# Witwatersrand Water Ingress Project – Information Management System (WWIPIMS), South Africa

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Das Witwatersrand Water Ingress Projekt des südafrikanischen Council for Geoscience (CGS) befasst sich mit der Erfassung ehemaliger Bergbaue, deren Risikobewertung sowie der Entwicklung von Strategien zur Rehabilitierung der Witwatersrand Bergbauregion. Das Hauptziel des Projektes ist, Wassereintritt in das vorhandene Minensystem zu verhindern sowie zukünftige Wasseraustrittsszenarien zu prognostizieren. Zur Datenhaltung der diversen zu erfassenden Grundlagen- und Messdaten wird eine zentrale Projektdatenbank aufgebaut. Diese Datenbank wird um eine benutzerfreundliche Windows-Anwendung erweitert, die den einfachen Zugriff auf die aktuellen Daten für alle Projektmitarbeiter mit Hilfe verschiedener Module und einer GIS-Komponente ermöglicht. Die so strukturiert abgelegten Daten bilden die Grundlage weiterer Modellierungen des Wasserhaushaltes. Weitere Funktionen wie das Erzeugen von Kartenlayouts, umfangreiche Abfragen, Im- und Export von Daten und Diagrammen komplettieren das System.

The Witwatersrand Water Ingress Project at the Council for Geoscience, South Africa (CGS) deals with an inventory, a risk assessment and the development of rehabilitation strategies for abandoned mining sites in the Witwatersrand Mining Basin. The main focus is the prevention of water ingress and to understand the future decanting scenario. An Information Management System consisting of both a relational database and an application for the Witwatersrand Water Ingress Project is established for accessing and managing all project-related data. This easy to use application makes the data available to all staff at the CGS via several modules as well as a GIS-component for accessing and querying spatial data. This will enable the scientists to derive further knowledge of the water flowing processes by directly using all of the existing up-to-date data. Many additional functions, such as the support for map printing on demand, extensive possibilities for inquiries, data import and export, diagrams and a GIS-viewer for spatial inquiries do complete the system.

## 1 Introduction

The Council for Geoscience (CGS), South Africa, has been appointed by the Department of Minerals and Energy (DME), June 2003, to execute a project regarding the ingress of water into underground mine voids. In the course of this project Beak Consultants GmbH, Germany was appointed by the CGS to develop a project-database and an application for the handling of all relevant project-data to provide a comprehensive access to the data to all project members.

## 2 The Witwatersrand Water Ingress Project

This chapter is based on (CROUKAMP & HEATH 2004).

### 2.1 Background

Since 1886 the Gauteng gold reefs between Springs in the east and Westonaria in the west, have been extensively mined for gold and some uranium. The area of the Witwatersand mining basin is located in the South African Gauteng province around the city of Johannesburg (see Fig. 1). Most of the mines have since closed down, with only one each operating in the Far East Rand, Central Rand, West Rand and a few in the Far West Rand. Because these mines are largely interconnected, the entire

Witwatersrand mining area is now divided into only five separate hydrological underground water basins namely; the Far Eastern, Central, Western, Far Western and Rietfontein basins. Oxidation of sulphides in the gold ore leads to the acidification and severe pollution of ingress water flowing through the mine voids.
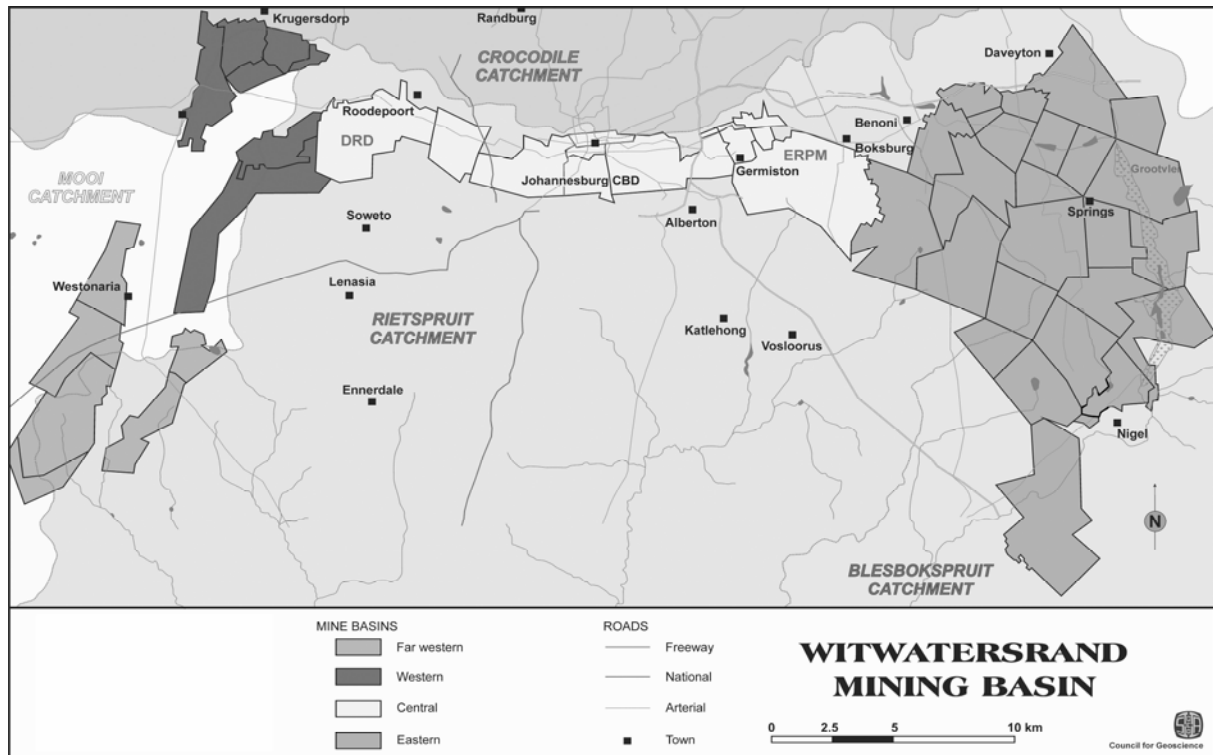


**Fig. 1    Project Area**

If this problem is not addressed, it is likely that once all mining operations have ceased, polluted water will seep into the natural environment throughout the Witwatersrand via the groundwater system by decanting from abandoned shafts and surface openings into the surface water system. This has already started to occur in the Johannesburg and Randfontein area, with impacts being detected in both the local surface and groundwater systems both on mine property and in the adjacent Krugersdorp Game Reserve. Such scenarios are not only restricted to the gold mines in Gauteng but have been reported from the coalfields of Northern Kwa-Zulu Natal and in mining regions throughout the world.

## 2.2  Aim

The main aim of the project is the prevention of ingress of extraneous water into the mine workings to facilitate their continued operation and thus minimizing the potential for pollution of water resources. Currently extraneous water is being pumped at a considerable cost by the mining companies and in some cases subsidies for pumping are being paid to the mines by DME. If the ingress of surface water could be prevented or minimized it would lead to a cost saving in terms of pumping subsidies with the added benefit of preventing the sterilization of existing resources by flooding.

## 2.3  Previous and current work

Studies undertaken on behalf of DME in the past indicated that water inflow at surface mining outcrops is about 14 % whilst the contribution from groundwater is 40 % and with a 46 % contribution from surface streams and other water bodies. The salt load introduced into surface streams in the region totals to 48 tons/day.

Based on the studies available the CGS was tasked to investigate the building of canals over extensive areas of shallow undermining and reef outcrop and the closure of openings at surface (shafts, subsidences, etc.) that actively contribute to water ingress.

By perusing old mine plans, aerial photographs and field visits more than 500 openings on surface have been detected which range in size from 1-50m (in diameter) and a few meters to several hundreds of meters deep. They were classified or ranked according to their level of water contribution.

A study to investigate methods of closure that ensure an impermeable seal and which do not cause further environmental damage is also being undertaken. Apart from the standard manner of plugging with concrete and then backfilling with any available materials, other new methods were investigated. In the United States, polyurethane foam (PUF) has been used extensively and successfully to close abandoned unsafe mines. This method involves the mixing of 2 chemicals which expand approx. 30 times to form a rigid foam. It is suitable for smaller diameter holes (up to 3m), is reasonably cost effective and is environmentally friendly. One such hole has already been successfully closed. This opening will be tested further and monitored to measure performance.

Another method being investigated is that of bulk filling the mine void or shaft with a mixture of fly-ash, a cheap environmentally friendly, byproduct of the power stations, and cement. Fly-ash mixed with 2- 10 % cement can be used to produce a slurry that flows easily but sets to produce a strong, impermeable fill.

One of the tasks executed is the sampling of surface and underground water with the aim of looking at the macro chemistry as well as isotopes, to determine water pathways from surface sources down through to the underground workings. Most of the underground water originates from fissures and has a range of chemical composition. Interestingly to note, is that the water samples from the east Rand have a pH of 7-8 whilst that in ERPM (central Rand) have a typical pH of 3-4. This could indicate the buffering influence of the overlying dolomites on the east Rand. Sodium and chloride levels are also higher than expected for the Witwatersrand type geology which could indicate a surface source. The stable isotopes tested to date further indicate that the water in the mines has a 30 % contribution from surface.

The final aim of the project is the creation of conditions where long-term care, maintenance and costs are minimized. Although some of the actions mentioned above will have an immediate impact on existing mines, the impact of contaminated groundwater could persist indefinitely. Since the State will eventually have to assume all these responsibilities, it is in the interest of the State, on behalf of the people of South Africa, to find solutions quickly which offer long-term sustainability.

## 3   The Project Information Management System (WWIPIMS)

### 3.1  Principle Requirements

There are a lot of diverse data to be gathered for the project. To handle them effectively and to support the scientific work Beak Consultants GmbH was tasked to develop a central project database. Topped with an easy to use application it shall assist the scientists at the CGS to efficiently work with their data. The application consists of two main parts, one for managing the factual data of the database and a GIS-part for viewing and editing the spatial data.

For the planning process of modelling the data, it is prerequisite to handle all data in a modular and network-like way to allow further developments later on easily. All data to be handled were put into a relational database structure avoiding redundancies that are always sources of errors and might hinder further developments.

The WWIPIMS was developed in a Windows like style with clearly structured user-friendly interfaces. This will help raising the acceptance of the system and enable intuitively usage.

### 3.2  Data Management

The WWIP-database stores and handles unstructured, factual and spatial data. It is implemented on a Microsoft SQL Server 2005 with ArcSDE 9.1 for the handling of spatial data. Some external data from another database are linked to the database by the application where necessary, but stay at their original place. This applies to data of the "GEODE"-database that is hosted on an ORACLE-server.

Relevant digital files such as scanned mine-plans are stored in file-systems on the server, managed by the WWIPIMS with a meta-data part inside the database.

As both the factual database and the GIS database (ArcSDE) will use the same SQL Server, it is possible to merge both databases into a single one with main tables for the solely factual data and feature tables for data holding geometries.

The maintenance of the data will be done by authorized users only. Therefore a system of differentiated user-rights is required.

See Fig. 2 for a composition of principle components regarding the data handling of the WWIP IMS.
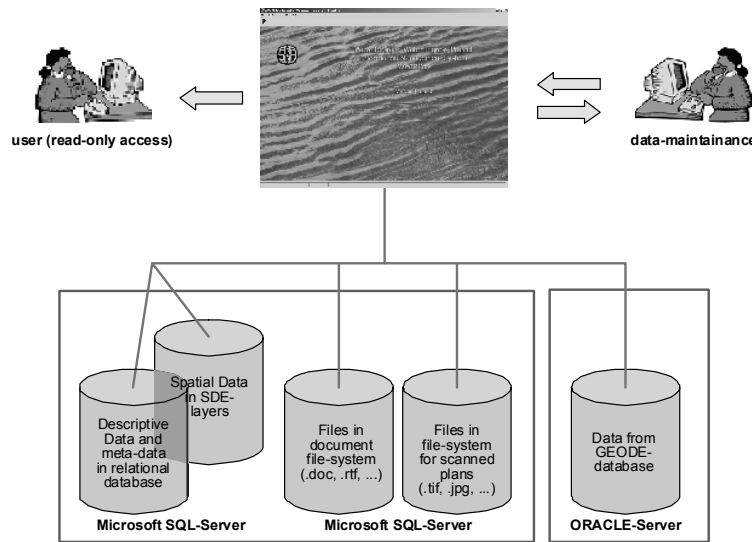


**Fig. 2**     **Principle components of datahandling**

The structured relational WWIP-database acts as the core of the system. It holds all data in linked tables. The spatial data is stored in ArcSDE feature tables in the same database and linked with Key-Values to the relevant factual data-tables.

Besides the relational database there will be file-systems for non-structured data like scanned plans. They are located on the server in specified folders. The file-systems can hold data in any existing file-format. The WWIP-database manages the metadata of these entities and the link to the physical file. In this way, the application provides the file information in a user-friendly way and the user is able to open the related document with a function (button) from the application. The principle database structure is illustrated in Fig. 3.
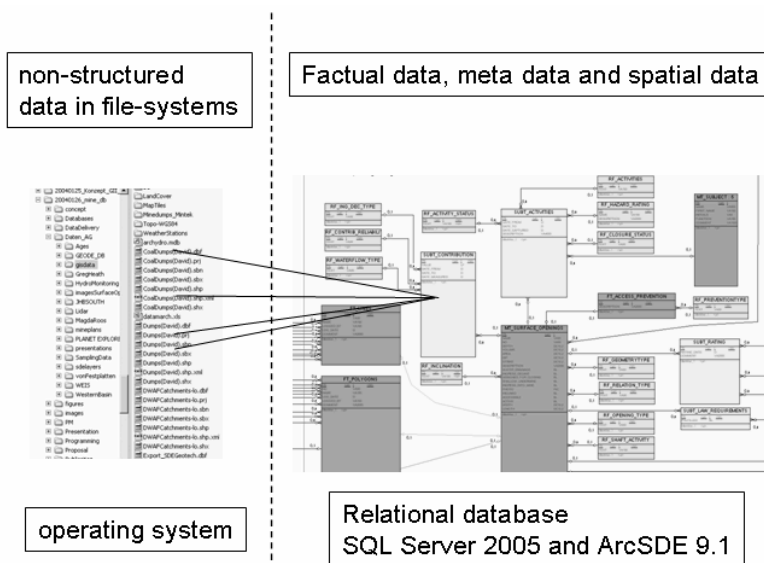


**Fig. 3**     **Principle database structure**

## 3.3  Data Modelling

The WWIP-database consists of a number of entities, which are presented to the user by separate software modules. The main entities to be handled are

- Surface Openings / Ingress-Decant sites

- Pumping Tests

- Hydrological Monitoring

- Samples / Analyses

- Groundwater Boreholes

- Dumps

- Caves

- Meteorological Stations

- Persons / Companies

- Reports / Documents

Some necessary entities will not be stored in the WWIP-database itself but will be retrieved on a read-only basis from the existing nationwide "GEODE"-database at the CGS. They are

- Exploration Boreholes

- Engineering Dolomites

- Samindaba (Mines / Deposits)
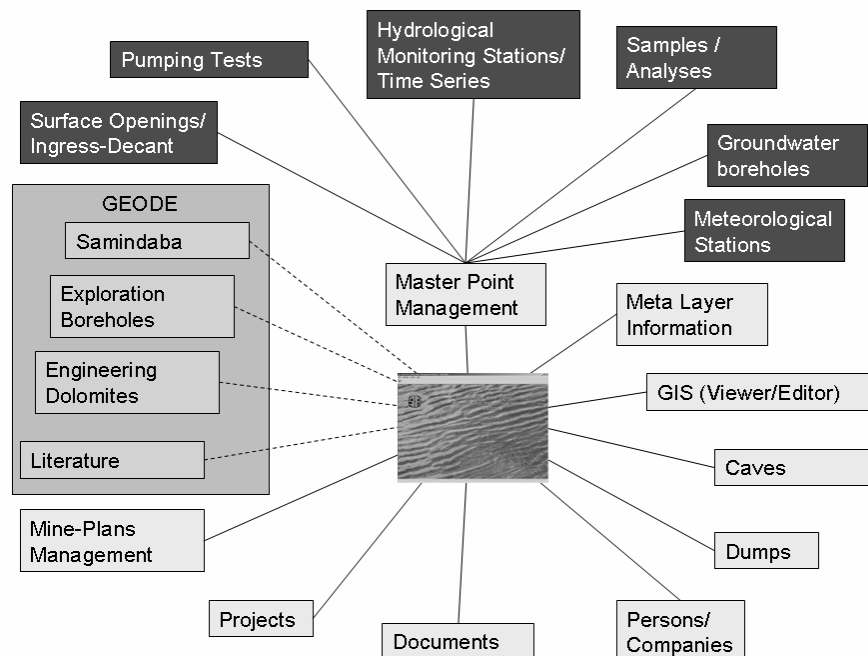
- Literature



**Fig. 4    Main Modules**

Those modules that handle point information are linked to a central point table, which is handled by the Master Point Management module. This module holds the coordinates and all basic point-data that will be the same regardless of which type of point it is. This approach of storing the geometrical data centrally with logical links to the factual data has the advantage that many other features can be

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assigned to a single geometry. For instance one point can be reflected as a borehole, an ingress point and a monitoring point at the same time and the actual coordinates are only stored once. This reduces potential errors and minimizes redundancies. Fig. 4 shows the main modules the WWIPIMS consists of. The modules that are connected with a dashed line show data from the separate "GEODE"-ORACLE-database. They are accessed on a read-only-basis and not directly linked to other data of the WWIP-database.

## 3.4 Application Development

The WWIPIMS application is developed with Visual Basic .NET for the database interfaces, ArcObjects for the GIS-Editor, being an ArcMap-Extension and MapObjects for the internal GIS-Viewer that is integrated into the application as a module.

Generally, the look and functions of the Information Management System intend to be self-explanatory and easy to use. The application modules are inter-connected the same way as the database entities are. Wherever there are data links to other entities, there are buttons in the application that allow the user to jump to the connected modules and view the referenced records.

Each module consists of the same basic elements menubar, toolbar, main window and status bar. The main window is divided into a region with the data of the current record and tab-pages for detailed and referenced information. The basic structure of the modules is shown in Fig. 5.
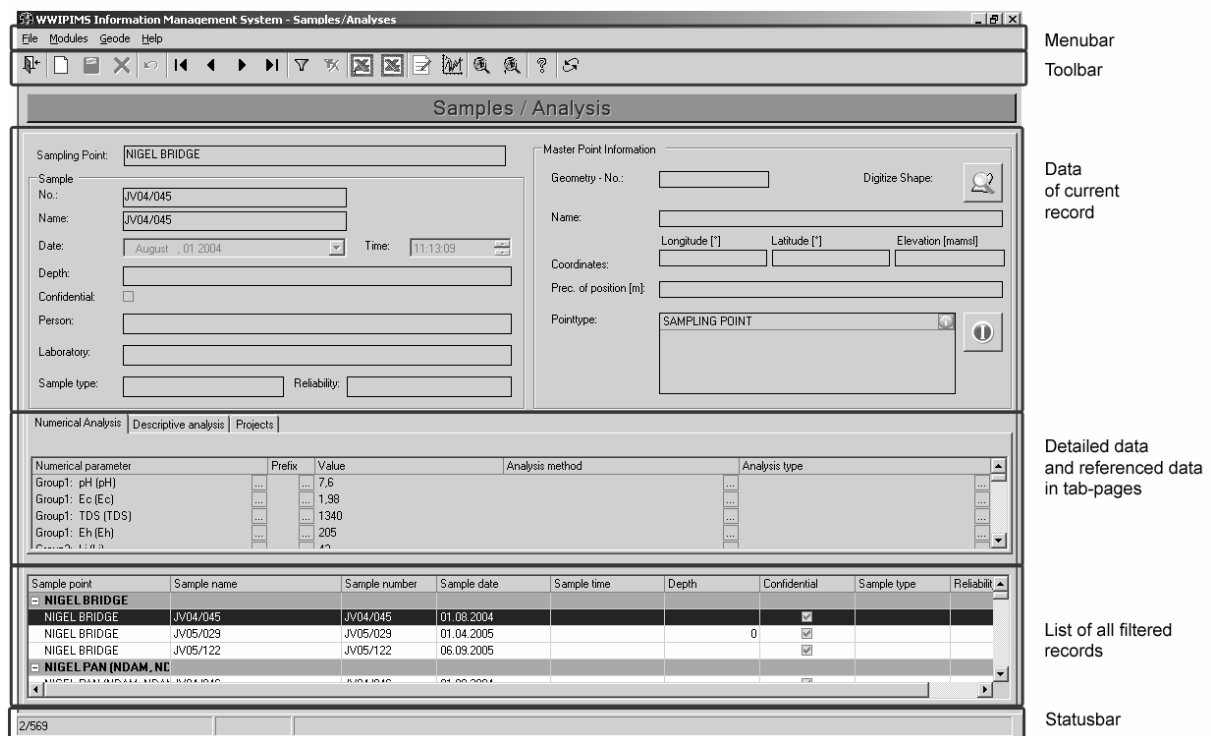


**Fig. 5**     **Basic components of modules**

## 3.5 GIS Components

The WWIPIMS application consists of two approaches for viewing spatial data, the GIS-Viewer and the GIS-Editor. The GIS-Viewer is based on MapObjects and can be used without having ArcMap 9.1. It is fully integrated in the application and appears as a separate module (see Fig. 6). After making a spatial selection in the GIS-Viewer there are functions to jump to the modules with detailed information about the selected elements or to the Meta Layer Information module showing the meta-data of the GIS-layer. From any module holding data connected to a GIS-layer, the GIS-Viewer opens when clicking on the GIS-button, showing the corresponding layer and zooming to the selected elements.
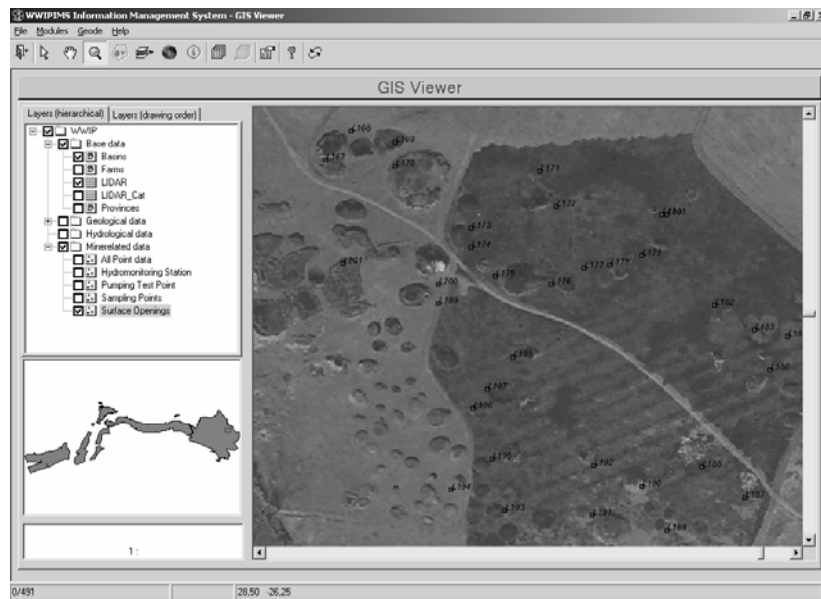
**Fig. 6      GIS-Viewer**

The GIS-Editor is an ArcMap-Extension (see Fig. 7). It is available for those users having a local installation of ArcMap 9.1. When clicking on a GIS-button in any module, ArcMap opens, showing the corresponding layer and zooming to the selected elements. In addition to the functions available in the internal GIS-Viewer, there are functions to edit the GIS-data.
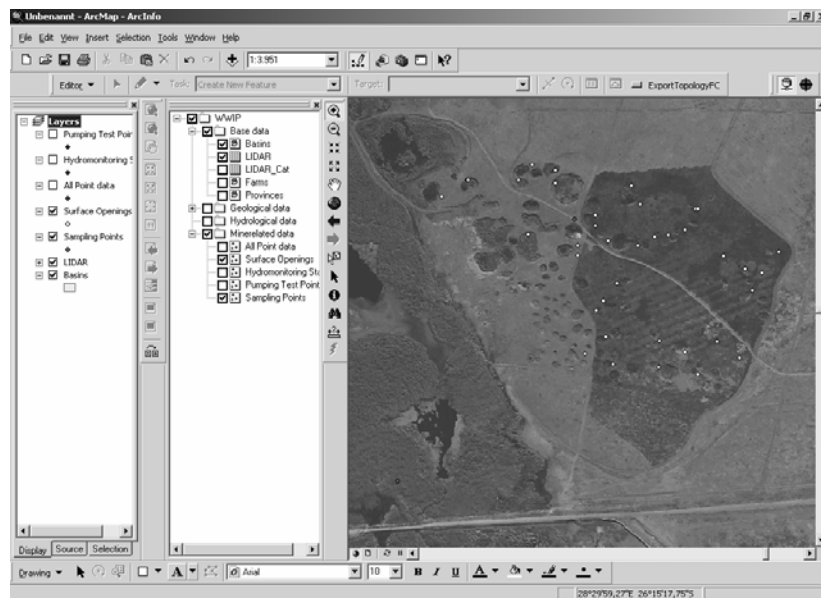


**Fig. 7      GIS-Editor (ArcMap)**

## 3.6  Special functions

Besides the basic functions like adding of new records, editing and deleting of records, which are available in all modules, there are some special functions. They include

- Extensive possibilities for inquiries

- Support for map printing on demand

- Support for data import and export

- Data-diagrams

Those functions are available wherever they are applicable.

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## 4   Conclusion

With the Information Management System of the Witwatersrand Water Ingress Project (WWIPIMS) a powerful database-application was developed to support the data handling for the WWIP-project. All relevant data can be accessed through easy to use interfaces with comprehensive sorting and inquiring functions. A GIS-component tops the application off, making provision for further spatial inquiries as well as spatial data editing and creating of map layouts for map-printing on demand.

This system forms the fundament for the efficiently handling of the diverse project-data.

## 5   Literature

CROUKAMP, L. & HEATH, G. (2004): Project Showcase – Witwatersrand Water Ingress Project – Council for Geoscience – In: South African Institute for Engineering and Environmental Geologists – Newsletter, Volume 02-04, June 2004, p. 6-7