take place. The mask is provided to the Model as a layer or shape file. In Figure 5 the measurement targeted areas are provided as points (green dots) while the mask areas surrounding them are provided as polygons (blue squares).
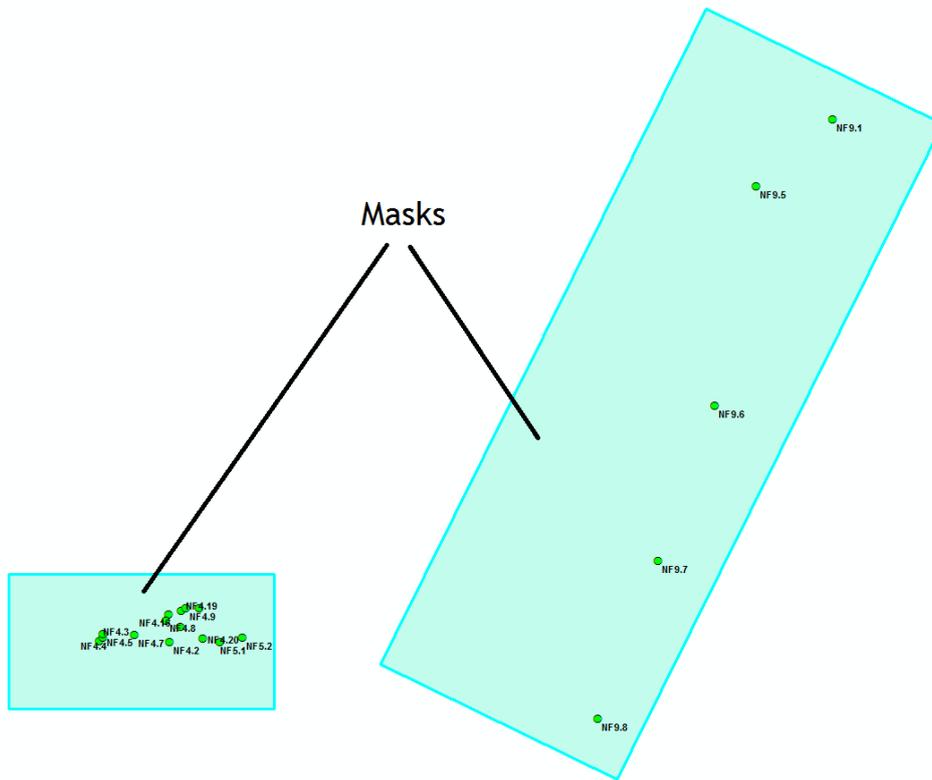
Masks

Figure 5

As mentioned earlier the interpolated surfaces can only be interpolated for more than 4 known values (points). So, after the first step is completed, we need now to check the Final measurements number with the **Get Count** tool, and only if the result is above 4 measurements for a targeted area, then the interpolation takes place, as shown in Figure 6 below (handled by script). If this constraint is true then we interpolate the entire surface with the **IDW** tool, providing the corresponding chemical parameter and area limits, and simultaneously selecting the corresponding mask areas (polygons), intersecting measurement (point) locations.
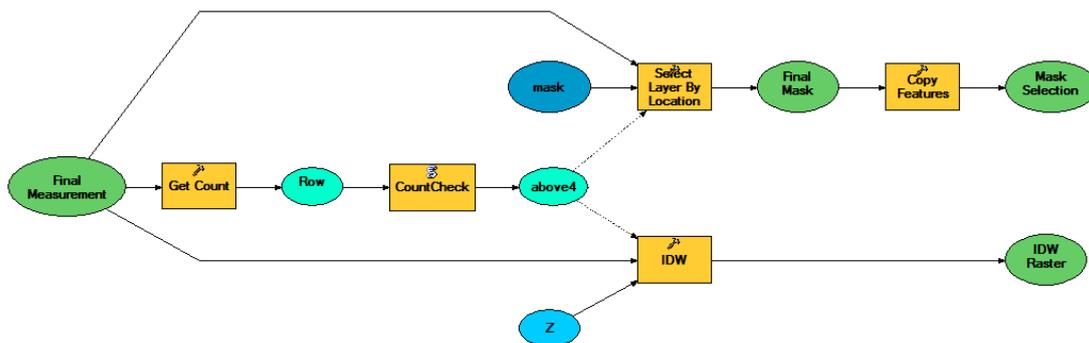

Figure 6

At this phase of the model building we actually have the entire interpolated surface, with the corresponding mask areas, depending on the measurements (more than 4) according to depth, date and chemical parameter selection. The next step which is described in Figure 7 is to extract the *masked* interpolated surface map. This process is done with the **Extract by Mask** tool that outputs the result as a raster file, which is converted to a layer file with the **Make Raster to Layer** tool.
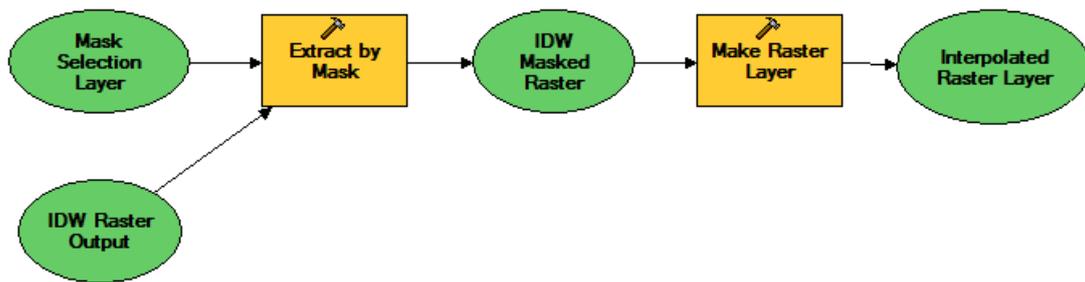

Figure 7

The extracted layer file is needed in order to provide a symbology layer upon it, which denotes the degree risk with a color scheme as shown in the figure below. Knowing the minimum and maximum variable limits, the red value shows a high risk area of the certain chemical parameter while the blue one a low risk.
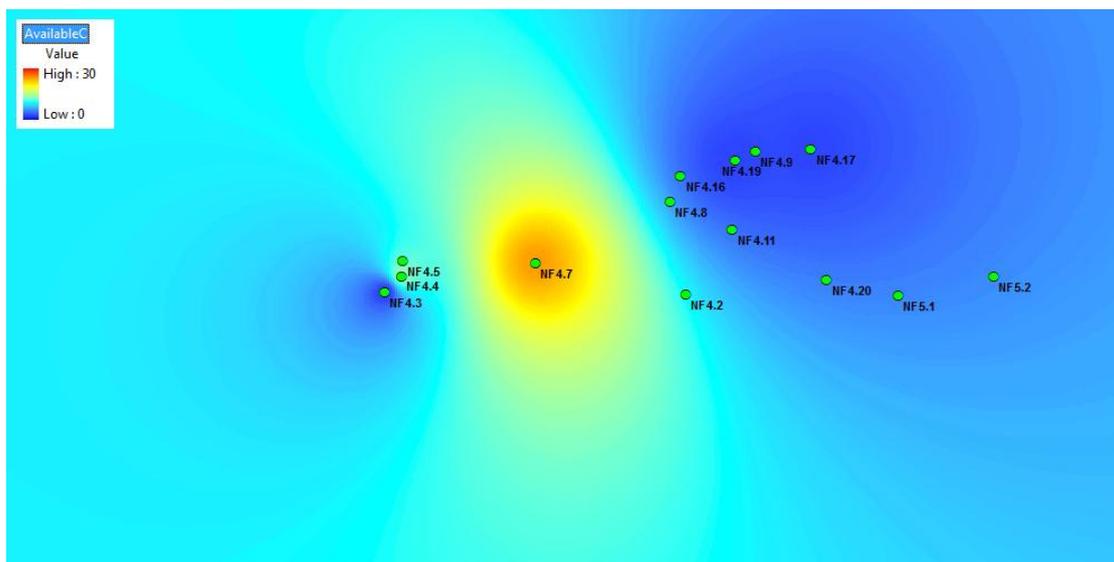

Figure 8

6

Because the ModelBuilder constructs in its process step (tool) the derived layers temporarily, we needed to save only the final layer, the interpolated, masked, symbology applied layer, in order to provide it as an input to the **Layer to KML** tool, which constructs our final KML file, an XML format file suitable for the Google Earth API application that we later on integrate to the website. The final process steps are shown below in Figure 9.
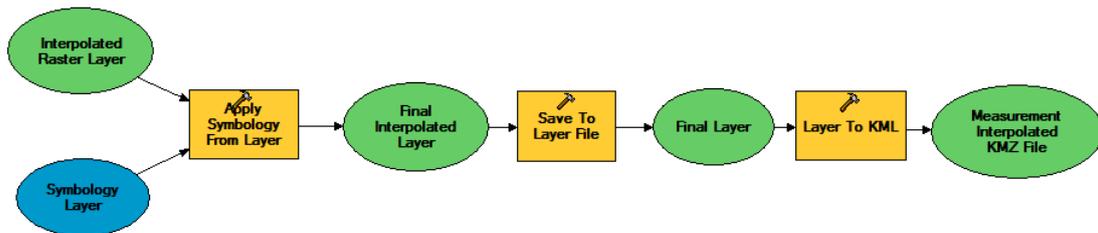

Figure 9

The whole surface interpolation process described, as shown in Figure 3, was just for one variable, while the flowchart of the entire Model for all chemical parameters is shown in Figure 10.

Depending on the date and depth of the measurements, in every loop, a set of 28 KML files are constructed by the Model. At the end those files need to be merged by parameter, denoting for each file the date/depth inside the merged KML file. In the next final section we are going to describe the Google Earth API application (web based) implementation and usage, depending on those KML derived files.
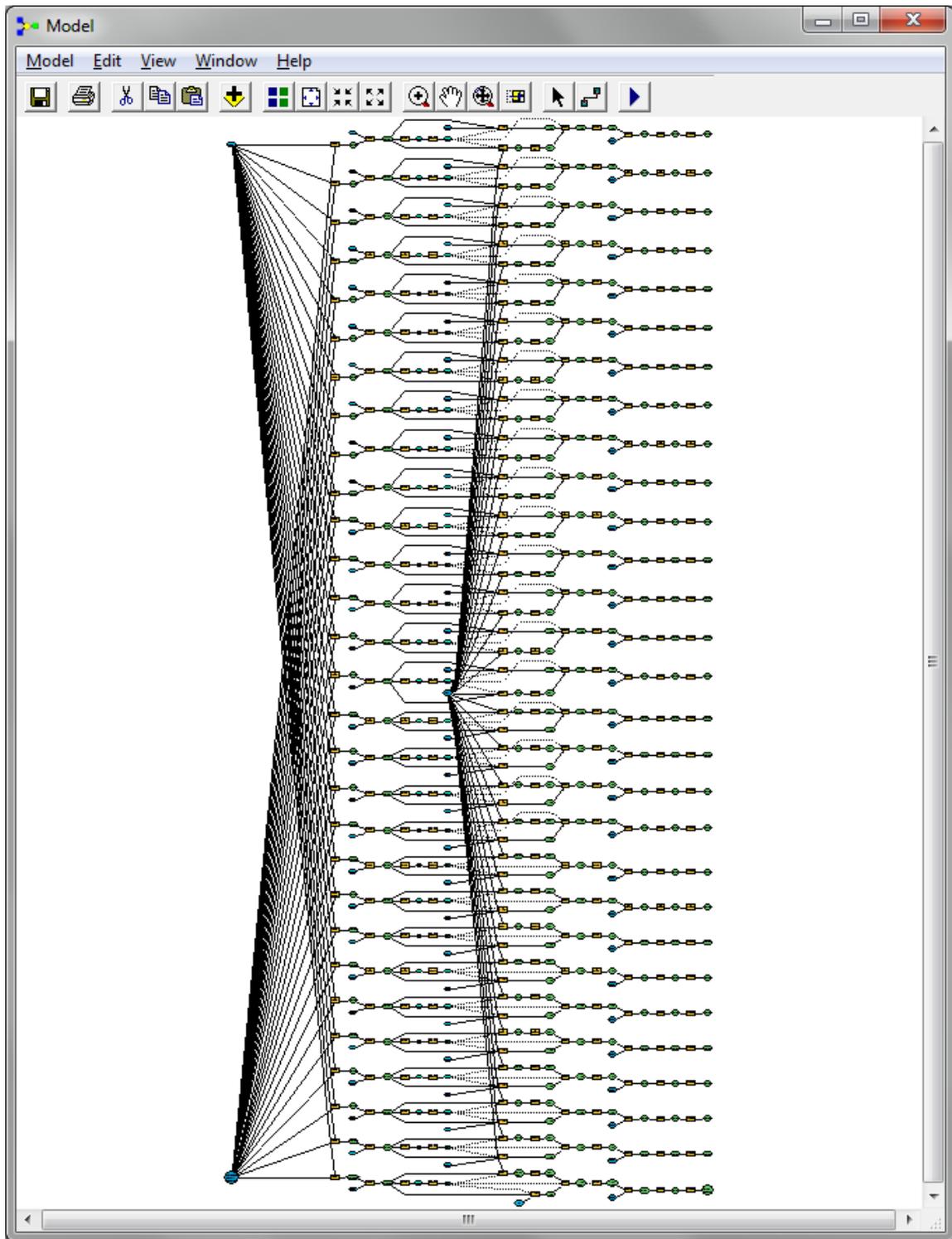
Figure 10

Google Earth API Application

The Google Earth API it is a JavaScript API which let us embed Google Earth, a 3D digital globe, into Prosodol Web site. Using the API we can load KML files, allowing us to build a 3D map application. The reason we use this

API is because of the time plug-in, where time information contained to the derived KML files (as a feature) of the Model previously described, can be introduced to the plug-in and attached as a map view.

The implementation of the map application is quite straightforward; no need to get in details at this point, and it was handled with JavaScript over PHP pages of the Prosodol web site. By selecting the user defined measurement (chemical parameter in fact), measurement's depth, and submitting the information to the application, the corresponding interpolated surface map is loaded.

In Figure 11 below the interface of the map application is presented. Let's describe the several features that are shown, that allows a user to find the information needed in order to view a specific interpolated surface area.
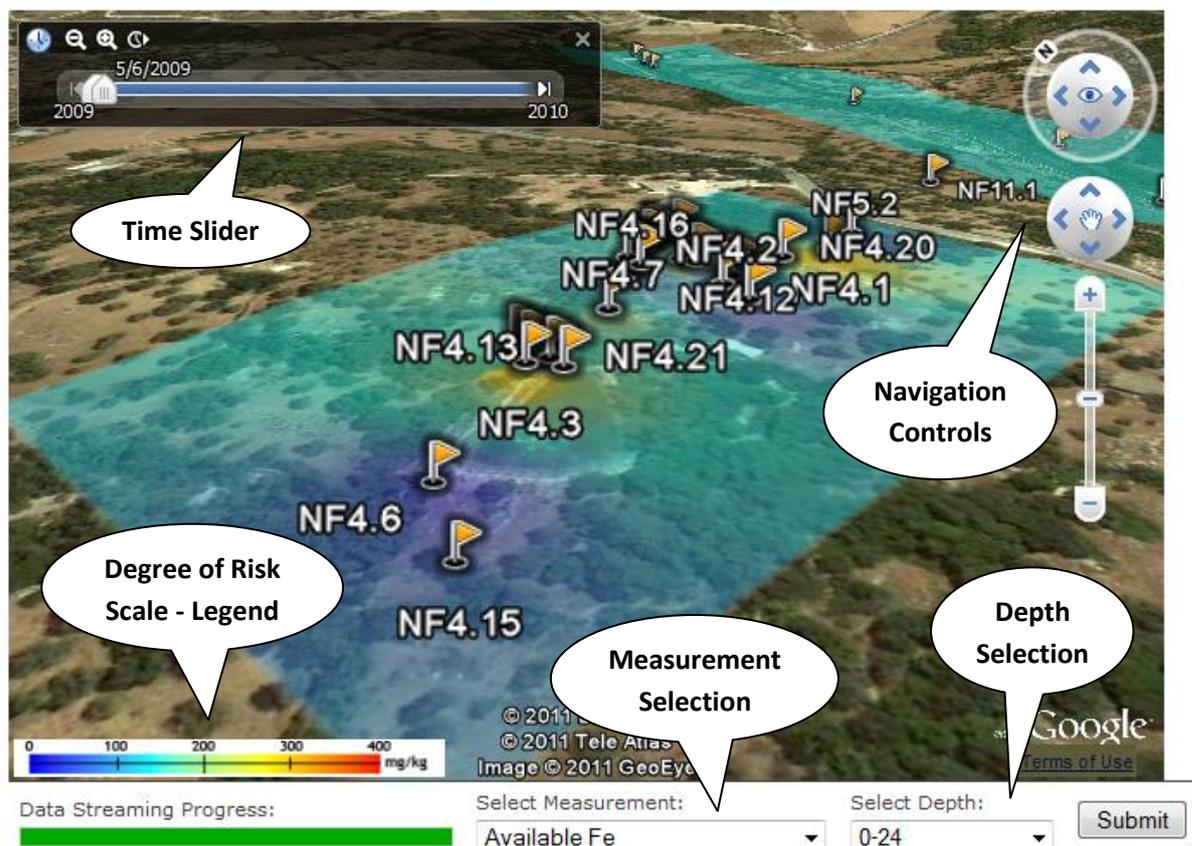

Figure 11

Measurement Selection – The user selects the needed measurement's chemical parameter name in order to see the corresponding interpolated surface map.

Depth Selection – By selecting and the measurement's chemical parameter depth, a user can submit the information provided, and the map application starts to stream the data needed for the map application to present the corresponding interpolated surface map.

Navigation Controls – The user may navigate inside the map through the navigation controls, in any direction, angle, pan and zoom, giving him the freedom of any view perspective.

Time Slider - Once time is introduced to the plug-in when the KML file is loaded, a time slider appears, allowing the end user to manipulate time. An animation of the interpolated surface area map can be viewed through different time periods on the Google map.

Degree of Risk Scale – Legend – When the interpolated surface map is loaded the corresponding scale of the risk degree of the selected chemical parameter is shown.

The 3D map application was designed in such a way, where the end user can easily and effectively use, and retrieve the surface interpolated information needed.