S.05-64

SIMON FRASER UNIVERSITY

Senate Committee on University Priorities
Memorandum

TO: Senate

FROM: John Waterhouse
Chair, SCUP
Vice President, Academic

RE: Centre for Natural Hazards Research (SCUP 05-041)

DATE: April 22, 2005

Attached is the proposal for the establishment of the Centre for Natural Hazards Research submitted for consideration by Dr. Mike Plischke, Dean, Faculty of Science. This will be a Schedule A Centre reporting to the Dean, Faculty of Science in accordance with Policy R 40.01.

The Senate Committee on University Priorities reviewed the proposal at its April 20, 2005 meeting, and it was unanimously approved. Once approved by Senate, the proposal will be submitted to the Board of Governors.

Motion:

That Senate approve and recommend to the Board of Governors the establishment of the Centre for Natural Hazards Research as a Schedule A Centre under Policy R40.01.

Attach.

c. M. Pinto
M. Plischke
J. Clague
G. Nicholls

SCUP 05 - 041

SIMON FRASER UNIVERSITY

MEMORANDUM
OFFICE OF VICE-PRESIDENT, RESEARCH

TO: Glynn Nicholls, Secretary
Senate Committee on University Planning (SCUP)

FROM: B. Mario Pinto
Vice-President, Research

RE: Centre for Natural Hazards Research

DATE: April 8, 2005

Attached is a proposal from Dr. Michael Plischke, Dean, Faculty of Science, for the establishment of the Centre for Natural Hazards Research as a Schedule A Centre.

The Governing Committee for Centres and Institutes recommends that the Centre be granted approval by SCUP. Once approved by SCUP, the proposal is to be forwarded to Senate, followed by submission to the Board of Governors.

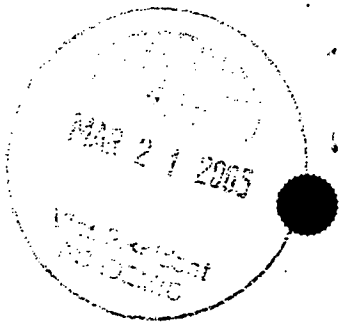
Governing Committee:

Dr. John H. Waterhouse
Vice-President, Academic and Provost

Dr. B. Mario Pinto
Vice-President, Research

Attachment

C: Dr. Michael Plischke, Dean, Faculty of Science
Dr. Diana Allen, Chair, Department of Earth Sciences
Dr. John Clague, Department of Earth Sciences



SIMON FRASER UNIVERSITY
Office of the Dean of Science
MEMORANDUM

TO: J.H. Waterhouse
Vice-President Academic

FROM: Dr. Michael Plischke, Dean
Faculty of Science

RE: **Centre for Natural Hazards Research**

DATE: March 17, 2005

I support the enclosed proposal from Professor John Clague, Department of Earth Sciences, for the establishment of a Centre for Natural Hazards Research at Simon Fraser University. If approved, this will be a Schedule A Centre, reporting to the Dean of Science.

The proposed constitution seems to be in order with appropriate provisions for appointment of a Director and other administrative procedures. I note that item 6 of the constitution envisages the creation of a new full-time position for a Manager. I will try to find the resources to create such a position but cannot guarantee that these resources will be available in fiscal year 2005/2006.

M. Plischke

Michael Plischke

c Diana Allen
John Clague

SIMON FRASER UNIVERSITY

Department of Earth Sciences

MEMORANDUM

TO: Mike Plischke, Dean of Science
RE: Centre for Natural Hazard Research

FROM: Diana Allen, Chair
DATE: March 16, 2005

Mike,

Attached please find a copy of a proposal by Dr. John Clague for the establishment of a Centre for Natural Hazard Research (CNHR) at Simon Fraser University. As you will recall, CNHR was central to an infrastructure request from CFI, which was backed by the University last year. While the proposal did not receive funding, the researchers involved, and most particularly Dr. Clague, are extremely committed to moving forward with the establishment of the Centre itself.

The Department of Earth Sciences recognizes that it has a very strong group of faculty doing research in the area of natural hazards. This strength is translated to our graduate and undergraduate students, *vis à vis* training. Commitment on the part of the Department to this area of research is seen in our support of the nomination of Dr. Gwenn Flowers to a Tier II CRC in glaciology (glaciers are a key geologic hazard on the west coast of BC). In our departmental review last year we noted that Environmental Geoscience at SFU has seen a rapid period of growth and has become one of the strongest research programs in Canada. A Centre for Natural Hazards Research will ensure that this growth continues and will lead to SFU becoming an international centre for environmental geoscience research.

Diana Allen

Diana Allen, Chair

CONSTITUTION
CENTRE FOR NATURAL HAZARD RESEARCH

1. OBJECTIVES

The activities and programs of the Centre for Natural Hazard Research (CNHR) are intended to promote teaching and research in the field of hazardous Earth processes and natural disasters. CNHR supports and initiates research, publication, non-credit and credit instruction, colloquia, conferences, visiting speakers and researchers, and national and international collaborations. In support of these objectives, CNHR provides support to individual, departmental, and cross-departmental activities at Simon Fraser University in the area of natural hazard research.

2. ADMINISTRATION

2a. The Centre for Natural Hazard Research shall be governed in accordance with University policies including R.40.01, CENTRES AND INSTITUTES. If this document and University policies differ on any issue, University policy shall prevail.

2b. The Centre for Natural Hazard Research is a Schedule A Centre (R.40.01, page 2) and comes under the direct authority of the Dean of Science

3. APPOINTMENT OF DIRECTORS

3a. The Director of CNHR shall be appointed by the President on the recommendation of the Governing Committee for Centres, which in turn acts on the recommendation of the Dean of Science and the advice of the Centre Steering Committee. Term of office shall normally be for three years.

3b. In the absence of the Director, an Acting Director may be drawn from the Centre Steering Committee.

4. INTERNAL GOVERNING PROCEDURE

4a. CNHR shall be governed by a Steering Committee made up of five Simon Fraser University faculty members and up to three representatives from the community. The Steering Committee shall include the Director and Manager of CNHR. Members will be appointed by recommendation to the Dean of Science by the Director. Appointments shall be for a three-year term.

4b. The Steering Committee shall be chaired by the Director of the Centre. Meetings shall normally take place at least twice a year.

5. ASSOCIATE MEMBERS OF THE CENTRE FOR NATURAL HAZARD RESEARCH

The Centre for Natural Hazard Research shall consist of a body of interested associates from both within the University and outside it and individuals linked to the Centre through the projects and other activities it sponsors and supports.

6. RESOURCE REQUIREMENTS

The activities of the Centre for Natural Hazard Research will be conducted using the existing University infrastructure. No new library resources or space are required by CNHR. The Centre requires one new full-time position – a Manager working under the supervision of the Director to run CNHR, organize and coordinate its activities, and promote the Centre nationally and internationally. A budget of $2000 per year is required to effect a visiting speaker series.

CENTRE FOR NATURAL HAZARD RESEARCH

Executive Summary

Natural disasters are complex phenomena; as such, approaches to risk reduction that rely on single disciplines and linear thinking address only one aspect of the problem and tend to fail. Success requires a broad-based, innovative approach; such an approach is central to the vision of SFU's Centre of Natural Hazard Research (CNHR). CNHR is a network of physical, social, and economics researchers working toward common goals, and integrated effectively into the larger, non-academic community.

The Centre for Natural Hazard Research (CNHR) will be the first scientifically based, natural hazard research facility in western Canada. CNHR will conduct innovative research on geophysical processes that are a threat to the inhabitants and the economic infrastructure of the region. The Centre will have a western Canadian focus; however, the findings of the research and the methodologies developed will be transformative and will impact the whole of Canada and the international community.

CNHR will foster a program of inter- and multi-disciplinary natural hazard research involving geologists, geomorphologists, remote sensing and geographic information system (GIS) specialists, geophysicists, biologists, and social geographers. A key element of the Centre will be the inclusion of public policy research on how to effectively transfer results of scientific research to the people who need and can use it. The integration of physical science with social and policy research at CNHR will lead the way in Canada to a society that is more resilient to natural disasters, and where planning and investment result in more sustainable communities. CNHR research will contribute not only to a fundamental knowledge base but also to improvements in engineering design, better land-use decisions, and a more informed public.

The principal objectives of the Centre are to facilitate cooperation and collaboration among natural hazard researchers and practitioners. The Centre will capitalize on existing strengths in several departments and schools at SFU. It will also involve faculty at other universities in western Canada, and Geological Survey of Canada (GSC) and US Geological Survey (USGS) scientists. CNHR will showcase SFU as a centre of excellence in natural hazard research in Canada and will attract the best graduate students to the university.

The Research

CNHR will mount an internationally recognized earth science research program aimed at better understanding hazardous geophysical processes, principally earthquakes, tsunamis, volcanic eruptions, avalanches, floods, and landslides, and at quantifying risks associated with these processes. Research will also be conducted on related environmental issues such as the impacts of climate change on natural processes and the landscape. The Centre's program will have three main elements: (1) original and innovative scientific research on natural hazards; (2) training of graduate and senior undergraduate students and postdoctoral fellows for professional careers in the private sector, government, and schools and universities; and (3) transfer of scientific knowledge to the public, emergency preparedness personnel, and government policy makers, from whom CNHR will seek input on the types of information they require.

The major research thrusts of CNHR (and its principal researchers) are:

Earthquakes and tsunamis (SFU: Calvert, Clague, Hutchinson, Mathewes, Stead; others: Atwater, Bobrowsky, Hyndman, Rogers, Spence, Wang)

The Cascadia subduction zone, where the oceanic Juan de Fuca plate moves eastward beneath North America, extends from northern California to central Vancouver Island. The proximity of the subduction zone to the population centres of western British Columbia results in a significant seismic risk, arising from three primary earthquake sources: (1) earthquakes within the subducting oceanic slab, with sources at depths of 40 km and 80 km ("inslab earthquakes"); (2) very large earthquakes at the boundary between the subducting and overriding plates ("subduction earthquakes"); and (3) earthquakes at relatively shallow depth (less than 20 km) within the North American plate ("crustal earthquakes"). Recent geological studies indicate that the average recurrence interval for the subduction earthquakes (of magnitude 8-9) is about 600 years. Although infrequent, these huge earthquakes are capable of damaging all cities on the West Coast, from Portland to Vancouver; estimates of probable damage reach into the hundreds of billions of dollars. They also generate large tsunamis that are a significant hazard to coastal residents and infrastructure. Smaller (magnitude 6-7) crustal and inslab earthquakes are much more frequent and pose an even greater hazard than larger subduction quakes. Ten crustal and inslab earthquakes have occurred in southwestern BC and northwestern Washington in the last 130 years; the most recent of these, in February 2001, caused over $1 billion damage. An earthquake on Vancouver Island in 1946 was larger than the catastrophic quake at Kobe, Japan, in 1995, which caused over $200 billion damage. Unfortunately, the likelihood and locations of future crustal and subcrustal earthquakes in BC are unknown because the faults on which they occur have not been identified and studied, and the pattern of deformation of the crust in southwestern BC has not been adequately documented.

CNHR researchers will conduct research aimed at determining the frequency, magnitude, and effects of earthquakes in the recent geologic past. The focus of the research will be western BC, where the earthquake threat is greatest. The research will contribute to an understanding of earthquake sources and the damage likely to be caused by future earthquakes. Specific research topics include geological investigations of prehistoric earthquakes and tsunamis, geophysical modelling of surface deformation related to strain accumulation in the crust, assessment of the liquefaction potential of sediments in earthquake-prone areas, the response of rock slopes to seismic shaking, three-dimensional imaging of the near-surface and deeper crust to identify faults capable of strong earthquakes, and onshore mapping and interpretation of geological features indicative of recent crustal deformation. The research program will include collaborative studies with GSC and USGS geophysicists and geologists.

Landslides (SFU: Clague, Stead, Ward; others: Bobrowsky, Cruden, Evans, Geertsema, Hungr)

Research will be conducted on the causes, mechanisms, distribution, and age of landslides in western Canada to provide a better understanding of landslide hazard and risk. CNHR will collaborate with the University of Alberta, UBC, BC Forest Service, and the GSC to create a broad-based, cooperative landslide program. The CNHR program will include field-based studies of landslides, mapping, laboratory investigations of soil properties.

The main areas of CNHR landslide research will be: (1) characterization of landslides in forested terrain in BC; (2) risk assessment in forestry-related landslides; (3) integrated numerical modelling and field instrumentation of major rockslides; (4) coupled groundwater-mechanical modelling of landslide failure mechanisms; (5) application of rock and soil engineering principles

in landslide hazard assessment; (6) application of GIS in landslide investigations; (7) application of remote sensing techniques in landslide research; (8) damage mechanisms, with particular emphasis on rock slope failures; (9) application of acoustic emission techniques in the investigation of rock slope failures; and (10) analysis of rock-slope stability in fiords and modeling of tsunamis that would be produced by failures of fiord walls.

Avalanches (SFU: Clague; others: McClung)

Avalanches kill, on average, about 15 people in western Canada each year. The winter of 2002-2003 was particularly deadly – more than 30 skiers, snowmobilers, and climbers lost their lives in the mountains of BC. Avalanche fatalities will probably increase in the future because the number of skiers and snowmobilers using wilderness areas in winter is growing.

CNHR will support the research of Dr McClung (UBC, Geography), one of Canada's top avalanche authorities. Dr McClung will work with Dr Clague and his students to produce maps of high-use winter recreation areas in BC that depict avalanche hazards and risk. The maps will be made available to the public and to groups responsible for public safety through a partnership with the Canadian Avalanche Association. Public meetings will be jointly organized by CNHR and the Canadian Avalanche Association to educate winter recreationists in order to reduce avalanche injuries and loss of life.

Volcanism (SFU: Clague, Williams-Jones; others: Hickson, Russell, Shimamura, Simpson, Singhroy, Smith, Stasiuk)

CNHR and the GSC will collaborate on research on hazards posed by young volcanoes in western Canada, including Mount Baker, Mount Garibaldi, Mount Cayley, and Mount Meager, with insights on aspects of active volcanism from other areas (e.g., Central America, Hawaii). The hazards include ash fallout, pyroclastic flows, landslides, lahars (volcanic debris flows), outburst floods from lakes impounded by landslides on the flanks of volcanoes, and downstream aggradation of floodplains. Dr Clague has collaborated with Drs Simpson and Stasiuk (GSC) in a hazard study of Mount Meager volcano and plans to undertake a similar study with them on Mount Baker lahars in the Fraser Valley near Sumas. Dr. Williams-Jones integrates geophysical observations with geochemical and remote sensing data to investigate precursory eruption signals and the mechanisms that trigger eruptions. The focus of CNHR research will be documenting downstream effects of eruptions and landslides on volcanoes using stratigraphic and geophysical methods, and furthering our capabilities to predict volcanic eruptions.

Floods (SFU: Clague, Brennand, Flowers, Hickin; others: Evans, Geertsema, Whitfield)

One of the greatest hazards in Canada is flooding. The 1948 Fraser River flood caused about $200 million damage (in 2003 dollars). Today some $10 billion in infrastructure lies on the Fraser River floodplain behind protective river dykes and is at risk from large floods. CNHR scientists and students will examine different types of floods in western Canada to better understand their causes and to evaluate risk to existing economic infrastructure on floodplains. Flood types that will be studied include rainfall- and snowmelt-triggered floods, ice-jam floods, and outbursts from moraine-, glacier-, and landslide-dammed lakes. Flood occurrence will be evaluated within the context of climate change. Research will focus on antecedent conditions associated with different types of floods, relations between flooding and high sediment supply to rivers, floodplain hazard mapping, and quantification of flood risk. Flood research will involve

collaborations with hydrologists at UBC, the National Hydrology Research Centre in Saskatoon, and the BC Government.

Climate change (SFU: Allen, Brennand, Clague, Flowers, Lertzman, Mathewes; others: Evans, Moore, Whitfield)

The possibility of rapid climate change caused by human modification of the Earth's atmosphere is increasingly being recognized as a hazard. CNHR research in this area will focus on impacts of climate warming on physical processes and the landscape. Particular attention will be given to destabilization of mountain slopes due to massive snow and ice loss, melt of permafrost, changes in the frequency of outburst floods from glacier- and moraine-dammed lakes, impacts on groundwater resources, interaction of groundwater with surface waters, impacts of sea-level rise on shorelines and fresh water resources, changes in vegetation, and changes in river hydrology and planform. The research will involve mapping, geomorphic, hydrologic/hydrogeologic, stratigraphic, sedimentological, and paleoecological studies, numerical modeling, and comparison of aerial photographs spanning the last 70 years.

Sea level may rise under a warming climate due to melting of glaciers, thermal expansion of oceans, and changes in ocean circulation. A rise in sea level will result in more frequent flooding of low-lying coastal areas, erosion of some shorelines, and seawater incursion into freshwater aquifers, adversely affecting coastal development. CNHR and the Centre for Coastal Studies will model the impacts of various sea-level rise scenarios on the BC coast. The modelling will utilize field observations, detailed topographic maps produced from aerial photographs, and a GIS. CNHR researchers will use downscaled global climate model predictions to drive hydrologic models to determine runoff and groundwater recharge. By coupling hydrologic and hydrogeological models, they will determine impacts on groundwater levels, interactions with surface waters, and seawater intrusion. They will also conduct process-based field studies and undertake glaciological modeling to address specific questions related to glacier-climate interactions. Through Dr Gallaugher, the Centre for Coastal Studies will organize community meetings in areas where critical research is being planned or conducted in order to involve the public and other stakeholders.

Remote sensing (SFU: A. Roberts, and numerous other CNHR researchers)

LIDAR, InSAR, airborne digital multispectral, photogrammetric, and other spatial data will be integrated in natural hazard studies under the direction of Dr A. Roberts and in cooperation with CCRS. The research projects supported are diverse. As one example, Drs Clague and Roberts will conduct research aimed at making high-resolution multispectral digital images available for spectral interpretations, interactive photographic interpretation, and softcopy photogrammetric production of custom digital elevation models (DEM).

Public policy and communications (SFU: Anderson, Clague, Gallaugher, Pierce; others: Haque, Pearce, Slaymaker)

Reducing the human and economic costs of natural disasters does not lie wholly within the realm of science and technology. Because disaster risk reduction is a human-centred issue, it also has political, sociological, economic, and psychological dimensions. Two of the principal reasons for establishing a Centre for Natural Hazard Research are to increase public awareness of natural hazards, and to influence public policy so as to reduce economic losses and injuries from natural disasters. Key to CNHR's program of reducing disaster losses is research leading to hazard

identification and vulnerability analysis that is integrated into community planning and decision-making. Research on public policy can help shape land-use practices and resource management.

Policy research will be conducted on societal vulnerability and resilience to natural disasters, societal preparedness for natural disasters, risk perception, disaster management systems, disaster planning and training, disaster forecasting, reconciliation of natural hazard research with human well-being, psychological and social impacts of natural disasters, community response to natural disasters, sustainable development in areas of potential natural disasters, and integration of scientific information into the political decision-making process. The research will be fostered through partnerships with the Disaster Research Institute of the University of Manitoba (Dr Emdad Haque) and the Insurance Bureau of Canada.

The research of Drs Slaymaker, Haque, and Pierce bridges the very real and formidable gap that exists between scientific analysis of natural hazards and the need for public action. CNHR will lease video-conferencing facilities at the Morris J. Wosk Centre for Dialogue to enable Drs Slaymaker, Haque, and Pierce to conduct research on methods for facilitating the integration of information gathered by scientists at the Centre into the public and political decision-making process. CNHR will bring together people involved with natural hazards, including academics and practitioners in the private sector, universities, and government, in person or by video-conferencing, to exchange ideas, information, and data. Education and social change are dependent on such an exchange.

Research projects will be jointly sponsored by Simon Fraser University and agencies responsible for public safety. Faculty, graduate students, and postdoctoral fellows will involve the public and other stakeholders in their projects through community workshops and presentations. Information and key findings will be reported to the public and to public officials in an understandable and useful form through reports, posters, maps, websites, and articles in newspapers and magazines.

Policy research at CNHR will complement that of the recently established Centre for Coastal Studies at SFU. The Centre for Coastal Studies actively promotes public awareness of research developments that link science with local knowledge in an effort to effect policy change. It is able to facilitate multi-stakeholder dialogue, involving outreach and research partnerships with all levels of governments, including First Nations, and with community and industry groups, NGOs, and academics, to identify solutions based on academic research and practical knowledge. Dr Patricia Gallaugher, Director of the Centre for Coastal Studies, has strong connections with government and community groups. The Centre for Coastal Studies also coordinates the Linking Science with Local Knowledge node of the DFO/SSHRC-funded national Ocean Management Research Network (OMRN).

Dr Anderson is developing innovative, space-based and terrestrial wireless communication systems that will allow CNHR researchers to communicate efficiently with one another, both in the field and the office, creating a "virtual research centre" for researchers who are not based at SFU. They will also be useful for informing the public and emergency planners about natural hazards.

CNHR Researchers

SFU

- Diana Allen (Earth Sciences) – groundwater, climate change
- Peter Anderson (School of Communication) – communication emergency preparedness

- Tracy Brennand (Geography) – geomorphology, glaciation, sedimentology
- Andy Calvert (Earth Sciences) – geophysics
- John Clague (Earth Sciences) – Quaternary geology, climate change, natural hazards
- Gwenn Flowers (Earth Sciences) – hydrology, glaciers, climate change
- Patricia Gallaugher (Centre for Coastal Studies) – science and public policy
- Ted Hickin (Geography and Earth Sciences) – floods
- Ian Hutchinson (Geography) – earthquakes and tsunamis
- Ken Lertzman (School of Resource Management) – wildfire, climate change
- John Pierce (Geography) – economic geography, policy
- Rolf Mathewes (Biological Sciences) – climate and environmental change
- Arthur Roberts (Geography) – remote sensing
- Doug Stead (Earth Sciences) – landslides, rock slope modelling
- Brent Ward (Earth Sciences) – Quaternary geology, landslides
- Glyn Williams-Jones (Earth Sciences) – volcanology, remote sensing, applied geophysics

Others

- Brian Atwater (USGS) – earthquakes and tsunamis
- Peter Bobrowsky (GSC) – earthquakes and tsunamis
- David Cruden (University of Alberta, Civil Engineering) – landslides
- Stephen Evans (University of Western Ontario) – landslides, floods, climate change
- Marten Geertsema (BC Forest Service) – landslides and forestry, floods
- Emdad Haque (University of Manitoba, Natural Resources Institute) – social and public policy
- Cathie Hickson (GSC) – volcanology
- Oldrich Hungr (UBC, Earth and Ocean Sciences) – landslide hazards and risk
- Roy Hyndman (GSC) – geophysics, neotectonics
- Murray Journeay (GSC) – neotectonics, data management
- Arthur Lerner-Lam (Lamont Doherty Earth Observatory, Director of Center for Hazards and Risk Research) – partnership, student and researcher exchanges
- David McClung (UBC, Geography) – snow avalanches
- Dan Moore (UBC, Geography) – hydrology, climate change
- Garry Rogers (GSC) – seismology
- Kelly Russell (UBC, Earth and Ocean Sciences) – volcanology
- Willy Scott (USGS) – volcanology
- Kirstie Simpson (GSC) – volcanology
- Olav Slaymaker (UBC, Geography) – geomorphology, social and public policy
- Mark Stasiuk (GSC) – volcanology
- Chris Tucker (Office of Critical Infrastructure Protection and Emergency Preparedness) – emergency preparedness
- Paul Whitfield (Environment Canada, Adjunct Earth Sciences, SFU) – hydrology, climate change

More than 100 researchers from universities, government agencies, and private sector firms will contribute to the Centre for Natural Hazard Research. These researchers will supervise students and collaborate on projects.

Training

CNHR will train university students and postdoctoral fellows in an area of critical importance to Canada. Consistent with the SFU Strategic Research Plan, the Centre will be interdisciplinary and will create a new model for educating students in earth sciences at SFU. The unique environment of the Centre will create a stimulating training environment by exposing students to geology, physical and social geography, economics, biology, geophysics, physics, chemistry, mathematics, and computing science. SFU has a world-class school of computing science and strong programs in remote sensing, environmental earth sciences, resource management, and communications.

PhD and MSc students and postdoctoral fellows will study and conduct research under the direct supervision of Drs Allen, Anderson, Brennand, Calvert, Clague, Flowers, Gallaugher, Hickin, Hutchinson, Mathewes, Pierce, Roberts, Stead, Ward, and Williams-Jones. Some students will be co-supervised by: Drs Bobrowsky, Evans, Hickson, Hyndman, Rogers, and Stasiuk (GSC); Drs Hungr and McClung (UBC); Dr Menounos (University of Northern BC); and others. Some projects will be supported by government agencies and private sector firms, including the GSC, BC and Alberta Government ministries, Environment Canada, BC Provincial Emergency Program, Canada Office of Critical Infrastructure Protection and Emergency Preparedness, BC Hydro, CN Rail, and CP Rail. Such support will ensure practical training that will lead to rewarding and interesting jobs for students when they graduate from SFU. Graduates will find employment with the aforementioned agencies, as well as with private sector geotechnical and environmental firms.

Examples of training

Access to dedicated, knowledgeable faculty, will make SFU an extremely attractive location for gifted graduate students. The following are a few examples of opportunities that will be available to students at CNHR.

CNHR projects that involve acquisition of offshore seismic data will provide excellent training for students under the supervision of Dr Calvert. The students will process and interpret seismic data using the state-of-the-art computation facilities included in this proposal.

Dr Stead's research will provide students with training in the use of innovative computer simulation, visualization, and modelling tools for landslide hazard research. Graduates with strong backgrounds in earth science and engineering geology, and with skills in state-of-the-art visualization/modelling techniques will be highly sought after by employers in industry and academia. Dr Stead has already trained numerous students who are now occupying senior positions in Canadian geotechnical companies.

Dr A. Roberts provides undergraduate and graduate students with training in remote sensing. Environmental monitoring and resource mapping and evaluation are of crucial importance to Canada and can be met, in part, through remote sensing. Canada's environmental and resource industries are not making full use of remote sensing because they lack a sound understanding and appreciation of its benefits to their business. CNHR will help bridge this gap by developing simple procedures for resource management applications, and by training skilled researchers in the use of these procedures in data analysis.

Drs Gallaugher, Haque, Pierce, Slaymaker, and other researchers will facilitate the social and policy training of graduate students involved in natural hazard research. They will also foster collaborative research and will involve community stakeholders in CNHR activities. There is a need at the PhD and MA/MSc levels to develop interdisciplinary expertise in public policy and

planning through the establishment of 'best practices' guidelines in the design and implementation of remedial action plans. Equally important, and relating to collaborative research, is the need to better understand adaptive behaviour in the face of natural risk and uncertainty. SFU's Centre for Policy Research on Science and Technology (CPROST), the Centre for Public Policy Research, and the newly created Centre for Behavioural Economics afford a unique opportunity to pool expertise with CNHR, and train students in the underlying behavioural, strategic, and counterfactual patterns of decision-making under uncertainty.

Research Collaborations and Partnerships

Faculty involved with CNHR collaborate with natural hazard researchers in universities throughout Canada and abroad. For example, Dr Clague has long-standing collaborations with Dr Mathewes (Biological Sciences) and Dr Hutchinson (Geography) to assess botanical evidence for climate and environmental change, earthquakes, and tsunamis. Clague will collaborate with Dr Anderson (School of Communication) to develop technologies for real-time wireless transmission of field data; with Dr A. Roberts (Geography) on remote sensing imagery for natural hazard research; and with Dr Gallaugher (Centre for Coastal Studies) on public policy concerning natural hazards.

SFU has one of the top-ranked schools of computing science in North America, with experts in computational science, graphics, and 3-D visualization, including Drs T. Moller, M. Ester, and R. Zhang. Faculty members in the Department of Earth Sciences are involved with this group in state-of-the-art computer simulations of natural hazards, including rock slope modelling using coupled finite and discrete element techniques and the use of virtual reality technology.

Collaborators at UBC include Drs Clarke, Eberhardt, and Hungr (Earth and Ocean Sciences; expertise in glaciology, landslides, and rock slope modelling), Drs Bovis, Church, McClung, Moore, and Slaymaker (Geography; climate change, hydrology, landslides, floods, and avalanches). Dr Clague and Dr Smith, and Dr Allen and Dr Moore collaborate on research on climate change. Dr Cruden (Civil Engineering, Univ. of Alberta) will participate with Dr Stead and others in landslide research at CNHR. Dr Calvert and Dr Spence (Earth and Ocean Sciences, Univ. of Victoria) will conduct research the structure of the Pacific margin. The two recently worked together on the SHIPS project in the Strait of Georgia and Puget Sound, and are currently collaborating on the CASSIS project. These academic connections, extending beyond SFU, strengthen the Centre's research and its program of instruction for graduate students.

CNHR researchers will consult with officials from the Canada Office of Critical Infrastructure Protection and Emergency Preparedness, the Provincial Emergency Program, provincial government ministries, BC Hydro, CN Rail, and CP Rail in order to tailor research projects to meet the needs of these groups, create mechanisms for transfer of useful scientific knowledge, and provide students with opportunities to carry out research projects with the public and private sectors.

Drs Clague and Evans work with Mr Geertsema, a landslide expert with the BC Forest Service. Ninety percent of BC's forests are publicly owned, and the BC Ministry of Forests is responsible for their management. CNHR research will be vital for quantifying future risks facing BC's forests. Dr. Stead is the Forest Resources BC Endowed Chair at SFU and collaborates extensively with scientists in the Ministry of Forests and the private sector on slope stability in BC.

A partnership with the Geological Survey of Canada has been established through a formal, signed agreement to allow GSC and CNHR researchers to collaborate on projects of joint interest. The GSC has groundwater, landslide, volcano, and earthquake monitoring programs. Dr Clague was a research scientist at the GSC for 24 years before coming to SFU, and he has a strong record of collaboration with scientists who are leading these programs, including Drs Blais-Stevens, Bobrowsky, Brooks, Couture, Dragert, Evans, Hickson, Hyndman, Rogers, Simpson, and Stasiuk, and Mr Shimamura. Dr Allen currently collaborates with Drs Journeay and Turner on groundwater resources and public outreach. Dr Williams-Jones collaborates with Dr Simpson. Establishment of CNHR will also facilitate new partnerships with the Institute for Catastrophic Loss Reduction (University of Western Ontario), Disaster Research Institute (University of Manitoba), Insurance Bureau of Canada, and the Canadian Avalanche Association.

Dr Stead is currently collaborating on natural hazard research with the Engineering Geology Group at ETH, Switzerland, and with the University of Exeter, England. His work on the Randa Rockslide instrumentation scheme with Dr Eberhardt (University of BC) is one of the most innovative and multidisciplinary rock slope failure investigations undertaken to date, involving engineering geologists, rock mechanics engineers, hydrogeologists, and geophysicists. Dr Stead also collaborates with Dr Allen on the application of groundwater modelling in the investigation of slope hazard phenomena; with Dr Ward on the application of soil mechanics principles in investigations of forestry-related slope failures; with Dr Hungr on landslide simulation using a suite of numerical codes, including dynamic rheologic, finite element, finite difference, and distinct element models; with private sector researchers in the use of GIS to delineate slope hazards; with BC Hydro in the application of numerical codes to simulate slope failure; and with Parks Canada and the BC Ministry of Forests in remote sensing applied to landslides. CNHR's laboratory and field infrastructure is essential to sustain and further these collaborations.

Dr A. Roberts has research links with BC Provincial Government ministries, the Canadian Forest Service, Environment Canada, Department of Fisheries and Oceans, GSC, Parks Canada, and social service agencies. He will foster new linkages with other university, government, and private firms by capitalizing on the benefits of an integrated approach to spatial information science.

Dr Mathewes works with several scientists in other countries on reconstructing past climate and vegetation: Drs T. Ager (USGS), O. Lian (Univ. College of Fraser Valley), W. Shotyk (Director, Inst. of Environmental Geochemistry, Univ. of Heidelberg), and C. Whitlock (Univ. of Oregon). He is also collaborating on a Swedish-Canadian research project, led by Drs B. Wohlfarth (Univ. of Stockholm) and J. Clague, on climate and vegetation change over the last 2000 years. This project involves student and faculty exchanges among four universities (SFU, Lund Univ., Univ. of Stockholm, and Okanagan Univ. College), and is supported by the Swedish government through its Foundation for International Cooperation in Research and Higher Education.

Dr. Williams-Jones collaborates with scientists in Canada and abroad on active volcanism: F. Amelung (Univ. Miama), T. Elias, M. Poland, and A. Sutton (USGS), L. Flynn, K. Horton, and R. Wright (Univ. Hawaii), J. Gottsmann (CSIC, Spain), D. Johnson (Univ. Washington), H. Rymer and D. Rothery (Open Univ., UK), and J. Stix (McGill Univ.). His collaborative studies of active volcanoes in the Americas, Europe, and Hawaii will provide insight into potential future activity at dormant Canadian volcanoes.

Internationally, Dr Clague and other CNHR researchers also collaborate with Drs J. Chow (Univ. of Taiwan), M. Cisternas (Univ. Catolica de Valparaiso), D. Clark (Western Washington

Univ.), E. Eberhardt (ETH Zurich), A. Goodie (Oxford Univ.), F. Guadagno (Univ. of Benevento), Y. Ikeda (Univ. of Tokyo), F. Nanayama (Geol. Survey of Japan), A. Nelson (USGS), Y. Ota (Senshu Univ.), P. Owens (Cranfield Univ.), D. Petley (Univ. of Warwick), K. Sassa (Kyoto Univ.), K. Satake (Geol. Survey of Japan), C. Scavia (Turin Polytechnic Univ.), T. Spencer (Cambridge Univ.), I. Stewart (Univ. of Edinburgh), Y. Tsuji (Univ. of Tokyo), K. Ueda (Univ. of Tokyo), and Y. Yang (Nanjing Univ.).

Drs Clague, Anderson, and Hutchinson will establish collaborations with international researchers working on tsunami hazards and risk in the Asia-Pacific region. The tsunami disaster in the Indian Ocean in December 2004 highlighted the need for scientific research on the tsunami threat in the North Pacific and for studies of state-of-the-art communication systems for providing timely warning of approaching tsunamis.

Benefits of CNHR

The Centre for Natural Hazard Research will support research that will lead to major, improvements to society and the environment in Canada, and will galvanize natural hazard research and policy-making.

CNHR can be considered a vitally important "insurance policy" for Canada. Economic damage and personal loss caused by natural disasters are increasing rapidly. Losses in the 1990s were 17 times larger than those in the 1960s. In the last 50 years alone, losses due to natural disasters in Canada have exceeded $25 billion, and even greater losses can be expected in the future. The long-term goals of CNHR are to create a society that is more resilient to natural disasters and to save Canada lives and billions of dollars in economic losses from disasters. These goals will be achieved through innovative scientific research on natural hazards, training of graduate and senior undergraduate students for professional careers in earth science, and transfer of information to the people who need it. The direct benefits to Canada, in addition to a reduction in losses from disasters, are improved public safety, a better-informed public, and wiser land-use decisions. Indirect economic benefits include stimulation of innovative engineering design and services to the public (e.g. seismic retrofitting of unsafe buildings, innovative construction methods, and earthquake preparedness kits).

Specific benefits of CNHR to Canada are numerous. (1) **The National Building Code**: CNHR research will provide greater protection to Canadians and public and private infrastructure through partnerships with the National Research Council of Canada (Institute for Research in Construction) and Natural Resources Canada (earthquake and landslide hazard programs). (2) **Land-use planning**: Improved understanding of natural hazards will aid land-use planners in making the best possible use of their resources for protective structures such as dykes, thus reducing the economic and social costs of both natural disasters and the protective infrastructure. (3) **Critical infrastructure and hazardous waste**: Many hazardous natural processes can damage critical infrastructure, including hazardous material storage facilities. Spillage of pesticides and petrochemicals could imperil Canada's food and water supplies, with significant health and economic impacts. Preventative measures and established clean-up plans, made possible with information and strategies provided by CNHR, will reduce these impacts. (4) **Security of food and water supply**: CNHR will contribute to the Federal Government's goals of strengthening the security of the food supply and ensuring the safety of drinking water, as stated in the most recent Speech from the Throne. (5) **Climate change**: Canada and the international community are working to mitigate the effects of climate change

caused by human modification of Earth's atmosphere. CNHR research into the potential effects of climate change will provide individuals, businesses, and policy makers with the information they need to adapt to climate change and minimize its negative economic impacts. CNHR will work to ensure that policies are developed to encourage adoption of techniques and technology that will minimize impacts of climate change, especially drought and soil erosion. Partnerships will be sought with policy makers, the agricultural industry, and insurers to accomplish this goal. (6) **Knowledge dissemination and emergency planning**: Major natural disasters can have national, even global, effects. The earthquake in Kobe, Japan, in 1995, for example, extended the recession in Japan, the second largest economy in the world. International organizations, such as UNESCO, have played an active role in increasing awareness of natural hazards, encouraging sound planning, land use, and construction, and facilitating the sharing of information among researchers, policy makers, industry, and the public. CNHR will support these activities by disseminating information, not only locally and nationally, but internationally through partnerships with overseas natural hazard research centres. CNHR will archive natural hazard information and make it available in a useful form to governments to reduce the impact of future disasters. Research conducted by CNHR into the impact of natural disasters on humans will lead to the creation of effective educational materials and emergency plans. (7) **Retention of HQP and business development**: Through improvements in education, prevention, and emergency preparedness, CNHR will contribute to the retention of businesses and HQP in Canada. It will also attract new economic ventures and encourage skilled personnel to relocate here, thus promoting economic development. (8) **Environmental protection**: CNHR will provide input into environmental impact assessment that will benefit forestry and mining operations and the public.

Although they occur infrequently, natural disasters have a high social and economic toll that should concern all Canadians. Potentially catastrophic earthquakes of magnitude 7 occur, on average, once every 30 years on the West Coast. The most recent of these quakes, in February 2001, caused about US $1 billion damage in Washington State. This damage, however, pales in comparison to that of the earthquakes at Northridge, California (January 1994, magnitude 6.4), and Kobe, Japan (January 1995, magnitude 7.1), which amounted to US $20 billion and US $147 billion, respectively. Earthquakes larger than those at Northridge and Kobe can occur in British Columbia. Damage from a large, shallow, crustal earthquake near Vancouver or Victoria could reach several tens of billions of dollars, perhaps more. Research at CNHR will provide information on the frequency and magnitude of past earthquakes and tsunamis, and on the likely effects of the next large earthquake in the region. As part of the immediate benefits of its research, CNHR will strive to have its information used when the seismic provisions of the National Building Code of Canada, which ensure that buildings and other structures are more earthquake-resistant, are revised. The information will also be useful to emergency planners and officials in the BC Provincial Emergency Program, as it will allow them to postulate scenarios that are more realistic in order to prepare for damage caused by earthquakes.

The eruption of Mt. St. Helens in May 1980 and its recent reactivation demonstrates the need for expanded research on Canadian volcanoes. The 1980 eruption claimed 57 lives and caused more than US $1 billion damage. A similar eruption at Mt. Baker or Mt. Meager athe the north end of the Cascade volcanic belt could affect populated areas of south-coastal BC. Collaborative research at CNHR, GSC, and USGS will assess the probable impact of future

eruptions in the region so that appropriate emergency preparedness measures can be implemented.

Landslides cause $100-200 million in damage in Canada every year. As Canada's population increases, more people will be at risk from landslides in mountain and rural areas. This year marks the centennial of the Frank Slide, which destroyed part of the town of Frank, Alberta, and claimed about 70 lives. Even small landslides, however, are a threat to transportation infrastructure as they disrupt the movement of goods, and are costly to clear. For example, in 1991, a small landslide near Logger's Creek, north of Vancouver, damaged a major highway; the cost to clear and repair the highway was $7 million. Construction of more roads and rail links increases the likelihood of transportation infrastructure being disrupted by landslides. Moreover, the economic costs of landslides are not limited to roads and railways. In the past, underwater landslides off the coast of British Columbia have destroyed wharves and warehouses. In 1914, a landslide at Hell's Gate, BC, prevented salmon from returning to their spawning grounds. Economic losses, in terms of reduced salmon runs, are estimated to be in the hundreds of millions of dollars and are still being felt, almost ninety years later. CNHR will conduct innovative research on landslides and rock mass creep, identify areas of high landslide risk, and notify appropriate provincial and municipal agencies of its findings. Government agencies will use this information to make informed and sensible decisions on expenditures of monies for landslide prevention measures and remediation.

Floods are the most damaging natural hazard in Canada. Large floods can destroy bridges, inundate populated land, and contaminate drinking water, causing major damage and disrupting normal economic activity. The 1948 Fraser River flood caused $200 million (2003 dollars) in damage and forced about 16,000 people from their homes. In 1993, a major flood in Winnipeg caused $500 million in damage. Further development of Canada's hinterland will result in increasing economic losses should a flood or other disaster strike. To reduce such losses, CNHR will strengthen existing collaborations and establish formal partnerships with the GSC, UBC, UVic, UNBC, University of Alberta, BC Hydro, Environment Canada, and some BC Government ministries. The information provided by CNHR will be transferred to the public, land-use planners, and government bodies to reduce exposure of people and property to floods. The reduction in risk will be accomplished through government ordinances that limit development on floodplains, improve dyking systems, and strengthen emergency preparedness measures.

Protection of surface and ground water is a key concern to all Canadians, as evidenced by the recent Walkerton tragedy. Dr Allen currently sits on the provincial Ground Water Advisory Board that is developing recommendations for regulations pertaining to the Drinking Water Protection Act and the Water Act. She collaborates with GSC, Environment Canada, BC Ministry of Water, Land and Air Protection, Agriculture Canada, and university researchers. CNHR scientists will undertake groundwater research aimed at better understanding groundwater availability and vulnerability to contamination, the role of preferential pathways for recharge and contaminant transport, resources sustainability in the face of climate change, and the nature of interactions between groundwater and surface water.

Some natural disasters, such as floods and landslides, may occur more frequently as climate changes due to global warming. Climate change could also cause sea level to rise due to melting of glaciers, thermal expansion of oceans, and changes in ocean circulation. Sea-level rise will cause more flooding in coastal areas as well as changes in the position of the saltwater-freshwater interface in coastal areas. Mining and forest harvesting may, in some

cases, increase the risk of landslides under a new climate due to changes in runoff. CNHR will contribute to a better understanding of the underlying causes of climate change by conducting research into past changes in Earth's climate. Its scientists will examine historic and current climate trends, current trends and will assess the likely impacts of climate warming on the hydrologic cycle (glaciers, runoff, groundwater recharge, interactions between groundwater and surface water) and on ecosystems.

Research on natural hazards significantly benefits Canadians. In 1993, early warning of a landslide at Lemieux, Ontario, provided residents with enough time to evacuate, avoiding loss of life. Better safety standards and construction techniques have been developed in response to improved knowledge of earthquakes on Canada's Pacific coast, ensuring that the next quake will be much less deadly than it would be otherwise. As a result of better risk assessment, Canadians are also less likely to live in disaster-prone locations. Thankfully, a disaster of the scale of the 1915 Jane Mine landslide in BC, which killed 56 people, has not been repeated.

Avalanches kill, on average, about 15 people in western Canada each year. Avalanche fatalities will probably increase in the future because the number of people using wilderness areas in winter is growing. Improved understanding of avalanche formation and movement will be used to produce maps of high-risk avalanche areas in BC.

The innovative research conducted by Dr Clague and his colleagues will be used by other research scientists, the Insurance Bureau of Canada, Environment Canada, the Office of Critical Infrastructure Protection and Emergency Preparedness, the Canadian Avalanche Association, BC Provincial Emergency Program, provincial government ministries in western Canada, BC Hydro, CP Rail, CN rail, private sector environmental and engineering consultants, educators, and the general public.

Research personnel, including graduate students and postdoctoral fellows, who work in the proposed centre will gain expertise in a wide range of disciplines. Upon graduation, students will find stimulating employment with agencies in the private and public sectors, including Environment Canada, the GSC, provincial government ministries, BC Hydro, CP Rail, CN Rail, and environmental and geotechnical firms. Without the establishment of research centres such as the Centre for Natural Hazard Research, the demand for highly qualified personnel capable of natural hazard and risk assessment will not be met in Canada.