

National Exposure Information System (NEXIS) – A Capability for Evidence Based Disaster Management

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SUMMARY

Disaster management is most effective when it is based on evidence. Evidence-based disaster management means that decision makers are better informed, and the decision making process delivers more rational, credible and objective disaster management outcomes. To achieve this, fundamental data needs to be translated into information and knowledge, before it can be put to use by the decision makers as policy, planning and implementation.

Disaster can come in all forms: rapid and destructive like earthquakes and tsunamis, or gradual and destructive like drought and climate change. Tactical and strategic responses need to be based on the appropriate information to minimise impacts on the community and promote subsequent recovery. This implies a comprehensive supply of information, in order to establish the direct and indirect losses, and to establish short and long term social and economic resilience.

The development of the National Exposure Information System (NEXIS) is a significant national project being undertaken by Geoscience Australia (GA). NEXIS collects, collates, manages and provides the information required to assess multi-hazard impacts. Exposure information may be defined as a suite of information relevant to all those involved in a natural disaster, including the victims, the emergency services, and the policy and planning instrumentalities.

NEXIS is able to provide comprehensive and detailed information for a disaster site anywhere in Australia. This information is accurate down to the level of individual buildings, and includes structure types, occupant numbers, household income and replacement value. Additionally the system provides building usage information, business type, turnover and associated employee and customer capacity for economic impact analysis. NEXIS is developing exposure information on institutions (educational, health, emergency, government and community buildings) and lifeline support infrastructure. Building level exposure data enables NEXIS to aggregate information for an area of extreme hazard or disaster consequences footprint anywhere in the nation.

Population data may be critically important when disaster strikes. A framework was originally developed based on available demographic data sets to provide a generic exposure definition, but NEXIS is currently adding datasets from state and local governments and private data providers to refine the quality of the information. This paper examines typical NEXIS

applications which include climate change adaptation, energy efficiency, bushfire tactical response and cyclone consequences.

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1. INTRODUCTION

In 2002 the Council of Australian Governments announced that it was committed to establishing “... a nationally consistent system of data collection, research and analysis to ensure a sound knowledge base on natural disasters and disaster mitigation” (COAG, 2002). In response to this, Geoscience Australia (GA) began the development of the National Exposure Information System (NEXIS).

Moderating the social and economic impacts of natural hazards and disasters is always a challenge for the all levels of government. As the *Emergency Management Information Development Plan* (Harper, 2006) emphasises, a nationally consistent database is essential when planning a response to disasters, which addresses the four phases of Prevention, Preparedness, Response and Recovery (PPRR). *Exposure information* is fundamental in the development of risk-assessment models for natural hazards, critical infrastructure failures and consequences of climate change, and to support early warning systems and national priority initiatives.

NEXIS is a significant national initiative, capable of providing the necessary exposure information for policy and planning. It can supply the comprehensive and nationally consistent exposure information required for disaster impact reduction, derived primarily from reliable and publicly available datasets. NEXIS maintains information at building level compatible with vulnerability assessment models for multi-hazards - earthquake, tsunami, floods, bushfire, pandemic, blast etc. Exposure information includes population demographics, income demographics, number and type (construction) of buildings (residential, commercial, industrial and institutions), age of buildings, type of businesses (4 digit ANZSIC), financial turnover, employees, usage of institutions (education, health, community halls, stadiums etc.) and infrastructure associated with sectors such as transportation (roads, railway, tunnels, bridges, airports, sea ports).

NEXIS was designed to provide exposure information for regional impact analysis. In its current form it is not intended to provide precinct analysis involving one or two buildings, which needs more specific information about the exposure to estimate the risk at the micro level. However this will be improved as NEXIS obtains more specific datasets from data custodians including governments and private data providers..

NEXIS has been integrated with the Earthquake Risk Assessment Model (EQRM) developed by Robinson, et al., 2005, tropical cyclone hazard models (Arthur, 2008), site specific wind risk risk assessment model (Krishna et al., 2007), tsunami inundation and risk assessment model (Neilson et al., 2006) and Critical Infrastructure Protection Modelling and Analysis (CIPMA) at GA. It is being used by the *National Coastal Vulnerability Assessment Project*

(Skene et al., 2008) for climate change adaptation initiatives, and residential energy efficiency improvement initiatives by the federal government.

2. METHODOLOGY

Multi-disciplinary teams of engineers, economists and social scientists were consulted to compile the information variables required to assess risks and impacts from natural hazards. NEXIS was divided into four major components: residential, business (commercial and industrial), institutional and infrastructure. For NEXIS to cover the entire nation demands an enormous amount of resources and will take several years to complete.

2.1 System Architecture

The conceptual architecture of the NEXIS is shown in figure 1. The basic datasets were sourced from a variety of data custodians. A reference database was designed to maintain and collate the key datasets, with varied resolution, licensing conditions, coverage and metadata in a centralised relational database. Specific software applications were developed for residential, commercial (city buildings), commercial (small town centres) and industrial areas.

Preparing the highly complex production systems for real-time application has been extremely time-consuming. The NEXIS database will be updated quarterly, and take account of any major updates occurring in the reference databases. Decision support tools have also been prepared for models including EQRM, Tropical Cyclone, Tsunami, floods and critical infrastructure protection.

NEXIS is designed to meet two differing needs. The *generic* version has a national template and data, making it able to provide immediate information if required. The *specific* version includes specific data from various providers to improve local or limited information. Metadata records are able to provide the source of data elements for clients.

2.1.1 Generic Approach

The fundamental organisation of NEXIS is embodied in its components, their relations, development, environment and the governing principles for its design. Policy, planning and accountability to reduce real-time and real-world risk will be greatly assisted by the availability of relevant, comprehensive and high quality exposure information. However the nature of data requirements for tactical response and strategic planning is highly complex and not readily available. *Exposure information* is highly diverse and must be extracted from, and integrated, from more than one dataset. It must take into account structural vulnerability, economic vulnerability, demographic vulnerability and infrastructure vulnerability, all subjected to the cascading effects of a hazardous event. Exposure information available for risk assessment or estimation is in varied resolutions (state, post code, census collection district, buildings or personal) and difficult or impossible to collect and collate for the entire nation. Given these limitations, a heuristic approach was adopted to develop the NEXIS framework, deriving the information from a number of basic datasets.

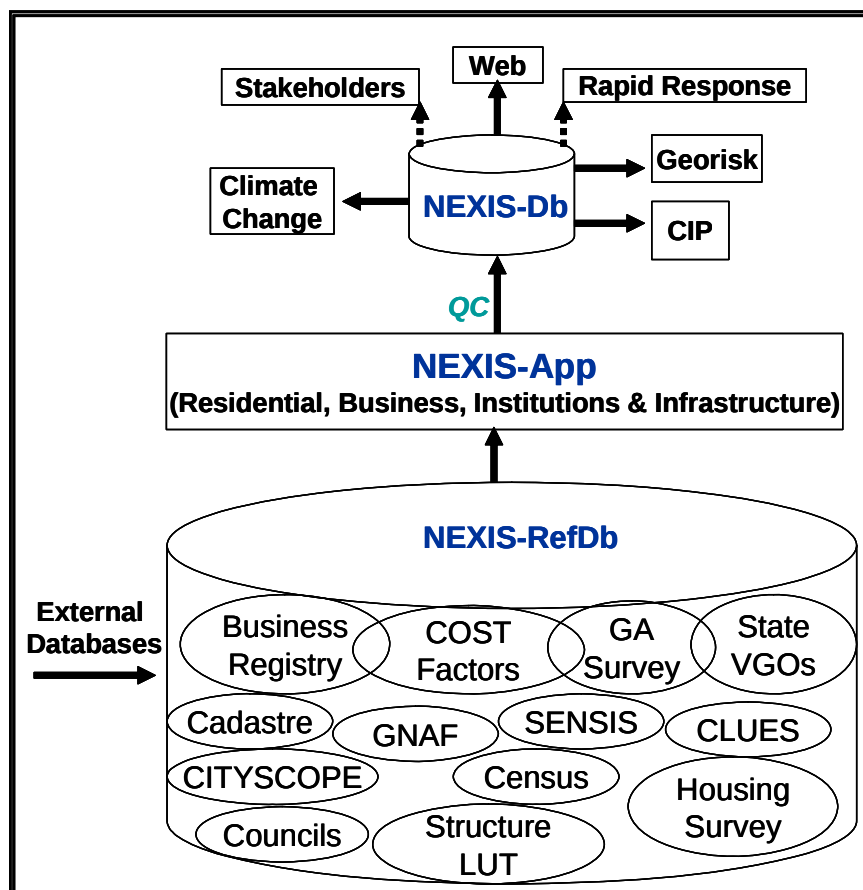


Figure 1: NEXIS system architecture depicting the dataflow.

NEXIS information is categorised into residential, business, institutions and infrastructure exposure. The information is collated using reasonable and logical assumptions and expressions to achieve an exposure definition that is consistent with available aggregated data.

The generic version of the **residential** component of NEXIS is the most significant for assessing socio-economic impacts on communities and emergency management. The variables required to assess risk for residential areas are primarily spatial, structural and demographic. The *spatial* location is critical for assessing risk from cyclones, tsunami, flooding and bushfires. National datasets like the ABS Census provide demographic information aggregated at Census District (CD) level, though the risk from natural hazards is not uniformly distributed across the CD. The spatial location is derived from Geo-Coding National Framework (GNAF), *structural* details from a small sample of housing survey, building age is derived from historical census data sets and the *demographic* information from the Australian Census (Census 2006).

The **business** component of NEXIS is further divided into (a) commercial in Central Business Districts (CBD); (b) commercial – nonCBD; (c) industrial buildings based on the construction type and usage of the building. Information was derived from a number of building- and business -related datasets. Building location was derived from the Cityscope database in Central Business Districts (CBD) areas and GNAF for the nonCBD areas. Cityscope provides information about the size, number of stories, refurbishment and usage. Business activity is derived from Australian Business Registry and SENSIS (Yellow Pages). Small and medium size industrial buildings were also derived from the address framework database. Replacement value was estimated in a similar manner as that of commercial buildings. Aggregated small and medium size industrial building numbers and replacement values are included. Contents, stock inventories and plant (means of production) are not included in this exposure information.

Exposure information for institutional buildings is critically important for demographic impact analysis, particularly in the case of rapid onset events such as earthquakes, tsunamis and explosions. The **institutions** component of NEXIS includes information about childcare, aged care, education, health, government, community, sports and emergency related buildings and their associated populations. Information, including population demographics, appropriate for risk assessment at an institution or building level needs to be collected and maintained. A primary school, for example, contains children aged five to eleven years, between nine and three o'clock on a typical working day, while the crowd in a sport stadium will be based on the event at the time. Information about evacuation centres and other refuges is essential for assessing tactical responses at a higher level.

NEXIS collates and maintains the publicly available **infrastructure** datasets suitable for assessing the risk in a region or from a disaster. It does not make use of industry specific datasets which have confidentiality requirements. Infrastructure data for transport (roads, railway, airports, sea ports, bridges and tunnels), communication (radio antenna, mobile antenna, and towers), energy sector (power and fuel) and water play a significant role in impact analysis on lifeline support utilities. It will support the risk assessments from critical infrastructure failures as well.

2.1.2 Specific Approach

Specific datasets have been targeted which will improve the quality of exposure information when they are integrated into the system. Information about residential structures is being obtained from local councils who maintain building approvals and structural records. City precincts will be analysed for vulnerability to various hazards, based on an engineering surveys of buildings in the precinct. Business information is derived from business profile surveys such as the Census of Land Use and Employment (CLUE, 2008) in Melbourne, floor space and employment survey 2006 in Sydney and Australian Yellow Pages for small service-oriented businesses. Feedback from other stakeholders, who use NEXIS as a central platform, will be important in refining the performance of NEXIS. Institutions and infrastructure agencies will be engaged through Commonwealth Government initiatives.

3. Results

The NEXIS *residential* component is being used by a number of natural hazard risk research projects within GA. These include cyclone or severe wind risk assessment modelling; flood modelling and predicted impacts on residences in Perth; tsunami risk assessment modelling for WA; and post-incident analyses following Cyclone Larry in Queensland. A rigorous quality assessment is built in to NEXIS to identify any shortcomings, and to supply more meaningful and realistic exposure information. Figure 2 depicts the spatial locations of the residential, commercial and industrial buildings distribution in the Gold Coast.



Figure 2: Spatial location of residential, commercial and industrial buildings in Goldcoast, Australia.

3.1.1 Validation

The generic residential buildings exposure was validated against the Tasmanian Valuer General's database of 2007. This data is primarily maintained for taxation purposes by local government. In residential suburban areas the number of buildings recorded in this data is more than ninety percent accurate. Roof and wall type information is reasonably accurate when considering large sample areas, however replacement values for Hobart city were

overestimated by up to ninety five percent. NEXIS *exposure value* was calculated using an estimated replacement value for a building of the same size using current (2008) standards.

In rural areas accuracy of number and spatial location decreases significantly to around seventy five percent. To assess rural residential exposure, NEXIS uses areas of Victoria as a benchmark. However in these periurban areas, near to the major cities, where land parcels are quite large, the spatial location provided by GNAF at the centre of the land parcel which differ significantly from the actual location building location.

3.1.2 Applications

In 2007, the Hunter Region and Central Coast of New South Wales were subject to extensive flooding causing damage and loss of life. This was caused by an intense low pressure system which developed off the coast; starting on June 8. Rainfall exceeded 300mm in some areas and vital support services were cut off or disrupted.

ALOS satellite imagery for the flooded region was acquired following the event. ALOS was the only satellite to capture a view of flood affected areas without cloud cover during the peak of flooding on 10 June. Rapid mapping of the extent of flooding in urban areas can be difficult and uncertain due to ground visibility limitations.

In Newcastle and the Hunter Valley urban areas, satellite imagery was augmented with water height interpretations using a one second DEM (digital elevation model) to prepare the preliminary disaster footprint (flood extent map). The disaster footprint was used to extract the residential exposure information from NEXIS.

Such a quick and reasonably accurate estimate of exposure is very valuable for public policy and planning for social support organisations in the government. The exposure information was aggregated to suburbs and provided to the stakeholder. Summarised information indicating the number of residential buildings, building types and people exposed in the inundation zone for both event stages is listed in the Table 1.

In the weeks after the event, the mapped area of flood inundation was further refined using additional satellite imagery and ground-truth data from the NSW State Emergency Services. It became evident that the impact of the flood was in two clear stages: storms (short duration) and riverine (longer duration). This refined disaster footprint (Figure 3) allowed more accurate exposure information to be extracted from NEXIS, giving planners essential information for arranging long-term evacuation and social assistance for residents.

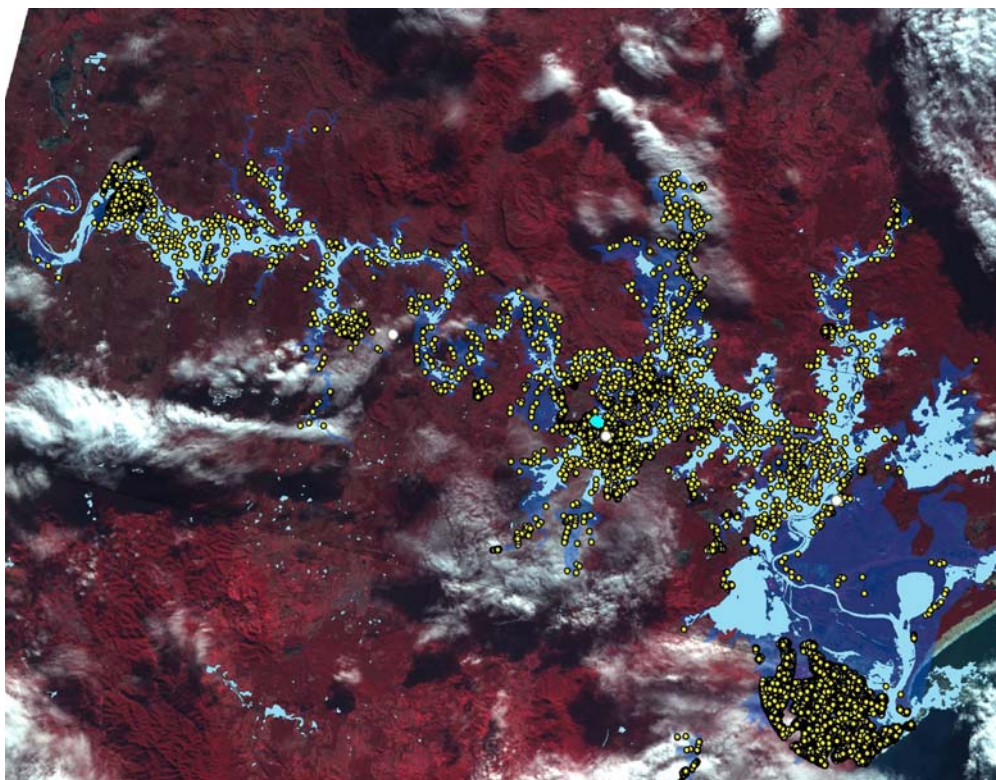


Figure 3: Newcastle disaster footprint displaying inundation immediately after the storm (blue) and riverine (cyan) floods overlaying ALOS data 10 June 2007. Yellow points indicate affected residential buildings.

Table 1: Summary of residential exposure for both stages of the Newcastle flood event.

Exposure Category	Exposure to Flooding (000's)	
	Storm (short)	Riverine (long)
Residences	98.2	2.5
Residential buildings	69.6	1.36
Separate houses	57.4	0.69
Semi-detached houses	8.8	0.6
Apartment buildings	3.4	0.05
People	216.5	3.8

4. CONCLUSIONS

Developing a system of *exposure information* at a national level is an extremely complex undertaking, and depends on fundamental datasets of widely varying quality and resolution. However the generic approach has enabled the system to identify information gaps and has shown the way to acquiring high quality datasets and investing in data inventory so as to provide more accurate information for disaster response.

Population dynamics is a critical component in the response to dramatic events such as earthquakes and explosions. It is essential, for example, for emergency services to know the number of people at a particular location at a given time, such as at a train station or at shopping mall. Development of models for casualty numbers or crowd behavior in mass evacuation need an understanding of, and sound data about, population dynamics. This is also critical for community resilience after a disaster, in terms of business continuity, employment and restoring the infrastructure.

In the longer term, beyond local disaster management, NEXIS information is fundamental for evidence based decision making in climate change policy initiatives.

REFERENCES

- Arthur, W.C., Schofield, A., Cechet, R.P. and Sanabria, L.A.: 2008. Return period cyclonic wind hazard in the Australian Region, 28th AMS Conference on Hurricanes and Tropical Meteorology, Orlando, FL, USA
- CLUE, (2008) Census of land use and employment, City of Melbourne, <http://www.melbourne.vic.gov.au/info.cfm?top=91&pa=2089&pg=3681>, dated 18 July 2009.
- COAG - Council of Australian Governments (2002) Review of natural disaster relief and mitigation arrangements 2002, Natural disasters in Australia: Reforming mitigation, relief and recovery arrangements, Department of Transport and regional services, Canberra.
- Floor space and employment survey, (2006) Sydney floor space and employment survey, <http://cityofsydney.nsw.gov.au/AboutSydney/CityResearch/FloorSpaceAndEmploymentSurvey.asp#2006map>, dated 18 July 2009.
- Harper, P. (2006) Emergency management information development plan, Information Paper, ABS Catalogue No. 1385, Australia.
- Nadimpalli, K., Cechet, B. and Edwards, M. (2007) Severe wind gust risk for Australian capital cities – A national risk assessment framework, MODSIM 07, Christchurch, New Zealand.
- Nadimpalli, N., Edwards, M. and Mullaly, D. (2007) “National Exposure Information System (NEXIS) For Australia: Risk Assessment Opportunities”, In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp. 1674-1680. ISBN : 978-0-9758400-4-7.
- Nielsen, O., Roberts, S., Gray, D., McPherson, A. and Hitchman, A.. 2005. Hydrodynamic modelling of coastal inundation. MODSIM 2005 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australian and New Zealand, 518–523.
- Robinson, D., Fulford, G. and Dhu, T. (2005) EQRM: Geoscience Australia’s Earthquake Risk Model, Technical Manual version 3.0, Geoscience Australia, Record 2005/01, Australia.
- Skene, D., Sharples, C., Mount, R., Nadimpalli, K., Wallace, L., Lacey, M. and Baker, C., (2009), A GIS modelling approach to a ‘first pass’ national coastal vulnerability assessment, Conference Proceedings of IGARSS 2009, 12-17 July 2009, Capetown, South Africa.

BIOGRAPHICAL NOTES

Krishna Nadimpalli was mastered in Geology and Land Ecology, completed PhD in "Geoengineering". He has twenty years of experience in land resource inventory, land evaluation, spatial infrastructure and risk assessment from natural hazards. Currently he is the project manager for Engineering, Economics and Exposure for Risk and Impact analysis Group at Geoscience Australia.

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