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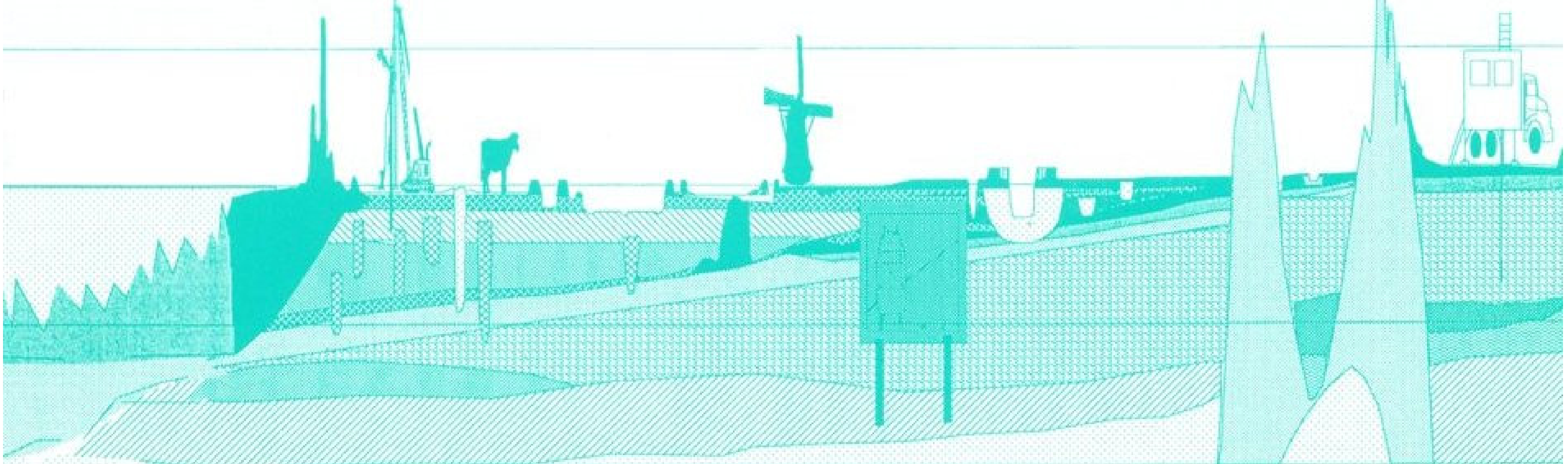

Editorial

Dear readers

It is our pleasure to bring you this issue, no 9, of Ingeokring Newsletter. Although the article submissions are not at desired rate the Ingeokring board and editorial board are determined to keep the quality of the newsletter high and to increase the number of releases in the near future. Thus, your contributions are very welcomed. Many contributions make this issue of the newsletter interesting to read. Below I provide snapshots of these papers.

In his message the outgoing president of the Ingeokring, Dr. Robert Hack shares his views on the status of engineering geology and engineering geologists in the Netherlands. He passes some important messages on how the future of the engineering geology profession should be shaped based on his broad experience and six years of Ingeokring chairmanship.

An article, submitted long ago by Prof. Dr. Ed F.J. de Mulder, discusses the social and environmental impacts of civil engineering activities in the Netherlands. He elaborates the past 25 years of engineering geological practice with four case histories dealing with large infrastructure projects in which the merging of civil engineering, earth science and social science disciplines is nicely presented. These examples illustrate the ever-increasing role of engineering geologists in subsurface, environmental, and geo-information technology projects.

In the book and CD-ROM review section, J.W.P de Bont reviews two books extensively. The books "Numerical models in geomechanics" and "FLAC and numerical modeling in geomechanics" are reviewed both from finite element and finite difference modeling perspective and also from application perspective. The application areas presented include modeling of underground structures, foundations, slope stability analysis, subsidence analysis, dynamic analysis of liquefaction due to seismic events, thermal analysis of nuclear waste isolation, etc.

Many of TU-Delft and ITC engineering geology graduates will remember their fieldwork days in Spain when reading the report on the excursion to Canalles dam. In this report R.M. Schmitz and S. Gyaltsen present a short history on the construction of the Canalles Dam, the site geology, engineering geological problems encountered during and after the construction of the dam, and the corrective measures which took many years and resources until proven successful.

M. Huisman provides a detailed overview of the road construction project in the north east of Spain, near the town of Riudecols. The project involves the realignment of a 4 km long stretch on the N420 road between the towns Coll de la Teixeta and Coll Negre. The design aspects of the cuts, excavation methods, and engineering geological characteristics of the area were introduced. The scope of the paper is the stability analysis of cuts and to introduce a new weathering classification of rock and soil masses.

R.M. Schmitz and others share their observations from the excursion to a suction hopper dredger. The excursion was guided by Robin Koster of HAM and found very enlightening by the participants.

A. Duque and others present the results of joint project carried out by the collaboration of Dutch (ITC, TUD) and Colombian (CRQ) organizations. The project, Rapid Inventory of Earthquake Damage (RIED) was aimed at a rapid assessment of earthquake damage right after a seismic event. The methodology is implemented in the city of Armenia that was hit by Quindio earthquake (M 6.1) in January 1999. The paper elaborates on the importance of aerial photography on rapid inventory tasks and presents the use of GIS to produce seismic microzonation maps including both topographic effects and subsurface conditions.

The guests of the "in focus" section in this issue are Ir. Marco Huisman and Ir. Siefko Slob. The interviews by S.R.K Vos and J.J. Heerema of DIG.

Last year (in 2000) two PhD fellows from TU-Deft Engineering Geology Section have completed their doctorate studies and obtained their Dr. degrees. In this issue we have included the summary of the PhD thesis of Klemens Heinrich, with a preface by his promoter Prof. Dr. D.D. Genske. The next issue will include the summary of the PhD thesis of M.A. Alvarez Grima. The summary provides the application of fuzzy sets and fuzzy logic in the assessment of contamination potentials. The application of these concepts in Multi Temporal Desk Study (MTDS) and the development of an expert system; Soil Assessment Fuzzy Expert System (SAFES) are also explained.

The sections on thesis abstracts, recently published papers and the others make this issue of the Newsletter worth reading. Thanks to all of the contributors and hope to see you very soon in the next issue.

Senol Ozmutlu

From the chairman of the Ingeokring

Dear Members,

This is the last time I will be addressing you as President of the Ingeokring. Throughout my period of office of six years, I have been addressing you with certain regularity in the Newsletter of the Ingeokring. This gave the option to express my personal opinions and concerns related to engineering geology. Looking back over the last six years some major changes have occurred in the engineering geological society in The Netherlands as well as how the work in the profession is done as in how the profession is organized. Information technology further penetrated the profession. More or less all-engineering geologists use GIS, databases, drawing programs, and computer aided statistics to facilitate their work. Six years ago, a novelty was a bored tunnel; nowadays they have become a normal feature in the Dutch soil and the work of many engineering geologists is related to bored tunnels. Another new field is the rapid grow of the hazard and risk analyses by engineering geologists and the involvement of engineering geologists specialized in hazard and risk assessment in management consulting firms. Seemingly, the Dutch engineering geologist is a species that easily adjusts to new techniques and methodologies.

On the education front major changes occurred. When I started the office the late Professor David Price had just retired. A new professor was appointed and left two years later. After his departure, an uncertain time started as the impression was sometimes given that appointing a new professor for engineering geology had no high priority. The 50 % appointment of Keith Turner was therefore highly important, as it returned to engineering geology its position and status within the academic world. The educational system of ITC changed completely and prohibited a full integration of the TUD and ITC engineering geology courses as had been usual during the last twelve years. In September 2001, this will be partially resolved as a new International Master of Science course given in cooperation between the TUD and ITC will start. In Amsterdam and Utrecht, the related education in applied geology and applied geomorphology underwent major changes. Regrettably, mostly negative, due to reduction of staff and merging or dissolving of different educational fields. Throughout the Netherlands, the reduction of the number of Dutch students in the earth sciences is worrying. If no students are coming clearly education will stop, and after some time the profession will die.

Another point of concern is still the professional registration. The integration of Europe also causes changes for the engineering geologist in The Netherlands, although at the moment this is not too obvious. It is likely that within due time the EU will require professional registration of all engineers, e.g. all engineers that independently will advice on engineering constructions involving social, human, environmental, or financial risks. In itself this is a good idea. The profession will get rid of many impostors who may have read a book on engineering geology, but are by no way engineering geologist. However, a typical Dutch problem will arise. In the Netherlands, the final degree is based on the first years of education. Engineering geologists educated in their first three years as geologists obtain the title of ‘drs’ and engineering geologists educated the first three years as engineer obtain the title of ‘Ir’, both having followed exactly the same engineering geology education in the last two years of their study. The registration of the engineers may be no problem, as this will be organized via the European Federation of Engineers, with which the KIVI is associated. For the geologists the situation is less straightforward. The European Federation of Geologists is unlikely to obtain the right to register engineers or engineering geologists, and above all is a dying or dead body. Hence, in the future engineering geologists originating from geology may first have to become a KIVI member and may have to register by doing an examination in engineering or engineering geology. Alternatively, they can join, for example, one of the British Institutions, register via the British Engineering Council, and become a European Engineer (as your president is). Both ways seem not optimal and it neglects the importance of engineering geology in the Netherlands in its own right. A far more attractive option would be an independent registration body for engineering geologists that registers engineers and geologists, provided they have the necessary minimum education and expertise in engineering geology. This is similar to the arrangement in the US where the Association of Engineering Geologists acts as accreditation body and facilitates the state registration as an engineering geologist, which is required by law in many American states.

Employment for engineering geologists has never been a problem, but certainly not now as the market is booming and engineering geologists are a species wanted by many. A negative side affect is that everybody seems to be so busy that they do not have time to write for the Ingeokring Newsletter. Needless to say that I regret this very much. The editors have extreme difficulties to get appropriate articles and text for the Newsletter to have it published regularly. However, considering the number of members it is an achievement that a Newsletter is published at all, albeit irregularly.

In the last six years, the Ingeokring did very well. The number of members was more or less constant and about seven times per year a presentation or excursion was organized attended by respectable numbers of members. A successful congress was organized marking the celebration of 25 years engineering geology in the Netherlands. Further were held two seminars on topic of the contents of education in engineering geology.

These activities would not have been possible without the active members of the Board of the Ingeokring and of the DIG, and I like to take this opportunity to thank the members of the Board and the DIG in the last 6 years for all their work and efforts to make the Ingeokring to a success. My successor as proposed by the Board, has already been active in the Board and I trust that he will be able to continue the success of the Ingeokring.

For now, I say goodbye and wish you all a very good engineering geological future.

Robert Hack

Engineering Geology & Infrastructure – Environmental and Social Impact

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In this paper some experiences will be discussed concerning the impact of civil engineering activities with an environmental dimension on the subsurface conditions in the Netherlands and vice versa, as gained in the Geological Survey of the Netherlands over the past 25 years. These comprise the planned and later disbanded proposal to reclaim the Markerwaard polder and a feasibility study on geological storage of nuclear waste disposal in buried rock salt occurrences in the North-eastern part of the Netherlands. In addition, some attention is paid to the development of geology-based data information systems for urban areas. Finally, a vision is displayed on a system which would make the entire Dutch Delta, as one of the world's best known deltas, transparent. In the first pages of this paper some information is given on international cooperation in the fields of engineering and environmental geology.

INTRODUCTION

The title of this paper: Engineering Geology and Infrastructure suggests both terms are not dealing with the same issue. That suggestion is wrong. According to a leading Dutch Encyclopaedia, Winkler Prins, Infrastructure has two meanings. The first meaning is 'supportive structure' (onderbouw) often used in a non literally sense. It is applied for military and economic purposes as power plants, factories, waste dump sites, physical connections, but also for social purposes as organizations, even for laws, education level, public health care, hospitals and management structure. In short: everything needed by an organized society. The other meaning of Infrastructure is a geological one: it refers to the deeply seated, strongly folded and metamorphic parts or to the roots of mountain chains. So, both terms have one component in common: Geology. Geology provides the supportive structure to the Engineering geologist and provides literally and often non-literally, the roots for Infrastructure. Physical infrastructure is often constructed in the subsurface but even at surface or above surface infrastructure is physically linked with the subsurface. To emphasize this special dimension of infrastructure, the new Geological Survey of the Netherlands (NITG-TNO) has created a separate department on Geo-Infrastructure. The Engineering geologists in the Survey are all grouped in one Section, which is part of the Department of Geo-Infrastructure.

In this paper both terms Infrastructure and Engineering Geology will be used in a broad sense. According to the title of this presentation, as given by the organizers of this meeting, both terms in turn have to be linked with two non-physical terms: social and environmental impact. As there is no such thing as social impact of Engineering Geology it is understood that Engineering geologists deal with natural or man-induced geohazards on the one side but also with the natural or man-induced geo-assets on the other. As will be demonstrated later in this paper, these all have distinct socio-economic and environmental dimensions. We have now arrived in the fields of what is informally called Applied Geology, which may comprise the engineering geologist, the geomorphologist, the geochemist, the geohydrogeologist, etceteras. I will not attempt to give formal definitions to all these terms. What I do think that is important is that all these fields of expertise directly deal with Geoscience for Society, and that is what the organizers of the jubilee meeting of today are heading for.

On an international level we notice a struggle of the Engineering geologists to be linked with the environment. This struggle started about ten years ago when the environment suddenly emerged as a potentially profitable field, also for geoscientists. The environment was not yet claimed by one of the existing scientific bodies as the International Association of Hydrogeologists (IAH) and the International Association for Engineering Geology (IAEG). Therefore the International Union of

Geological Sciences (IUGS) created a new Commission on Geoscience for Environmental Planning (COGEOENVIRONMENT). This Commission was charged with the task to raise awareness in the public and among fellow geoscientists on the strong contribution geoscientific expertise can provide to solve or reduce environmental problems. COGEOENVIRONMENT has developed various new fields in Applied Geology through the International Working Groups on Urban Geology, on Environmental Geo-Indicators, on Geoscience and health and, this summer, on Geoscience and Ecology. Although the Engineering geologists united in IAEG were involved in this IUGS initiative right from the start, IAEG was not happy that the environment was not clearly visible in its logo. Finally, IAEG changed its name into the International Association of Engineering Geology and the Environment, in June 1997.

The International Association of Engineering Geology is a large professional body with over 5000 members, half of them from Europe and some 100 in the Netherlands, which is only 4%. Despite of its low number the Dutch have played a significant role in this association for many years. This is now acknowledged and materialized by the vice presidency of Niek Rengers.

This brings me to the role of the Engineering geologist in the Dutch context and more particularly to the distinction between civil engineers and engineering geologists. Traditionally, civil engineers are seen as the ones who constructed the Netherlands. They have protected our coastal zones and river plains against flooding and they have reclaimed most of our inland lakes and even parts of the sea. That was done long before David Price raised the first engineering geologist, starting in 1976. Geologists of the Geological Survey have been cooperating with civil engineers since the nineteensixtees in several coastal protection works in the Province of Zeeland and in land reclamation studies in Lake IJssel, trying to bridge the gap between civil engineers and the earth scientists. In general, civil engineers consider the subsurface as a highly unpredictable medium filled with all kind of nasty surprises. Therefore, civil engineers need to have as many data points as possible and they heavily rely on site investigations, preferably cone penetration tests because these can be quantified. Once possessing these data, civil engineers have great difficulties in extrapolation of the data into a spatial, three-dimensional context. The geologist on the other hand starts from a rough regional geological scheme and tries to zoom in into a specific spot. A geologist generally is optimistic about his or her abilities to predict the geological situation on that spot and considers the number of surprises very low. A geologist needs additional subsurface information only as confirmation of his or her views about the actual situation at a particular spot. The only problem with the average geologist is that he or she is unable to quantify or to express the geological conditions into terms, which form the basis for any construction. That, exactly, is the niche to be filled by the engineering geologist.

The evolution of the position of the engineering geologist in the Netherlands will be illustrated by means of four case histories as drawn from my own experience over the past 25 years.

CASE HISTORIES

Markerwaard

In the late 1970’s the Dutch government planned to reclaim part of Lake IJssel by using the polder model, i.e. constructing a circular dike in the lake and extracting some 5 meters of lake water by pumping. From earlier land reclamations it was anticipated that extracting large volumes of water would severely impact the groundwater tables and groundwater flow direction. This, in turn, would cause settlement of the thick bodies of peat and soft clay in the surrounding hinterland resulting in land subsidence and negatively impact the already weak foundations of numerous old houses in the historic towns surrounding Lake IJssel. In addition, lowering of the surface water tables by pumping would reduce the crop yield in the agricultural areas and reduce the number of animal species in the wetlands surrounding the new polder.

A team of experts consisting of geologists, geohydrologists, geomechanical engineers, civil engineers, and layman, was formed. They calculated the amount of settlement and land subsidence for the area in the wide surroundings of this to be reclaimed polder, the Markerwaard. Strong, local differences in results were explained by the detailed, applied geological maps, which the Geological Survey was able to provide because the regular geological mapping of the area was just completed. Based on this information a prototype of a GIS was build to calculate the expected costs of foundation failure to constructions and of lost crop yield due to the lowering of the surface water levels. Total costs to failed constructions, lost crop yield and ecological damage were calculated at approximately 800 million Dutch guilders, at the 1981 price level.

Remediation of the problems was considered possible by artificial recharge of fresh water into the aquifers through numerous infiltration wells, particularly situated around towns. Total remediation costs were calculated at 160 million Dutch guilders and for maintenance of the wells at another 15 million Dutch guilders annually. It has been the first time that such accurate figures on the economic and environmental impact of large-scale infrastructural measures could be provided by a professional team of scientific consultants before implementation. The anticipated costs of the planned construction of the Markerwaard polder seriously influenced the government decision in 1986 to postpone the decision for reclamation of this polder for at least two decades.

DISPOSAL OF RADIOACTIVE WASTE IN THE DUTCH SUBSURFACE

Another large-scale project in which many disciplines were involved is the study on the environmental impact of radwaste geologically stored in deep seated rock salt structures of Zechstein Age in the Dutch subsurface. Safe storage of hazardous waste materials can be considered as part of the nation's infrastructure. The first option for a geological disposal of nuclear waste in the Dutch subsurface was determined for rock salt. Huge rock salt diapirs and cushion shaped structures occur in the Northeast and East part of the Netherlands. Some of these are currently mined for salt. Rock salt has excellent sealing and heath transporting characteristics and many of such structures occur at possible mining depths in the Dutch subsurface.

In the period 1985 – 1993 several studies have been conducted on the safety of storage of high-level radwaste material in such rock salt structures. The first studies revealed the presence of 38 such structures the top of some of which is situated less than 100 meters below sea level, which approximately equals surface level (Rijks Geologische Dienst, 1989). These diapirs appear to be related to and developed from major fault structures in the subsurface. According to the Dutch safety criteria, high-level radwaste should be shielded from the biosphere for at least 100,000 years. Conservative hydrogeological contaminant transport modeling by means of the METROPOL model revealed that contaminants from leaking canisters stored in these dry caverns excavated in the rock salt bodies would normally not enter the biosphere within a period of less than 100,000 years. One of the studied scenarios concerned an expected ice age between 50,000 and 100,000 years, with partial coverage of the rock salt structure by 600 to 2,400 meters of inland ice. Civil engineers and engineering geologists jointly calculated the impact of this event on the stability of deep-seated rock salt structures. These studies showed that additional halokinetic rise of the salt bodies due to the ice load of maximally 6 meters is to be expected under the most extreme conditions which would not significantly put the structure at threat to erosion and exposure of the depository to the biosphere (Prij & Benneker, 1989). The worst case glaciation scenario for the next 100,000 years would however be the occurrence of deeply incised glacial tunnel valleys connected to the melting phase of specific glacial periods, as during the Elsterian, some 400,000 years ago. In combination with the effects of other (peri-) glacial processes such tunnel valleys may cause erosion of the salt rock structures up to depths of maximally 540 meters and may expose shallow depositories to the biosphere.

In 1993, the Dutch Parliament decided that storage of nuclear waste in the (deep) subsurface would be allowed only if such material could technically be retrieved at any moment in the future. Because of the geomechanical characteristics of rock salt having a high creep factor, repositories in rock salt caverns would, without measures, not be accessible after several centuries anymore. For that reason the Dutch program on safe storage of radwaste shifted focus towards consolidated clay bodies in the Dutch subsurface. Again, the geomechanical properties of this newly proposed host material are critical to determine the suitability of such buried bodies for final storage of nuclear waste and possibly also other hazardous materials in the Dutch subsurface.

In this case history, hydrogeologists, engineering geologists, and civil engineers worked together in predicting the effects of human-introduced hazards in the subsurface to the health and safety of future generations. In contrast to the Markerwaard case, the results of advanced environmental safety model calculations have not at all been decisive for the political decision for a retrievable storage. Also in contrast to the Markerwaard case, the economic dimensions of the proposed solutions were not considered relevant here. A final decision on this issue by the Dutch government is not expected to be taken in the coming 25 years.

UMIS

The completion of a very large project on the geomechanical subsurface quality in 200 Dutch towns in 1995, amongst others resulted in the addition of 6,000 digitized bore hole descriptions to the already large digitized files of subsurface data of the Dutch subsurface. Direct access to so many quality data brought the Geological Survey in the position to extend its geoscientific advisory work from the national and provincial levels towards the local levels. It was noticed that Dutch municipalities gradually become more interested in their subsurface conditions supported by digital data.

In 1995 the Geological Survey (NITG-TNO) developed an information system dealing with the subsurface quality of cities and towns, Ondergronds Gemeentelijk Informatie Systeem (OGIS) or: Underground Municipal Information System (UMIS). This system basically consists of three components: a database, a GIS, and calculation modules. The UMIS database is filled with digitized NITG-TNO borehole records and cone penetration tests relevant to the client's management area. The client's own subsurface data, including those on soil contamination, are digitized and added to this database. The accompanying Geographical Information System (GIS) is an Arc/Info and ArcView product, which can easily be converted into other systems, as e.g. Intergraph. The thematic map modules will enable automatic production of several types of maps based on a geological model of local subsurface conditions. Examples of such modules are: cross-sections of the subsurface along any desired line, foundation-depth and foundation-cost maps, maps on the average sand, clay and/or peat content at various depth ranges, maps showing potential settlement or differential settlement, groundwater-flow maps, salt-intrusion maps, and general subsurface pollution-distribution maps. During the UMIS development phase a customer advisory group of representatives of Dutch cities and towns proved to be of vital importance in designing the product. Each UMIS product is custom-made and differs from other types of information systems that it basically gives a three-dimensional representation of the subsurface conditions both in terms of the geometry of layers and of the characteristics of individual layers.

UMIS has received substantial attention, particularly abroad. It is user-friendly and no background knowledge of geology or geology-related disciplines is required. The system allows the user to evaluate ground conditions on the computer screen. Using the mouse, one may, on the screen, 'walk' along a street and 'split open' the ground, exposing a cross-section through the subsurface. Through UMIS, the subsurface implications of various plans can be evaluated and the approximate financial and environmental consequences of various options can be calculated at a very early stage, before (expensive) consultants are involved. UMIS has been applied for part of the city of Haarlem, the Netherlands.

This case marks a shift in approach from engineering geologists towards the potential users of geoscientific expertise. Were engineering geologists responded to invitations to participate in teams dealing with major infrastructure studies with a high economic (Markerwaard) or environmental (radwaste) impact, in this case geoscientists took a clearly proactive position towards the market.

DIGITAL DELTA

Where UMIS is particularly developed for limited areas, i.e. towns and cities, a similar concept may be applied for larger regions, e.g. provinces or even countries. Born from the understanding that so many digital subsurface data (>400,000 bore hole descriptions and cone penetration tests) are currently stored in and available from the files of the Geological Survey (NITG TNO), a three-dimensional representation of the subsurface conditions can be developed through a powerful GIS. Moreover, abundant subsurface data are presently scattered over numerous archives in practically all municipalities, with project developers, power line companies, consultants, provincial bodies and public works bodies in the Netherlands. A rough, but conservative estimation indicates that between 2,5 and 3 million cone penetration tests and bore hole descriptions have been made in the Netherlands which would be an average of more than 70 data points/km2. Obviously, these data will be spread unevenly over the country and most of these will be concentrated in the urban areas in the West. Nevertheless, this makes the subsurface of the Netherlands one of the best known deltas in the world.

The ambition of the Digital Delta concept, as launched in 1998, is translating as many as possible of the so far hidden, scattered subsurface data into digital formats that can be read by one or by different remote information systems operated by different suppliers. This would create a virtual multi-supplier database. The next step would be the geological interpretation of the data based on a proper understanding of the geological succession of layers in the delta. Implementation of these two steps would give access to a three-dimensional representation of the subsurface for wider regions in the delta. Since it would not yet be feasible to apply this concept for the entire delta, a regional approach of the Digital Delta can be realized on short notice. This instrument would be particularly helpful for the upcoming Dutch knowledge boosting programs, like Delft Cluster, dealing with spatial development, underground structures, and soil-subsurface management. Together with the notion that both politicians and the general public have now gained a significantly more positive view on the subsurface as potential problem-solving dimension, it is believed that instruments as Digital Delta would be more successful in the market than a decade ago.

This last initiative particularly marks a new approach of engineering (applied) geoscientists toward the potential markets: proactive, open to co-operation, arranging multi-partner teams for holistic solutions, integration of databases and data management systems, public private partnership, appreciating the benefits of an accessible, public data system, avoiding a single-supplier approach.

CONCLUSIONS

1. Engineering geology and Infrastructure have (literally and non-literally) subsurface roots in common;
2. Environmental and socio-economic issues are presently becoming integral parts of the geosciences, both in the Netherlands and abroad;
3. Applied and engineering geoscientists are in the process of moving from responsive towards proactive activities towards the market;
4. Particularly in the Netherlands, a substantial growth potential in the demand for applied geoscientific expertise is foreseen due to a significantly more positive view on the subsurface as a problem-solving dimension by politicians and the public;
5. The Dutch subsurface has been perforated already by more than 3 million bore holes or cone penetration tests averaging close to 100 data points/km2.
6. The abundance of data together with a century-long geological mapping practice makes the subsurface of the Netherlands one of the best known deltas in the world;
7. The newly established co-operation among the major players in the fields of the applied geosciences both in academic circles and in the private sector, lubricated by the Dutch knowledge boosting programs, will accelerate a three-dimensional understanding of the subsurface structure and its properties. This will result in a better predicting performance by engineering geologists, and, consequently, will generate higher market demands. Engineering geologis ts will all win through co-operation.

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Book & CD-ROM review

Numerical models in geomechanics

G.N. Pande, S. Pietruszczak, H.F. Schweiger (editors), 1999, A.A. Balkema, Rotterdam/Brookfield, pp. 676, ISBN 90 5809 095 7, price: EUR 110.00

FLAC and numerical modeling in geomechanics

C. Detournay, R. Hart (editors), 1999, A.A. Balkema, Rotterdam/Brookfield, pp. 512, ISBN 90 5809 074 4, price: EUR 100.00

The first book, 'Numerical models in geomechanics' contains the proceedings of the 7th international symposium on numerical models in geomechanics (NUMOG VII), held in Graz, Austria, 1-3 September 1999. The second book 'FLAC and numerical modeling in geomechanics' contains the proceedings of the first international FLAC symposium on numerical modeling in geomechanics, held in Minneapolis, USA, 1-3 September 1999. This symposium was organized as a way to celebrate the 15th birthday of the FLAC finite difference program. As both books cover the same field of specialization it was considered sensible to present them in a combined review article.

"Numerical models in geomechanics" presents an overview of the type of geomechanical modeling research that is currently being performed throughout the world and therefore also gives an indication of those areas within the field of geomechanics where knowledge is not yet at the level desired for practical problems. This makes the book interesting not only for people concerned with computer aided modeling and development but also for those with a more general interest in geomechanics. The book is, as all publications presenting multiple individual contributions of different authors in one volume, not readable in a straightforward manner. Most included papers require an in-depth mathematical understanding of related phenomena, but offer the reader interested in the subject usable openings for related research.

The book is divided in five sections, each of which contains contributions related with a certain subject. Section one presents papers on constitutive relations for geomaterials. Many papers in this section are related to research on elastic-plastic and elastic-viscoplastic material behavior in soils. Some advances have been made on the specific modeling of unsaturated soils, but most contributions deal with general time-dependent or anisotropic soil behavior. Damage-theory and hypoplastic models have been adjusted for such behavior.

Section two focuses on modeling of instabilities and strain localization in geomaterials. Here the main attention is on shear deformation in granular soils, mostly modeled using shear bands. A number of papers relate to polar effects in such shear bands, others describe the influence of initial anisotropy. Interesting are developments on mesh refinement used in strain localization methods.

The third section contains contributions on numerical algorithms. Contributions are nearly all based on finite element modeling. Advances have been made using parallel computing, while one paper focuses on inverse analysis to be used for parameter determination from in situ tests. Constitutive behavior that is being modeled in the proposed algorithms again mainly relates to soils.

Section four deals with modeling of transient/coupled and dynamic problems. Few authors investigated problems including heat transfer; fluid-solid coupling was given more attention. A number of authors investigated the behavior of unsaturated soils under coupled flow-deformation problems, including a paper on unsaturated drying. Several papers in this section should be interpreted more as practical applications than as theoretical investigations. An interesting contribution in this regard is a paper on the behavior of pile groups founded in liquefiable sand under dynamic loading.

The last section focuses on practical applications and is subdivided in four different parts (underground structures, foundations, slope stability and other applications), which together cover half of the total publication. The part on underground structures contains a number of papers that are interesting for tunneling practice in the Netherlands. For example, a description is presented of force-redistribution within piles due to shallow tunneling, ultimately leading to plastification of piles. Furthermore expert system assessment of ground movements and related damage on structures when constructing tunnels, as well as the calculation of stresses within tunnel tubes, has been investigated by other authors. An interesting case history relates to the design of the Bolu tunnels in Turkey. These three-lane twin tunnels are being constructed since 1993 in the immediate vicinity of the North Anatolian Fault Zone in highly squeezing ground; some severe problems have arisen and been solved.

The foundation part contains a number of analyses on pile foundations, among which are investigations concerning ordinary piles under liquefaction and cyclic lateral loading conditions. Furthermore several authors have performed research on different aspects of offshore construction foundations. For example a modeling sequence performed on bucket foundations is reported in a convenient way. Similarly understandable are two contributions on anchored offshore structures. One relates to suction anchors, while the second relates to drag-anchors. Here, the authors focused on the interaction between the anchor fluke and the soil during kinematic analyses. Finally, an author's contribution is worth mentioning which describes research performed on the lately developed plate-penetrometer. This piece of equipment can be used in site investigation related to offshore geotechnical engineering.

Part three, with focus on slope stability problems, again contains properly readable and interesting papers, three of which are worth mentioning here. Firstly, an analysis has been carried out using discrete element methods on granular flow behavior. The authors investigated the process of inverse grading during such flow and checked their results with laboratory experiments. Secondly two authors contributed a paper regarding finite element analysis of slopes reinforced with piles. Factors of safety were based on limit equilibrium conditions. Finally a procedure has been proposed for stability assessment of cuts and fills. This procedure uses a technique developed for collapse settlement analysis to simulate strength reduction, leading to an appropriate way to determine factors of safety.

The last part of section five contains all papers that could not be appropriately categorized above, most of which are quite interesting and easy to follow. Some of these papers refer to problems that are not readily related to geomechanics, but to environmental issues instead. For example, alkali-aggregate reactions in concrete hydraulic structures, soil compaction due to agricultural traffic and biodegradation in waste refuse are discussed. Other authors describe problems that are not extensively encountered, but not easy to overcome either. For example the mechanical and thermal interaction between ice covers and hydraulic structures is analyzed on the basis of a case history. Also a dynamic analysis is included of rockfall restraining nets constructed of ASM rings, which has resulted in complete computational software. Finally a contribution should be mentioned based on the analysis of unreinforced masonry shear walls, using a lower bound in-plane strength criterion.

The second book, ***"FLAC and numerical modeling in geomechanics"***, relates very much to similar topics as are discussed in the first book. All calculations described by the authors of papers presented in this book are performed using the commercially available code FLAC (Fast Lagrangian Analysis of Continua). The book is divided in eight sections, each focusing on particular types of problems encountered in geomechanics.

Before starting the discussion on the contents of this book, we will first describe the FLAC code in short. As stated above, FLAC is based on a Lagrangian calculation scheme, which means that during each time step incremental displacements are added to renew the position of material points. In contrast, one can describe a material by keeping track of its deformations at fixed gridpoints: the Eulerian approach. The Lagrangian approach makes FLAC well suited to describe large distortions. Furthermore FLAC uses an explicit calculation scheme: the constitutive and equilibrium equations applied in each time step govern direct relations between forces and displacements for each element. Implicit methods on the contrary govern indirect relations, while every element is related to every other element. Whereas implicit methods are quick in resolving linear, small distortion problems (in which case no time-stepping is needed), explicit methods (time-stepping always needed) are usually more optimal when investigating large problems with non-linear material behavior.

The first section of the FLAC volume contains contributions related to embankment and slope stability problems. Several authors tested the calculation of different types of slope stability problems using the method of shear strength reduction in comparison to more established methods like limit equilibrium calculations. Others have tested the possibilities of modeling complicated failure behavior of slopes in FLAC. Such testing was mostly performed by back analysis of either natural or constructed slopes of which a large number of monitoring data was available; a single author used results gained from centrifugal testing. Some specific case studies are included, two of which are interesting as they discuss the complicated influence of some natural phenomena on stability problems. The first paper relates to wetting-drying cycles and their influence on soil slope deformation. Using deformation properties that were determined by triaxial testing, numerical modeling results were compared to observed slope behavior. The second author describes the influence of seepage and soil suction on riverbank stability. Comparison between calculated and measured effects due to flooding in two rivers showed that both location of failure and geometric forms of failed masses can well be predicted. The main cause of failure in stratified riverbanks is the combination of low soil suction values and high seepage forces. These conditions are governed by the presence of low permeability layers during the drawdown phase of a flood.

Section two focuses on coupled processes and fluid flow. Here FLAC has for example been used for consolidation prediction of tailings and fluid flow through fractures. Furthermore a solution is proposed to deal with thermoporoelastic problems in FLAC. A combined calculation of thermal effects and groundwater flow is not possible in the current version of FLAC. Therefore some algorithms have been established in which the groundwater calculation is suppressed during thermal calculation and vice versa within each cycle of calculation. The algorithms were tested on situations for which an analytical solution existed; they proved to perform properly.

Failure and collapse analysis are dealt with in the third section. Five papers are presented here, all equally interesting and all using FLAC to model very specific problems. One author demonstrates the usage of a code based on the same techniques as FLAC to model lithospheric rifting and buckling with special attention to problems encountered when modeling large scale faults. Strain localization techniques are used in another paper to predict similar large scale fault patterns in typical geological situations. In a third contribution it is demonstrated how problems related to glacial dynamics can be investigated using an implemented anisotropic flow law. Furthermore research is described which has been performed and evolved during the past decade, in which fracture of rock particles by crushers is modeled. It is shown here that in this respect FLAC can well emulate with distinct element and particle flow codes. Finally the shrinkage cracking pattern within continuously reinforced concrete pavements is analyzed and compared to results from experimental tests.

The fourth section relates to underground cavity design and mining. Some elasto-plastic and damage analyses of tunnels are included, as well as a number of case histories regarding subsidence due to different mining methods. More interesting however are the case histories on several tunnels currently being constructed in major urban areas throughout the world. One of these tunnels is a twin road tunnel in Gothenburg, Sweden. The tunnels are constructed in rock, with their roofs more or less at the level of the bedrock-overburden boundary. The eight meter overburden is overlain by some six meters of moraine. A portal of these tunnels happens to be located below the corner of a large, subsidence sensitive building. The pressure of two pillars of the building foundation will have to be transferred through the tunnel to the bedrock below. A numerical simulation has been carried out to investigate the stability of both the building and the tunnel portal. Deflection in the tunnel roof was calculated to be about four times larger due to the pillar pressures then under normal conditions.

The fifth section deals with nuclear waste isolation. Nearly all papers in this section focus on thermo-mechanical effects around underground repository sites. Both near and far field calculations are described. One author discusses the stability of a shaft leading to a repository gallery which has been constructed in 1982 in Mol, Belgium. The shaft was constructed through some 188 meters of sand and 35 meters of clay. Its stability was calculated in FLAC by simulating the entire excavation phase by phase.

Dynamic analyses are discussed in section six. The two main issues being described and discussed here are liquefaction due to seismic events and mining tremors related to induced seismicity around mines near major fault zones. Research has furthermore been performed on calculation of rock mass damage model parameters using microseismic measurements. Input data like material properties and location and size of the microseismic events result in softening and anisotropic rock mass deformation properties. Another interesting contribution relates to shock-wave propagation in soil. Soil-structure interaction after bomb explosions was regarded by inserting a typical time-spectrum shockwave occurring after such an explosion.

Section seven contains further papers on soil-structure interaction. A complete scala of case histories is included, e.g. on bridge abutments, diaphragm walls, caisson and raft foundations, pipejacking, etc.. We will not discuss these any further.

The last section relates to constitutive models. Most interesting is a critical state soil model useful

to model inelastic behavior of overconsolidated clays. The model includes hysteretic damping in undrained situations and can very well be used for cyclic behavior.
As can be seen in the above described examples, the FLAC volume in comparison contains much more practical applications than the NUMOG volume. Apparently FLAC is not often used as a true research tool. This can be explained from the fact that, although the program contains possibilities to implement e.g. new constitutive models via so-called FISH-functions, users do not have direct access to its source code. The latter is usually essential for long-term or complicated research to investigate and expand the possibilities of a numerical program; many institutes tend to develop their own software. The NUMOG volume furthermore describes certain subjects (e.g. hypoplasticity, nano-scale modeling, shear bands and strain localization) that are not or only marginally addressed in the FLAC volume. On a whole the reader will therefore gain information on current possibilities of computer aided modeling within the geomechanical workfield from both books; when interested in the latest research developments one should read the NUMOG volume. Finally it should be said that proper understanding of tensor analysis and partial differential equations is required to be able to read these books fluently.

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Excursion to the Canalles Dam

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It was the 3rd of May when the staff and the students of ITC and T.U., Delft at Cambrils had to wake early in the morning in order to be able to leave for the excursion to the Canalles Dam by 7 am (see figure 1). The weather didn't seem to be favorable as dark clouds filled the skies and it was not long before we left Cambrils that the rain started pouring. It continued to rain the whole day with slight variation in the intensity.

The group left Cambrils at 7:15 am in the six vehicles that were rented for the fieldwork and the first stop was made at 8:45 am at a roadside restaurant for breakfast. The restaurant was very good, however it's services was not appreciated by most of the students. It took more than 20 minutes for some of the students to get what they wanted and the drawback of not being able to speak Spanish seemed to be one of the reasons as priority was always given to the Spanish speaking customers who arrived later than us.

Figure 1. *The location of the Canalles dam. Cambrils is located near to Tarragona. (Source ENHER brochure of the Canalles dam).*

It was at 12:30 p.m. when the convoy came to halt and we had the first sight of the Dam. The staff members pointed out the key features of the Dam and asked us to note the orientation of the joints on the left side of the Dam. Within a few minutes drive from the last stop we arrived at the site office of MITGA, who was responsible for the construction and the operation of the Dam. A senior staff of the company along with two of his colleagues welcomed the group and explained briefly through Mr. Sooters about the features of the Dam. The group was then taken around the dam and all the key sites were shown. The following were the various observation made:

The Canalles Dam was built on Jurassic limestone. The bedding of the limestone was favorable for the construction of the dam. However some geotechnical parameters, i.e. the presence of the karst in the limestone, the orientation of the joints along the sides that were either ignored or overseen during the construction phase turned out to be major problems for the success of the dam project.

The problems related to the infilling of the dam are due to the geological problems on the right and left bank of the river. As the problems are different on the two sides, their geology will be discussed separately.

GEOLOGICAL PROPERTIES

The left bank of the dam (see figure 2)is located in the Massive Jurassic Limestone of Blancafort which are folded.

The main lithologies are :

Estratos De Margas Hondas = deep marls
Calco Arenitas = limey marl and sandstones
Calizas Blancas = gray limestones showing indications of karstifications
Capa Negra = black layer
And again: Calizas Blancas which are outcropping into the reservoir.

These strata are dipping upstream and folded with it's fold axis, parallel to the flow of the river. This geological setting and the misinterpretation of the geotechnical properties of these strata were responsible for the main problems during the filling of the reservoir.

Problems arose on the right side of the dam due to the unfavorable joint orientation with respect to the stress distribution by the dam. This called for additional remedial measures to be taken.

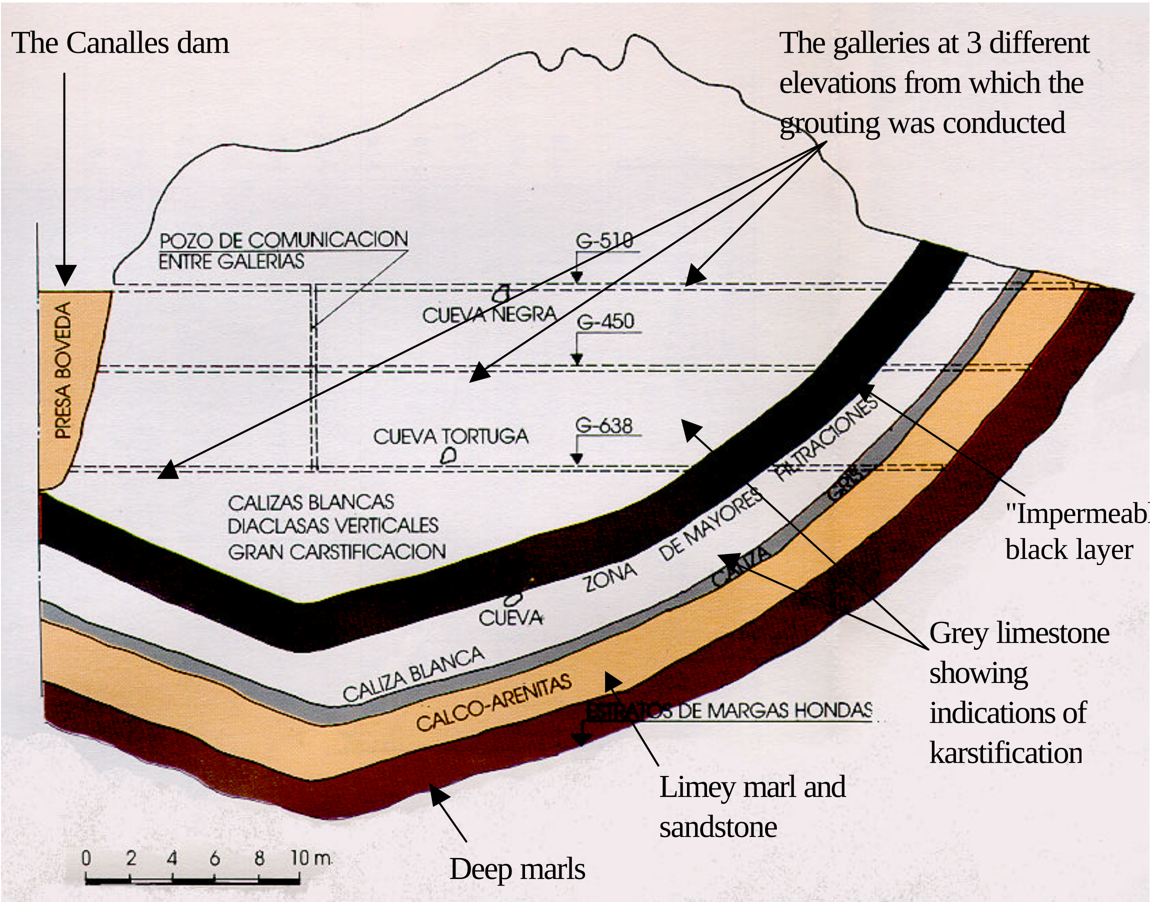

Figure 2. *A geological section through the left bank of the dam.(source ENHER brochure of the Canalles dam).*

LOCATION AND DIMENSIONS

The dam is situated on the border of the provinces of Huesca and Lérida, in the riverbed of the Noguera-Ribagorzana (see figure 3), (average water flow 30m^3/s) a tributary of the Ebro river. Of the several dams on Ribagorzana river, the Canelles dam has the largest reservoir. It is the highest dam in Spain.

Its height is 151m, the length of the coronation is 210m. The reservoir has a maximum capacity of 688 Hm^3, the workable volume is 560Hm^3. The reservoir can be filled to a maximum level of 506m above MSL.

CHRONOLOGY OF THE DAM WORKS

Site investigation started during the Spanish civil war and was resumed during 1951-1953. The Cannelles dam was designed by D.Eduardo Torroja. The client was E.N.H.E.R. the owner of the dam till now. Construction of the dam was completed in 1958 and infilling started thereafter.

FACTS FORESEEN

The danger of Karst in the upper Grey Limestone was already known since Roman Times.
To deal with the problems of karst it was assumed to be prevented by screening down to the Black Layer which deemed to be impermeable.

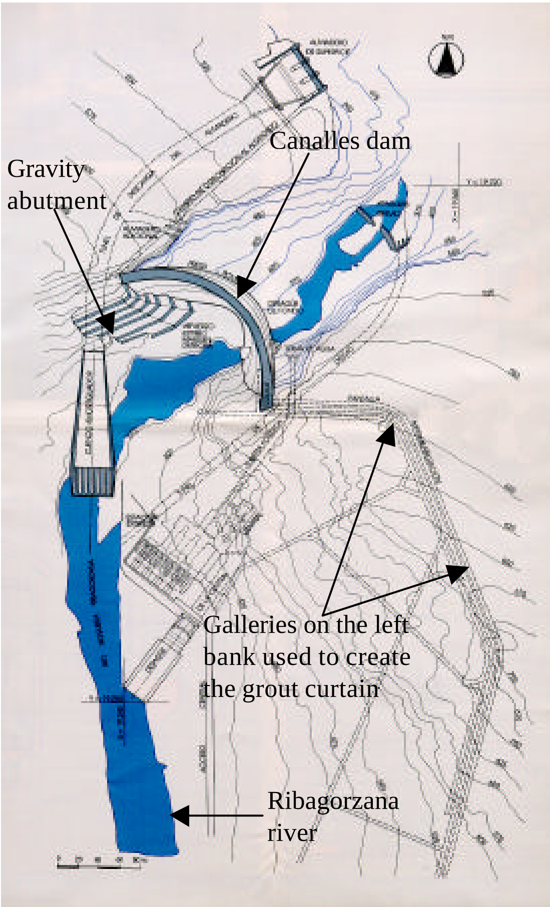

Figure 3. *The site map of the Canalles dam. (source ENHER brochure of the Canalles dam)*

PROBLEMS FACED

During the infilling of the lake a leak of 400 l/s was noticed. The possible cause for this leak was assumed to be due to a large cavern in the gray limestones, at the 350m level. The cave was plugged but the leak reduced only to a disappointing 300 l/s. Until 1961 search continued for other possible causes. After 4 years of trial it was concluded that the Black Layer was not as impermeable and continuous as presumed. The overall strategy of using the black layer as the impermeable boundary was not changed and therefore they decided to grout the whole layer. Grouting started in 1961 but upon infilling a sudden uncorking led to a leakage of $7m^3/s$. Further grouting was done in 1962 and 1963 and upon filling the reservoir, the loss of water was reduced to $4m^3/s$ and $1.5\ m^3/s$ respectively.

These losses were considered unacceptable and strategic changes in dealing with this problem was initiated in 1969 which led to the concept of a continuous screen going down to the Deep Marl Layer instead of the Black Layer along with grouting to be done from galleries at a level of 510m, 450m and 380m.

Implementation of the concept began in 1971. In 1972 the reservoir was emptied and in 1974 the work was completed. This reduced the loss to 70 l/s.

For security reasons the water level was not raised until 1974-1975. Since 1989 operation as planned is carried out.

COMMENTS

Karstification was assumed to be the result of dissolution during the Quaternary. There are evidence that the canyon at which end the dam was built has been subjected to numerous periods of infilling and erosion. This is important because this implies numerous changes in groundwater head, by which limestone formations at greater depth were able to come into contact with water not entirely saturated with carbonates. Hence presence of karst below the black layer should have been anticipated. Presence of the karst in the deeper gray limestone along with the higher permeability of the black layer caused the high loss of water from the reservoir.

GALLERIES ON LEFT SIDE

The purpose of the final grout curtain made, was to create a seal on the left bank of the reservoir starting at the contact point, i.e. dam-rock mass towards the highest point of the deep marls. This means that the synclinal fold axis had to be crossed grouted towards the east causing a height difference of 405m between the highest water level and the deepest point of the Deep Marls. This enormous height required to be grouted compelled the constructors to carry out the vertical grouting through three galleries constructed at 380m, 450m and 510m.

In order to avoid construction of deeper galleries for grouting deeper levels due to the general dip of the lithological units being upstream, the direction in which the galleries were driven were up-dip, i.e. SE.

In view of the large amount of concrete required to fill the huge cavities/karst and the high cost involved, a special technique of grouting was used. Large blocks were inserted with the injection of resin under high pressure. The resin under high pressure formed crystals and served as an obstruction to the flow of the concrete.

GRAVITY ABUTMENT AND LARGE SCALE ANCHORS ON RIGHT SIDE

On the right side the most striking feature to an Engineering geologist is to see that the orientation of the dam is parallel rather than perpendicular to the major joint set (see figure 4). Shifting of the position of the Dam by about 20m towards North could have increased the shear strength of the rock mass and avoided the problems that arose in this part of the reservoir. The problems that arose were mass movement of the material due to the additional shear stress induced by the dam with the filling of reservoir. To counter this mass movement, a gravity abutment was raised on the right side towards the downstream. The abutment consist out of six separate concrete slaps 18m in height "hinched" on separate 2m height blocks in order to develop a high stress perpendicular to the rock face and to the joint surfaces.

Figure 4. *During the excursion the orientation of the discontinuities had the full attention of Mr. Maurenbrecher.*

The large scale anchors ranging in length from 60 to 80 meters and a diameter of app 3.5m. The anchors were constructed by first driving a tunnel of 2.2m x 1.6m and then reinforcing it with a number of steel cables of 3cm diameter and casting it. The pre-stressed steel reinforcement in the equivalent-anchor provides the main tensional stress.

INSTRUMENTATION

It was noticed that there was large amount of water flowing in the galleries. To monitor the build up of the pressure in the dam, a number of pressuremeters were installed at various locations.

A number of Tell Tail type of extensometers which were protected were provided to monitor the possible rock mass movement

To monitor the movement of the dam under normal operation, infilling and due to the rock mass movement, the surface of the structure is covered by a number of observation points which are continuously registered by laser guided equipment.

CONCLUSION

First of all we want to thank ENER which made this unforgettable experience possible. It was the first time that most of us got an opportunity to see Engineering geological problems and the remedial measures carried out in this scale by a project. All aspects of the dam and the possible geotechnical problems that could arise in such a geological setting were observed.

The most important lesson learned from this excursion is that priority should be given to a thorough site investigation at early stage for all projects.

It has also been observed that in this particular project, success came only after the initial failure.

The Canalles dam is still a matter of concern to many ITC and TUD geotechnicians. This article will soon be followed by a "Geotechnical guide of the Canalles dam" by Mr. Maurenbrecher.

Case: Reconstruction of the N420 road in the province of Tarragona, Spain

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As a part of ongoing research into slope stability and the degradation of geotechnical characteristics of soil and rock masses in time, a study was made of a road construction project in the north east of Spain, near the town of Riudecols. The part of the road currently under construction is approximately 4 km long and comprises 17 slopes and 14 fills; the road alignment cuts through a zone where Carboniferous siltstones, sandstones and slates alternate with intrusions of Carboniferous to Permian age. These intrusions consist mainly of granodiorite and are associated with the Hercynian orogeny. The Carboniferous rocks are partly affected by contact metamorphism.

A combination of factors including topography, joint systems and faults has led to a widely varying degree of weathering in the materials found in the slopes. This has a strong influence on the overall stability of these slopes and has led to partial collapse at several locations. In order to develop a methodology with which problems like this can be assessed in the design stage of a project, three cuts were investigated in detail. Based on rock mass classifications with a system specifically validated for the area, strength measurements and weathering classifications using a newly developed rating system the site is going to be modeled in a GIS, which also includes topography, geology and hydrology. By doing this both the designed and realized slopes can be evaluated with regard to their stability using deterministic modeling.

In the following paper the project is presented. An adapted rock mass weathering classification system is discussed as well.

INTRODUCTION

To many Dutch engineering geologists the province of Tarragona is a well-known one: in the last ten years this has been the setting for the combined fieldwork for TU Delft and ITC students. Around 1990 one of the main roads in the area, the N420 that runs from Cordoba to Tarragona, was slightly realigned for most of the stretch between Reus and Falset, in order to accommodate the increasing traffic. One part of approximately 4 kilometers long, between the Coll de la Teixeta and the Coll Negre close to the village of Riudecols, was not reconstructed at that time, mainly because of the difficult geotechnical nature of the site. At the end of last year however, reconstruction of this stretch started (refer to Figure 1).

The existing road was designed to follow the contours of the landscape as much as possible. In this way a low gradient was ensured, but it also meant that the road would have many sharp curves. Because of this the cars and especially the heavy trucks that use the road cannot keep up a constant speed. With regard to the construction of the road however this was at the time the easiest solution, since there was no need for large cuts or fills.

The newly designed road alignment leaves the current road at Coll Negre to run more or less straight through a valley to the south of the existing alignment, climbing slightly upwards in the direction of Coll de la Teixeta. There, the road will run through a cut-and-cover tunnel to emerge again a little to the west of this Coll, close to the turn-off to the small village of Pradell. The curves in the road are designed so that a speed of 80 km/hr can be maintained.

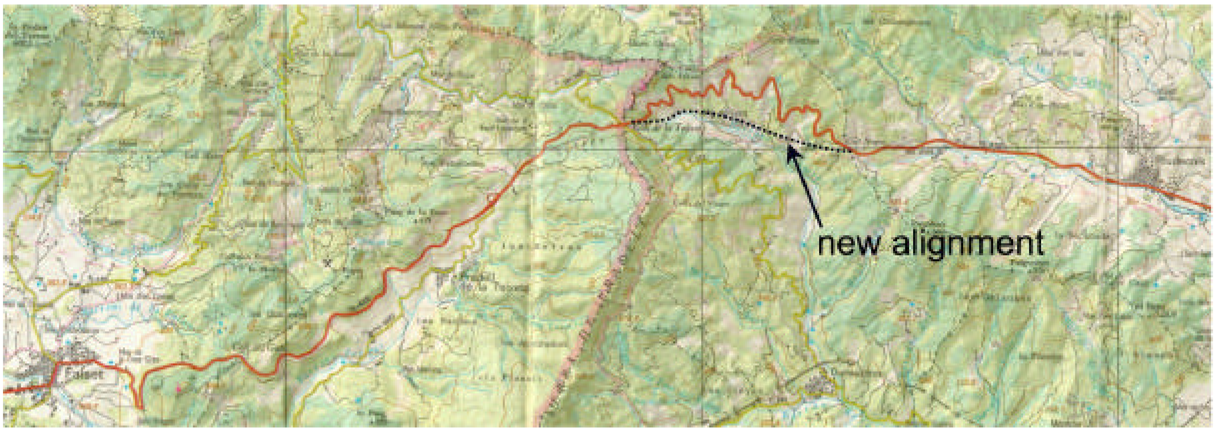

Figure 1. *The project area, southwest of Barcelona; grid distance is 5 km*

PROJECT OVERVIEW

The total alignment under construction has a length of just over 5 kilometers. About 1,5 kilometers of this stretch basically involve a slight realignment and widening of the existing road, whereas the remaining 3,5 kilometers consist of a completely new road (Figure 1). In the table below, the main characteristics of all cuts are listed. The reconstruction of the existing road involves the slopes D1 to D7; D8 to D17 are all in the newly constructed part. Most of the new cuts can be seen in Figure 2, a view from the west end of slope D17 (approximate location 4+660) towards Coll de la Teixeta. The new alignment climbs gently upwards from the level of Coll Negre and ends just below Coll de la Teixeta (just to the left of where the arrow for “D8” is pointing). Here, a cut and cover-tunnel is planned at a maximum depth of about 30 meters below the existing road level, which will emerge again at the Falset side of the Coll. Above the tunnel a crossing with the TP7401/T313 road is planned.

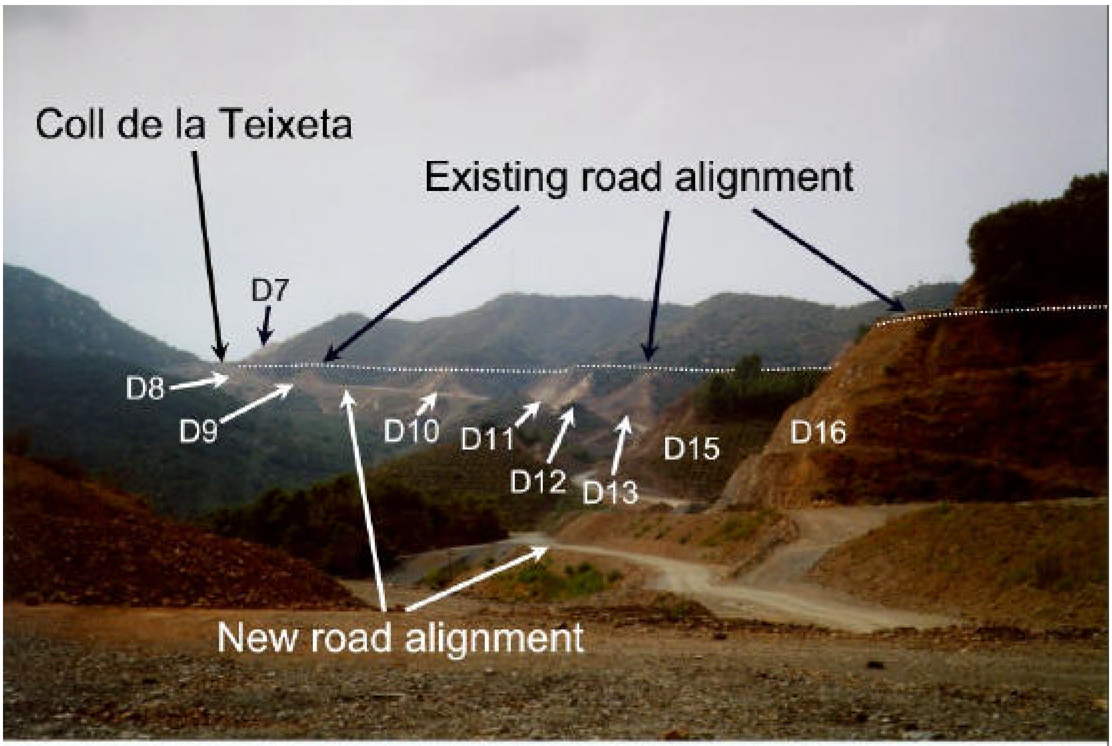

Figure 2. *A view from slope D17, close to Coll Negre, towards Coll de la Teixeta with the visible slopes indicated*

Table 1. *An overview of the slopes; locations are given in [km+m] with 0+000 on the Falset side of Coll de la Teixeta. Coll de la Teixeta is at 1+800, Coll Negre at 5+150. Source: Jolsa Ingenieros Consultores en Geotecnia.*

		South slope			North slope			Bedding, cleavage		Joint sets
Cut	Excavation method	Location	Orientation	Max. height [m]	Location	Orientation	Max. height [m]	Orientation	Friction angle	Friction angle
D1	Blasting	0+700-0+850	308/71	13	0+780-0+850		11	250/06	28	40
D2	Blasting	0+900-1+020	285/71 310/71	27				315/08 330/40 180/72	28	40
D3	Mechanical	1+100-1+280	310/71	10				168/35	28	40
D4	Mechanical and blasting in the bottom	TUNNEL 1								
D5	Mechanical and blasting in the bottom	1+300-1+620	001/71	13				008/28	28	40
D6		1+780-1+900	/37	16						
D7		TUNNEL 2								
D8		2+100-2+280	/37	10	2+060-2+280	/37	16			
D9	Mechanical	2+340-2+400	/45	11						
D10	Mechanical and blasting in the bottom	2+580-2+710	345/53	4	2+580-2+710	165/63	24	237/40 274/44	20	35
D11	Blasting	2+840-2+940	359/63	8	2+840-2+960	179/56	31	067/62	25	35
D12	Mechanical and blasting in the bottom	2+960-3+080	012/56	15	2+960-3+050	192/63	34	200/35	20	40
					3+050-3+090	192/34				
D13	Mechanical and blasting in the bottom	3+180-3+420	002/45	25	3+200-3+430	182/56	40	220/70 180/35	20	35
D14	Mechanical	3+640-3+680	022/39	3	3+640-3+680	202/53	17	028/42	20	35
		3+680-3+720	020/63		3+680-3+720	200/53		231/68		
D15	Blasting	3+830-4+100	015/51	20	3+890-4+110	195/51	42	025/55		
D16	Mechanical	4+340-4+520	020/45	16	4+330-4+540	200/51	39	045/55	25	35
D17	Mechanical and blasting in the bottom	4+640-4+720			4+650-4+690	200/37		222/56	20	35
		4+740-5+000	020/53	31	4+700-5+000	200/45	15			

For this project an extensive study was made of the geotechnical characteristics of the area. This involved detailed geological mapping, geotechnical rock mass classifications using a system resembling the SSPC-system (Hack, 1998), stability analysis of the slopes with Wulff-net plots of the discontinuity sets as well as with numerical calculations and an assessment of the hydrological situation in the area. Based on this study most of the slopes were designed with gradients close to 1:1 (refer to Table 1), which seems to be very steep; experience in similar geotechnical units in the area has learned that a slope angle of more than approximately 30° will lead to instability phenomena.

Excavation of the slopes was for the main part executed using standard machinery, although in the lower parts of most slopes blasting was applied to loosen the rock material. In some slopes (D14, D16) berms were made, whereas the other slopes have one continuous face. The following photographs show some scenes from the project.

***Figure 3**. Construction work going on at slopes D11, D12 and D13; existing road alignment just above center*

***Figure 4**. Drilling blastholes at slope D13; D11 and D12 in the background*

Figure 5. *Blasting of the lower part of slope D13*

GEOLOGY

The geology of the project site is rather complicated from an engineering point of view. More or less on the Coll de la Teixeta, a major fault is encountered which separates the Carboniferous formations and intrusives in the north from the Mesozoic sandstones and limestones of the Buntsandstein and Muschelkalk in the south. At the Coll, the reconstructed road runs close and more or less parallel to this fault for several hundreds of meters, with one slope in the Buntsandstein and the planned tunnel in the fault zone itself. On the Falset side of the tunnel, the road turns into the Mesozoic formations and out of the Carboniferous. The roadcuts on this side of the Coll are in the Muschelkalk 1.

Buntsandstein	Red coarse-grained sandstone, thickly bedded, large blocky. Slight degree of weathering according to the B.S. classification (B.S. 5930).
Muschelkalk 1	Microcrystalline gray-bluish bioturbated limestones and dolomites, thickly bedded, large blocky. Degree of weathering according to the B.S. classification varying from fresh to slight.

The newly constructed part of the alignment on which this paper focuses cuts through the Carboniferous sedimentary and metamorphic rocks with several intrusive dykes north of the fault. Three units are distinguished in this part:

Bizarre grips	Grey slate with some intercalations of sandstone (arenisca gris); degree of weathering according to the B.S. classification varying from slightly to completely, block size and shape very small to large tabular.	
	Slightly weathered material:	U.C.S. = 116 MPa
		B.T.S. = 17.3 MPa
Arenisca gris	Grey sandstone with intercalations of slate (pizarra gris); degree of weathering according to the B.S. classification varying from slightly to completely, block size and shape very small to large tabular.	
Porfido granitico	Grey-white to yellow granodiorite; degree of weathering according to the B.S. classification varying from fresh to residual soil, block size and shape apart from residual soils medium/large blocky to columnar.	
	Fresh material:	U.C.S. = 175 MPa
		B.T.S. = 11.5 MPa
	Slightly weathered material:	U.C.S. = 68 MPa
		B.T.S. = 5.3 MPa

It is to be noted that within these units the degree of weathering changes dramatically. Both the Carboniferous rocks and the intrusives may occur as fresh to slightly weathered material as well as completely weathered material or residual soil, and this may even occur within one slope. Since for each slope only one gradient is considered in the design stage, this causes notable changes in the slope stability at various locations and the variable weathering thus leads to a variable stability as well.

SLOPE STABILITY

Even apart from the differential weathering, the stability of the slopes in the new alignment is negatively influenced by a combination of factors. The Carboniferous rocks have a small block size caused by the dense cleavage and the large number of joint sets (4 to 5 easily recognizable), and a low friction angle on the cleavage and joint planes of 20° to 35°. Together with the steep slope gradients that have been chosen, this means that probably in every slope sliding may occur on at least one discontinuity set. Apart from sliding of blocks, rotational slides may occur as well where the block size is very small, and indeed this has already happened on quite a large scale in the lower part of D16 (see Figure 6). These large slides are of course not the only problem; small instability phenomena like sliding of small blocks occur much more often and, being in itself already quite dangerous, this will gradually weaken a slope until a major collapse will take place.

Figure 6. *Slope D16, looking north – the scar of a rotational slide in the lower right part*

Another problem apart from the slides is the gradual regression of the steep slopes towards their 'natural' stable angle, of about 30°. Because of this the top ends of the slopes on the north side of the alignment will move towards the existing road. In the case of slope D16 for example, this meant that the top part of the slope now actually cuts through this road, which had to be realigned slightly to avoid collapse.

The problems with the newly excavated slopes already became apparent during the early stages of construction. For example, the rotational slide shown in Figure 6 occurred in early May 2000, only about half a year after the excavation. For a number of slopes an additional geotechnical study was made and some remedial measures will be taken, such as applying drainage systems and slightly changing the slope gradients. Because the alignment is already more or less fixed, major changes in slope gradients are not possible without affecting the existing road.

WEATHERING CLASSIFICATION

In his Technical Note in the Quarterly Journal of Engineering Geology, Price (1993) put forward a method to classify rock mass weathering from an engineering point of view. Rather than the B.S. classification introduced in 1981, which is more orientated towards the changes in material and mass without paying attention to the engineering significance of this, his system tries to take into account the consequences of weathering and classifies a rock mass based on the engineering application. During the study of the N420 project, the Price system was slightly adapted in the course of classifying the slopes and mapping the differential weathering. Changes include different ratings for the various categories and the addition of the weathering class "slightly weathered".

This rating system to classify a rock mass is based on the proportions of the material and discontinuities that have certain weathering characteristics. First, a material classification is made which gives the material rating: To the material rating, a discontinuity rating is added. For this we distinguish between sedimentary and metamorphic rocks, igneous rocks and geotechnical soils. The total rating is the sum of the material and discontinuity ratings. Based on the total rating, rock masses are put in the respective classes that are described in Table 2 below:

Table 2. *Weathering classification based on the recognition of engineering significance; adapted from Price (1993).*

Descriptive term	Igneous rocks	Sedimentary rocks	Limestone	Metamorphic rocks
Effectively unweathered **Class A**	Engineering problems related to material properties, discontinuity properties etc. No influence of weathering.	Engineering problems related to material properties, discontinuity properties etc. No influence of weathering.	Engineering problems related to material properties, discontinuity properties etc. No influence of weathering.	Engineering problems related to material properties, discontinuity properties etc. No influence of weathering.
Slightly weathered **Class B**	Rock material notably affected by weathering and some loss of strength, but not yet adversely influencing engineering work. With further degradation of the rock mass, influence on engineering works will be significant.	Rock material notably affected by weathering and some loss of strength, but not yet adversely influencing engineering work. With further degradation of the rock mass, influence on engineering works will be significant.	Rock material notably affected by weathering and some loss of strength, but not yet adversely influencing engineering work. With further degradation of the rock mass, influence on engineering works will be significant.	Rock material notably affected by weathering and some loss of strength, but not yet adversely influencing engineering work. With further degradation of the rock mass, influence on engineering works will be significant.
Significantly weathered **Class C**	Reduction in joint strength gives problems in slope stability and tunneling.	Reduction in joint and bedding plane strength gives problems in slope stability, tunnels, foundations on slopes.	Opening of bedding planes and joints leads to major increase in permeability and discontinuity strength problems in tunneling. Problems in excavations using explosives.	Reduction in strength of foliation planes gives problems in slope stability, tunnels, foundations on slopes.
Severely weathered **Class D**	Major slope stability problems by release of corestones, irregular bearing capacity particularly for small dimension foundations. Corestone/soil strength contrast difficult for tunneling.	Major impairment of bearing capacity for foundations. Slope stability approaches stability of residual soils. Poor ground for tunneling.	Rock mass cavernous. Problems for all types of engineering work. Localized subsidence problems.	Influence of basic anisotropy in rock type and contrasts between weathering sensitivity of layers give major problems in slopes, foundations and tunneling, particularly in mica rich schists and gneisses.
Geotechnical soil (without relict disc^ies^) **Class S1**	Weathered material geotechnically a soil, so all engineering works designed on soil parameters.	Weathered material geotechnically a soil, so all engineering works designed on soil parameters.	Residual soil very different from original rock, often highly ferruginous and clayey.	Weathered material geotechnically a soil, so all engineering works designed on soil parameters.
Geotechnical soil (with relict disc^ies^) **Class S2**	Weathered material geotechnically a soil, so all engineering works designed on soil parameters, but with added handicap of potential sliding planes of relict discontinuities.	Weathered material geotechnically a soil, so all engineering works designed on soil parameters, but with added handicap of potential sliding planes of relict discontinuities.	Not applicable to crystalline limestones. May be calcareous mud with some relict planes in much softened calcilutites and calcisiltites. Major problems for all engineering works.	Weathered material geotechnically a soil, so all engineering works designed on soil parameters, but with added handicap of potential sliding planes of relict discontinuities.

FURTHER RESEARCH

At present, a M.Sc. research project by Ms. D. Franco of ITC is concentrating on the slope stability problems for this project. Both the designed and realized slopes are being evaluated with regard to their stability using deterministic modeling with GIS. This evaluation includes the

classification of the slopes into differentially weathered zones, each with their own strength parameters; basically, this means that not only the geological units are mapped, but also every weathering grade that is present for each unit. The focus of this study is the slopes D10, D14 and D17 which all include several geological units and weathering classes. In this way, an overview will be made of the actual factors of safety of the slopes indicating hazardous zones. Following the same methodology slopes with appropriate factors of safety can be designed avoiding the need for remedial measures during and after construction.
Apart from this M.Sc. study, the degradation of geotechnical characteristics of soil and rock masses in time and its bearing on slope stability is being investigated as part of a Ph.D. research by the author.

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Excursion to the Geopotes 14

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Dark clouds massed over the North Sea. The waves clashed against the bow of the ship. The rain drizzles on the deck. This is how our Nepali ITC colleague must have felt. For the dredgers of the HAM this was just another ordinary day on the Geopotes 14. It all started a week before, when Robin Koster of HAM put up notes at Mining Engineering at the TU Delft and at ITC to invite the students, (students only) to join the crew on the Geopotes 14 to see some dredging in action.

Figure 1. *The Geopotes 14 as seen from the Panter*

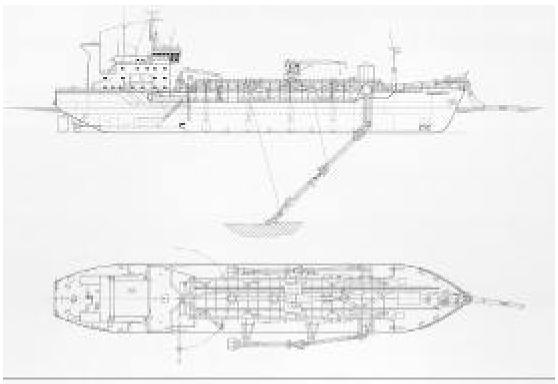

Figure 2. *Technical drawing for Gepotes 14*

The gathering point was the semi permanent office of the HAM at the Hoek of Holland, where the dredging of the Harbour of Rotterdam was controlled for over three years now. After a short introduction by Robin Koster, the tour started on the Panter, a small boat which supplies the Geopotes with food and crew day in day out. As we boarded the Geopotes 14 it just returned from the North Sea with a shipload of clean sand which was going to be deposited deeper in the harbour.

Table 1. *Technical data on Geopotes 14*

Name	Geopotes 14	
Type	Trailing suction hopper dredger [twin screw]	
Dynamic positioning system	completely integrated DP-system connected to survey and process computer	
Classification B.V.	13/3 E hopper dredger [deep sea aut-ms]	
Year of construction	1984	
Tonnage	7950 GT - 2385 NT	
Dimensions	length overall: moulded breath: depth: draught:	127.78 m 20.63 m 9.53 8.66
Hopper capacity	6,590 m3	
Dredging depth*	32.00 m	
Number of suction pipes	2	
Suction pipe diameter	1,000 mm	
Speed loaded	15.40 knots	
Total installed power	11,330 kW	
Pump drive	3,280 kW	
Discharge	16 bottom valves or suction	

system	installed coupled to dredge pumps
Accommodation	42 beds
***Dredging depth can be increased to 47.00 m by lengthening suction pipes**	

From this collection point other contractors will use this sand for many applications. Not far from here the dredging suction hopper took on some 1000 m^3 harbor sludge. To see this process in action we left the control room and went to the deck. It has to be reminded however, that a fully loaded vessel lays deeper in the water.

Figure 3. *Water on deck*

The disadvantage of being on deck on a fully loaded suction hopperdredger.

This experience caused the visitors to continue the day with soaked pants.

With the sludge on board we left the harbor and headed for the open sea. During this trip we were invited to visit the other interesting parts on this ship like the engine room and the kitchen where we were able to enjoy the meal served for us.

After the deposition of the harbor sludge the Geopotes 14 again set for the harbor. On the way some clean sand was picked up and the cyclus was completed. The Panter who just brought in some fresh food was ready to take us back to the land.

All the students agreed upon this: It was a superb excursion, and we thank HAM for the effort taken.

Rapid Inventory of Earthquake Damage (RIED)

Adriana Duque[1], Robert Hack[2], Lorena Montoya[3], Tom Scarpas[4], Siefko Slob[2], Rob Soeters[2], Cees van Westen[3]
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2) International Institute for Aerospace Survey and Earth Sciences (ITC), Centre for Technical Geosciences, Kanaalweg 3, 2628 EB Delft, The Netherlands
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The 25 January 1999 Quindío earthquake in Colombia was a major disaster for the coffee-growing region in Colombia. Most of the damage occurred in the city of Armenia and surrounding villages. Damage due to earthquakes is strongly related to topographic and subsurface geotechnical conditions underneath structures and houses. The RIED project used aerial photographs to obtain a rapid inventory of the earthquake damage right after the seismic event. This inventory was subsequently used to identify any existing relation with subsurface- and topographic conditions.

Hazard zonation maps were made on the basis of seismic response analysis of a three-dimensional model of the subsurface that has been created in the GIS. Also indicative zonation maps were created outlining potential areas where topographic amplification may occur. These seismic zonation maps delineate those areas that are most likely affected by subsurface and topographic resonance effects during a future and similar earthquake. The maps have been presented to the city planning authorities of Armenia so that reconstruction of the damaged areas can be carried out in such a way that high risk areas will be avoided or that structures and houses will be built according to the standards for high seismic risk areas.

INTRODUCTION

The coffee region is located in the western part of Colombia, an area that contributes greatly to Colombia's economy. Armenia, which is the capital city of the Quindío Department, has a population of approximately 270,000 inhabitants. Pereira, another important city, located 31 km north of Armenia, is the capital city of the Risaralda Department and has a population of approximately 380,000 (see Figure 1). The 25 January 1999 Quindío earthquake, with a magnitude of 6.1 on the Richter scale, killed more than 1,100 people and about 4,800 persons were injured. Approximately 45,000 houses were either destroyed or damaged (Photo 1). In order to make a rapid assessment of the damage inflicted by this earthquake and to make recommendations for the reconstruction of the damaged areas, the Dutch government offered assistance to the Colombian authorities. The ITC and the Delft University of Technology (TUD) in The Netherlands were subsequently requested to carry out this task.

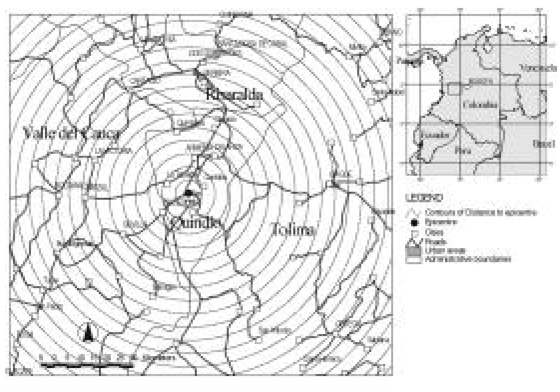

__Figure 1.__ Location map

Photo 1. *Neighborhood in the city of Armenia that was almost completely destroyed by the earthquake*

AERIAL AND FIELD SURVEY

A few weeks after the earthquake a team of Dutch experts from ITC and the TUD went to visit the two cities in the Quindío area that were affected most. The task was to make a first inventory of the damage and acquire all relevant geographic, topographic, and geologic information. An aerial survey was conducted during which several series of high-resolution aerial photographs were taken. It is important to carry out this kind of survey as soon as possible after an earthquake, because immediate cleaning, removal and rebuilding operations that are carried out may hamper a proper assessment of the inflicted damage.

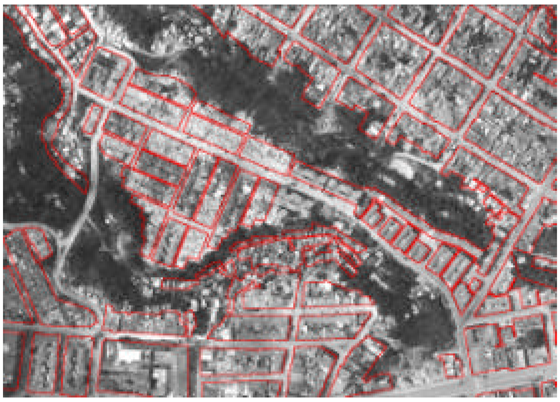

Figure 2. *Digital orthophoto combined with existing cadastral data in the GIS*

The aerial photographs were ortho-corrected (removal of camera- and topographic distortion) and with existing cadastral and topographic information a comprehensive Geographic Information System (GIS) database was set up in a short amount of time. The aerial photographs were interpreted in order to assess for each individual house or building whether it was damaged and what type of damage was inflicted (see Figure 2). The damaged structures have been classified and marked on aerial photographs and simu ltaneously imported in a GIS. Maps for various types of damage to structures have been made and analyzed. In this way a large database was constructed with in total more than 33000 observations. An example of an analysis carried out on the basis of this damage inventory is given in Figure 3.

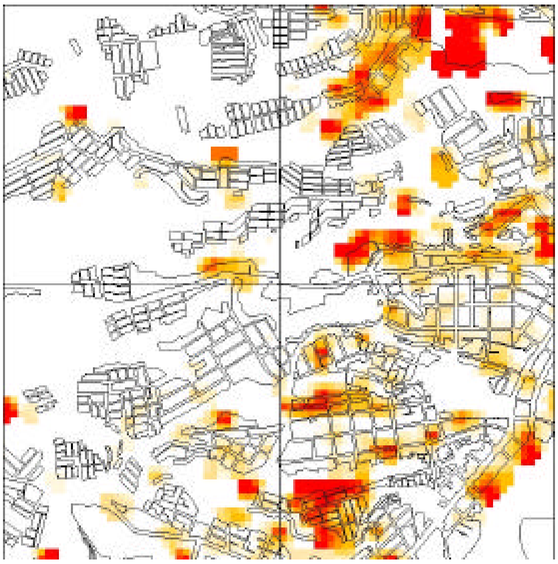

Figure 3. *Damage intensity (damaged buildings as percentage of the total number of buildings)*

GEOLOGY AND GEOTECHNICAL SUBSURFACE CONDITIONS

The region around Armenia is located in the western piedmont of the Central Cordillera, and consists mainly of metamorphic and sedimentary rocks from Paleozoic to Cretaceous ages. Volcano-clastic deposits (the so-called Quindío Glacis) of Plio-quaternary age cover these rocks. The deposit consists of several lenses and layers of alternating and interfingering pyroclastic- and lahar flows. In the Armenia area two main (active) faults have been identified. A lineament analysis of the area of Armenia has been executed on 1:20,000 aerial photographs of 1981. The identified lineaments are defined by anomalies in the drainage pattern as well as slight topographical events in the surface of the "Glacis del Quindío". Near surface all sub-surface materials have been weathered to residual soils with varying thickness.

Man-made landfills consist of materials (natural or man-made) that are used to fill natural depressions or enlarging level terrain in urban areas. In Armenia the most common places for landfills are the natural drainage channels. The

landfills are mixtures of organic soils with ashes and lapilli's, construction material, spoil heaps, organic material, garbage, etc.
The residual soil and landfill material creates particular poor circumstances for foundations during earthquakes as in these materials amplification of the earthquake tremor occurs. The damage inventory survey clearly showed the relation between the thickness of loose materials and actual damage due to the 25 January earthquake.

TOPOGRAPHIC INFLUENCE

The presence of topographic undulations (Figure 4) has a marked influence on the surface accelerations of an earthquake. Near steep slopes an amplification of the effects of an earthquake can be expected. Also resonance effects are possible if the dimensions of ridges in the topography coincide with the frequencies of the major tremor of the earthquake. The locations where this resonance effect may take place has been modeled in the GIS and an example of this analysis is given in Figure 5. Both topographic effects can be correlated to the damage patterns of the city of Armenia.

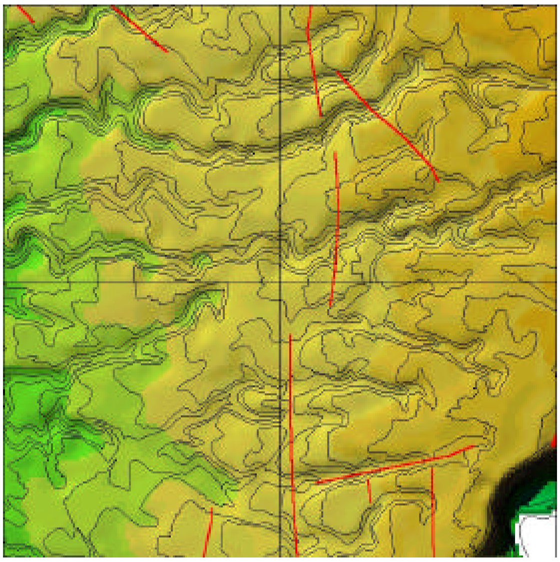

Figure 4. *Topographic relief*

SEISMIC RESPONSE ANALYSIS

Certain geological conditions (the characteristics of the subsurface) can result in serious amplification of the seismic signal, causing increased intensity of earthquakes at these locations. How the subsurface reacts on a certain seismic wave can be modeled. For this purpose a three-dimensional subsurface model was constructed in the GIS which was subsequently used as input for the seismic response model. On the basis of the results of this seismic response analysis different seismic microzonation maps have been made which delineates the difference in seismic responses throughout the area as a function of the subsurface geology. Examples of these microzonation maps are given in Figures 6 and 7.

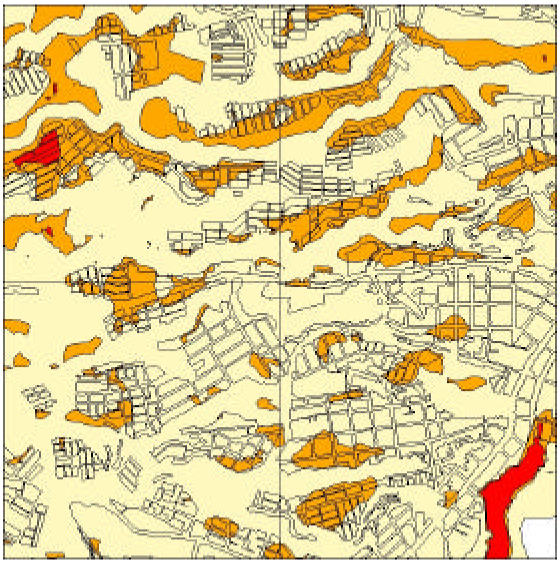

Figure 5. *Potential areas where the topographic resonance effect may take place*

Additional measures should be taken to reinforce the constructions in those areas, or to avoid building structures in such areas. The aerial photographs also show that three-dimensional site effects occur on some of the ridges in the topography. As there is very little known of these effects a research study has been initiated to study in more detail the three-dimensional aspects of topographic effects on seismic response.

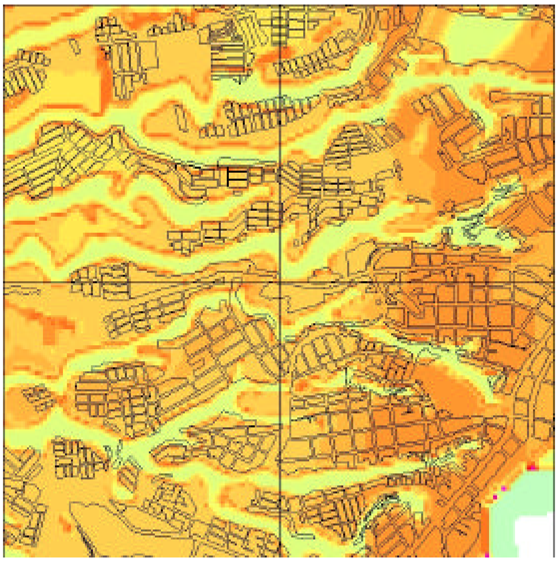

Figure 6. *Seismic acceleration response distribution for 1-2 story buildings*

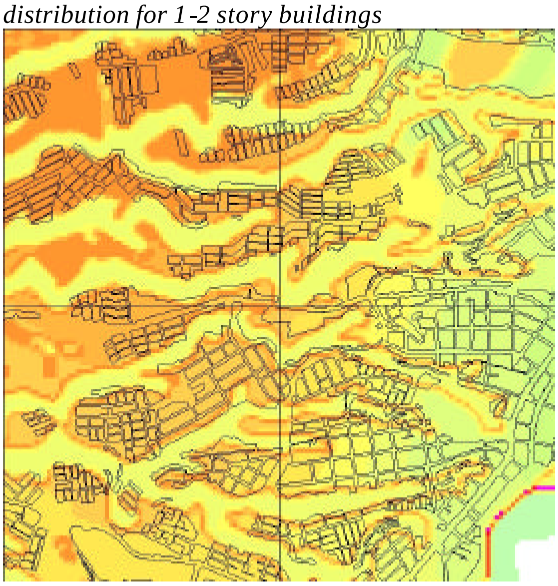

Figure 7. *Seismic acceleration response distribution for 2-4 story buildings*

RESULTS

The damage inventory made by aerial photographs clearly shows that the damage is concentrated in a more or less wedge-shaped area bounded by the Armenia fault on the East side and by alignments in the topography on the West side. The coincidence of this alignment with the boundary of the most damaged areas may indicate that the alignment in the topography is in fact a fault trace. The damage inventory shows further that topographical effects are of important influence on the damage inflicted on the surface structures. The a-priory assumed influence of the landfills on the damage of structures is less obvious from the inventory by aerial photographs. The damage inventory from aerial photographs has been correlated with a ground survey of the damage done by various organizations in Armenia. Both methods have their own merits and in future rapid damage inventories such as this study, it would be recommendable to combine both methodologies to achieve a more comprehensive approach. Generally, the results of the damage inventory by aerial photographs shows that for reconstruction purposes the damage inventory using aerial survey gives a reasonable impression of the damage. Major geological, geotechnical, and morphological features that have influenced the damage inflicted on surface structures are generally easily recognizable. The results of an inventory of damage by aerial photographs can be available very soon after an earthquake compared to a ground survey. This should be of large benefit to the reconstruction planning.

Biography

Adriana Lucia Duque Velasca, Head of the Section City planning of the Corporacion Regional del Quindio (CRQ), Ministerio del Medio Ambiente, in Armenia, Colombia. BSc Civil Engineering.

Robert Hack (project coordinator), Head Section Engineering Geology. B.Sc. Geology, M.Sc Engineering Geology (Delft) and Exploration Geophysics (Utrecht), PhD Technical University Delft, The Netherlands. Worked in Middle East, Indonesia, and Africa in civil engineering as geotechnical consultant. Is a chartered engineer and president of the Dutch Association for Engineering Geology.

Lorena Montoya. Lorena Montoya is currently a lecturer for the Division of Urban Planning and Management (UPM) at ITC. She obtained her Licentiate's degree in Architectural Engineering at the Autonomous University of Central America (UACA) in Costa Rica followed by an MSc. degree in Geo-Information for Urban Planning at ITC. She is also presently conducting Ph.D. research on the topic of Risk Assessment for Urban Planning at ITC.

Siefko Slob, Lecturer in the Section Engineering Geology. B.Sc. and M.Sc. in Engineering Geology (Delft). Worked for many years in civil and geotechnical engineering, and regional hazard and risk studies.

Tom Scarpas, Associate Professor. Coordinator, Program of Mechanics of Structural Systems, Section of Structural Mechanics, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Netherlands. Bachelor of Engineering (Civil), McGill University, Canada, 1979, Master of Engineering (Earthquake Engineering), University of Canterbury, New Zealand, 1981, Research interests: Innovative finite element techniques, material constitutive modeling, non-destructive testing.

Rob Soeters, Senior Lecturer in the Section Engineering Geology. B.Sc. and M.Sc. in Mining Engineering. Worked on many projects throughout the world on aerial photograph studies for civil engineering, applications of geographical information systems, and hazard and risk assessment for natural hazards.

Cees van Westen, Senior Lecturer in the Division Applied Geomorphology Surveys of ITC. B.Sc. and M.Sc. Physical Geography (Utrecht), PhD Technical University Delft. Worked on projects throughout the world in physical geography, natural hazards, and application of geographical information systems.

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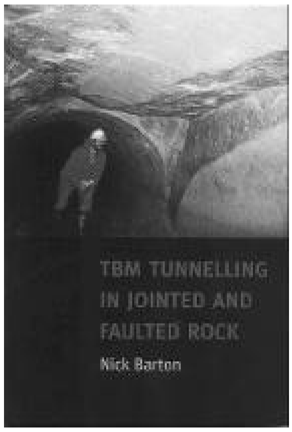

Shimada, Mitsuhiko 90 5809 316 6
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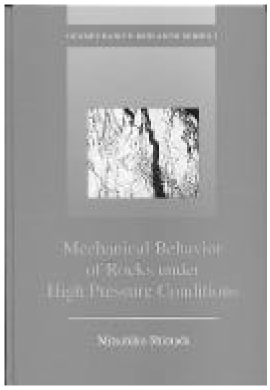

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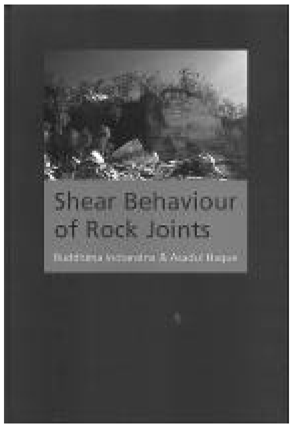

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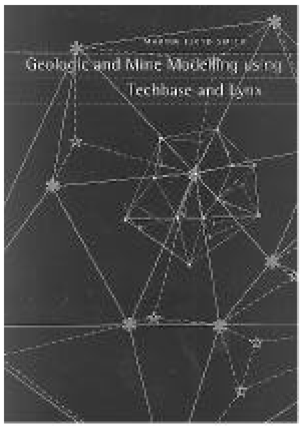

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In focus: Marco Huisman and Siefko Slob

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In the year of 1972 Marco Huisman was born in Gouderak. Right then it was not clear yet what would become of him. In the 28 years that followed, he developed himself into a promising engineering geologist. Every day one can see him traveling in his blue sporty Mazda from his home in Vlaardingen to ITC Delft or Enschede.

After his secondary school (VWO-β) in 1990 Marco started studying at Delft University of Technology, at the faculty of Mining Engineering and Petroleum Exploration. In 1995 he graduated with distinction on the subject of "green-strength of limy sandstone". The production of this artificial product starts with a mixture of lime, sand and water that is compressed by hydraulic presses. The next step in the process is to transport the compressed, dewatered material ("green-stone") in blocks to the autoclaves. In the autoclaves the blocks of semi-product are hardened to form the final product. By order of the industry that produce blocks of this material, Marco had to investigate the losses that appeared during the transportation of the semi-product to the autoclaves. To obtain knowledge on what was really causing the losses, strength tests had to be performed on the material correlated with the material's composition and mineral content. For his perfect performance in this project he received the annually awarded Graduation Price.

After his graduation in 1995 he started working at the " Waterloopkundig Laboratorium" in Delft as a project manager. Here research was done for several contractors and machine builders in the field of tunnel construction and dredging technology. The projects were mainly experimental of nature and were aimed at improving already existing and inventing new machinery or methods.

Being a project manager meant that Marco was managing a project team and was dealing with the financial aspects of the projects as well. This gave him a lot of experience that became very useful for him in the rest of his career.

In January of 2000 he accepted his present job: university lecturer in engineering geology at the International Institute for Aerospace Survey and Earth Sciences (ITC). While he is giving lectures on the subjects of soil mechanics, slope stability and numerical modeling, he is also concentrating on his PhD-thesis. In this PhD-research he is investigating erosion, weathering and slope stability and the effects that degradation of soil and rock masses have on the stability in an engineering lifetime of a construction (i.e. ranging from 50 to 100 years). For this research data of slope stability and rock mass- and soil classification are used from the TUD-ITC fieldwork in Spain and the gathered (more qualitative) data from the fieldwork areas in Austria of the University of Amsterdam. Both fieldworks have been carried out for about ten years in a row now and provide a good picture of the effects of degradation processes on slope stability in two different climatic zones.

The main positive points he experiences from being an engineering geologist for ITC are the many foreign visits he is able to make and the fieldworks he can attend as a staff member. These trips enable him to practice his hobby mountain-climbing. In fact, and the authors speak out of own experience, he never leaves without his climbing gear in his backpack.

Siefko started his Mining Engineering study in 1988, and finished his thesis in 1994 at the section Engineering Geology.

His thesis was on mining damage in Tsjechia, near the city of Ostava. Here, after intensive mining activities, severe subsidence problems were occurring. Together with fellow student Robin Koster, Siefko had to map the risks in the area with the help of GIS.

Siefko's first job as a qualified engineer brought him into contact with ITC. The GTIP-project (Groundwater Technology Investment Program) involved setting up a large information system for the civil engineering industry.

When this task had been completed, quite an interesting job came up at the Royal Museum for Central America. This is a Belgian Scientific Institute that performs research in the former colonies, and it gave Siefko a task of researching a volcanic area in the Philippines for the UNESCO project GARS (Geological Applications of Remote Sensing). A map of the volcanic risk zones had to be made, in order to make planning of evacuation routes and building projects possible. To gather information, a fieldwork of 6 months was needed. The tropical temperatures and the rainforest (which also did a nice job of covering any underlying geology) made working conditions difficult.

Although the jungle was fairly inaccessible, it or its animal inhabitants weren't the biggest problem. It turned out that communist guerrilla troops were roaming the jungle, and anytime Siefko wanted to work somewhere he had to give notice to the army, so that they would be able to swipe the area 'clean' before Siefko and his gear entered. But not only the rebels were to be feared, which Siefko learned soon enough as he was determining his position with his GPS equipment, in front of an army base camp. Apparently the soldiers thought they were dealing with a VERY daring rebel, so they approached our Siefko to ask him what he thought he was doing with that GPS antenna in front of their base camp. Luckily Siefko was able to explain the situation to a stage where they believed him. His career would probably have been a short one otherwise.

Eventually however, Siefko gathered enough geological info and GPS data to be able to make the requested maps, and he returned to safe and cold Holland in one piece.

His next project, also part of the GARS-program, in 1998 required him to go to Eastern Uganda, where radar interferometry techniques were applied to produce topographical maps on a 1:50 000 scale. These maps were to be used for exploration projects in the area. Similar to the Philippine project, working conditions were dangerous. Nomads were fighting each other for cattle and even children were carrying Kalasjnikovs.

In 1999 Siefko came back to ITC, where he has started his promotional research on variability of geotechnical parameters in 3D, coupled to risk models. He is also staff member of ITC and teaches on GIS and remote sensing subjects at this institute.

At the same time, he is working on yet another UNESCO project, called RAPCA (Regional Action Program Central America). This project involves giving workshops to Central American engineers/cartographers on the subject of mapping of disaster risks. A pilot project is currently running in Costa Rica. In November a new workshop will be given in Guatemala.

Siefko believes that the knowledge he gained during his study time is still very useful to him in his job as GIS-expert, since he needs both civil engineering and geological knowledge for the tasks that he is asked to perform.

Assessment of Contamination Potentials by applying Multi-Temporal Desk Study and Fuzzy Set Theory

Preface (by Dieter D. Genske)

In urban agglomerations with high population density virgin land is rare - particularly where industrial and commercial acquisitions require vast development areas. Derelict industrial sites are often contaminated and for ecological, socio-economic and political reasons, such 'brownfield' have to be remediated[1]. Land-recycling or brownfield rehabilitation mitigates soil and groundwater pollution, while simultaneously reducing the pressure on virgin land (greenfields). Greenfields would be taken out of a more or less functioning environmental context elsewhere, to be consumed, for instance as building lots.

In order to improve a sustainable management of the resources 'soil' and 'space', land-recycling is an essential precondition, although not an inexpensive one. Public spending augmented with the increased environmental awareness in the 80s and early 90s. For instance, the first inventory of contaminated sites in the Netherlands after the Lekkerkerk incident in 1981 resulted in an estimation of several hundred sites to be potentially polluted. In the 80s this amount increased and estimations assumed about 110.000 potentially contaminated areas and a corresponding financial remediation effort of fl. 50 billion (Kammerstukken II, 1990). In 1993, 200.000 sites were rated potentially contaminated (Dutch central bureau of statistics in CBS, 1993). Consequently, remediation policy changed, and that not only in the Netherlands, but also in the USA and the unified Germany. 'Soft' remediation techniques such as in-situ bioremediation and phytoremediation became increasingly interesting. To sell the new idea the term 'Natural attenuation' was coined.

This approach integrates processes reducing or immobilizing contaminants. Notions such as 'risk based decision making' and 'flexible emission control' became popular in the 'remediation-community'. However, all this could hardly disguise the fact that basically economic reasons have lead to a fundamental change of mind in revitalizing degraded urban land. Similar to a pendulum movement 'overcleaning' swung back to 'undercleaning'. New research initiatives were started. In the light of the new concept, toxicological knowledge progressed and advanced exposure/resorption models were introduced. The question 'How clean is clean' was reopened – or rather reformulated to a more fashionable 'How dirty is dangerous'.

While this discussion picked up momentum, Klemens Heinrich launched his research initiative that finally resulted in a PhD-thesis. A sheer endless demand of site investigation data appeared to be necessary in order to meet the complex challenge of recycling urban land. In order to reduce this demand the concept of the so-called multitemporal desk studies (MTDS) had to be reviewed and improved. The approach appeared promising, especially since the quality of site

[1] We refer to reclamation as the process of regaining degraded land, remediation as the process of healing the damage done to the site by former users, revitalising as the process of re-integrating of the site into an existing urban context and infrastructure, rededicating as the introduction of a new utilisation that diverts from the former one. Land recycling is a general term indicating the effort to reuse a degraded site. Rehabilitation again refers to a reintegration of the site into a given or planned infrastructure. The northern American term of brownfields re-development would in this context be related to the general term of reclamation, greenfieds are 'virgin' land, i.e. not affected by any negative anthropogen influence (after Genske 2000, modified).

investigation stands and falls with the degree of preparatory investigation (NVN 5725, 1998). Furthermore, being the most economical part of hazard assessments, the MTDS was expected to become increasingly important. Growing numbers of remediation cases demand more accurate a priori-knowledge to allow cost-effective approaches for the assessment of the distribution of contaminants in the subground.

Although the base for decision is widened constantly by incoming data from the progressing assessment and remediation process, the presence of imprecision, uncertainty, vagueness remains, calling for a heuristic[2] approach. Among other factors, the heterogeneous character of urbic anthrosols and small-scale variations of pollution are responsible for this. "Fuzzy Assessment of Contamination Potentials" (Heinrich, 2000) features a method for handling these inherent difficulties. A Fuzzy Expert System[3] called SAFES (Soil Assessment Fuzzy Expert System) was developed to model site factors during hazard assessment. Uncertainty prevails throughout hazard assessment and remediation. To exemplify the use of fuzziness, the assessment of contamination potentials[4] at a wastewater purification plant (WP) was performed by means of SAFES. The refinement lies in the integration of soft data in a computer model with a subsequent standardization of the evaluation process. Fuzzy expert judgment that always existed and played an unspoken role in evaluation is now integrated in the risk assessment. This additional knowledge enhances the quality of the desk study as the basis for the sampling strategy.

More and more, industry as well as academia become aware of the potential of this tool and intend to apply fuzzy approaches in one way or the other. The thesis at hand serves not only as an eye-opener but also – since it is published in the right point in time – as inspiration for further applications not only in geosience. For instance, the Swiss Federal Institute of Technology in Lausanne is planning, in co-operation with the World Health Organisation (WHO), to apply fuzzy desk studies in order to identify high risk communities with respect to insufficient sanitation and related adverse health effects (Briod & Heinrich, 2000). Every year more than two million people, especially children, die from diarrhoeal diseases. Some billions in the developing world are suffering at any one time from one or more of the six main diseases associated with hygiene, sanitation and water supply which are diarrhoea, ascaris, dracunculiasis, hookworm, schistosomiasis, and trachoma. Also in this field fuzzy mapping strategies may help to identify communities at risk and to reduce the death toll in regions where only little data is available but immediate help is needed urgently.

2 Technique of investigation and problem solving that can be acquired solely by practice and experience using inductive reasoning

3 In this thesis the term expert system refers to computer systems

4 Detailed definition of the term 'contamination potential' in section 4.2.1

Fuzzy assessment of contamination potentials (K. Heinrich 2000)

MULTI-TEMPORAL DESK STUDY (MTDS)

A MTDS is an effective tool for environmental assessments of contaminated land (brownfields). Much of the assessment uses aerial photos, which in Europe, date usually from the late 1920's. MTDS aids to qualify and quantify natural changes, anthropogenic impacts and management effects. Where retrospective monitoring over long periods is needed (e.g. brownfield rehabilitation), aerial photography - as a snap shot of reality - often represents the sole source of synoptic information. As backward-looking appraisal, MTDS facilitates the documentation of baseline conditions, falling back on spatio-functional and temporal changes and trends for the design of a sampling plan for the field campaign. However, the interpretative character of an MTDS needs a revived discussion about uncertainties involved and their proper handling.

FUZZINESS IN MTDS

Besides the appraisal of hard data, brownfield rehabilitation is frequently characterized by uncertainties, involving desk studies, field reconnaissance, site investigation with sampling and geo-technical and chemical analyses, their interpretation and the subsequent derivation of a remediation and monitoring strategy. That means, partial ignorance, errors, uncertainties, vagueness, imprecision, ambiguity, variability and data gaps are present in the evaluation and modeling during hazard assessments. These types of uncertainties are described by the term 'fuzziness'. The handling of fuzziness is embodied in the so-called fuzzy set theory. According to fuzzy-logic theorists, classical logic oversimplifies the concept of Cantorian set membership by categorically including or excluding an element, whereas fuzzy logic manifests itself by the degree to which an element relates to (or is member in) a set. Membership in fuzzy sets is expressed in possibilities or degrees of confidence taking values in a continuum ranging from 0 to 1. The degree of confidence (or membership) is determined by a so called membership function that permits a gradual as well as complete membership.

Figure 1 illustrates the difference between crisp and fuzzy sets for the descriptive term ‘large volume of a liquid waste tank’.

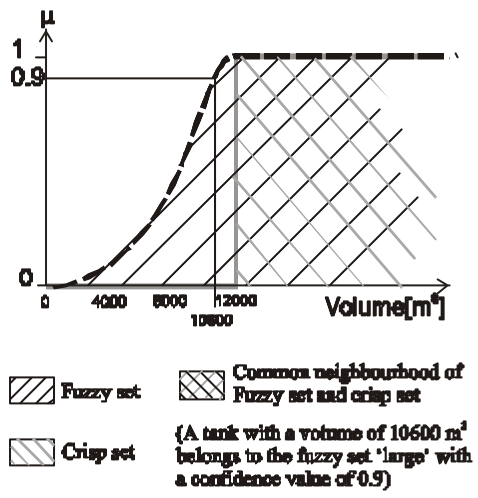

Figure 1. *Difference of crisp and fuzzy sets*

Fuzziness in MTDS and geoscientific evaluation is usually bridged by interpretation employing natural language with semantic heuristic descriptors. Natural language is a flexible, powerful and common tool of interpretation. Fuzzy set theory provides a method to include this flexibility in computer modeling. Fuzziness within traditional evaluation approaches exists, but was often not acknowledged as such. Hitherto, during environmental assessments, it has been also good practice for geoscientist to evaluate, model, and translate an interdependent and heterogeneous fuzzy body of evidence. During evaluation, any linguistic manifestations of an entity (soft data), such as ‘very true’, ‘highly permeable’, ‘extremely contaminated’, etc., is interpreted externally without computers, i.e. within the minds of experts. If possible the external interpretation is somehow translated into a single crisp value (crisp = not fuzzy) before starting high precision modeling using geostatistics and Geographical Information Systems (GIS). In the context of environmental monitoring, the use of high precision tools such as GIS can therefore result in superimposed pseudo accuracy. In consequence, the results may be unrealistic.

Thus, any system and method that introduces external mental fuzzy reasoning processes of experts adequately into computerized modeling processes contributes towards better transparency of evaluation and quality of modeling. The Soil Assessment Fuzzy Expert System – SAFES - is a contribution to an enhanced handling of inherent fuzziness in brownfield rehabilitation in general and multi-temporal desk studies in particular. The inference by means of a Fuzzy Expert System (FES), results in an enhanced standardization of the evaluation and transparency of the deduction process is improved. Simultaneously, the advantages of lexical flexibility during interpretation is kept.

The awareness of wide spread uncertainties in retrospective hazard assessment and site remediation made the use of fuzzy set theory self evident, in particular as a tool for describing, processing and predicting soil contamination. After having concluded that fuzziness is inherent to any hazard assessment of brownfields it was investigated, if a FES, being capable to handle soft data and uncertainties, can possibly improve the base line for planning of field reconnaissance and site investigation. A further question was whether it would be worthwhile to extend the FES to other steps within the hazard assessment procedure, such as the field campaign during site investigation.

SOIL ASSESSEMENT FUZZY EXPERT SYSTEM - SAFES

SAFES has been developed for the MTDS of an industrial wastewater purification plant (WP). The outcomes of a SAFES consultation are contamination potentials related to observed items (OBI’s), such as installations, surface discoloration, necrotic vegetation, etc. However, the inquiry was generalized in order to reach broad applicability. The development of knowledge and rule base of SAFES, is based upon characteristics of environmental relevant entities, the specific range of features (spatially and temporal), their relative intensity and a semantic code for description of the entities (OBI’s). The semantic descriptors helped to define values, shape, and number of membership functions over a certain part of the universe of discourse (in this case all possible observable features at the WP).

SAFES is conceptually simple. The system consists of an input stage, a processing stage and an output stage. During the input stage, the assessor’s data entries are mapped to appropriate membership functions. The mapping results in confidence values – CF (confidence values or membership degrees). The inference engine invokes each appropriate rule when $0 < CF \leq 1$. It combines and aggregates the results of the rules. During the output stage, the conversion of the aggregation back into crisp output values results in contamination potentials for OBI's.

REAL WORLD MODEL VERSUS MODEL OF CONTAMINATION POTENTIALS

After implementation of SAFES, the MTDS evaluation was performed by assigning to all OBI's a contamination potential. Based upon this, a map displaying discrete contamination potentials and two spatial models was developed:

Figure 2 shows a multi-temporal batch map, displaying all OBI's ever observed within one information layer (batch). The assigned contamination potentials refer to discrete OBI's

Figure 3a shows an interpolated (kriged) map of the real-world contamination distribution based upon a site investigation for hazard assessment.

Figure 3b shows an interpolated (kriged) map of SAFES contamination potentials

The comparison between the real-world contamination situation and SAFES contamination potentials has been performed by means of the (kriged) GIS models. This area-wise comparison showed a good matching result. However, a reverse order of field campaign and MTDS caused some limitations and distortions in the evaluation of the SAFES contamination potentials (Cp's). The real-world model may be erroneous at locations with high SAFES contamination potentials because these points have never been sampled during the field campaign. Also other drilling sites were not placed optimally. Besides this, a potential dynamic component of pollutants (migration) due to geo-hydrological effects was not considered in the real-world model.

Despite the adverse facts mentioned above, the area-wise comparison shows encouraging results; when allowing a maximum error of one class width over- or underestimation (in figure 4, the white and speckled areas), about 92% of the total area have been estimated correctly. In one subarea (Zone C - homogeneous utilization, relatively short contamination history) 60% of the predictions were correct and when permitting a maximum deviation of one class, more than 92,5% of Zone C was assessed correctly by the SAFES supported MTDS.

The area-wise comparison proves the inherent quality of SAFES and shows the robustness (that still can be improved) of the fuzzy set approach for the interpretative (remote) assessment of contamination potentials within the scope of an MTDS.

A harmonization between a high quality MTDS, comprising of a batch map with discrete OBI related contamination potentials, and an interpolated map of these Cp's leads toward a reduction of costs for sampling and sample analyses without reducing the quality of the real-world model.

The thesis shows that fuzziness is inherent to environmental assessments. Generally, the acknowledgement of fuzzy components in environmental science should be promoted without neglecting other traditionally applied techniques of modeling. The fuzzy approach is reaching its full strength in combination with other modeling methods. Each of these methods should be applied according to their inherent strength and if possible be combined.

So far SAFES is based upon a single case. In future it would be advisable to test the system at other sites in order to improve its performance.

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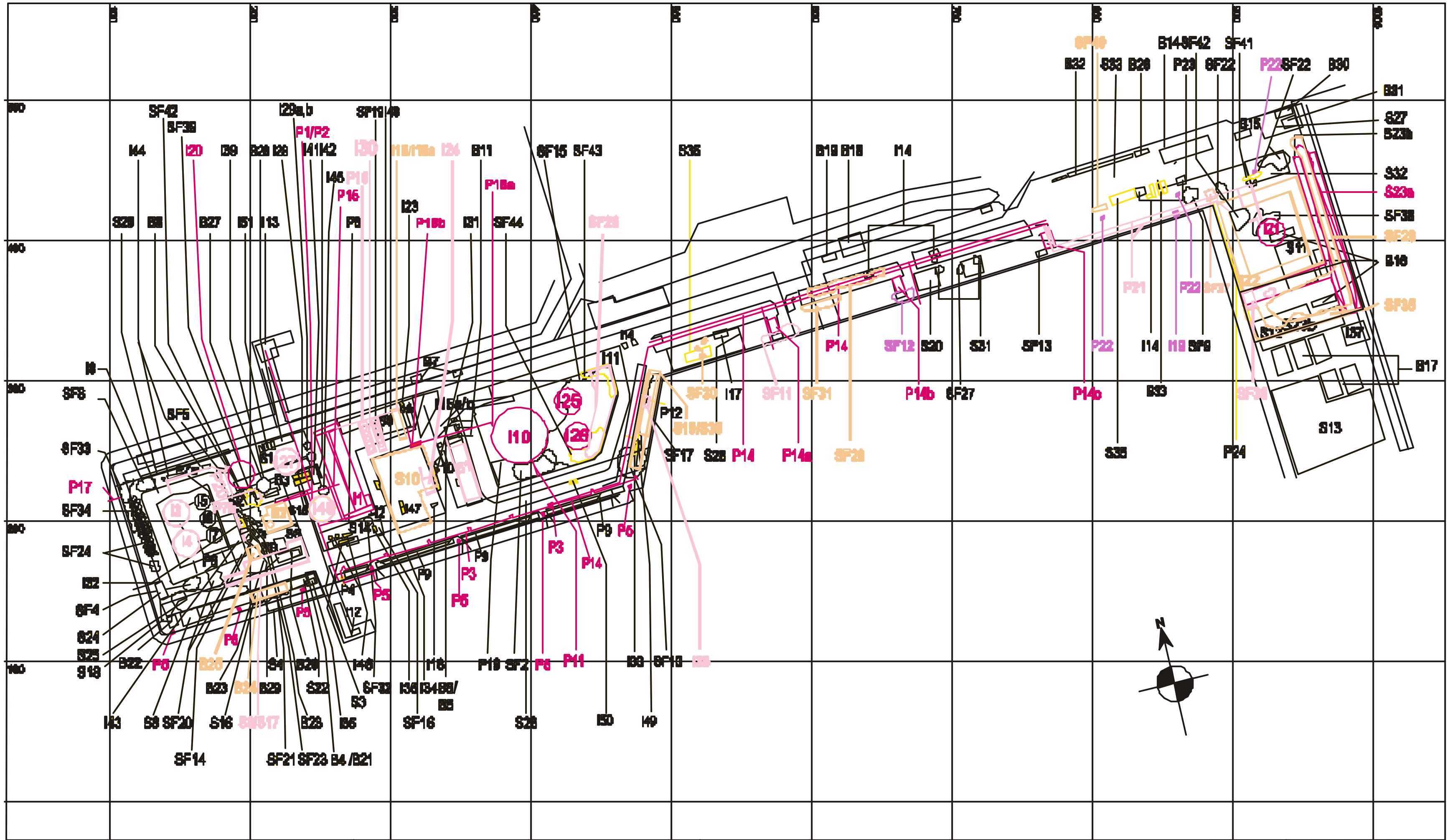
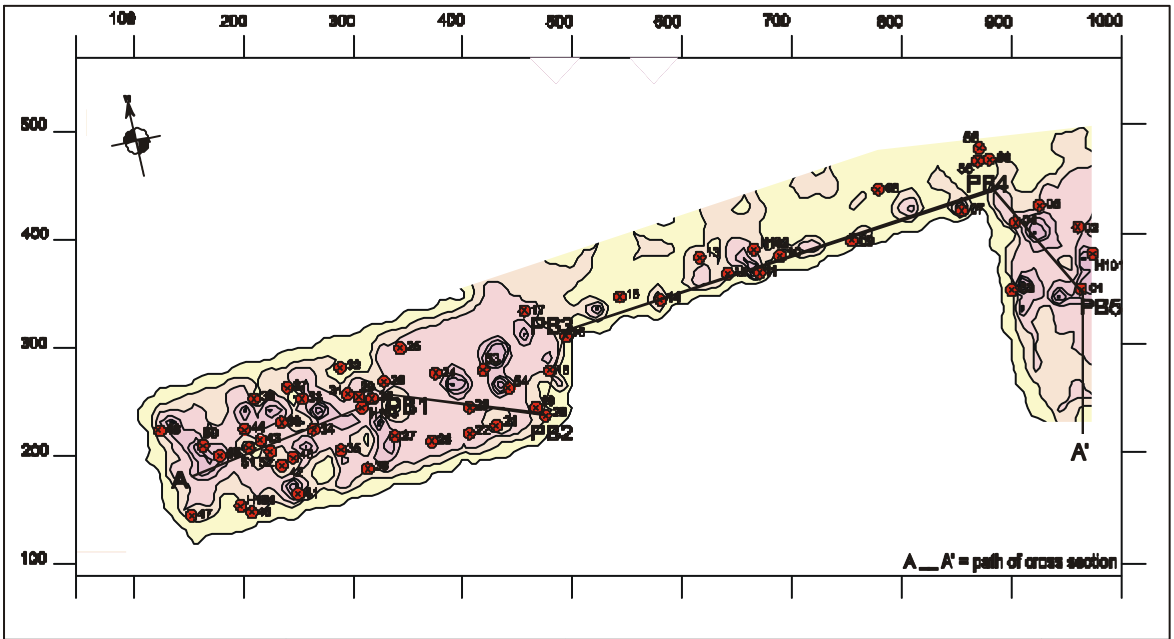
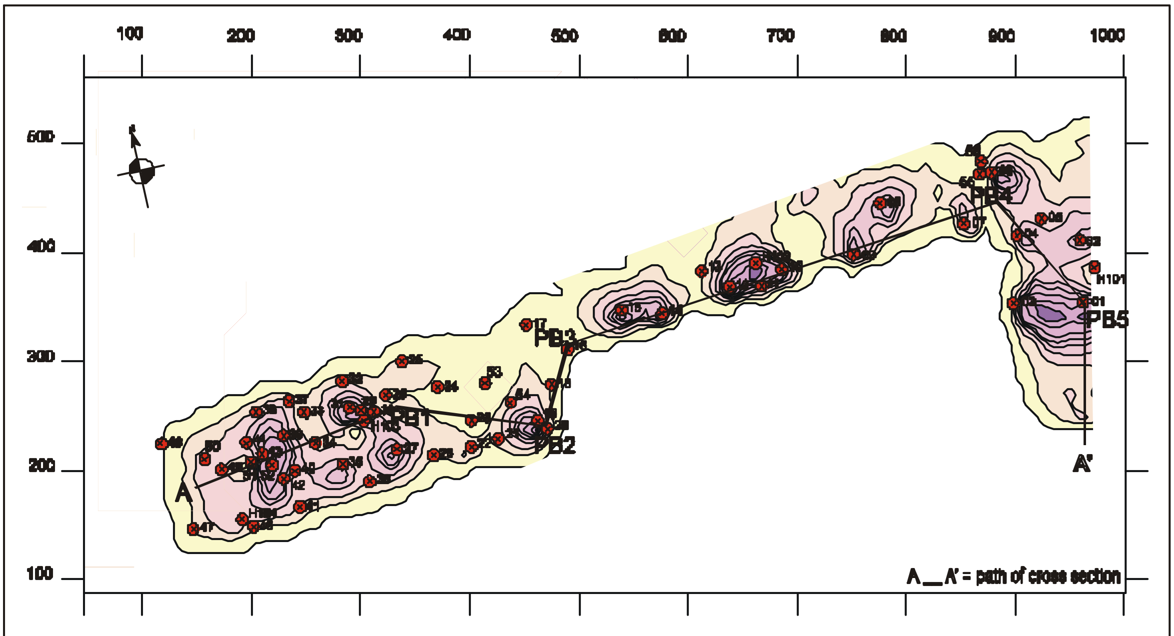


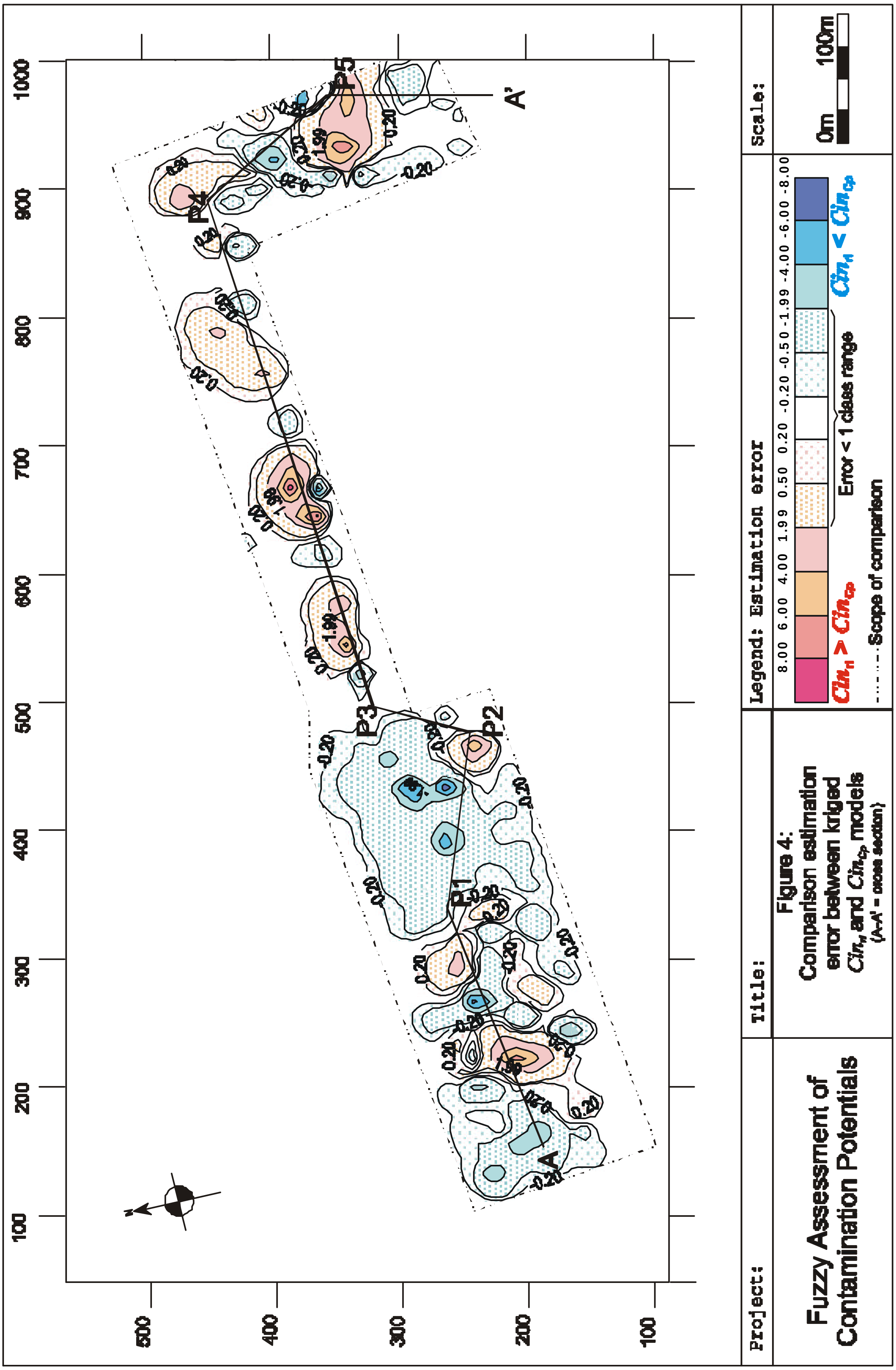
Project:	Title:	Legend: Classes of contamination potentials	Scale:
Fuzzy Assessment of Contamination Potentials	Figure 2: Multi-Temporal Aerial Photo Interpretation: Batch map of final contamination potentials of the years 1955-1995	0 - 2 Potentially not contaminated >2 - 4 Low contamination potential >4 - 6 Medium contamination potential >6 - 8 High contamination potential >8 - 10 Potentially contaminated	0m 100m



Project:	Title:	Legend: Degree of entity (Contamination Potential)	Scale:
Fuzzy Assessment of Contamination Potentials	Figure 3a: Kriged contamination potentials (Cin_o)	0.25 0.5 1 1.5 2 4 6 8 10 Potentially not contaminated Low Medium High PC (White area = water or external terrain; not assessed)	0m 100m



Project:	Title:	Legend: Degree of entity (Contamination degree)	Scale:
Fuzzy Assessment of Contamination Potentials	Figure 3b: Kriged real-world contamination indicators (Cin_r)	0.25 0.5 1 1.5 2 4 6 8 10 Potentially not contaminated Low Medium High PC (White area = water or external terrain; not assessed)	0m 100m


Project:
Fuzzy Assessment of Contamination Potentials
Title:
Figure 4: Comparison estimation error between kriged Cin_{n} and Cin_{cp} models
(A-A' - cross section)
Legend: Estimation error
8.00 6.00 4.00 1.99 0.50 0.20 -0.20 -0.50 -1.99 -4.00 -6.00 -8.00
$Cin_{n} > Cin_{cp}$
Error < 1 class range
$Cin_{n} < Cin_{cp}$
Scope of comparison
Scale:
0m 100m
P1
P2
P3
P4
P5
A
A'
100 200 300 400 500 600 700 800 900 1000
100 200 300 400 500

Thesis abstracts

This section is aimed at the introduction of M.Sc. (Ir.) level research at the Engineering Geology divisions of the Faculty of Applied Earth Sciences, Delft University of Technology, and that of International Institute for Aerospace Survey and Earth Sciences. We will include abstracts of two randomly selected theses in each volume. Our intention is to give some idea to the geoscience community about the type, and diversity of research undertaken in engineering geology sections of these two institutions.

Neurofuzzy Modeling of TBM Performance with Emphasis on the Penetration Rate

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Faculty of Applied Earth Sciences,
Section Engineering Geology
December 1998

This thesis deals with the performance of tunnel boring machines (TBM) in hard rock with the emphasis on the penetration rate. At the Section of Engineering Geology, research has been conducted to the performance of rock cutting tools, which started with the work of Deketh and Verhoef and is currently continued by Alvarez Grima Last year the Section of Engineering Geology got hold of a database which was compiled at the University of Texas, and contains data on 640 tunnel projects, which makes this database the largest, freely available database on the performance of TBMs in rocks.

During the research at the Section of Engineering Geology to the performance of rock cutting tools, new modeling tools, like fuzzy and neural network modeling have been applied, A relatively new technique called neurofuzzy modeling combines the advantages of both these techniques. The aim of this research is therefore to develop a model for the prediction of the performance of hard rock tunnel boring machines using neurofuzzy modeling.

The most important performance parameters of a TBM are the penetration rate, the utilization, the advance rate, the wear rate and the stability. The emphasis of this research is on the penetration rate, although preliminary modeling strategies for the other performance parameters are presented as well.

The results in this thesis are limited by the quality of the database. We do not have access to the most detailed parts of the database because of confidentiality reasons. Also the origin of the data is confidential, the records can therefore not be verified. The size of the database will make sure that the entire domain of TBMs is reasonably well covered.

For the development of any predictive model it is essential to understand the processes involved, but also the contents of the available data base. For this reason a thorough literature study has been performed and with the aid of a detailed investigation of the available data it was possible to develop a modeling framework that can be used for modeling the performance parameters with the available data. Only the penetration rate was further modeled, since it gives the best chances of success.

To develop a neurofuzzy model is not a straightforward operation, so that a four step modeling strategy had to be developed. This strategy included preliminary structure selection, development of a neurofuzzy model, model validation and comparison. The preliminary model structure selection resulted in 18 different models. With the different training and checking sets, and different modeling options the number of developed neurofuzzy models reached into hundreds. From these models, four were selected for further interpretation and validation. The result is a single model that includes a measure of the core fracture frequency, the unconfined compressive strength, the thrust per cutter, the diameter of the cutter and the RPM. The performance of the neurofuzzy model was than compared to an empirical model and several linear and non-linear models.

The research shows that it is possible to use neurofuzzy-modeling techniques to predict the penetration rate. The errors of the neurofuzzy model are lower than those of the other models. The interpretability is also the best with the neurofuzzy model, but can be improved by using different algorithms. The modeling strategy adopted performed very well and can be used for other problems as well. The strength of the modeling strategy lies in the combination of different methods.

Comparative Settlement Analysis by Using 3D GIS and 2D FEM Approaches: A Case Study in Sliedrecht Area – the Netherlands

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International Institute for Aerospace Survey and Earth Sciences, Section Engineering geology
July, 2000

The surcharge due to buildings and roads affects subsurface and ground behavior and causes settlement problems. Since resulting damage and repair work may cost considerable amount, an accurate modeling of subsurface conditions and prediction of ground-structure interaction call help avoiding such undesirable foundations. In this research, settlement analysis by using three dimensional geographic information system (3D GIS) and two dimensional finite element (2D FEM) modeling are both carried out and the results are compared and correlated.

Settlement analysis by using 3D GIS approach is performed for two different geometrical conditions by using modified Terzaghi or so-called Koppejan Formula for long-term settlements. The compressibility coefficient involved in the formula has been determined considering three different approaches and the analysis is performed for each of them. Thereafter the settlement results are presented as settlement prediction maps for comparison purposes and as 3D isovolumes to reflect the real picture of settlement predictions.

After performing the 2D based settlement analysis on the sections taken from the 3D-geology model the results are compared and correlated visually and statistically with 3D analysis results at the same sections. Statistical analysis results showed that there is a significant linear relationship and a very strong correlation between 2D FEM based and 3D GIS based settlement analysis results. The order of magnitude difference between 2D FEM based and 3D GIS based results is mostly due to constitutive laws of the softwares and the parameters and equations used in calculations. Terzaghi equation, which is used in 3D settlement calculations, is a logarithmic function whereas the 2D analysis is based on a linear function according to Hooke's Law of linear elastic stress-strain relationship. Five different soil units, which have different E values and C' values determined on the basis of different approaches, thickness of layers considered in two approaches, volume weighted average method used in 3D settlement analysis are the other factors that play a role in the difference in the order of magnitude of settlement results. The number of variables affecting the results restrained the comparison between the results of 2D and 3D settlement analysis to be qualitative rather than quantitative.

CALL FOR CONTRIBUTIONS TO THE NEW SECTION:

<u>“Amazing Projects”</u>

The contributions to this section should bring to the readers notice the “unusual aspects” of the projects that you take part in or that you have read in a magazine, journal, book or in a newsletter. The “unusual aspects” of the project can include scientific, technical, financial, legal, social etc., extremes. For example, the unusually high or low values measured in an experiment or the very expensive or very cheap contracting of a project, or examples of very bad or very good decision making in an engineering problem etc.

Recently published papers

Most members of the Ingeokring are working in the field of Engineering Geology and related fields of expertise. By virtue of the interdisciplinary character of Engineering Geology the topics of work and study of the members of the Ingeokring range widely, and as a result their work is published in journals and proceedings of different nature. Because of this, not all publications come to the attention of the different members. To ease the access to the publications of different Ingeokring members, the authors of recently published papers are given the opportunity to present a short abstract (15 lines) of their publication, in the Newsletter. In addition the authors should give a name and address, to which persons that are interested can respond to for more information.

Estimating error in geophysical sub-bottom profiling

Accuracy 2000. Proceedings of the 4th International Symposium on spatial accuracy in natural resources and environmental sciences. Amsterdam, The Netherlands, July 2000. Eds.: G.B.M. Heuvelink, M.J.P.M. Lemmens. p. 457- 464. Uitgever: Delft University Press. ISBN: 90-407-2085-1. (CA 2402).

Two complimentary approaches, statistical and analytical, are considered when estimating the accuracy of surveys that are carried out to determine quantities of sediments for dredging. Early surveys for such estimation are done by sampling on a grid system that gave little indication of the variability of such sediments between the sampling points so that only rough estimates could be made of the quantities. This could result in substantial cost overestimation in the order of many millions of Euros. Continuous geophysical reflection surveys were made at numerous locations in the Netherlands as well as case studies in the harbors of Bergen and Gothenburg. The accuracy of seismic-reflection surveys (also referred to as sub-bottom profiling) is a function of the frequencies of the acoustic signal the frequency at which values are obtained from the acoustic profiles (sampling frequency fs), position, and interpolation between traverse lines. Other factors play a role such as interpretation, poor, virtual or migrated reflectors, sediment mobility, truthing and, ultimately, objectives of the sediment survey. The variability of the top sediment could be determined along a traverse line and is compared with the resulting variability obtained from interpreted contouring between the traverse lines. An example is presented for a survey carried out in the Alvsborg basin of Gothenburg Harbor. Top sediment isopach variability corresponds to the average variability of the profiles. Coefficient of variation (CoV) is used to quantify variability. Sampling frequency and sedimentation energy levels both have an effect on variability

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Statistical analysis of benchmark stability prior to natural gas extraction in a Holocene clay and peat area, province of Friesland, The Netherlands.

Proceedings of the 6th International Symposium on Land Subsidence, Ravenna, Italia, 24-29 September 2000. Eds.: Carbognin, L.; G.Gambolati, A.I.Johnson, Padova, Italy. ISBN: 88-87222-06-1. p. 237-254. (CA 2402).

Benchmarks attached to civil structures are used for monitoring of land subsidence above natural gas extractions. Many of the structures are founded on compressible clay and peat layers. Autonomous vertical velocities of the benchmarks (- 6.75 to + 1.75 mm/year), mainly related to excessive lowering of polder water levels, which cause the oxidation of peat, give a component in measured bruto height differences between successive surveys, which has to be eliminated, to reach the true land subsidence value.

Statistical K-means cluster analysis was found suitable to classify the data set of historical vertical velocities of the benchmarks, prior to the start of the natural gas extraction. The optimum number of clusters appeared to be three, with clay thickness as the leading parameter and to be the most important factor in the process causing the vertical velocities. The other parameters used in the analysis were peat thickness and polder water levels. Not enough data was available on foundation conditions to be used in the analysis, although from the interpretation of

cluster results the generally known foundation conditions in the area could be reasoned.

If validated with data sets of similar areas and further developed, the described method may serve as a basis for selecting benchmarks with an acceptable confidence level of autonomous historic vertical velocities, to be used in surveys for land subsidence measurement.

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Overview modelling gas production-induced seismicity mechanisms

Published in: Proc. Eurock 2000 Symposium, 27-31 March, Aachen, Germany

Several studies have been carried out at Delft University of Technology in order to analyze seismicity that might be related to gas production. An overview will be given in this paper.

Models show that the sensitivity for fault activation due to differential compaction evidently depends on the fault-reservoir geometry. This behavior is supported by several subsequent case studies of fault behavior in producing gas reservoirs. Examples of such reservoirs, presented in this paper, are Eleveld and Bergermeer in the Netherlands. A comprehensive study about an anticline-shaped reservoir concluded also in activation of a normal fault at reservoir level as dominant mechanism. In another study, the effects of gas storage on the relationship between pore pressure variations and fault slip are investigated. The results from this numerical modeling are that during the initial production phase, fault slip might occur locally, due to compaction of the reservoir, and that no significant amounts of additional slip occur when the reservoir is subjected to alternating injection / extraction periods.

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The Netherlands

News and announcements

SIXTH INTERNATIONAL SYMPOSIUM ON IN SITU AND ON-SITE BIOREMEDIATION
San Diego, California, June 4–7, 2001

Information: Bioremediation Symposium Registrar, The Conference Group, 1989 West Fifth Avenue, Suite 5, Columbus, OH 43212-1912, USA, 1-800-783-6338, (614) 424-5461, fax 614-488-5747.
E-mail: conferencegroup@compuserve.com

2001: A GEO-ODYSSEY, GEO-INSTITUTE CONFERENCE ON FOUNDATIONS AND GROUND IMPROVEMENT
Blacksburg, VA, June 9-13, 2001

Information: J. Michael Duncan, CEE Department, 200 Patton Hall, Virginia Tech, Blacksburg, VA 24061-0105, (540) 231-5103, fax 540-231-7532.
E-mail: jmd@vt.edu

IN SITU MEASUREMENT OF SOIL PROPERTIES AND CASE HISTORIES
Bali, Indonesia, May 2001

Contact: unpargec@home.unpar.ac.id, or slawi@bdg.centrin.net.id

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UNITED ENGINEERING FOUNDATION CONFERENCE: LANDSLIDES - CAUSES, IMPACTS, AND COUNTERMEASURES
Davos, Switzerland, June 17 - 21 2001

Chairs: Prof. Herbert Einstein, MIT; Prof. E. Krauter

Geo-International, Mainz, Germany.
E-mail: engfnd@aol.com
Tel:(212) 591-7836, Fax: (212) 591-7441

17TH INTERNATIONAL MINING CONGRESS AND EXHIBITION OF TURKEY
Ankara, Turkey, June 19–22, 2001

The Congress is organized by the Chamber of Mining Engineers of Turkey. The principal objective of the conference is to promote operational, economical and scientific information pertaining to all aspects of mining technology. The 17th International Congress will cover an entire range of topics in "Application of Advance Technology in Mining and Process Engineering" and "Practical Solutions to Mining Problems". The specific themes of the conference are: Advanced Technology in Mining, Rock Engineering, Production and the Environment, Mining Engineering Education in the New Millennium, Natural Resource Management, Computer Applications in Mining, Process Engineering, Health and Safety, and Practical Solutions to Mining Problems.

For information on the technical program and registration, please, contact the Congress Chairman:
Dr. Erdal Ünal
Department of Mining Engineering
Middle East Technical University
06531 Ankara / TURKEY
Phone: +90 312 2102669
Fax : +90 312 2101265
E-mail : eunal@metu.edu.tr

DIGITAL EARTH 2001
Fredricton, New Brunswick, June 24–28, 2001

Information: Sheri Flanagan, Public Relations Coordinator, Digital Earth 2001 Organizing Committee, 264 Rookwood Avenue, Fredricton, NB E3B 2M2, Canada, (506) 458-8533, fax 506-459-3849.

NEW PARADIGMS FOR THE PREDICTION OF SUBSURFACE CONDITIONS— EuroConference on the Characterisation of the Shallow Subsurface: Implications for Urban Infrastructure and Environmental Assessment
Spa, Belgium July 7-12, 2001

Information: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France, 33-388-76-71-35, fax 33-388-36-69-87.
http://www.esf.org/euresco/01/pc01148a.htm

ENVIRONMENTAL AND ENGINEERING GEOPHYSICAL SOCIETY (EEGS) ANNUAL MEETING
Birmingham, England, September 2–6, 2001

Important dates and deadlines!

May 1, 2001 Submission of abstracts
May 1, 2001 Deadline for early registration (reduced fees)
August 1, 2001 Final announcement
August 15, 2001 Deadline for acceptance of cancellations

Topics of the 7th Annual Meeting will include: Engineering site investigation, Cavity and void detection, Foundations and structures, Hydrogeology, Contaminated land and pollution monitoring, Waste disposal, Environmental investigation, Archaeology

For further details contact:
Helen Wilson, Michael Stephens
Address: Burlington House
Tel: +44 (0)20 7734 9944; +44 (0)20 7287 1433 Fax: +44 (0)20 7494 0579
Email: helen.wilson@geolsoc.org.uk; michael.stephens@geolsoc.org.uk

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ERES 2001: THIRD INTERNATIONAL SYMPOSIUM ON EARTHQUAKE RESISTANT ENGINEERING STRUCTURES
Malaga, Spain, September 4–6, 2001

WATER POLLUTION 2001: SIXTH INTERNATIONAL CONFERENCE ON MODELLING, MEASURING AND PREDICTION OF WATER POLLUTION
Rhodes, Greece, September 11–13, 2001

Information: Susan Hanley, Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK, 44 (0) 238-029-3223, fax 44 (0) 238-029-2853.
E-mail:shanley@wessex.ac.uk

INTERNATIONAL CONFERENCE ON ENGINEERING FOR OCEAN AND OFFSHORE STRUCTURES, *Singapore; December 18–19, 2001* and **INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING DEVELOPMENT,** *Singapore, December 20–21, 2001*

Information: Conference Secretariat, CI-Premier PTE Ltd., 150 Orchard Road #07-14, Orchard Plaza, Singapore 238841, (065) 733-2922, fax 065-235-3530.
E-mail: cipremie@singnet.com.sg

INTERNATIONAL ASSOCIATION OF MATHEMATICAL GEOLOGY (8TH INTERNATIONAL CONFERENCE)
Cancun, Mexico, 8–15 September 2001

Technical Sessions: Ground Water Applications, Computer-Aided Modeling in Marine Geosciences, Geochemistry, Geostatistics and Data Integration, Geophysics and Geoengineering, GIS applications and digital field data capture: integration of geologic database development, analysis, and map production, Mineral Resources, Mining, and the Environment, Geologic Modeling and Simulation of Sedimentary Systems, Building National and Regional Geologic Map Databases, Petroleum Geology, Prediction Models in Spatial Data Analysis, Statistics in the Earth Sciences, Numerical Methods and Applications, Fractal/Multifractal and Scaling Modeling and Geographical Information Systems

Contact: Gina Ross, Kansas Geological Survey
E-mail: aspiazu@kgs.ukans.edu; Website: www.kgs.ukans.edu/Conferences/IAMG/index.html

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INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS, "NEW APPROACHES TO CHARACTERISING GROUNDWATER FLOW" (31ST INTERNATIONAL CONGRESS)
Munich, Germany, 9–15 September 2001.

Contact: Munich 2001, Institute of Hydrology, GSF National Research Centre of Environment and Health GmbH, Ingolstädter Landstr. 1, D - 85764 Neuherberg, Germany; Phone: +49 89 3187 2585; Fax: +49 89 3187 3361; E-mail: seiler@gsf.de; Website: agh.iaag.geo.uni-muenchen.de/

EngGeolCity – 2001, INTERNATIONAL SYMPOSIUM ON ENGINEERING GEOLOGICAL PROBLEMS OF URBAN AREAS
Ekaterinburg, Russia, 30 July – 2 August, 2001

Organized by the International Association for Engineering Geology and the Environment (IAEG), the National Group of Engineering Geologists of Russia, and the Association of Economical Interaction Between Areas and Republics of the Ural Region.

Topics: Engineering geology and rational use of urban areas, Engineering geological and engineering environmental site investigations on urban areas, Natural hazards and stability of urban areas, Technogenous changes in urban geoenvironment, Use of urban underground space, Protection of historical, architectural and cultural sights, Geoinformation systems of urban geoenvironment

Milestones: More information will be provided in Bulletin No 1,2.

Correspondence: Secretariat of EngGeolCity – 2001, UralTISIZ 79, Bazhov str., Ekaterinburg, Russia, 620075, Tel: (3432) 559 772, Fax: (3432) 550 043, E-mail: UralTIS@etel.ru

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AGGREGATE 2001 CONFERENCE, ENVIRONMENT AND ECONOMY
Helsinki, Finland, August 6-10, 2001

Organised by the Finish National Group of IAEG and the Aggregate Commission of IAEG.

Topics: Geological grounds for aggregate production, Classification of aggregate and available production techniques, Prospecting and testing raw materials for aggregate production, Mineralogical studies and long term durability of aggregate, Environmental influences of quarrying and processing aggregate, Importance of aggregate industry for national economies.

Milestones: November 1999 – Bulletin 2, conference registration form, April 30, 2000 – submission of abstracts, December 30, 2000 – submission of full papers.

Correspondence: AGGREGATE 2001, Tampere University of Technology, Laboratory of Engineering Geology, P.O. Box 600 FIN-33101, Tampere, Finland, Fax: (358) 3 365 2884,
E-mail: kuulavai@cc.tut.fi, or
pekka.ihalainen@luvy.fi

15TH INTERNATIONAL CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING (XV ICSMGE)
Istanbul, Turkey, 27-31 August, 2001

Correspondence: Prof. Ergün Togrol, Chairman Organising Committee, Faculty of Civil Engineering, Istanbul Technical University, 80626 Ayazaga, Istanbul, Turkey.
Tel: +90 212 285 3747 Fax: +90 212 285 6587

4TH INTERNATIONAL CONGRESS ON ENVIRONMENTAL GEOTECHNICS (4TH ICEG)
Rio de Janeiro, Brazil, September 2002

Correspondence: Luiz Guilherme de Mello,
4 ICEG-Rio 2002 c/o Dr Maria Claudia Barbosa, Programa de Engenharia Civil, COPPE-UFRJ, Cidade Universitaria û Ilha do Fundao, PO Box 68506, Rio de Janeiro 21945-970, RJ, Brazil
Fax: +55 21 280 9545
Email: 4iceg@pec.coppe.ufrj.br / lgdmello@usp.br

THIRD INTERNATIONAL CONFERENCE ON UNSATURATED SOILS
Recife, Brazil, 2002

Organised by: Brazilian Society for Soil Mechanics and Geotechnical Engineering (ABMS), Federal University of Pernambuco (UFPE), and International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)

Topics: development of modern unsaturated soil mechanics, theoretical and practical aspects of unsaturated soils, earth dams, landfills, foundations on expansive and collapsible soils

Correspondence: unsat@npd.ufpe.br

9TH INTERNATIONAL CONGRESS OF THE INTERNATIONAL ASSOCIATION OF ENGINEERING GEOLOGY AND ENVIRONMENT
Durban, South Africa, September 16-20, 2002

Organised by SAIG, the South African Council for Geoscience and the International Association of Engineering Geology and Environment (IAEG).

Topics: Engineering Geology for Developing Countries (Appropriate Technology), Waste Management, Engineering Geology Mapping and Site Investigations, Engineering Geology and the Environment, Groundwater, Construction Materials, Information Technology Applied to Engineering Geology, Gondwana Rocks and Engineering Geology, Groundwater.
Milestones: More up to date information will be available on the Internet early in 1999.

Correspondence: The technical committee, 9th IAEG Congress, P.O. Box 1283, Westville 3630 South Africa

The Netherlands Students Award for Engineering Geology

The Ingeokring, the Netherlands National Group of the International Association for Engineering Geology and the Environment (IAEG), has established a prize for the best ir., drs. or MSc thesis in the field of Engineering Geology submitted to a Netherlands institute of higher education. The prize consists of a sum of NLG 1,000 and a certificate, to be handed out at the annual meeting of the Ingeokring in the spring of 2000. The thesis must be a contribution to the application of earth scientific knowledge to the solution of problems in civil engineering, mining engineering or environmental engineering.

We invite the submission of theses produced in the academic year
September 1999 - August 2000

Individuals can send in their own thesis or the thesis of others. Membership of the Ingenieursgeologische Kring is not required. Three complete copies of the thesis (including figures, photographs, annexes) have to be submitted by January 1, 2000 to the secretary of the Ingeokring. The committee which will select the best thesis is composed as follows:

* Dr. H.R.G.K. Hack (chairman, Ingeokring)
* Ir. C.M. Breukink (IWACO)
* Ir. A.H. Nooy van der Kolff (Boskalis Westminster BV)
* Dr. J. Rupke (University of Amsterdam, Dept. of Physical Geography)
* Dr. P.N.W. Verhoef (TU Delft, Dept. of Applied Earth Sciences)

Criteria used for the selection will be:

* Relevance for earth sciences and engineering
* Scientific quality
* Originality of approach
* Quality of presentation

The Award is sponsored by:

* Ingenieursgeologische Kring
* Boskalis Westminster BV
* Fugro Engineers BV
* Ballast Nedam Engineers BV
* IWACO
* Rijks Geologische Dienst
* Geocom Consultants