Critical Needs for the Twenty-first Century

The Role of the Geosciences

2012

AGI american geosciences institute

Geoscience to Meet the Needs of the Twenty-first Century: Natural Resources, Environmental Quality and Resiliency

The geoscience community provides the knowledge, experience, and ingenuity to meet society's demands for natural resources, environmental quality, and resilience to hazards. Here we outline some critical needs of the nation and the world and provide policy guidance to grow the economy while sustaining the Earth system.

The Earth system includes complex linkages among the atmosphere, hydrosphere, biosphere, and lithosphere. Natural resources we rely on are derived from the Earth system and include the following broad categories:

- Energy resources
- Water resources
- Soil resources
- Mineral, metal, and building material resources
- Ecological resources, such as forests, coastal systems, and the oceans

With a burgeoning human population, rising demand for natural resources, concerns about food security, and a changing climate, it is critical to more fully integrate Earth observations and Earth system understanding into actions for a sustainable planet. The geoscience community of more than 250,000 geoscientists represented by member societies of the American Geosciences Institute stands ready to help meet the challenges of modern life in a delicately linked Earth system.

Critical Needs

1. Ensure reliable energy supplies in an increasingly carbon-constrained world
2. Provide sufficient supplies of water
3. Sustain ocean, atmosphere, and space resources
4. Manage waste to maintain a healthy environment
5. Mitigate risk and build resilience from natural and human-made hazards
6. Improve and build needed infrastructure that couples with and uses Earth resources while integrating new technologies
7. Ensure reliable supplies of raw materials
8. Inform the public and train the geosciences workforce to understand Earth processes and address these critical needs

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Key Recommendations

» Ensure a Natural Resource Advisor within the White House Office of Science and Technology Policy to advise the President on stewardship of natural resources based on scientific understanding and technological advances. The advisor will highlight connections among the different resources; improve integration among research, development, technology, and demand for resources; and advise the government on policy, management, and risk reduction – all in a global context.

» Support mapping, monitoring, assessments, and state and federal surveys of natural resources. Ensure that data are integrated to provide the context for understanding climate change, supply and demand scenarios on global to local scales, and risks from hazards.

» Support research and development to understand Earth processes because sustainable consumption and conservation of resources, enhancement of environmental quality, and resilience from risk depend on living with our dynamic planet.

Christopher Keane, AGI

1 Ensure reliable energy supplies in an increasingly carbon-constrained world

Energy is essential for economic growth, national security, international relations, sustainable communities, food security, and the overall quality of life. Energy resources must be cost-effective, reliable, efficient, and flexible. Fossil fuels have filled this role for decades and will continue to be part of our energy portfolio for many more decades (Figure 1A). Looking to the future, effective research and development of alternate energy resources should be balanced with continued research and development of cleaner and more efficient fossil fuels and newer carbon-based fuels. A key challenge is to sustain fossil fuel energy resources and increase other energy resources on commercial scales while dealing with climate change, pollution, water availability, and land use priorities.

The global climate is changing (Figure 1B) and these changes have significant effects on the environment. World leaders have agreed that unified global action is necessary to reduce greenhouse gas emissions as soon as possible to ameliorate the effects of climate change. Adaptation is fundamental to ensuring quality of life and economic growth. Mitigation and adaptation have costs – economic, social, and cultural - but provide opportunities. Geoscientists are needed to collect and interpret observations and models in order to develop an effective mitigation and adaptation strategy. Together geoscientists, policymakers, and the public can ensure the wisest use of natural resources now and in the future. Mitigation and adaptation involve a global effort and require strategic planning related to national security and international interests.

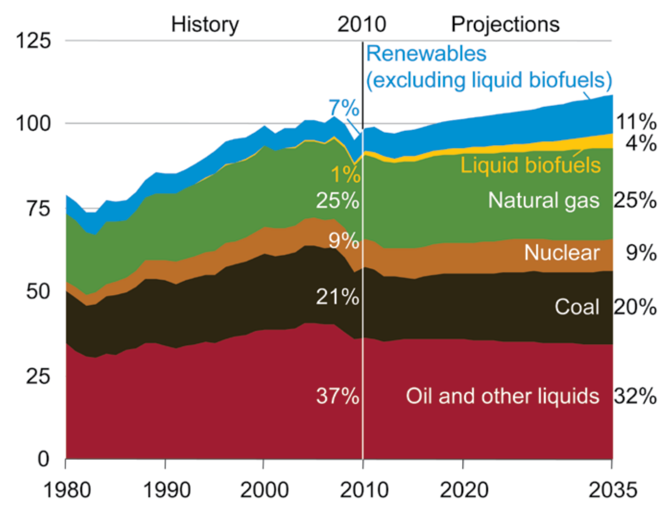


Figure 1A: The U.S. Energy Information Administration predicts total primary energy consumption in the U.S. will grow by 10 percent over 25 years (2010 to 2035). The fossil fuel share of energy consumption falls from 83 percent of total U.S. demand in 2010 to 77 percent in 2035. Units shown are quadrillion British thermal units (Btu).

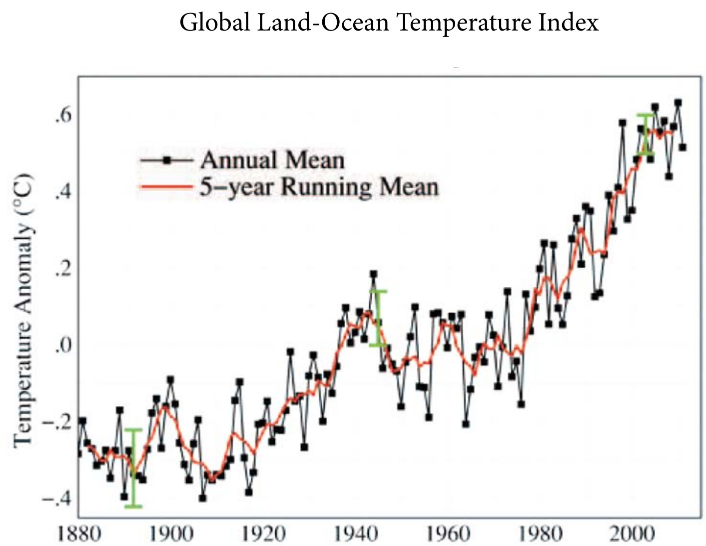


Figure 1B: Global surface temperature change from 1880 to 2009 in degrees Celsius. The black curve shows annual average temperatures, the red curve shows a 5-year running average, and the green bars indicate the estimated uncertainty in the data during different periods of the record.

Left: Energy Information Administration's Annual Energy Outlook 2012 Early Release; right: From NASA Goddard Institute for Space Studies (2010; based on Hansen et al., 2006, updated through 2009 at http://data.giss.nasa.gov/gistemp/graphs/)

Given the need for secure and reliable energy supplies in an increasingly carbon-constrained world, the geoscience community suggests that the following actions are needed to inform national policy directions.

1. Provide the President with continual and objective expertise on all natural resources, through strong and integrated leadership among the Secretary of Energy, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Defense, and other leaders.

2. Increase expertise in natural resources and environmental impacts among the staff and committees for Congress, the President's Office of Science and Technology Policy, the National Science and Technology Council, and the Council of Environmental Quality. Ensure that development of energy resources is considered in terms of impacts on water, soil, mineral and ecological resources.

3. Increase investment in a more comprehensive energy R&D portfolio that includes all energy resources, their life cycles, and their environmental footprints. Too often support for R&D focuses on one resource for a short time. Strategic and steady long-term support is needed to achieve breakthroughs.

4. Promote responsible exploration, production, and consumption of energy resources, including efficiency and conservation measures, through science and engineering advances.

5. Update and strengthen the goals of the U.S. Global Change Research Act of 1990 in light of current knowledge – in particular, the act should include research on regional and local effects related to climate change.

6. Complete a global climate change assessment for Congress and the Administration on a regular basis.

7. Ensure that investment in climate change R&D across all agencies is sufficient to meet national and international needs and improve coordination of these efforts.

2 Provide sufficient supplies of water

Clean water is essential for life and is our most precious commodity. Only about 2.5 percent of Earth's water is fresh water, the rest is salt water. Fresh water comes from lakes, rivers, streams and groundwater. Maintaining healthy ecosystems that support these sources is crucial.

Besides providing drinking water, water is harnessed for agriculture, energy, flood control and navigation (Figure 2). The U.S. population has grown from 5.3 million people in 1800 to over 313 million people in 2012 and our thirst for water has grown significantly. Withdrawals for thermoelectric-power generation and irrigation have decreased since their peaks in 1980, while withdrawals for public supply and domestic uses have intensified. The U.S. Climate Change Science Program identified significant challenges for water management because of climate change. Research and development from the federal government and states has allowed geoscientists and engineers to understand and map water sources, measure and protect quality and quantity within each source, and understand the effect of climate variability on water resources. It is primarily the responsibility of the individual states to assess and manage their water resources.

Geoscientists working within and across societal and political entities are needed to understand and cooperatively manage water resources within watershed, aquifer, and ecosystem boundaries rather than within solely political boundaries.

Estimated Total U.S. Water Withdrawals by Category (in million gallons per day)

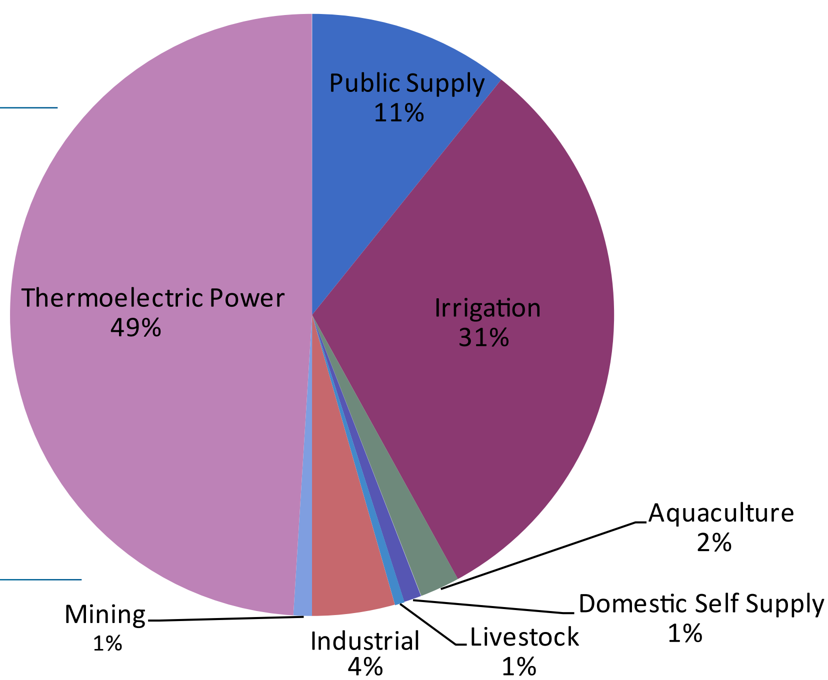


Figure 2: Surface water accounts for 80 percent of fresh water withdrawals and the rest comes from groundwater. On the basis of estimates from 1995, about 70 percent of withdrawals were returned to surface water bodies. Less data is available about current water withdrawals and consumption, making water management more challenging.

Figure is generated from data provided by "Estimated Use of Water in the United States in 2005," a 2009 report by the U.S. Geological Survey.

Given the critical need for water for a growing population in a changing environment, the geoscience community suggests the following national policy directions.

1. Prioritize and enhance the enactment of the Secure Water subtitle of the Public Lands Omnibus of 2009 (Public Law 111-11). Priorities of the Secure Water subtitle include:

    >>Surface and subsurface water assessments at local, regional and watershed levels.

    >>Monitoring of surface and subsurface water quantity and quality with a focus on enhancing the National Streamflow Information Program and building the National Groundwater Monitoring Network.

    >>Modeling and assessment of the hydrologic effects of water use and climate change.

2. Establish the U.S. Geological Survey as the lead water science agency for the federal government, to:

    >>Ensure integration of water R&D and monitoring for water planning across federal agencies.

    >>Ensure that federal initiatives are integrated with regional, state, and local entities that manage water resources.

    >>Ensure that federal initiatives are focused on the impact of land management on soil and water quality.

3. Implement the National Ocean Policy of 2010, which includes the Great Lakes, and integrate the policy with other federal initiatives.

4. Increase the use of recycled/reclaimed water through R&D and federal-level incentives for local, state, and regional water managers.

5. Develop water policy that:

    >>Emphasizes incentives to more effectively manage and conserve water resources.

    >>Strengthens watershed-level management and cooperation.

    >>Provides regular comprehensive assessments of water resources.

6. Increase investment in basic research in the geosciences to better understand the hydrologic cycle and water resources.

7. Focus some applied research on emerging water science issues, including:

    >>Enhance monitoring and research on emerging contaminants, such as pharmaceuticals, endocrine disruptors and nanoparticles.

    >>Consider short-term and long-term water resources management and planning for multiple uses.

    >>Improve modeling and assessment of point and non-point sources of contamination.

    >>Consider saline water use and advances in desalinization.

    >>Improve water conservation and efficiency for water-use processes, including extraction and manufacturing processes.

3 Sustain ocean, atmosphere, and space resources

Earth is the "blue planet" in the Solar System because of the size of the oceans. About 71 percent of the Earth's surface is covered by these saline water bodies. Oceans provide food, desalinated drinking water, and habitats for plants and animals. Oceans are coupled with the atmosphere and the solid Earth in driving weather, climate, ecosystems, and land processes. The 2004 Indian Ocean tsunami killed more than 230,000 people in fourteen countries. The 2011 Tohoku earthquake and tsunami, the most expensive disaster of all time according to the World Bank, caused a nuclear power plant meltdown and cost an estimated $235 billion. Both events attest to the power of the ocean as driven by large magnitude earthquakes.

The atmosphere couples with the solid Earth, oceans, and space. It affects water resources through precipitation, evaporation, and other parts of the water cycle, affects air quality as part of the carbon and nitrogen cycles, and moderates temperatures near the surface. The atmosphere shields us from harmful solar radiation and affects weather. Society relies on the atmosphere for aviation, wind energy, and other uses. The eruption of Eyjafjallajokull Volcano on April 14, 2010 shut down aviation over Europe for more than six days, affecting about 10 million passengers, costing airlines about $1.7 billion in revenue, and causing significant indirect costs and disruptions throughout the world.

Space is vast and mostly unknown, yet Earth orbit and the Sun to Earth interaction regions of space (Figure 3A) have been explored and monitored at a level that rivals oceanic and atmospheric exploration. According to NASA, there are about 3,000 active Earth orbiting satellites out of more than 8,000 human-made objects that have been launched into space (Figure 3B). Society relies on these satellites for navigation, communications, and other purposes. The United States Space Surveillance Network tracks more than 26,000 objects, in part to mitigate damage from space debris. Space weather, caused primarily by solar activity, can disable one or more satellites, threaten human space exploration, damage part of our electrical grid, or potentially harm life on Earth.

Geoscientists, working with other scientists and engineers, observe and understand Earth and space processes to effectively utilize these vast resources (e.g. oceans, atmosphere, and space). Earth observations need to be continuous and ubiquitous, as society's use of the oceans, atmosphere, and space are increasing and becoming more complex. While natural hazards, such as the ones described above, catastrophically remind society of our dependence on the oceans, atmosphere, and space, steady Earth observations are key to sustaining these vast resources for daily use.

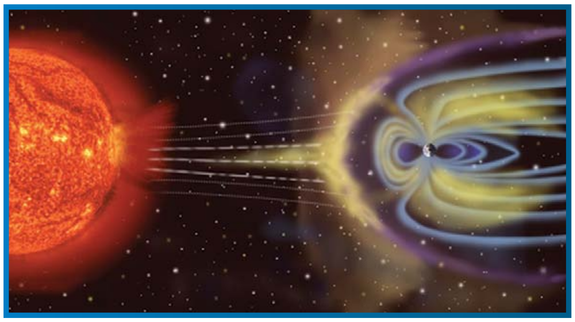


Figure 3A: The Sun is a magnetic variable star whose size and mass affect the orbit of the Earth. Radiation from the Sun moderates the temperature of the Earth and ejections of massive amounts of solar radiation can interact with Earth and the Earth's magnetosphere and affect radio, television, and telephone signals, satellites, and electrical power grids.

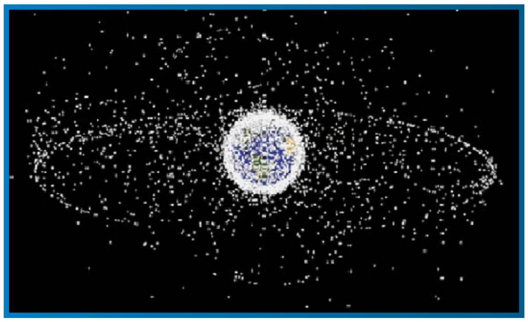


Figure 3B: Each white dot represents an object in orbit around the Earth. The ring represents objects in geostationary orbit such as many communications satellites. Due to their large distance from Earth, they are more susceptible to damage from solar particles. The swarm of objects around Earth includes objects such as the International Space Station and the Hubble Space Telescope. They are much better protected due to their proximity to the Earth's magnetic field.

Figures and caption courtesy of NASA http://hesperia.gsfc.nasa.gov/rhessi2/home/mission/science/the-impact-of-flares/

Given the increased use and dependence of society on the oceans, atmosphere, and space, the geoscience community suggests the following policy directions.

1. Support land and space-based observations and monitoring networks, mapping and analysis across agencies.

   >> Support the recommendations of the National Research Council's 2007 decadal survey, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, to conduct and support geoscience R&D, assessments, and monitoring.

   >> Support the recommendations of the National Research Council's 2012 decadal survey, Solar and Space Physics: A Science for a Technological Society, to better understand the Sun-Earth connection and reduce risks from space weather.

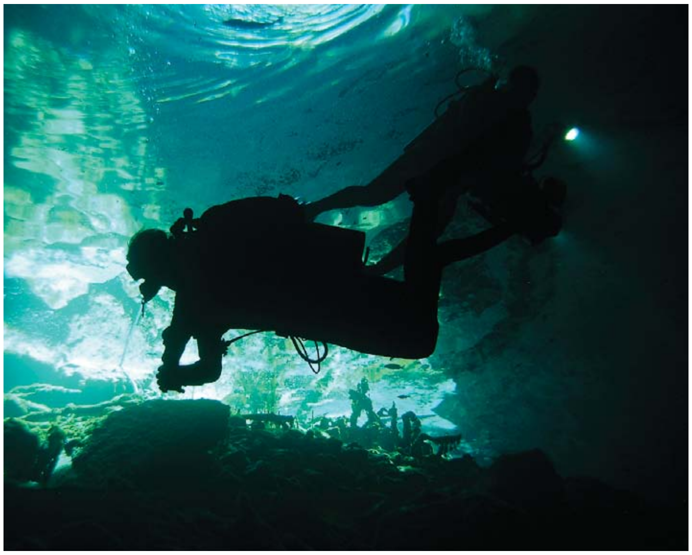
   >> Support computer modeling, computational infrastructure, and data archiving related to geoscience R&D, assessments, and monitoring.

2. Support ratification of the Law of the Sea Convention to enhance global cooperation related to the oceans, seafloor, and Polar Regions.

3. Implement the U.S. National Ocean Policy of 2010 to ensure that the resources and health of the Great Lakes and oceans are sustained.

4. Ensure that ocean policies are integrated with the nation's energy and climate change initiatives.

5. Develop strategies and plans based on sound geoscience to protect infrastructure, aviation, navigation, and communications in the oceans, atmosphere, and space.



4 Manage waste to provide a healthy environment

Each year the nation requires more waste treatment and disposal. Wastewater, sewage, contaminated water, nuclear waste, landfills, brown fields, superfund sites, recyclable waste, and non-biodegradable waste must be managed with great care. Long term planning and responsible execution are needed to prevent toxic waste build-ups, additional contamination, re-use of certain waste materials for biologic or nuclear weapons, and release of hazardous materials.

The challenge is to efficiently and securely treat and dispose of waste with a minimum impact on ecosystems and human health.

The tracking of mercury, originating from air pollutants to toxic methylmercury build-up in our food chain is a good example of what types of data and what levels of understanding are required to deal with the complexities of waste transport in the Earth system. All waste treatment and disposal solutions require geological, geochemical, geophysical, hydrological and biological expertise to determine the sources of waste, how the waste is transported, altered and/or concentrated in natural and man-made systems, and what methods may be most effective in remediation or recycling waste. Waste can be transformed into a useful resource with ingenuity, effective waste management, and innovation.

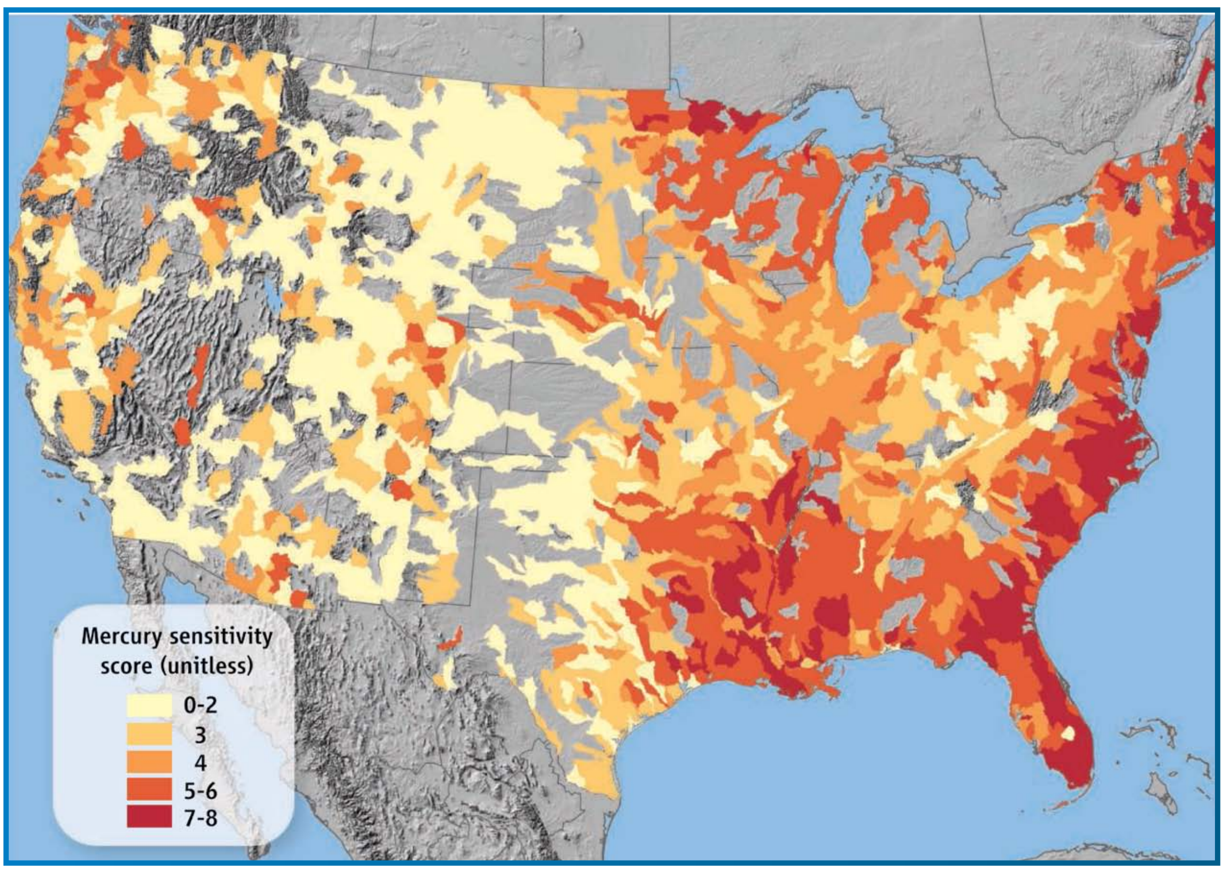


Figure 4: The U.S. Geological Survey maintains a mercury sensitivity map for the contiguous 48 states. The higher scores represent more sensitive ecosystems and the data are based on more than 55,000 water-quality sites and 2500 watershed measurements. Mercury pollution, primarily from power plants, accumulates in fish as methylmercury. Methylmercury is toxic for people and fish-eating wildlife.

More details are available from: http://www.usgs.gov/mercury/.

Given the need to deal with waste and to recycle where feasible, the geoscience community suggests the following national policy directions.

1. Provide incentives to support greater use of recycled materials, including reclaimed water, to reduce waste build-up and conserve resources.

2. Build a database of "waste resources" – places where economically valuable materials and services can be harnessed from waste streams.

3. Invest in upgraded and advanced water/wastewater treatment infrastructure.

4. Support more wastewater R&D, which is often overlooked and is segmented among different federal agencies.

5. Consider the Blue Ribbon Commission on America's Nuclear Future's 2012 final report and other recommendations.

6. Consider revisions to the Nuclear Waste Policy Act of 1982 based on current and future waste needs and advances in technologies.

7. Invest in nuclear energy/nuclear waste R&D with an appropriate fraction of the resources directed toward training of skilled professionals for the nuclear industry and outreach/education for the public.

8. Support clean-up of abandoned mines, brown fields, and superfund sites as a high priority; set priorities for what should be cleaned up first given that there are not enough funds to initiate clean-up at all sites concurrently.

5 Mitigate risks and build resilience from natural and human-made hazards

Natural hazards such as earthquakes, volcanoes, landslides, tornadoes, hurricanes, severe storms, floods, heat waves, and drought, exact a significant toll on society. Our goal as a nation should be to develop resilient communities where losses are limited and recovery is holistic, intelligent, and rapid. Although R&D has led to safer communities, improved forecasts to save lives and enhanced planning to limit damage, there are ominous signs of increasing risks, especially to the built environment. Climate change and other alterations to the environment are increasing the risks from natural hazards. Increasing development in high risk areas, increasing population density in urban communities and aging infrastructure can contribute to mounting threats from natural hazards.

The average cost of property damage from natural hazards in the U.S. has been increasing because of population growth and greater development in risk-prone areas. Single catastrophic events, such as Hurricane Katrina in 2005, with overall losses of $125 billion and 1,322 fatalities and the earthquake/tsunami in Japan in 2011, with overall losses of $235 billion and 15,500 fatalities, can greatly strain a nation's ability to deal with direct damage costs and indirect economic, social, and cultural losses. Geoscientists, working in cooperation with emergency managers, developers, insurers, and others, are needed to understand the natural and human factors that may make Earth processes more hazardous and to help develop strategies to mitigate their risks. With cutting edge advances and continual use of observational, analytical, and monitoring tools, geoscientists can help educate decision makers and the public about risks, in some cases forecast the timing, direction, intensity and targeted region for a natural hazard, and help develop strategies and technologies to reduce the risks. Research and development have served the nation well in saving lives and improving community resiliency and must be maintained to deal with the greater needs of a growing population and an expanding economy.

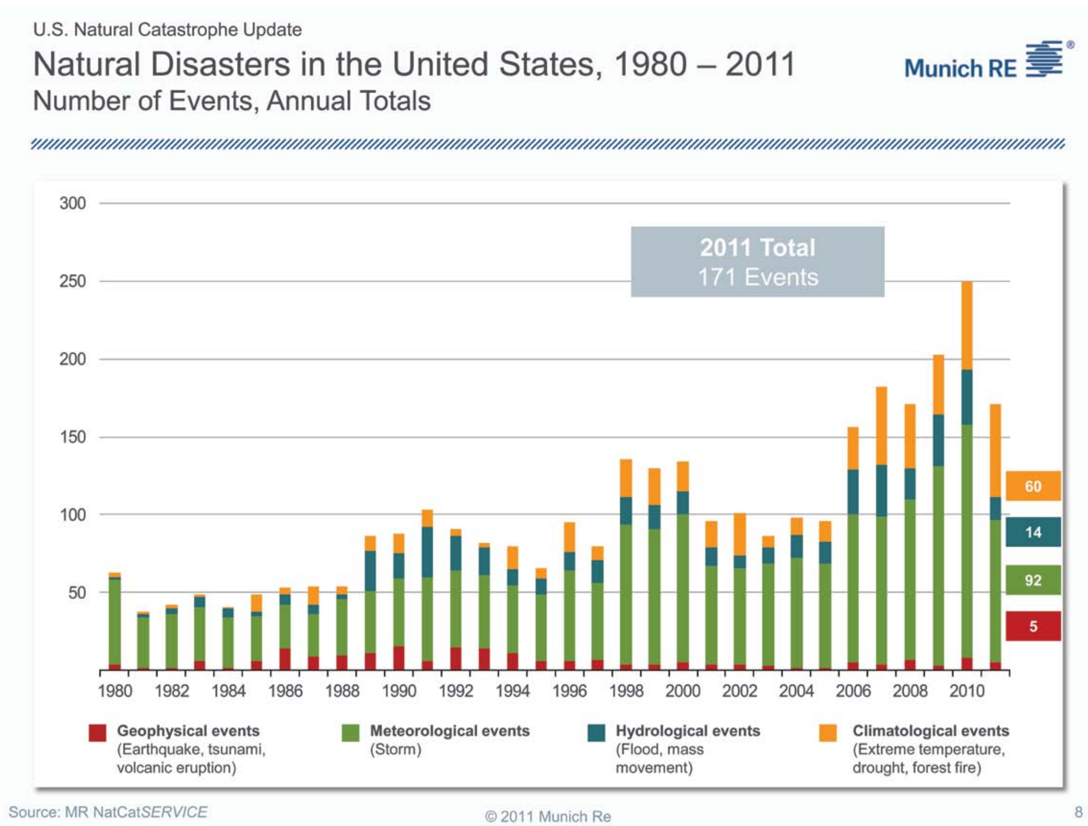


Figure 5: The number of natural disasters from 1980 to 2011 from Munich Reinsurance Company, NatCatService. A natural disaster is defined by being above a certain economic cost and/or number of fatalities level as determined by Munich Re.

http://www.ctnow.com/media/acrobat/2012-01/67158951.pdf

Given the need to make the nation less vulnerable to hazards, the geoscience community suggests the following national policy directions.

1. Federal and state governments, businesses, academic institutions and communities should be effective partners in supporting and strengthening:

   >>Research into the links between natural hazards and Earth processes.

   >>Real-time and long-term monitoring of Earth processes and the collection and management of data and models.

   >>Modeling that combines geophysical, hydrological, ecological, societal and economic aspects of disaster scenarios.

   >>Preparedness, education and mitigation efforts, focusing on the most-risk prone areas.

   >>Incentives to reduce high-cost and/or high-density development in more risk prone areas.

2. Federal agencies such as the U.S. Geological Survey, the National Science Foundation, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the National Institute of Standards and Technology, the Department of Agriculture, the Army Corps of Engineers, and the Federal Emergency Management Agency (FEMA) should:

   >>Coordinate natural hazards research, monitoring, training, education and public outreach efforts. The National Earthquake Hazards Reduction Program is an excellent example of a well-coordinated and effective program across four agencies.

   >>Maintain a robust and effective external grants program for research to complement federal efforts.

   >>Maintain a robust and effective external grants program for preparedness and mitigation through a non-competitive funding pool that is assessed based on practicality and cost/benefit.

3. Support the recommendations of the National Research Council's 2007 decadal survey, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, to conduct and support geoscience R&D, assessments, and monitoring.

6 Improve and build needed infrastructure that couples with and uses Earth resources while integrating new technologies

Infrastructure in the United States faces increasing pressure from a growing, more mobile, more complex, and more interconnected population. According to the Department of Transportation, since 1980, vehicle traffic has nearly doubled, air passenger-miles have increased by 150 percent, and railroad freight traffic has increased by 80 percent. The nation's energy infrastructure, from pipelines to electrical grids, is having trouble keeping up with demand. The nation's burgeoning telecommunications infrastructure, from fiber optics to satellites, has become more central to economic growth and emergency management.

Much of the infrastructure that provides critical lifelines is aging and in need of improvement while some is new technology that requires integration with existing systems. The American Society of Civil Engineers gave the nation's infrastructure an overall grade of "D" in 2009 and noted that a $2.2 trillion investment over five years is needed to improve existing infrastructure. Infrastructure is affected by significant geologic processes beyond normal wear and tear, including climate change, weather, hazards, chemical corrosion, and mechanical erosion.

The largest and oldest levee systems in the U.S. along the Mississippi River (Figure 6A) and the Central Valley of California are critical to the economic growth and resource management of the nation. These systems were primarily built to protect agriculture but are now relied upon to protect billions of dollars worth of commercial trade, communities, and critical natural resources. The potential for additional catastrophic failures beyond the aftereffects of Hurricane Katrina (Figure 6B) are significant because of the higher risk for earthquakes, floods, and hurricanes in these regions, the aging infrastructure and the unknown effects of climate change. Much more work and funding are needed to understand problems with ground subsidence and soil conditions, the effects on ecosystems and the effects of water control on the health and maintenance of these systems. Geoscientists and geotechnical engineers play a critical role in the siting and design of the built environment to increase its resilience to natural hazards and minimize its impact on the natural environment.

Figure 6A: The Mississippi River has the third largest drainage basin in the world, exceeded in size only by the watersheds of the Amazon and Congo Rivers. It drains 41 percent of the 48 contiguous states. The basin, which covers more than 1,245,000 square miles, includes all or parts of 31 states and two Canadian provinces. The Flood Control Act of 1928 authorized the Mississippi River and Tributaries (MR&T) Project, the nation's first comprehensive flood control and navigation act.

Figure and information from the U.S. Army Corps of Engineers web page - www.mvn.usace.army.mil/pao/bro/misstrib.htm

Given the critical need to modernize aging infrastructure and build new infrastructure, the geoscience community suggests the following national policy directions.

1. Assess infrastructure needs for the next 10, 50, and 100 years to provide a useful short-term and long-term outlook for planning purposes.
2. Assess the relationship of infrastructure development and environmental risks through research, monitoring, data collection, modeling and analysis.
3. Support an independent review of large U.S. Army Corps of Engineers' projects as required by the Water Resources Development Act of 2007.
4. Incorporate mitigation into infrastructure development or upgrades.

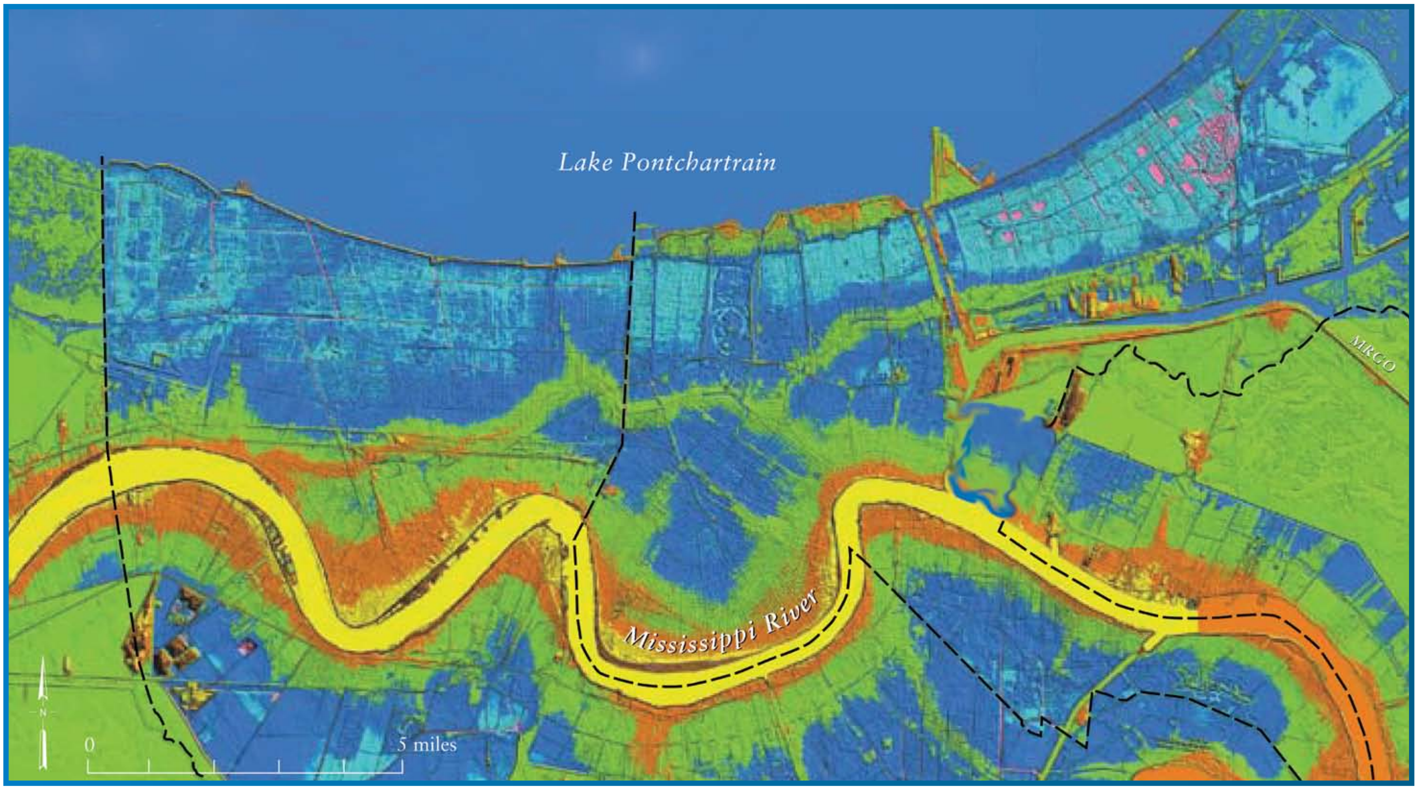


Figure 6B: Relief map of New Orleans metropolitan area indicating the extensive flooding as a result of Hurricane Katrina. In general, areas colored light and dark blue as well as magenta were flooded.

The figure is courtesy of the Louisiana Geological Survey and is from "Geology and Hurricane-Protection Strategies in the Greater New Orleans Area, 2006."

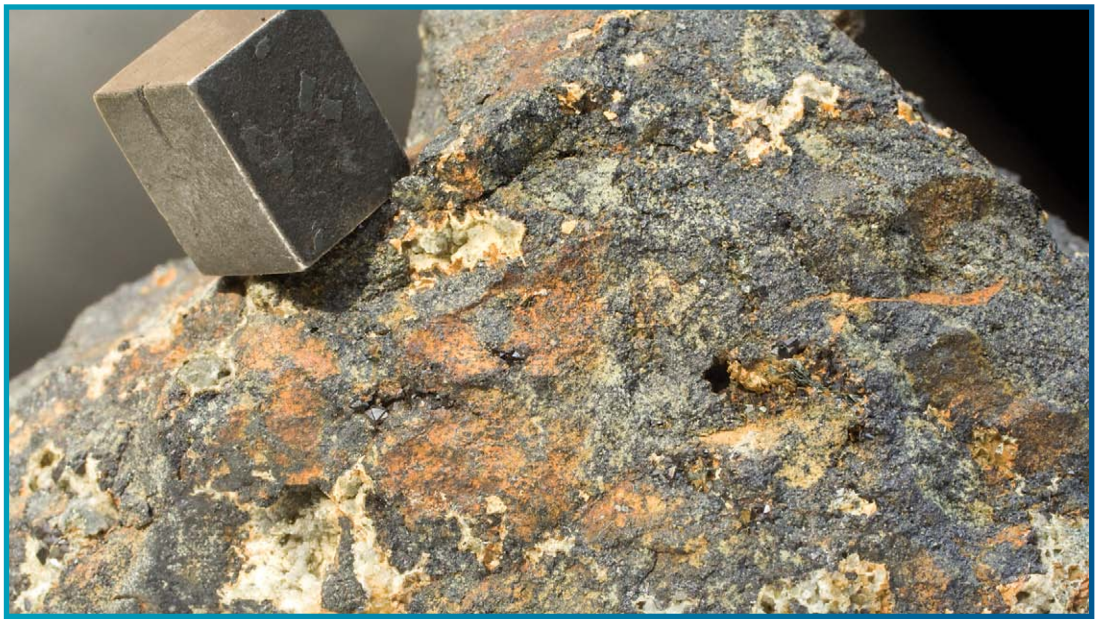
7 Ensure reliable supplies of raw materials

Minerals help to sustain life in numerous ways. They are natural or added supplements in food and drink. Minerals are essential in just about any product used in daily life from calcite in toothpaste to silicon in computers and solar panels. The global demand for metals, such as aluminum, copper, gold, and platinum, has led to a steep rise in their commodity prices. Rare earth elements (REEs) are increasingly critical to evolving technologies for use in fuel-efficient vehicles, electronic devices, and many military applications. The antiquated methods of extraction and processing of REEs, together with the near monopolistic production of REEs in China, leaves the U.S. vulnerable to national security and economic risks. The U.S. needs to invest in R&D to advance exploration and mining approaches for non-fuel minerals that are environmentally responsible and economically sustainable in the U.S. and the rest of the world.

Even current domestic mining production needs to plan for supply and demand fluctuations with the help of geoscientists. Aggregate, including sand, gravel, crushed stone, slag, or recycled crushed concrete, is an essential construction material as well as a critical ingredient in paint, paper, plastics, glass, other household products, and in medicines. Aggregate production accounts for more than half the volume of all domestic mining. More than half of all the aggregate produced in the U.S. in the 20th century was mined in the last 25 years of the century (Figure 7).

The foundation of agriculture and healthy ecosystems lies within the soil. Soil is a critical biozone that must be understood and sustained in order to maintain a robust agricultural system and a healthy ecosystem while dealing with other uses such as biofuel production. Soil filters and stores water and promotes our fresh water resources. There is an immediate need for greater understanding of the effect of multiple uses on soil sustainability.

All of these raw materials must be wisely managed and efficiently prepared for their final use. Geoscientists are needed to locate these materials, assess their quantity and quality, cleanly and efficiently manage their extraction or use in place, reduce byproducts or excessive waste, and assess strategic needs for low-supply critical materials that are in high demand or relate to national security.



Given the increasing need for raw materials in our daily lives, the geoscience community suggests the following national policy directions.

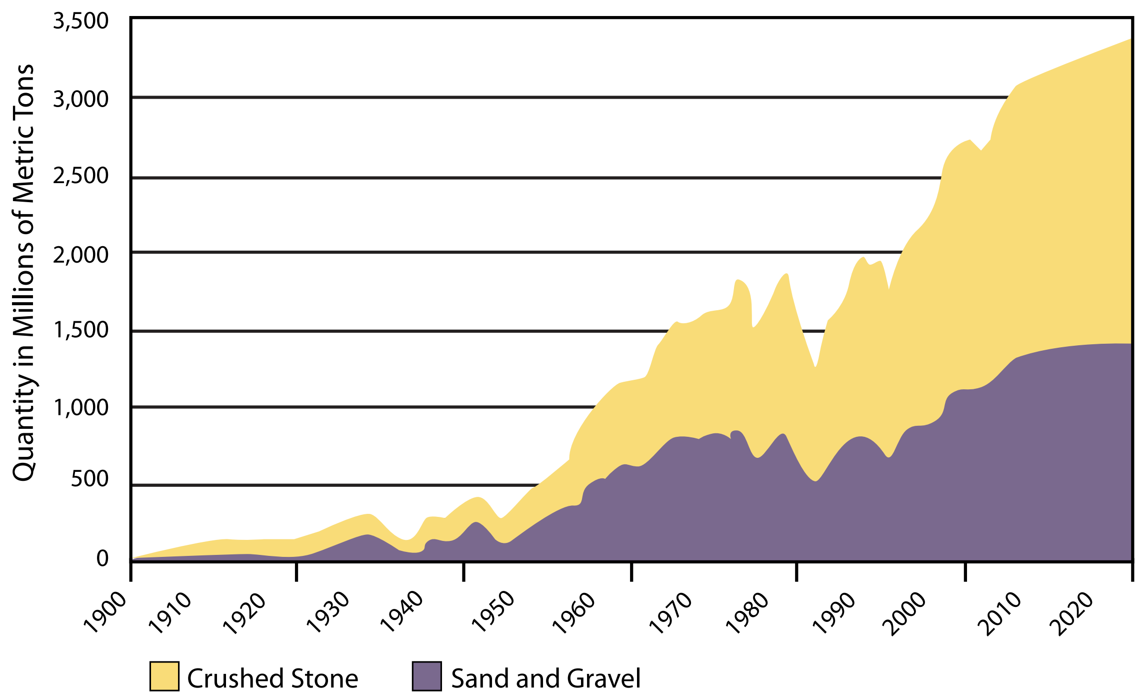
1. Increase support for mineral assessments of the nation and the rest of the world conducted by the U.S. Geological Survey, state geological surveys, and other geoscientists.

2. Support the completion of soil survey and ecological site descriptions on the more than 195 million acres of public lands managed by the Bureau of Land Management, Forest Service, National Park Service, Bureau of Indian Affairs, Natural Resources Conservation Service, and others.

3. Increase investments in geologic mapping and data preservation in support of assessments, exploration, and production of raw materials, led by the U.S. Geological Survey in cooperation with state geological surveys and other geoscientists.

4. Map, analyze and plan for multiple uses of surface and subsurface resources, such as carbon dioxide for enhanced oil recovery or carbon sequestration associated with former fossil fuel extraction.

Figure 7: The U.S. Geological Survey tracks supply and demand for natural raw materials, including non-fuel minerals such as aggregate. Graph shows aggregate production in the United States with projections to 2020, based on a growth rate of 1 percent for stone and 0.5 percent for sand and gravel.



U.S. Geological Survey

8 Inform the public and train the geoscience workforce to understand Earth processes and address these critical needs

There is a critical need for an increased number of people in the geoscience-based workforce now and in the future (Figure 8A). A geoscience-based workforce includes technicians, professional geoscientists, professional engineers, research and development managers, exploration managers, data managers, applied researchers, basic researchers and educators at all levels. Such a workforce has or will need a knowledge and understanding of the Earth system and Earth processes, computational and analytical skills, a sense of discovery and adventure, and strong problem-solving traits. In addition, this workforce is critical for teaching the next generation of workers, based on their sound understanding of geoscience concepts and their work experience.

The growth of a U.S.-based geoscience workforce and an educated public begins with the formal and informal education of the nation's children. According to the National Center for Education Statistics, Digest of Education Statistics, 2007, the number of high school students who have enrolled in an Earth science course for one semester (versus a full year for biology, chemistry or physics) has never exceeded 25 percent (Figure 8B). In addition the tens of thousands of Earth science teachers in K-12 grade levels have received little to no training in the geosciences during their formal education careers and must try to pick up expertise through summer workshops and other opportunities. Renewed emphasis on student and teacher education in the Earth sciences is necessary to provide the U.S. geoscience workforce of the future and help the nation deal with the critical issues outlined above.

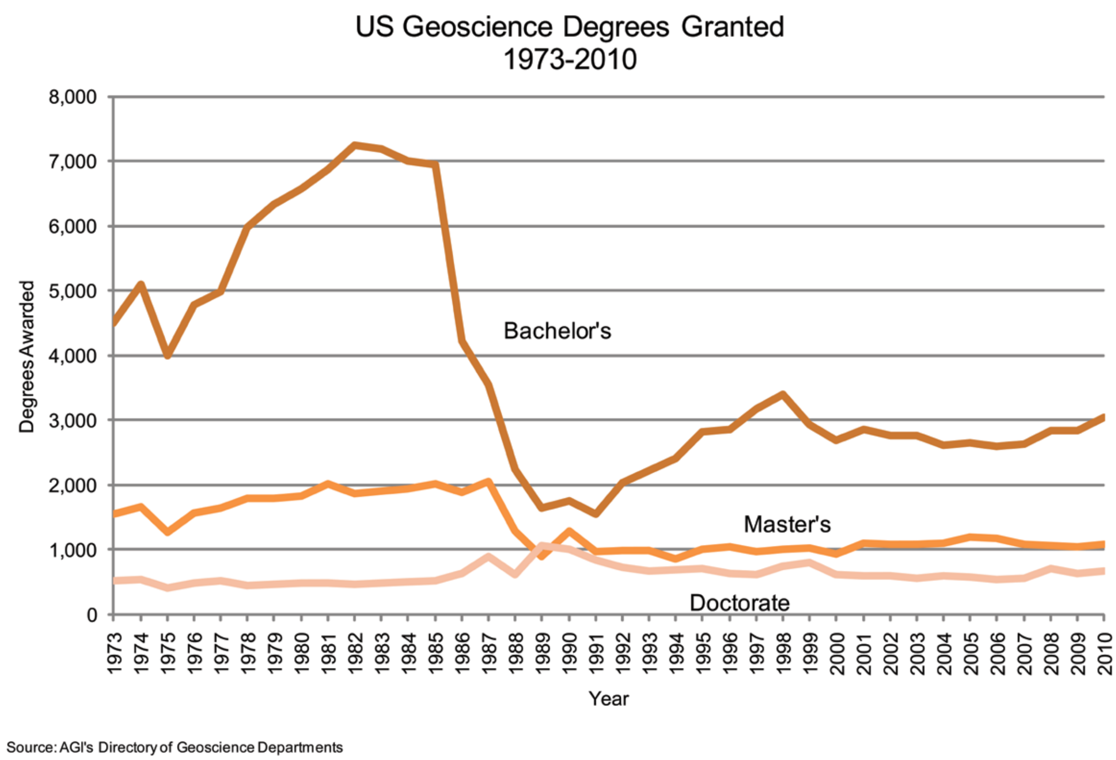


Figure 8A: Data collected by the American Geosciences Institute shows the decline in geoscience degrees granted. The public and private sectors face a dilemma of an aging workforce and a limited number of skilled new workers educated in the U.S. to fill the growing gaps.

Given the critical need for a skilled geoscience workforce and more robust geoscience education, the geoscience community suggests the following national policy directions.

1. Support inquiry-based education in geoscience for K-12 grade levels.

   >>Include geoscience as a core course in middle school and high school.

   >>Increase the rigor of geoscience courses and establish an Earth Science Advanced Placement class.

2. Support public outreach and informal education through specifically funded programs in geoscience at national parks, museums and other public venues.

3. Support geoscientists teaching in schools and encourage the Department of Education to recognize and support the importance of learning geosciences at the K-12 level.

4. Support assessments of the geoscience workforce to determine specific needs and concerns.

5. Provide greater support for scholarships, grants, and fellowships for students majoring in geoscience at undergraduate and graduate levels.

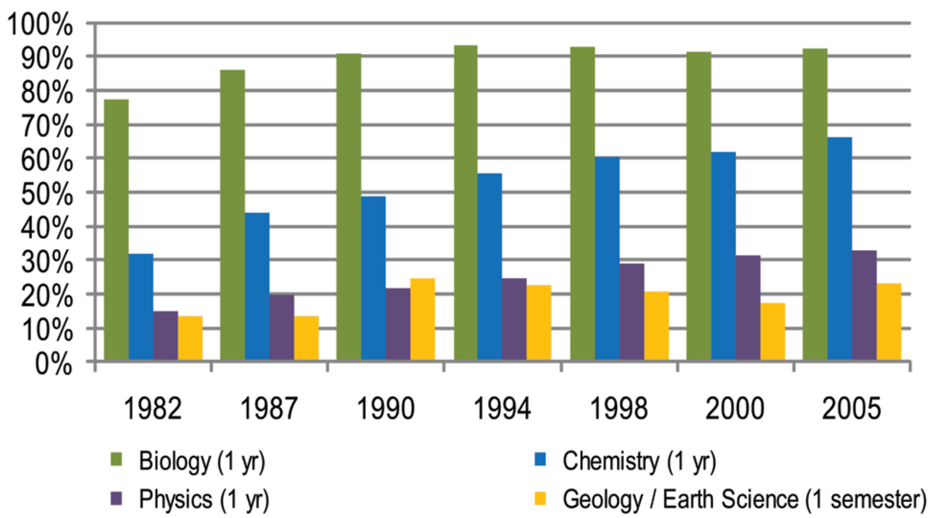
   >>Reinstate geosciences in the Department of Education's graduate assistantship grants for the program "Graduate Assistance in Areas of National Need."

   >>Support Research Experiences for Undergraduates (REUs) in the Geosciences Directorate of the National Science Foundation.

6. Provide more scholarships, grants and fellowships for students majoring in education with an emphasis on science teaching.

7. Increase incentives for universities to require geoscience courses for teaching degrees.

8. Provide incentives for teachers to gain additional geoscience training as a requirement for certification and advancement during their teaching careers.



Source: AGI Geoscience Workforce Program, data derived from NCES, *Digest of Education Statistics, 2007*

Figure 8B: Data collected by the American Geosciences Institute shows the very low percentage of public high school students taking just one semester of a geoscience class versus other science classes.

Concluding Remarks

Strategic, timely, and prudent investments in the geosciences are essential to integrate scientific understanding of Earth processes into effective national policies. This synopsis and the non-comprehensive list of references below provide only a summary of national needs.

The geoscience community, as represented by the American Geosciences Institute's member societies and the over 250,000 geoscientists that make up these societies, provides the information, ingenuity, innovation and education to meet demand for natural resources, environmental quality and enhanced resiliency against natural and man-made hazards.

The geoscience community can provide objective scientific advice about the critical issues in this synopsis. Please contact Dr. P. Patrick Leahy, Executive Director of the American Geosciences Institute at pleahy@agiweb.org or 703-379-2480 for additional information.

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Member Societies of the American Geosciences Institute

AASP-The Palynological Society (AASP)

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American Institute of Professional Geologists (AIPG)

American Rock Mechanics Association (ARMA)

Association for the Sciences of Limnology and Oceanography (ASLO)

Association for Women Geoscientists (AWG)

Association of American Geographers (AAG)

Association of American State Geologists (AASG)

Association of Earth Science Editors (AESE)

Association of Environmental & Engineering Geologists (AEG)

Clay Minerals Society (CMS)

Council on Undergraduate Research, Geosciences Division (CUR)

Environmental and Engineering Geophysical Society (EEGS)

Friends of Mineralogy (FOM)

The Geochemical Society (GS)

Geo-Institute of the American Society of Civil Engineers (GI)

Geological Society of America (GSA)

The Geological Society of London (GSL)

Geoscience Information Society (GSIS)

History of Earth Sciences Society (HESS)

International Association of Hydrogeologists/U.S. National Chapter (IAH)

International Medical Geology Association (IMGA)

Karst Waters Institute (KWI)

Mineralogical Society of America (MSA)

National Association of Black Geologists and Geophysicists (NABGG)

National Association of Geoscience Teachers (NAGT)

National Association of State Boards of Geology (ASBOG)

National Cave and Karst Research Institute (NCKRI)

National Earth Science Teachers Association (NESTA)

National Ground Water Association (NGWA)

National Speleological Society (NSS)

North American Commission on Stratigraphic Nomenclature (NACSN)

Paleobotanical Section of the Botanical Society of America (PSBSA)

Paleontological Research Institution (PRI)

Paleontological Society (PS)

Petroleum History Institute (PHI)

Seismological Society of America (SSA)

SEPM (Society for Sedimentary Geology) (SEPM)

Society for Mining, Metallurgy, and Exploration, Inc. (SME)

The Society for Organic Petrology (TSOP)

Society of Economic Geologists (SEG)

Society of Exploration Geophysicists (SEG)

Society of Independent Professional Earth Scientists (SIPES)

Society of Mineral Museum Professionals (SMMP)

Society of Vertebrate Paleontology (SVP)

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The American Geosciences Institute is a nonprofit federation of geoscientific and professional associations that represents more than 250,000 geologists, geophysicists, and other earth scientists. Founded in 1948, AGI provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment.

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