GHERG overview notes

Background

The Geotechnical and Hydrogeological Engineering Research Group was established at the Churchill Campus of Monash University in 2009 with project funding of $3.25M from the Department of Primary Industries and in-kind support from Monash University. The initial funding covered the period from 1st July 2009 to 30th June 2014.

The stated objectives for GHERG were:

a) to address the issue of insufficient expertise and skill shortage by providing broad range geotechnical and hydrogeological research and development support to the Latrobe Valley coal mines;

b) to foster research and innovation in coal geotechnical and hydrogeological engineering, particularly in the areas of mine stability, mine monitoring systems and interpretation, ground subsidence, effect on rigid structures such as infrastructure, ground and surface water control in mines, and evaluation of models used in practice;

c) to review and develop systems modelling approach to planning, involving issues such as mine water quality, quantity, contamination, ground subsidence, safety risks and bushfires;

d) to provide support to the Technical Review Board (TRB), which will review all mining operations and their potential impacts; and

e) to develop training programs for mine personnel through short courses presented by members of the research group, as well as local or international academic and industrial experts. Other training may be provided through elective units in current civil engineering courses and/or a Masters level course.

Identification of research needs occurred during the first year of the establishment project. The Senior Research fellow was appointed August 2010; the Foundation Professor and Head of the Group commenced May 2011; laboratory and office spaces were established during 2011 and the second Research Fellow was appointed February, 2012. The group was fully-operational from February 2012. Since then GHERG's research team has grown and the staff are undertaking a broad range of research and education activities to meet the group's objectives

On 1st January 2014, the Gippsland campus of Monash University merged with Ballarat University to form Federation University. Under the two University's agreement for the merger, GHERG was transferred from Monash University to Federation University. Federation University strongly supports the future development of GHERG. GHERG also maintains loose ties with Monash University.

The contract for funding by the State Government was renewed in September 2014 for five years to June 2019, with funding of $2.475M allocated for the continuation ($550K/yr).

Research and Education to 2014

GHERG's contributions to date can be broadly divided into five areas: historical data collection, material properties and processes research, mine rehabilitation, education and training, and inputs to the Technical Review Board. The contributions to the first four of these are summarised briefly below.

2.1 Historical Data Collection

A searchable database has been created containing the majority of the archived records produced prior to 1995 that cover the geotechnical and hydrogeological knowledge of the State Electricity Commission for Victoria (SECV). The database also includes the historical borehole logs, photographs, aerial photographs and construction drawings available for the area. The full database is available to all approved users/researchers through GHERG. Copies of the database have been provided to the mine operators. The database contains the considerable legacy of past research results of the SECV. The University currently hosts the archive of the paper collection of reports and documents previously held by GHD for continued access by stakeholders under an agreement with GHD, who remain the 'owners' of the documents.

2.2 Material Properties and Processes Research:

The research topics tackled by GHERG extend the knowledge created by the SECV rather than replicating it. *The aim of all current and planned research is to explain those features of coal movement that are not explained by previous understanding.*

1. *Coal depressurisation and consolidation*

   Consolidation rates for brown coal are more complex than indicated from the historical literature. The complexity arises from the presence of small but geotechnically-significant quantities of trapped free gas at low confining pressures and the compressibility of the coal grains. These components appear to explain the historical 'factors' used to adjust the predicted dewatering volumes during coal consolidation and may explain the short to intermediate term movements of the coal during de-pressurisation and re-pressurisation. A new mathematical model for consolidation that incorporates these processes/characteristics has been developed. Additional long-term cyclic and constant load consolidation testing has demonstrated the occurrence of extensive time dependent strain in the coal.

2. *Coal tensile strength*

   No historical information was found on this property. A range of standard test methods have been used to quantify the coal's tensile strength. The tensile strength data provide valuable support for GHERG's developing understanding of joint formation, crack propagation and unloading response of the coal. They provide important contributions to the analysis of batter slope stability and the propensity of the surface of the coal batters to move during water flows into shallow cracks in exposed coal.

3. *Coal creep and physical and chemical responses to environmental change*

   GHERG's initial creep investigations showed the propensity for brown coal to deform extensively under relatively small environmental changes. Following a detailed review of the existing coal chemical and physical literature the environmental effects on brown coal are being investigated using a combination of molecular dynamics modelling and controlled chemical testing.

Laboratory tests are focussed on groundwater interactions with the coal, with specific interest in coal oxidation and thermal changes. This investigation of creep is a long term project.

4. *Interseam residual shear strength*

   A major contributor to the instability of the mine batters is the relatively low shear strength of the interseam sediments that are embedded between coal formations. Available data are relatively few and considerable uncertainty in the appropriate values for stability analysis exists. The major interest has been the interseam residual shear strength applicable to the large deformations following unloading of the coal sequence during mining. There are recognised problems of measurement of this property using standard laboratory techniques, GHERG developed a modified direct shear apparatus that provides high quality residual shear test data on small 60 to 100mm length samples. Further, a ring shear apparatus for large coal and interseam testing under high loading has been built and tested. Test results with both techniques have been produced with samples from Loy Yang and Hazelwood mines. Aspects of composite material residual shear strength have also been investigated.

5. *Surface-subsurface water interactions*

   A review of the historical modelling of groundwater conditions showed that surface-subsurface water interactions across the Latrobe Valley are poorly understood. The historical groundwater models employ simplified and uncertain representations of these processes. GHERG's research in this area has concentrated on two activities: (1) field data gathering on stream/aquifer interactions and shallow soil hydraulic properties, (2) disaggregation of surface water hydrographs from upland catchments to estimate upper and lower bounds for recharge. Results from the stream-aquifer interactions research indicate that, for stream locations previously considered to provide negligible recharge to the underlying formations, a small but significant exchange is occurring. The disaggregation of upland catchment hydrographs has been able to constrain the upper bound for recharge for the studied catchment. There has been no success in constraining the lower bound for this recharge other than to show that it is not negative.

2.3 Mine rehabilitation

AGL Loy Yang is providing financial and in-kind support to GHERG to address aspects of the future closure of the mine and its rehabilitation. The three areas of particular concern are the surface soils to be applied to the mine final batters, the availability of fill materials to raise the mine floor and control heave and the long-term risks associated with the burial of the power station ash. The expectation of inadequate soils to meet the requirements for final rehabilitation has encouraged novel research into the use of mine and local industry wastes for the generation of 'artificial' soils that can provide a stable cover for the mine batters. Long term field trials have been initiated to test alternative soil mixes. Most of this work is now concentrated at Monash University.

Loy Yang is funding a PhD student to study the management and environmental implications of power station ash disposal into the mine void. This study targets both the identification of suitable void fills as well as the long-term risks associated with current ash disposal practices.

2.4 Education and training

GHERG's education and training program comprises short courses, a new Masters in Geomechanics and Geohydrology, and the supervision of undergraduate research projects.

1. *Short Courses*

   Since March 2012, GHERG has developed and delivered six one-day short courses, three half-day short courses, an introductory seminar covering GHERG's research, a two day workshop on the use of the Geotechnical modelling package Plaxis 2D and a one day advanced workshop on Plaxis 3D. The six one-day short courses in 2012 provided overviews and introductions to Engineering Geology, Hydrogeology and Geotechnical Engineering. The half-day courses in 2013 concentrated on developing a basic understanding of reliability and probabilistic risk assessment methods for slope stability analysis.

2. *Masters in Geomechanics and Geohydrology*

   The new Masters in Geomechanics and Geohydrology is a part-time, distance learning course that commenced in March 2014. The program can be taken over three years and is open to graduate engineers and scientists who wish to develop a career in open-pit mining. The course is a long-term commitment for GHERG but is expected to become self-financing within 4 years.

3. *Undergraduate Research Projects*

   Twelve-week student engineering and science projects have been supervised each year by GHERG staff on mining related aspects of coal and interseam shear and permeability testing, groundwater modelling, stream-aquifer interactions, desiccation cracking of overburden soils, mining induced land movements and artificial soils.

3 Research in Progress (2014 onwards)

GHERG's ongoing research program targets four technical areas. These are the geotechnical model for the Latrobe Valley; the identification of the precursor indicators of slope failure; geo-environmental change and mine rehabilitation.

The chart overleaf summarises the research that rolled over into the new funding period. Activities 1 to 6 are concerned with developing the geotechnical model; activity 7 addresses one aspect of environmental change; and activities 8 and 9 are concerned with mine rehabilitation.

	Research Activity	2014				2015				2016				2017			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Consolidation processes and properties	x	x	x	x	x	x										
2	Interseam shear strength characterisation	x	x	x	x												
3	In-situ stress determination	x	x	x	x	x	x	x	x	x	x						
4	3D batter stability analysis		x	x	x	x	x	x	x	x	x	x	x	x			
5	Overburden characterisation	x	x	x	x	x	x	x	x	x	x						
6	Creep investigations	x	x	x	x	x	x	x	x	x	x	x	x				
7	Surface water-groundwater interactions	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	Ash disposal into mines	x	x	x	x	x	x	x	x	x	x	x	x				
9	Artificial soils		x	x	x	x	x	x	x	x	x	x	x				

Notes:

a. *Activities 1,2,3,4,5 and 8 are Higher Degree by Research projects.*
b. *GHERG scholarship funding is co-supporting students undertaking activities 1,2, and 7*
c. *Monash, Federation and External scholarships are co-funding students undertaking activities 1, 3, 4, 5, and 8.*
d. *Activities 5 and 6 are funded exclusively by GHERG project funding.*
e. *Activities 8 and 9 are co-financed by AGL Loy Yang*
f. *Activity 9 is now largely undertaken at Monash University.*

Activities 1 to 6 will contribute to better understanding of the geomechanical and geohydrological behaviour of the coal, interseam and overburden materials, essential for quantifying both short and long-term movement risks. In each case the evaluation of alternative methods of measurement and the design of test equipment form part of the research. A further objective is to establish easily measurable indicator data that can be used for rapid inference of material properties to reduce the overhead of standard measurements and test procedures

The results from these studies will be added to the historical knowledge of the general unloading behaviour of the coal and interseam to build a unified model of the material properties for each of the

major formations. The unified geotechnical model will be incorporated into existing or new modelling software for general application in mine stability assessments.

The research will be most useful when it is placed within the context of the geological variations and structures in the Latrobe Valley mines. It is essential for more complete mapping of the formations covering the spatial variation of the material fabrics and joints. The research being undertaken by GHERG assumes that the required mapping falls within the normal actions of the mine operators.

In conjunction with the consolidation results from Activity 1, the outputs of the current groundwater research (Activity 7) are anticipated to further refine the regional groundwater models for the Latrobe Valley.

Activities 8 and 9 contribute to knowledge on mine rehabilitation.

4 Future Research (2015 onwards)

In addition to the activities underway and highlighted in the preceding section, there are further research activities that are essential for the improvement of ground control management in both the current and future brown coal mines in Victoria.

4.1 Improvement of the Geotechnical Model

The plan by the DEDJTR to fund a batter stability project is a unique opportunity that: explicitly permits targeted field sampling and field data collection on a single batter; allows for the full suite of standard and new geotechnical and hydrogeological testing on the sampled materials; and, provides for a focussed, long term field monitoring program. If successful, it should test current geotechnical understanding; constrain parameter uncertainty about 'averaged' material properties for predictive modelling; demonstrate the value of probabilistic approaches for batter stability analysis and test new hypotheses about the long term behaviour of the materials, post mining. If the project takes place, GHERG will align its research under the current funding to take full advantage of the opportunities for integration with the project to maximise the value of the program.

Integrated into the contributions of the batter stability project and the research already identified as ongoing, the four research areas that will further expand geotechnical understanding of the Latrobe Valley formations are:

a) Analysis of the time dependent behaviour of groundwater pressures between permanent water bodies and mine batters.
b) Geochemical controls on coal stress/strain relationships.
c) Coal and interseam elasto-plasticity investigations.
d) Quantification of the spatial correlation structures governing property variations in interseam and overburden material

These research areas will also inform the planned work on the monitoring strategies for slope stability assessment described below.

4.2 Monitoring to identify the development of conditions for slope failure

The apparent pre-cursors for critical slope failure are over-pressures in the coal and interseam formations and the development of pathways for significant surface water inflows into the coal joints. A

small amount of work on this has been undertaken by GHERG to date, but considerably more work is needed to provide predictive tools for assessing the risks of their occurrence. Detailed work is required to model the movements and processes leading to the development of 'new' pathways for surface water inflows. This work needs to examine the relationship between the overburden and coal movements, the mechanisms of piping and cracking through the overburden and the timescales over which these are likely to occur.

The consequences of chronic water ingress from permanent water bodies or indirect recharge need to be further modelled in terms of the localised groundwater pressure responses and the expansion of the pressure fronts through the formations. The dynamic response of coal joints to groundwater pressures must be understood, as must the exchange of water between joints and adjacent under-saturated coal blocks Equally important is the development of models that assess the transition from stable to unstable conditions, created for example by flow changes in horizontal drains or progressive rises in shallow groundwater pressures.

4.3 Geo-environmental change studies

There are two primary areas of environmental research to be progressed. The first concerns a significant expansion of the research on the shallow surface environment and the recharge processes at a local and regional scale. Understanding these in greater detail is essential for understanding the depressurisation and future rebound of the aquifer systems of the Latrobe Valley. It is also essential for understanding the geochemical transition from a dominantly upward migration of groundwater to a generally downward migration of surface waters around the mines. The local influence of downward migrating groundwater in the vicinity of the mines must be understood in terms of geochemically mediated creep processes that are likely to be operating in the immediate area of the mines.

The second concerns determination of the rate of cooling of the geological sequence at both a local and a regional scale. The substantial water withdrawals from the aquifer are likely to be changing the thermal balance of the upper parts of the geological sequence. In the presence of strong, spatially localised recharge there will be a net cooling from this activity. The magnitude and extent of cooling are important for understanding the changes that will be taking place in the regional stress regime from thermal contraction of the coal. Similarly, the local thermal balance within the mines is evolving and the same issues of thermal contraction and alteration of the stress regime can be considered to be occurring around the mine perimeter at an, as yet, unknown rate.

4.4 Mine rehabilitation studies

This is an area of critical concern for the future. The problem of ensuring large scale stability of the mines batters after final rehabilitation is compounded by the need to understand the small scale stability of the soils and the shallow disturbed coal/backfill sequences, the alteration of the regional water balance and the water quality of the surface waters that will form in the mine void. These all depend on plans for backfilling the mine void, including the choice of fill materials and surface treatments to control erosion and mitigate artesian pressures in the ground. There will need to be a holistic treatment of all contributing issues to establish a general strategy for brown coal mine restoration.

Research currently being developed around constructed soils and ash as a component of mine backfill will be expanded to investigate: mine water rebound; mine hydrology (chemical and physical) post rehabilitation; and, slope stability of the final engineered slopes.

5 Future Training Needs

Education and training continues to be important for the future. Under the establishment contract, funding was available only to support training activity using GHERG contract and affiliated staff. Funding was not available to mobilise external educators or trainers. This is remedied in the current funding agreement. There is clear value in having access to funding to bring in training contributions from experienced staff from other disciplines and locations.
The evolving situation in the Latrobe Valley with regard to continuing education provides elements of the solution for future education and training.

- The new Masters in Geomechanics and Geohydrology provides a broad range of general opportunities for short training courses on both introductory and specialised technical topics that will be supported by high quality on-line resources.
- The Latrobe Valley Geotechnical Network is preparing and delivering the program of seminars for continuing education provided by external invitees and mine and regional staff.

6 Deliverables

In accordance with the objectives for GHERG the expected deliverables in the next five years are summarised below.

Objective 1: to address the issue of insufficient expertise and skill shortage by providing broad range geotechnical and hydrogeological research and development support to the Latrobe Valley coal mines.

Deliverables: The research program comprises an additional five higher degree research students in addition to the current student cohort. GHERG's research training program will deliver well trained, well qualified scientists and engineers with expertise across the full range of geotechnical and hydrogeological issues relevant to the brown coal mine industry.

Objective 2: to foster research and innovation in coal geotechnical and hydrogeological engineering, particularly in the areas of mine stability, mine monitoring systems and interpretation, ground subsidence, effect on rigid structures such as infrastructure, ground and surface water control in mines, and evaluation of models used in practice.

Deliverables: GHERG's research will deliver new knowledge on all areas identified under this objective. In particular, outputs will include new knowledge of geotechnical processes and properties relevant the Latrobe Valley coal sequences; recommendations for effective monitoring of ground conditions; improved models of ground subsidence; and, better understanding of the Latrobe Valley groundwater regime. The use of state-of-the-art modelling software and the extension of this software to deal with all critical processes governing batter stability in the Latrobe Valley mines will provide important benefits for mine stability assessment.

Objective 3: to review and develop systems modelling approach to planning, involving issues such as mine water quality, quantity, contamination, ground subsidence, safety risks and bushfires.

Deliverables: Outputs from GHERG's research relevant to this objective are explicitly targeted on mine rehabilitation. A major output for mine rehabilitation is the development of a total system understanding

of future rehabilitation options that will address long term batter stability, ground surface management, land use management and surface and ground water control.

Objective 4: to provide support to the Technical Review Board (TRB), which will review all mining operations and their potential impacts.

Deliverables: Professor Mackay is currently appointed to the TRB for 1 year ending in June 2016. Depending on the results of activities being undertaken by the TRB, the role of the TRB and its composition may change. Irrespective of changes that may occur, GHERG will continue to provide support in an appropriate capacity to the TRB, on an as needed basis.

Objective 5: to develop training programs for mine personnel through short courses presented by members of the research group, as well as local or international academic and industrial experts. Other training may be provided through elective units in current civil engineering courses and/or a Masters level course.

Deliverables: The education and training program will cover: complete development of the Masters in Geomechanics and Geohydrology; organisation of seminars by national experts; short courses on topics relevant to the mining community; on-line training materials, including case studies; support to the LV Geotechnical Network; and, support for the bi-annual conference on Brown Coal Engineering.