ACTUARIAL SOCIETY OF SOUTH AFRICA

Methodology For Probable Maximum Loss Calculation And Potential Implications of Acid Mine Water For The South African General Insurance Industry

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Agenda

1. Acid Mine Water
2. Seismic Frequency
3. Historic Seismic Events
4. *b*-Value
5. Seismic Hazard and Risk Modelling Results
6. Effect on Buildings
7. Who Is Responsible?
8. Hydraulic Fracturing
9. Conclusion

Acid Mine Water

"From a South African context, the country is in the middle of this crisis after more than a century of intense, and sometimes careless mining activity" – *(Cover, 2011)*

Acid Mine Water

- Nature of the gold deposits in the Witwatersrand has led to formation of 'basins'
- As mines stop operating water flows into adjacent mines
- Eventually the last mine in a basin will cease operations
- Underground workings will flood
- Water level continues to rise until it reaches the surface
- Water is of poor quality owing to reactions with sulphide minerals forming iron-rich sulphuric acid

Acid Mine Water

Water entering the underground workings comes from a number of sources:

- Direct recharge by rainfall
- Groundwater, recharged by rainfall
- Surface streams that lose water directly to mine openings and to the shallow groundwater systems
- Open surface workings often connect directly to the underground workings
- Mine residues, in particular tailings
- Losses from the water, sewage and storm water reticulation systems

Acid Mine Water

Risks related to decant and mine flooding are:

- Serious negative ecological impacts on the receiving environments
- Regional impacts on major river systems
- Localised flooding in low-lying areas
- Contamination of shallow groundwater resources
- Geotechnical impacts, which are most likely to be experienced in low-lying areas directly affected by rising water levels
- **Increased seismic activity**

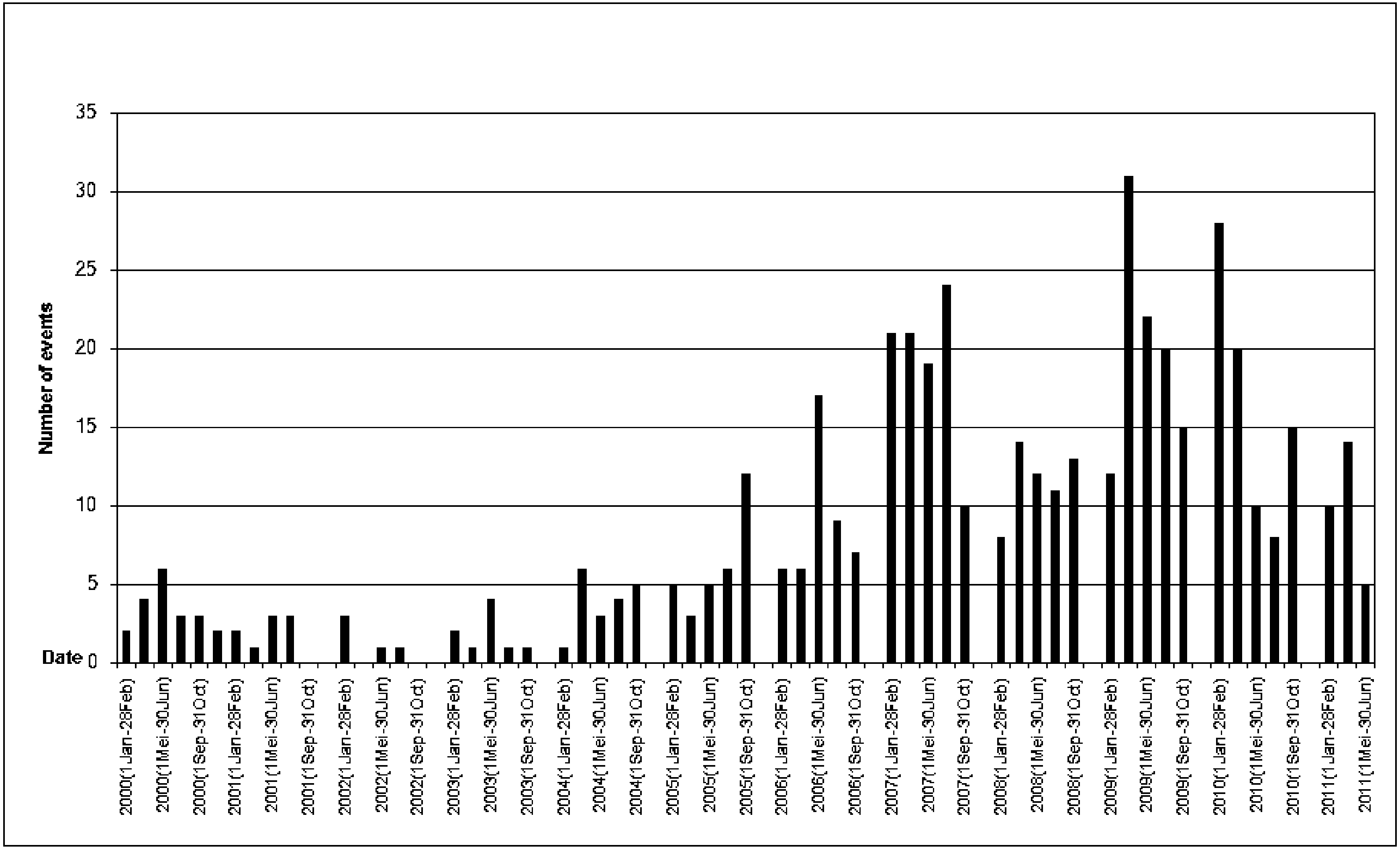
Seismic Frequency

- Fluids play fundamental role in the triggering of seismicity
- High water pressures owing to the flooding can affect the stability of artificial and natural fractures generating seismic events
- High pore pressures, coupled with lubrication of faults reduce clamping forces on the fractures/faults and can cause even previously non-seismic fractures to slip
- If saturated fractures are critically stressed, small changes in fluid pressures can trigger seismicity
- Clear increase in frequency of earthquakes over the past few years in Johannesburg area

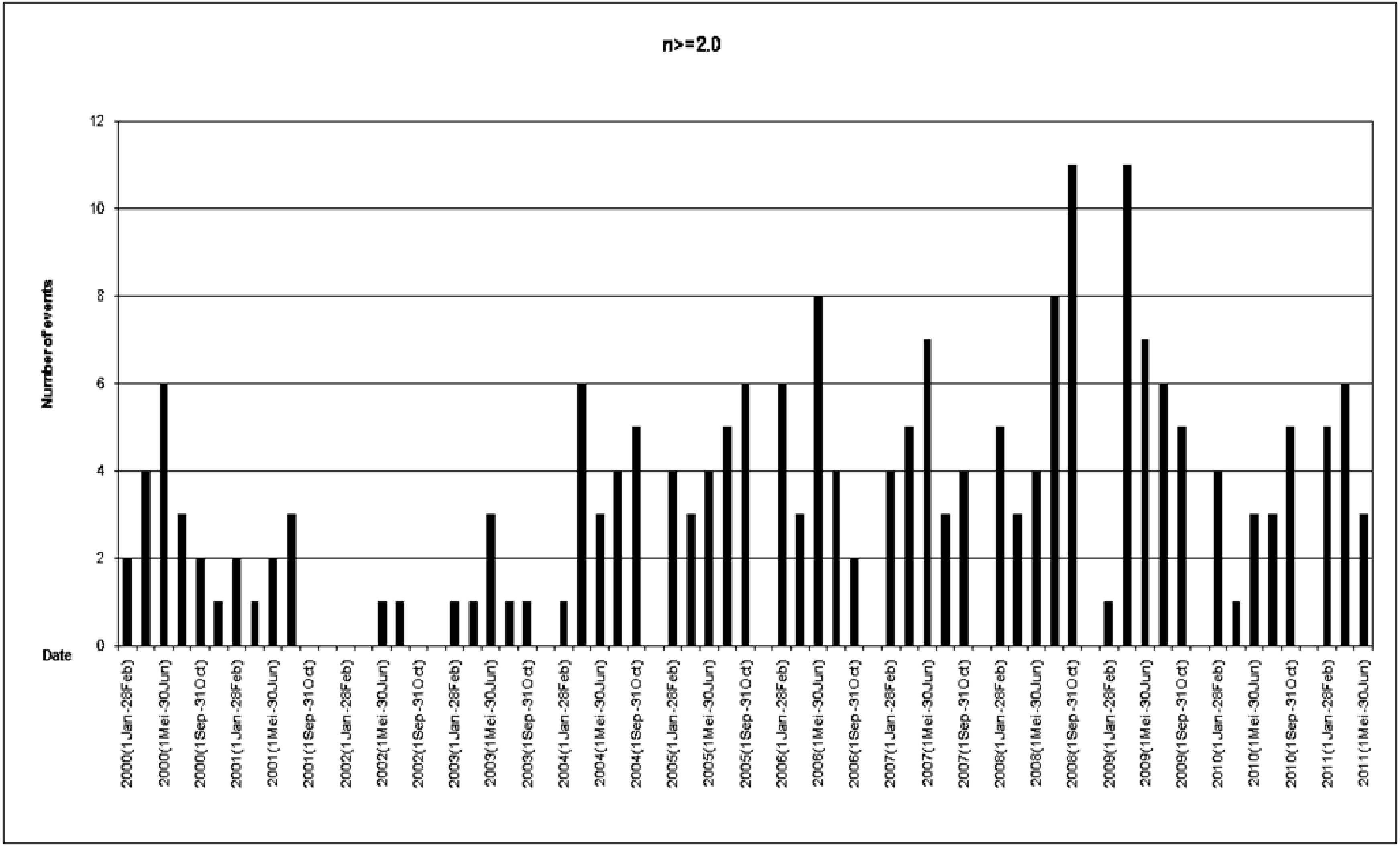
Seismic Frequency

- Data Source: *International Seismological Centre, United Kingdom*
- International centre collecting seismic data from around the world
- Catalogue 1: 2000-01-01 to 2005-06-30
- A comparison is made between the data and a hypothetical tectonic seismicity scenario in each case
- Please note that further studies and research will be required and South African Relevant data will have to be obtained from the Council for Geoscience

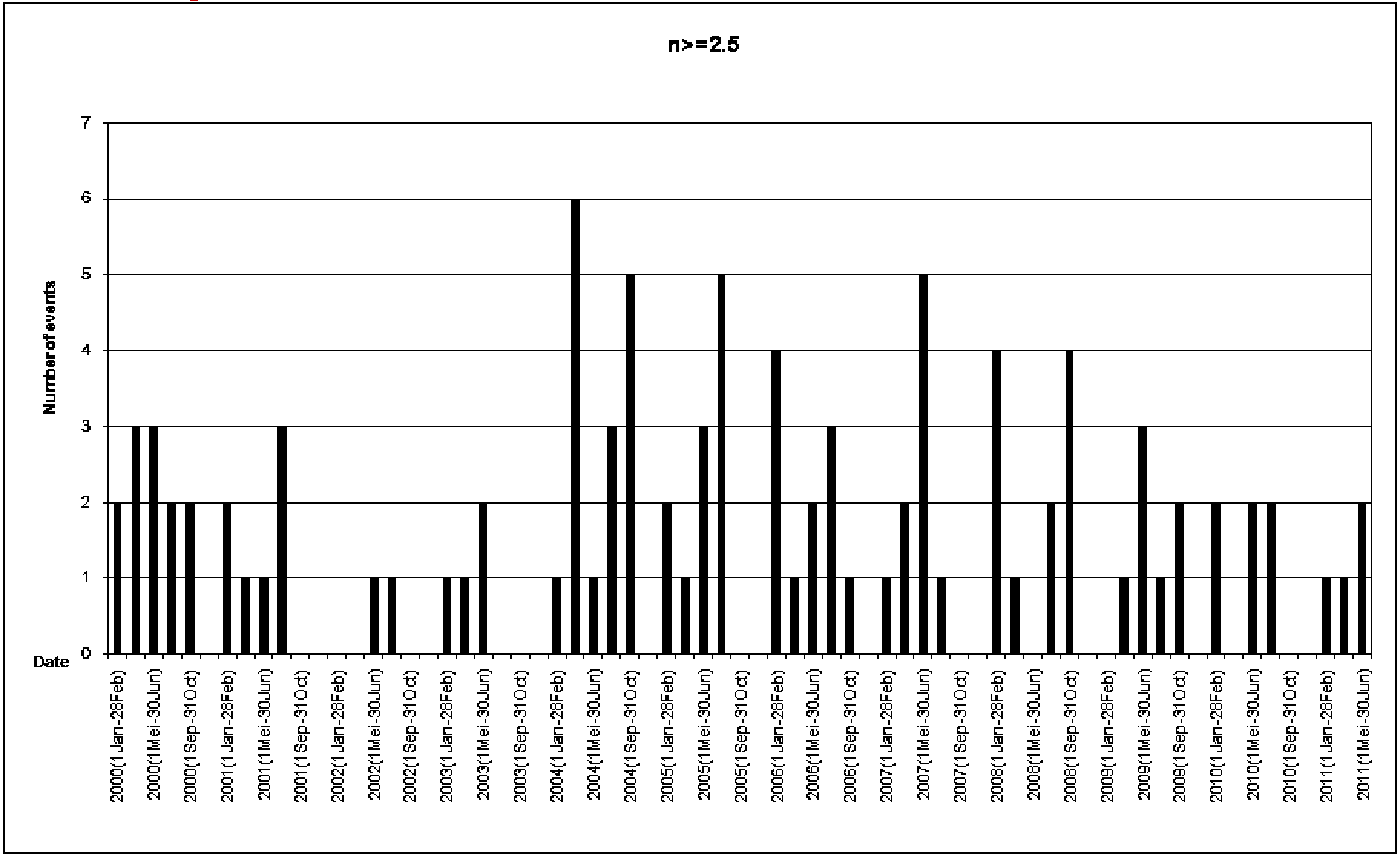
Bi-monthly Freq. of Number of Earthquakes in Greater JHB area



Bi-monthly Freq. of Number of Earthquakes: M_L>2.0



Bi-monthly Freq. of Number of Earthquakes: M_L>2.5



Welkom, Dec 1976, M_L 5.2

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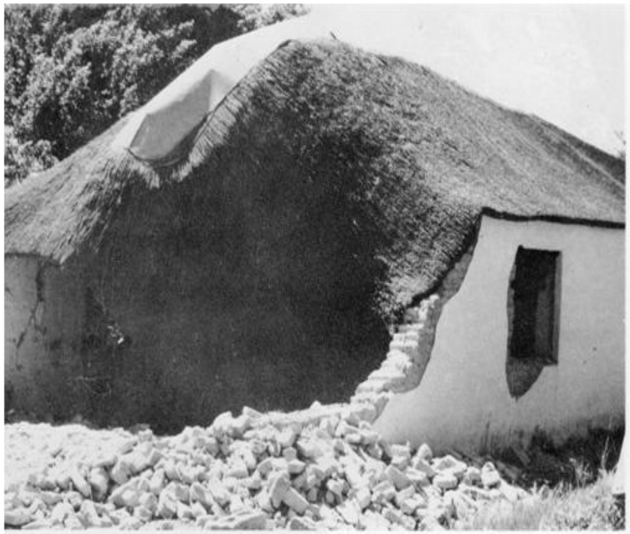
Stilfontein, March 2005, M_L 5.3

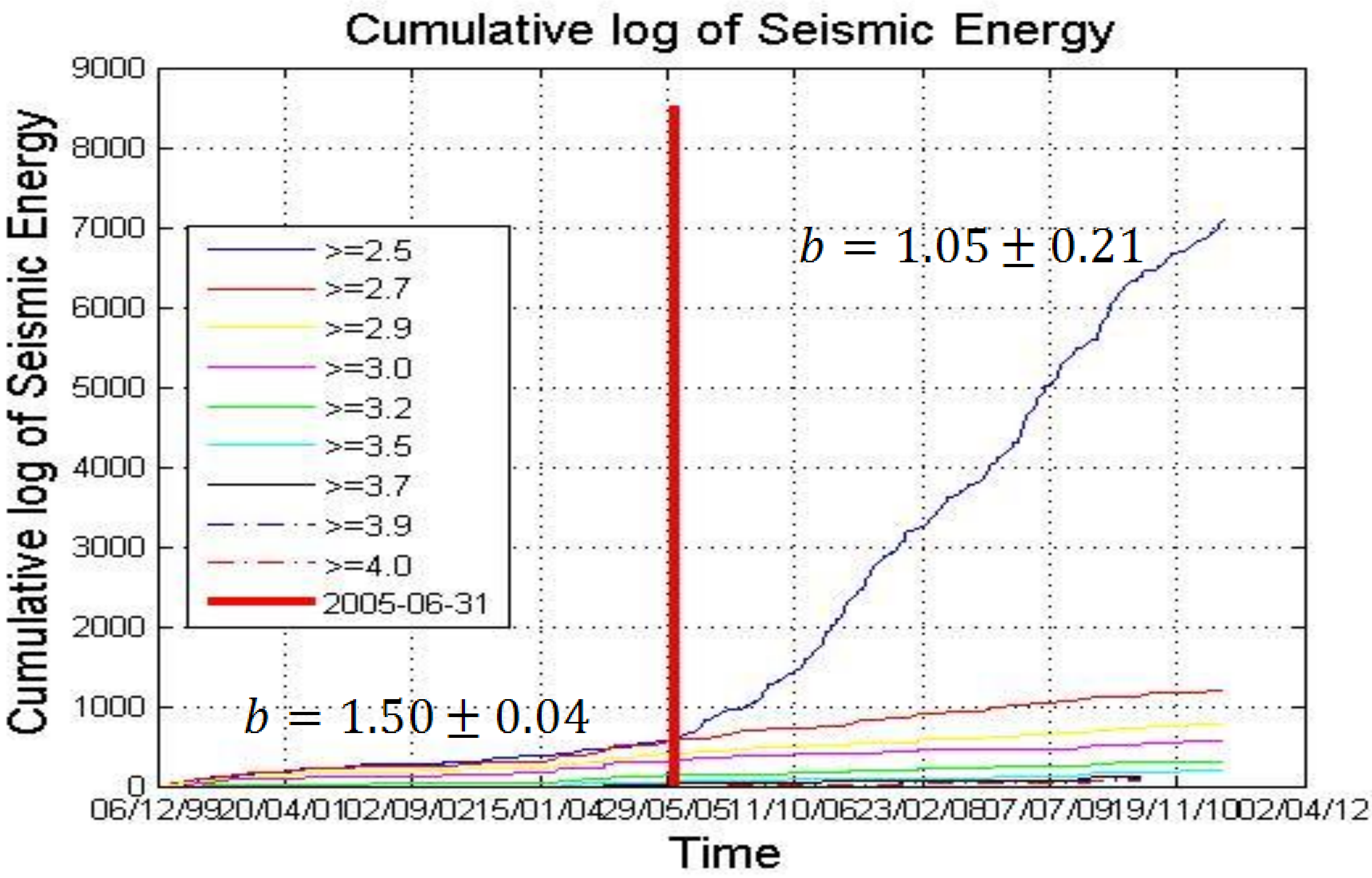
Ceres/Tulbagh, Sep 1969, M_L 6.3



b-Value

- Prediction parameter
- Ratio between weak and strong events
- *b*-value is a good indicator of the nature of seismicity
- Mining induced events tend to reflect a higher b-value, whereas natural events have a lower b-value
- Change in *b*-value for Johannesburg region in more recent years indicates a fundamental shift in the nature of seismicity

b-Value



Cumulative log of Seismic Energy
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Cumulative log of Seismic Energy
>=2.5
>=2.7
>=2.9
>=3.0
>=3.2
>=3.5
>=3.7
>=3.9
>=4.0
2005-06-31
$b = 1.05 \pm 0.21$
$b = 1.50 \pm 0.04$
06/12/99 20/04/01 02/09/02 15/01/04 29/05/05 11/10/06 23/02/08 07/07/09 19/11/10 02/04/12
Time

Hazard and Risk Modelling

- Seismic risk scenario analysis involves development of a particular seismic situation, from where damages/losses are calculated
- Sub-processes:
  1. Identify all earthquake sources capable of producing significant ground motion at the site
  2. Select source-to-site distance
  3. Select control earthquake, i.e. one that produces required level of shaking
  4. Calculate expected ground motion and related hazard
  5. Calculate expected damages/losses

Hazard and Risk Modelling

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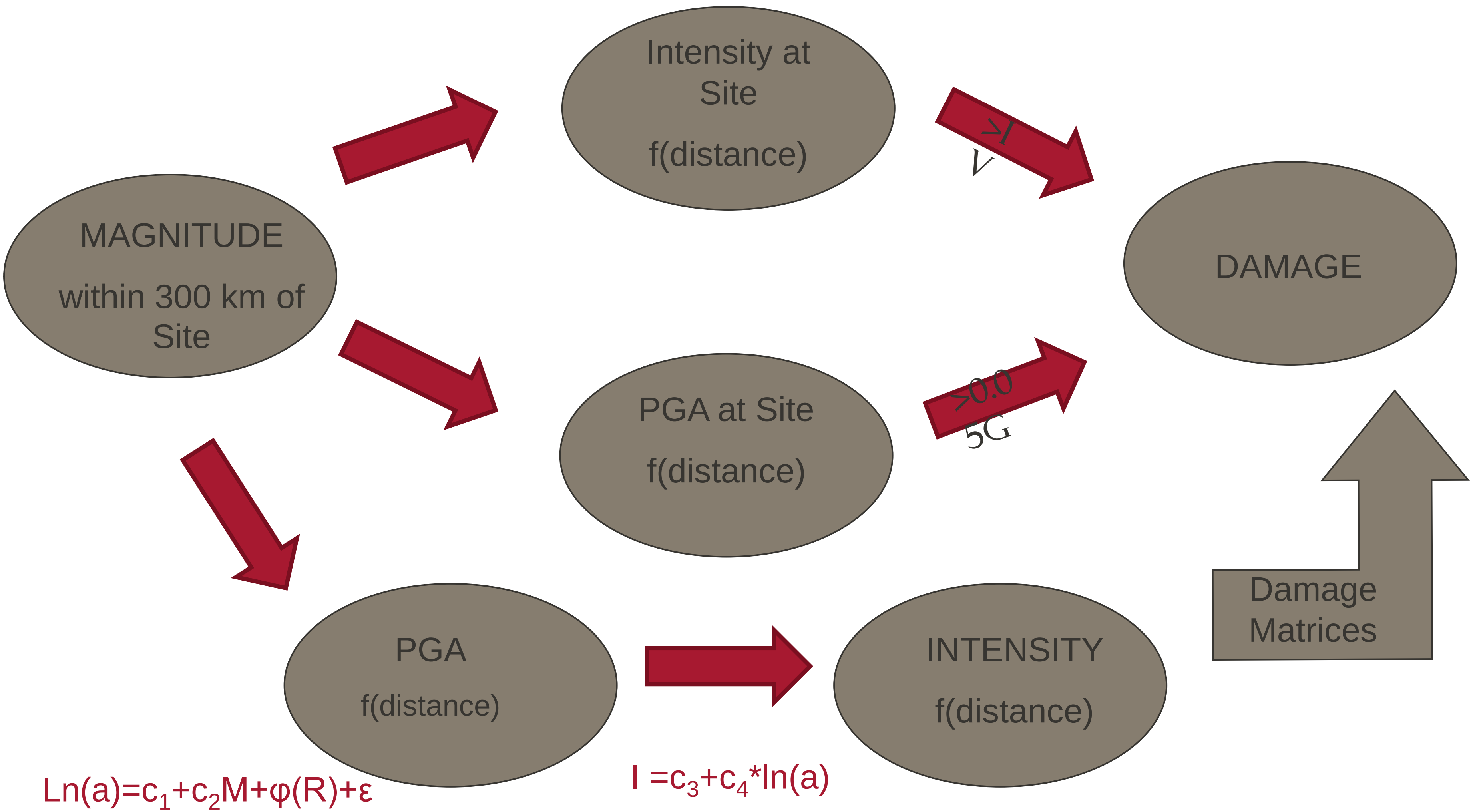
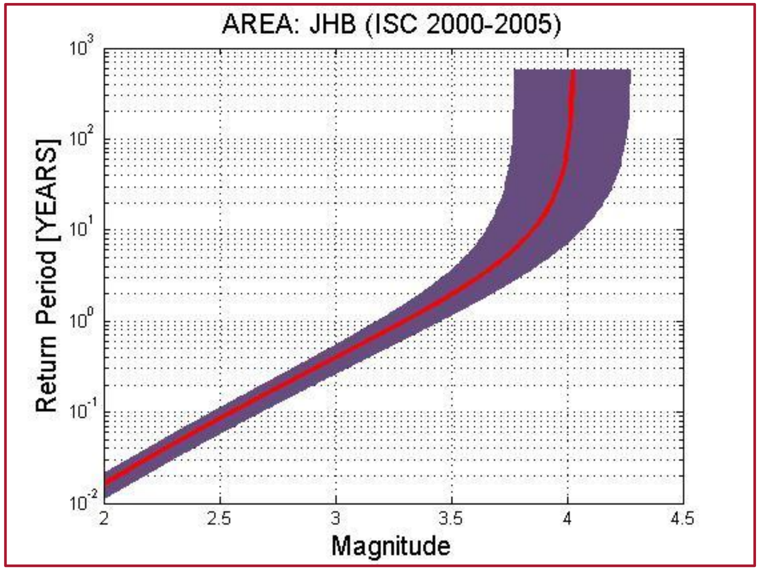
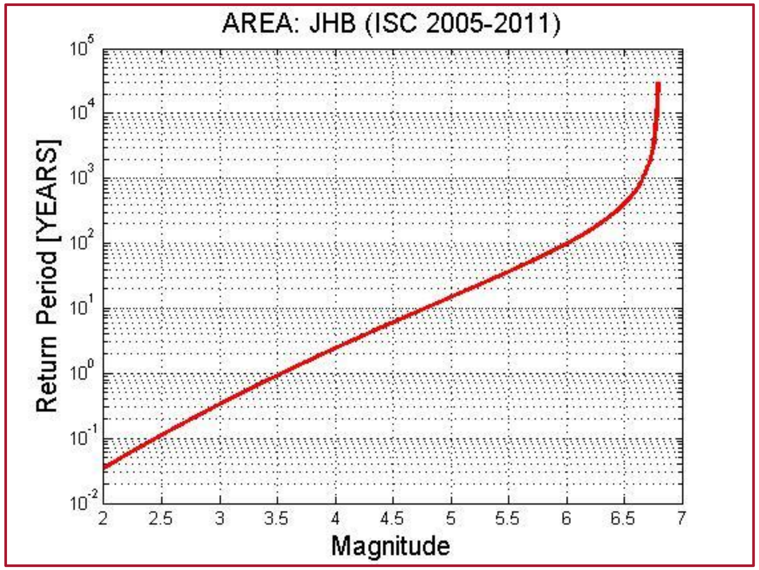


Hazard Modelling Results

Event	Magnitude (2000/01/01 – 2005/06/30)	Magnitude (Hypothetical Tectonic Seismicity Scenario)
1 in 200 years	4.01	6.3
1 in 250 years	4.02	6.4
Worst Case Scenario	4.03	6.8





Risk Modelling Results

Unreinforced masonry, with load bearing wall, low rise (#3)

Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)

Reinforced concrete shear wall without moment resisting frame, high rise (#9)

Risk Modelling Results

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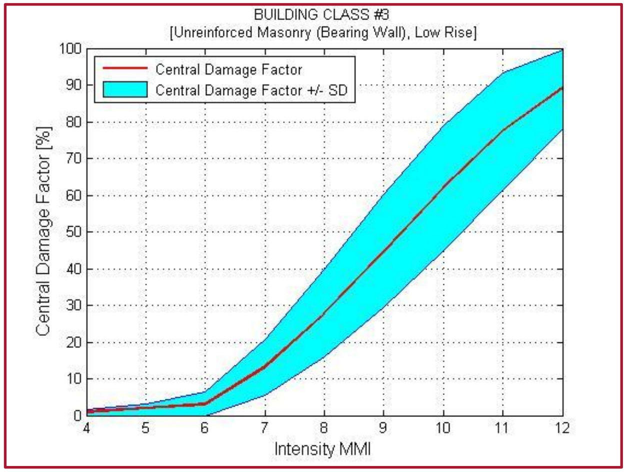
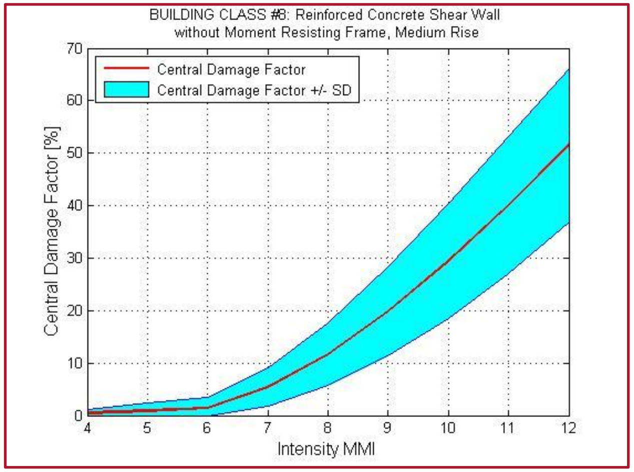
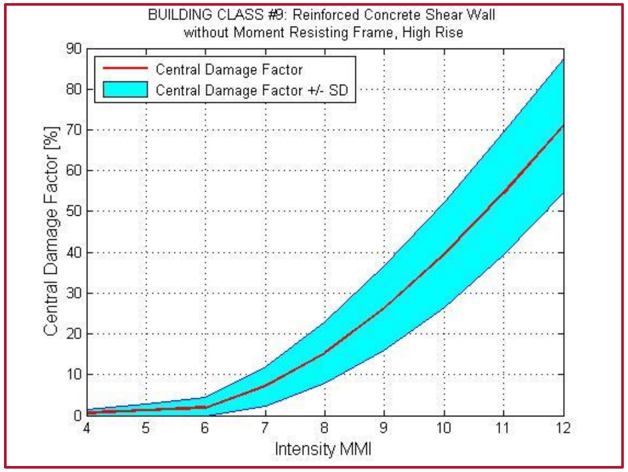
CATALOGUE 1 – MAGNITUDE 4.01
(1 in 200 year event)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	negligible	N/A
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	negligible	N/A
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	negligible	N/A







Risk Modelling Results

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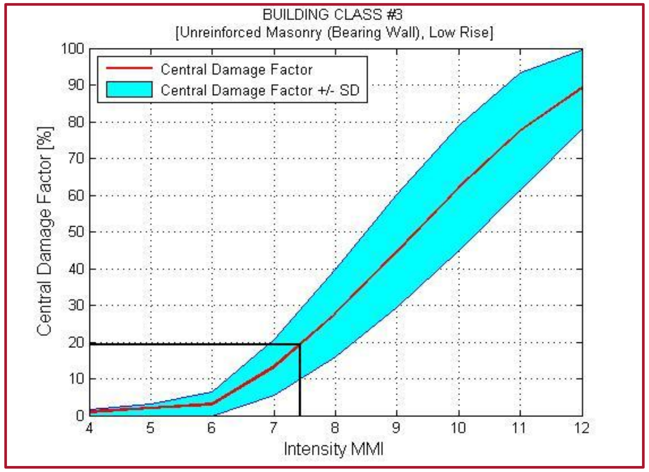
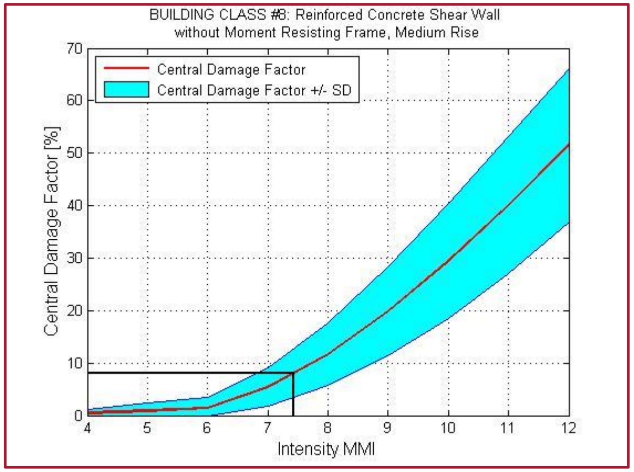
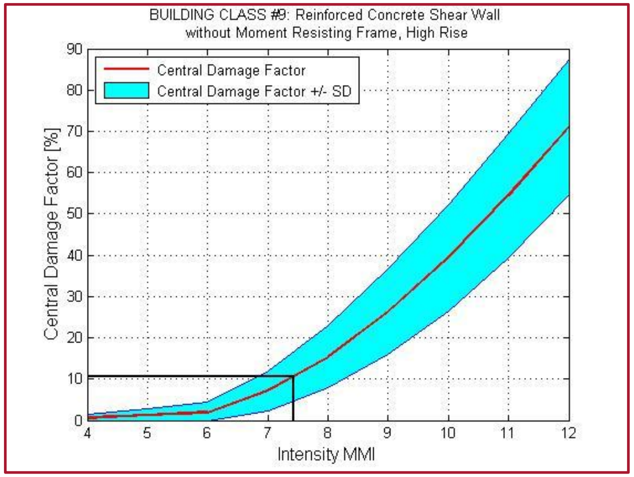
Hypothetical Tectonic Seismicity Scenario– MAGNITUDE 6.3
(1 in 200 year event)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	19.4	[10.0, 28.8]%
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	8.1	[3.4, 12.8]%
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	10.6	[4.7, 16.6]%



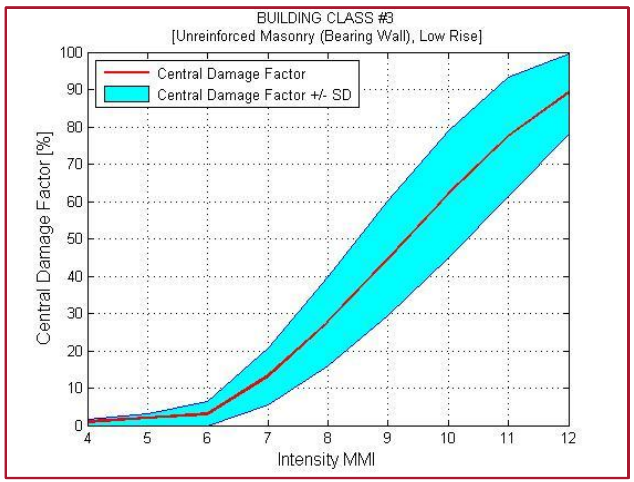


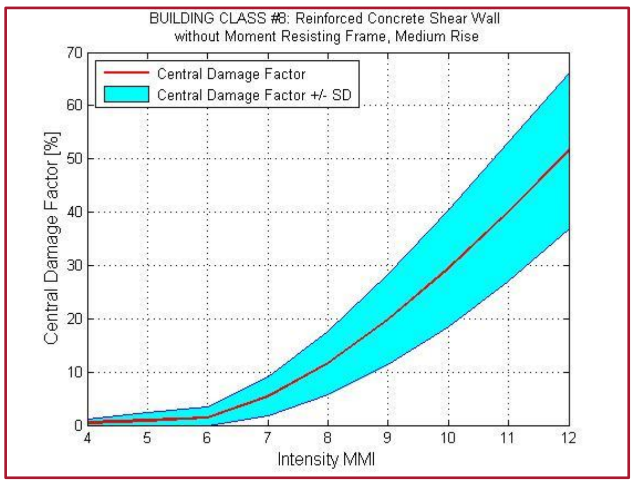


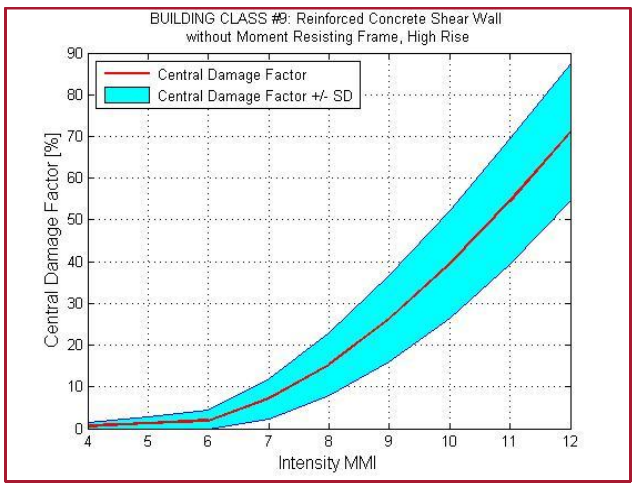
Risk Modelling Results

CATALOGUE 1 – MAGNITUDE 4.02
(1 in 250 year event)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	1.0	[0.0, 1.6]%
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	0.5	[0.0, 1.2]%
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	0.6	[0.0, 1.4]%



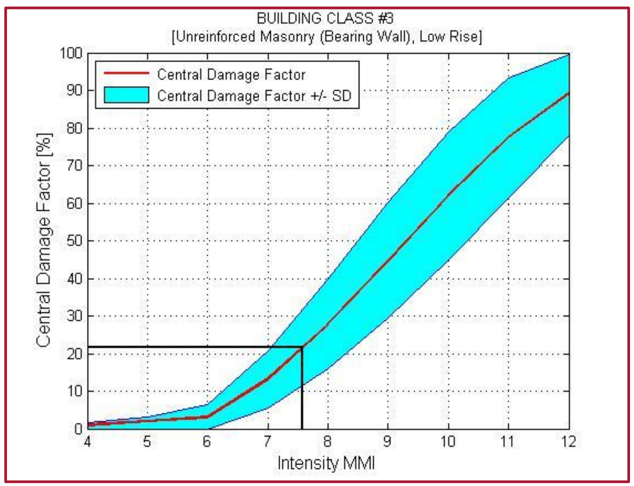


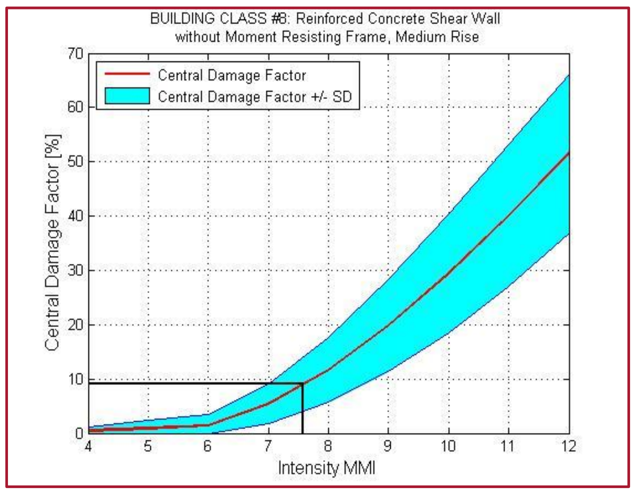


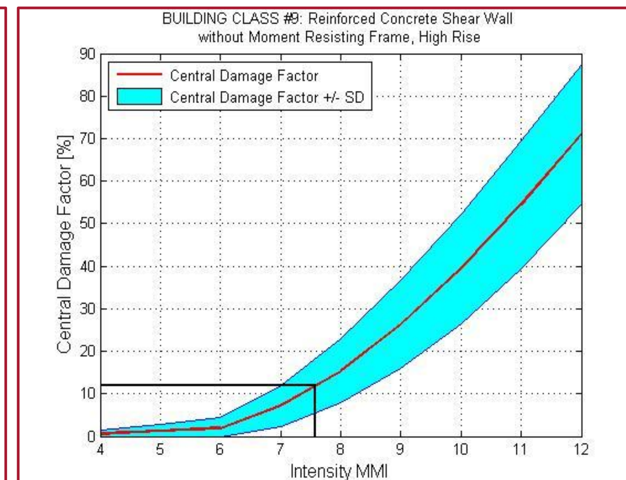
Risk Modelling Results

Hypothetical Tectonic Seismicity Scenario– MAGNITUDE 6.4
(1 in 250 year event)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	21.5	[11.5, 31.6]%
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	9.0	[4.0, 14.0]%
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	11.9	[5.5, 18.2]%







Risk Modelling Results

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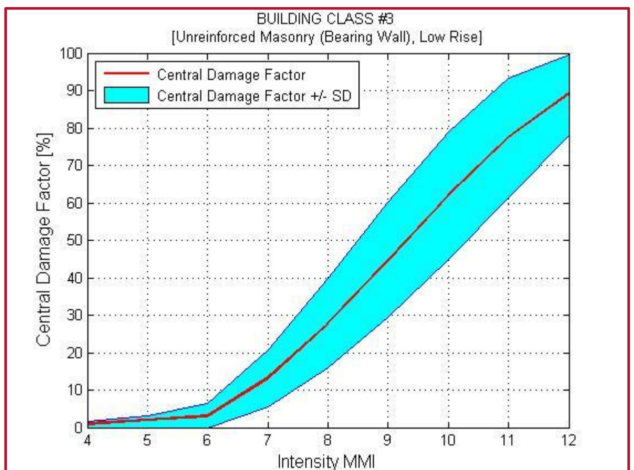
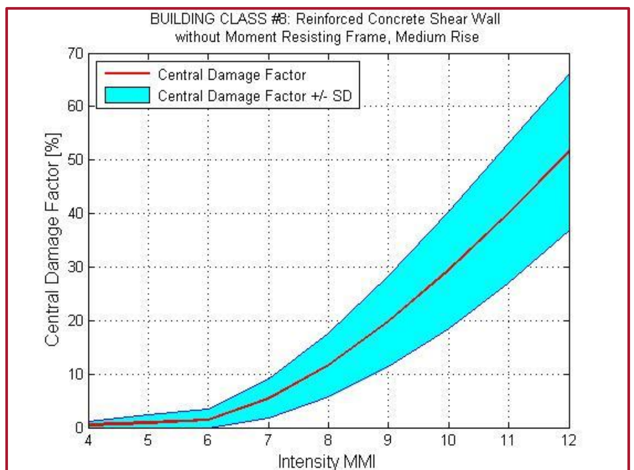
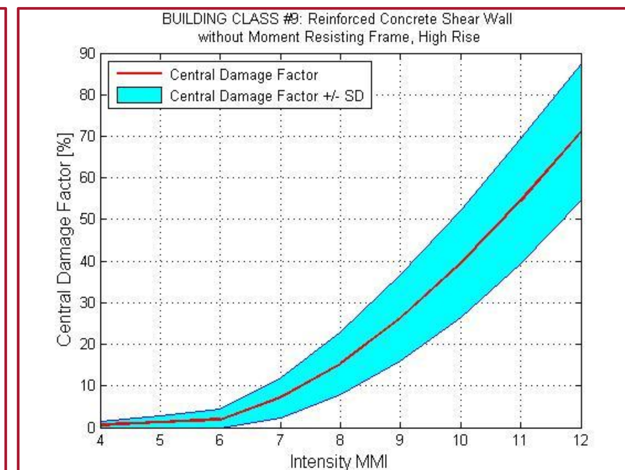
CATALOGUE 1 – MAGNITUDE 4.03
(Worst Case Scenario)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	1.0	[0.0, 1.6]%
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	0.5	[0.0, 1.2]%
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	0.7	[0.0, 1.4]%



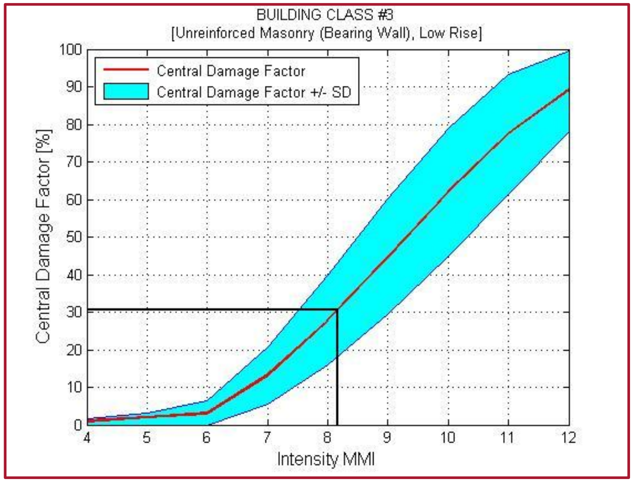


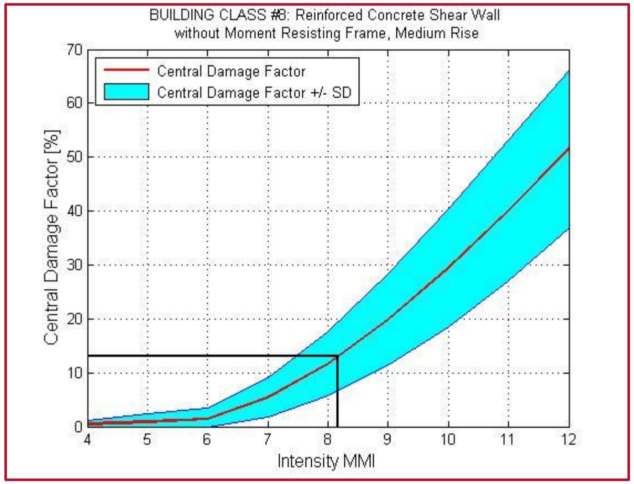


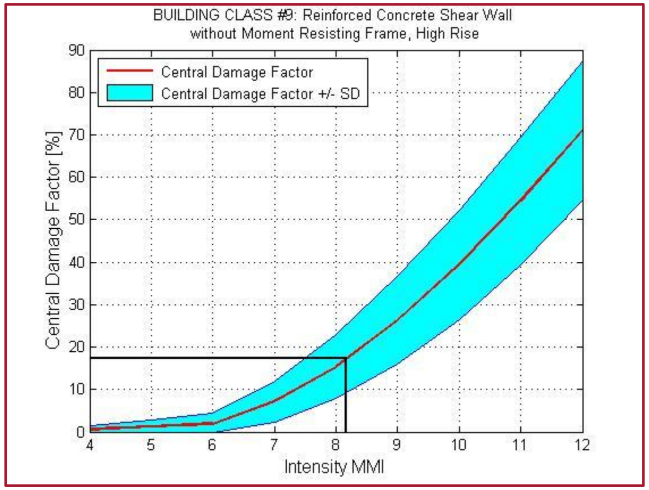
Risk Modelling Results

Hypothetical Tectonic Seismicity Scenario– MAGNITUDE 6.8
(Worst Case Scenario)

Building class	Expected damages	Uncertainty interval
Low rise, unreinforced masonry buildings having load bearing walls (#3)	30.7	[18.2, 43.2]%
Medium rise reinforced concrete shear wall buildings without moment resisting frames (#8)	13.1	[6.7, 19.5]%
High rise reinforced concrete shear wall buildings without moment resisting frames (#9)	17.3	[9.3, 25.2]%







Effect on Buildings

- Acid in mine water reacts with concrete in foundation
- Concrete “covers” provide protection for steel reinforcements within foundations
- Further chemical reactions triggered once acid water reaches steel within foundation
- Foundation strength reduces significantly
- Concrete covers in foundations: 50mm -75mm

Who Is Responsible?

- Liability difficult to establish
- According to law: polluter pays, i.e. mines responsible
- Some mines are closed down or sold - who bears responsibility?
- Not “sudden and unforeseen”- as industry is aware of the potential
- Difficult to prove tremors occur as a result of acid mine water
- Policy wordings differ - brokers and clients need to review cover

Hydraulic Fracturing ("Fracking")

- Process of extracting natural gas from shale rock layers deep within the earth using water, sand and an array of toxic chemicals
- Two concerns: pollution and geological safety
- SASOL stopped exploration activities in the Karoo
- Other companies showing interest:
  - Royal Dutch Shell,
  - Bundu Oil and Gas Exploration

Hydraulic Fracturing ("Fracking")

ACTUARIAL SOCIETY OF SOUTH AFRICA

- Injected fluid can migrate to an existing fault - fluid pressure in the fault is increased
- The higher the pressure, the more likely the fault will slip - resulting in an earthquake
- Real possibility that fracturing can trigger a seismic event

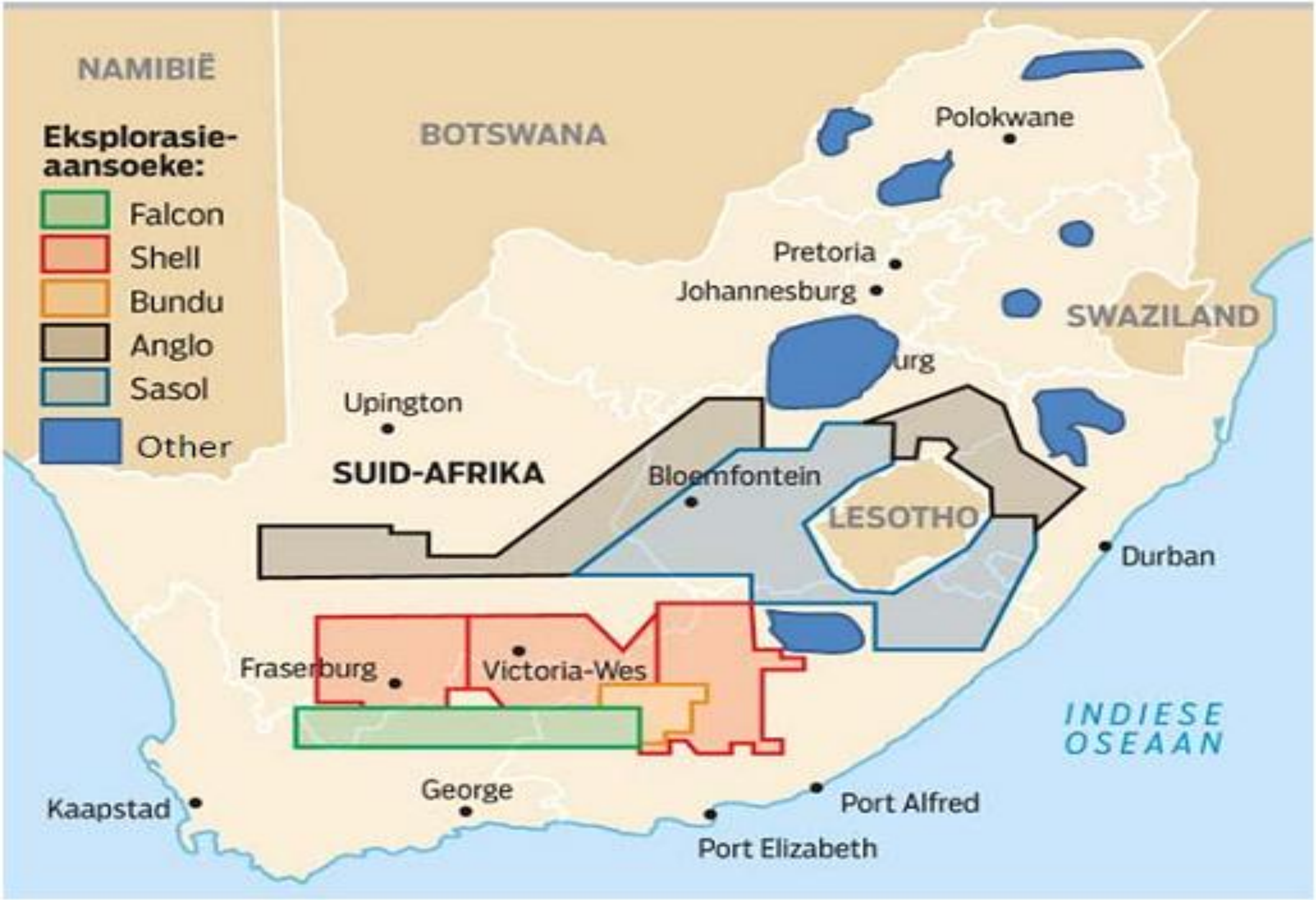
Hydraulic Fracturing (“Fracking”)

- UK, Blackpool - fracking suspended in June 2011
  - Report concluded high probability of correlation between fracking and seismic activity
- Youngstown, Ohio - 11 earthquakes
  - John Armbruster, seismologist from Columbia University, believes quakes are triggered by contaminated water, a by-product of fracking

Hydraulic Fracturing ("Fracking")

- M=4.7 - Arkansas, USA:1000 events since wells started
- M=5.2 - Rocky Mountain Arsenal, USA
- M=4.3 - Paradox Valley, USA

PASA (Petroleum Agency SA) Exploration Applications



Conclusion

1. Indication of increased seismic activity and change in nature of seismicity over the past few years
2. Research and tests on effect on building foundations
3. Effect of fracking on seismicity
4. FURTHER RESEARCH AND STUDIES

Conclusion

"The problems posed by AMD will have implications far into the future, with impacts likely to continue for many years. The process of management of these impacts will therefore need to continue, with ongoing assessments and adaptation as conditions change."

- *(Mine Water Management In The Witwatersrand Gold Fields With Special Emphasis On Acid Mine Drainage, 2010)*

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