

IGCP Project Proposal Form

IMPORTANT: Please fill in the boxes below using a computer, following closely the instructions, taking into account the above guidelines. For more general issues, please refer to the 'Call for IGCP Project Proposals'. For information on the necessary content of an application (e.g., allowable funding), refer to the detailed above guidelines.

Print a copy, sign it, and send it to:

IGCP Secretariat
Division of Ecological and Earth Sciences
UNESCO
1 rue Miollis
F-75732 Paris Cedex 15
France

Another copy should be sent as an attachment via e-mail to: igcp@unesco.org

Proposals must reach Paris by October 15th in order to be considered for funding for the following year.

1. Indicate the topic(s) into which the project falls.

For the Annually defined topics -if any- refer to the annual 'Call for IGCP Project Proposals'.

- (i) Topics of particular interest to IGCP
 - 1.1 The Deep Earth _____
 - 1.2 Global Change and Life Evolution _____
 - 1.3 Geohazards _____
 - 1.4 Geoscience of the Water Cycle √
 - 1.5 Earth Resources: Sustaining our Society √
- (ii) Annually defined topics _____
- (iii) Other relevant topics in basic/applied geoscience _____

If this is a Young Scientist Project proposal please tick here _____

2. Short title of the project

The short title of the project should be as brief as possible but still identify its main objective.

Environmental Change and Sustainability in Karst Systems (2011-2016)

3. Full title of the project

The full title should be limited to a maximum of around fifteen words.

Environmental Change and Sustainability in Karst Systems: Relations to Climate Change and Anthropogenic Activities (2011-2016)

4. Proposed by

Academic titles and names of the proposer(s) should be inserted. Provide also full mailing address(es), telephone, fax numbers, and e-mail address(es). The first listed name will be the focal point for future correspondence.

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5. Scale of the project

The scale of the project must be indicated among the choice given.

- sub-continental/regional
- continental
- inter-continental
- global

6. Brief outline of the project

Provide a maximum 600 words-long, self-contained summary of the project, including its societal benefits. It should be written in plain English and for the non-specialist using a minimum of terminology unique to the area of study.

Karst landscape/aquifer systems cover some 15% of the Earth's land surface and

are estimated to supply drinking water to some 25% of the world's population. A critical scientific and development gap concerns the fact that the evolution and dynamics of these systems remain incompletely understood while they present serious challenges to human development with regard to water access and quality, agriculture, and landscape stability, especially in the face of climate change. Four successful karst-related IGCP projects have been undertaken since 1990, and in 2008 the UNESCO Category II "International Research Centre on Karst" was established.

Following these successful projects, which have involved hundreds of scientists from some 40+ countries including many developing countries and leveraged hundreds of thousands of dollars to support research, training, and capacity building, we propose a successor IGCP project "Environmental Change and Sustainability in Karst Systems."

Major initiatives proposed for the new Project are tied by the fact that present and future environmental change will impact, and past environmental change is recorded in, karst systems at a range of time scales from hours to millions of years. Proposed topics of collaboration in research and education within karst systems include, for example 1) research to better understand how to protect key karst watersheds from changes in human land use that can catastrophically contaminate water supplies, guided both by hydrogeologic sophistication and participatory approaches that engage local, impacted communities; 2) studies to clarify processes by and quantify rates at which geologic interactions with carbonate rocks influence carbon cycling and in turn climate change; 3) better understanding methods for sustainable ecological and cultural resource protection within fragile karst systems spread across an awesome range of geologic, climatic and cultural landscapes and faced with a complex range of environmental challenges; and 4) quantification of environmental records that wait to be analyzed and interpreted within water, sediments, speleothems, and cultural records over these same timescales. Communication among scientists across these specialties, but bound by common and overlapping interests and experiences cannot help but richly fertilize ideas and nurture opportunities for the widely diverse group of international scientists engaged in this work that include geologists, geochemists, biologists and ecologists, chemists and geographers.

Specific objectives of the proposed Project include:

- 1) High quality, multi- and interdisciplinary basic and applied scientific research to advance the understanding of how environmental change over a variety of timescales impacts functions of karst systems, where appropriate to inform sound decision making;
- 2) Research into concepts associated with sustainability of karst systems, both with regard to human activities and health, and ecological protection. To support this the project has in place a strong program of academic capacity building.
- 3) Careful tracking of leveraging to quantify an example of how IGCP projects have engaged associated efforts that have added enormous financial, technical, and human resources. Enormous financial leveraging is perhaps the greatest single strength of the IGCP programme, but in many cases the specific results are anecdotal. In this project we

will ask participants to as accurately as possible quantify and report amounts of non-IGCP funding that was brought to projects reported under the auspices of the programme.

While many important results have followed the previous four projects, and necessarily some of the interdisciplinary concerns of them shared certain themes in common with the new proposed project, its focus on the impacts of environmental change on karst systems and the enormous number of people who rely on them has become increasingly critical as understanding the rates and impacts of climate change (and the impacts themselves) enter a completely new paradigm, and as pressure on karst water resources from population growth rapidly accelerates.

7. Estimated duration of the project

Maximum life-time of an IGCP project can be five years.

- 3 years —
- 4 years —
- 5 years ✓

8. Full description of the project (sections 8.1 through 8.10)

8.1 Aims and background

Describe the aims and rationale of the proposal. Include information on work already undertaken by the proposers that is relevant to the proposal. Maximum length: 2,000 words, including bibliography.

In recent years, increasing attention has been paid to increasing rates of global environmental and climate change and relations to the carbon cycle. Most of this work has been focused on terrestrial and ocean ecosystems, largely neglecting geological elements of the carbon cycle. Nevertheless, results from IGCP379 showed that CO₂ uptake from the atmosphere by carbonate rock dissolution processed may well be a component of the missing carbon sink which has been identified as necessary to balance the global carbon cycle, and that the magnitude of the carbon sink in an area on the continents from carbonate mineral weathering is a function of the local geochemical environment. Key scientific questions still need to be answered concerning how various geochemical environments on the continents and in the oceans influence carbon sources and sinks associated with carbonate mineral weathering and precipitation.

At the same time, environmental challenges are being presented from increasingly frequent extreme climate events, imprudent land use, and increasing populations within karst regions that creates pressure on karst water resources and associated environmental conditions. Environmental exploitation should be balanced with protection, and associated policy decisions must be based on appropriate, sound science-based understanding of the key processes. For the purpose of sustainable use of karst water, it is very important to clarify how the hydrological and water resources processes respond to different climatic and hydrogeological conditions, especially to extreme droughts and

floods, as well as circulating and regulating functions of karst watersheds and epikarst zones. Research is required to better understand anthropogenic impacts on karst water environments, ground water vulnerability assessments, and on the applications of karst disturbance indices.

We propose a multi-disciplinary approach to address the four major areas of emphasis for the project that focus on key temporal and spatial scales associated with environmental change in karst systems:

- 1) significantly better estimation of the carbon sink potential from carbonate rock dissolution on the continents with improvement of approaches used for these estimations that consider geobiological processes and anthropogenic influences;
- 2) research on the responses of hydrogeological behaviour of karst aquifers and water resource processes under the influence of different weather and climatic events, including extreme events of droughts and floods;
- 3) research on the improvement of methods for ground water vulnerability assessments to contamination and development karst disturbance indices in different karst landscape/aquifer systems;
- 4) quantification of records of environmental change within water, sediments, speleothems, and cultural records preserved within karst systems that provide information over various timescales.

As examples of key recent research results expressing the need for the research proposed in the current application, during the implementation of IGCP448 and IGCP513, several projects supported by China Geological Survey and Natural Science Foundation also were carried out by the IGCP China working group. One of these was the "Study of Environmental Geological Problems and Countermeasures in the Southwest China Karst Area". This investigation of underground rivers showed that water resources and environmental problems caused by the new round of national key project activities and mine exploration are creating severe challenges with a large area of influence area, especially mine drainage pollution. Simultaneously, identification of alternative water sources and underground water protection has become increasingly more difficult owing to the simultaneous, increasing widespread presence of severely polluted surface water. The problems of karst water protection in China in the face of rapid environmental change are so basic that it is strongly suggested that the current state of, and changes to, the karst water environment in China should be carefully considered in the next National Five-Year Plan's geologic survey.

Another was the "Fragility of the Karst Ecosystem and Ecological Restoration Capacity Under Multiple Pressures in Southwest China". It was shown that the high fragility of karst ecosystems in southwest China results from the facts that 1) calcium-rich and alkaline settings can inhibit soil nutrients from activation and release, 2) distributions of carbonate rock and vegetation have a significant negative relationship, and 3) human population distribution can be restricted by within areas of carbonate rock due to the low population bearing capacity in karst regions. Monitoring data showed that epikarst is highly sensitive to environmental change and the response time scale may be seasonal, daily, and even

hourly. It is necessary to consider water-rock-CO₂ as a whole (system) for the explanation of hydrochemical behavior of epikarst processes, furthermore, monitoring provided a foundation for calculation of water resources and its regulating ability in different epikarst systems.

About 15% of the land in the world is covered by some type of karstified rocks and karst water has been estimated to supply drinking water for about one-fourth of the earth's population. Due to the hydrogeologic characteristics of karst landscape/aquifer systems, especially considering commonly extreme permeabilities and thus rapid groundwater flow rates, groundwater in karst areas is often highly vulnerable to contamination. Karst areas often have little or no soil cover with little filtration and rainwater and surface contaminants can easily move down to the underlying karst aquifer. Flows in a karst drainage system are often conduit-dominated and the residence time is usually short. During storms, cave streams can rise very rapidly. In order to monitor the changing hydrochemistry of groundwater, high temporal resolution data are often necessary. The analysis of temporal variations of karst groundwater chemistry can offer insights into the functioning and structure of a karst system, such as the degree of karstification, residence time of water, the origin of water and flow paths, and the internal structure and geometry of karst aquifers.

It is well established that karst groundwater chemistry is typically determined by 1) the natural processes (e.g., lithology, groundwater velocity, quality of recharge waters, interactions of water with soil and rock, and in some cases interaction with other types of aquifers); 2) anthropogenic activities (e.g., agriculture, industry, urban development, and increasing exploitation of water resources); and 3) atmospheric input. Water-rock-gas interactions, the dominant process of karst formation and evolution, is in turn controlled by the climatic characteristics of a region. Through years of monitoring on dozens of karst sites throughout the world, patterns in the relationships between the hydrochemical behaviors of karst systems and influences of varying climate have been identified. These include relationships with rainfall (especially thunderstorm events), vegetation, and soil conditions. In particular, numerous studies using high-resolution automatic data recording at various sites has shown that hydrochemistry in karst groundwater is highly sensitive to the change of environmental surroundings and response times can be as short as hours or even minutes. It has been shown that the seasonal and diurnal variations of hydrochemistry likely co-vary with storm events. In addition, it has also been pointed out that the consideration of only water-rock interaction is not sufficient for understanding the hydrochemical variations in karst systems. The variable effects of CO₂ should also be addressed and the consideration of water-rock-gas interaction as a whole is required to understand the spatial and temporal variations of karst hydrochemistry under different climatic influences.

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8.2 Significance

Describe why the project is significant (scientific advancement, international cooperation, knowledge transfer, technological advancement, etc.) and why support through IGCP funding is crucial to its success. Maximum length: 1,500 words.

In terms of international cooperation, the implementation of four previous karst-related IGCP projects since 1990 has proven that IGCP funding has been a very important platform for bringing international group of scientists together with common interests,

producing enormous leveraging results supporting the initiation of international cooperation and the continued and evolving development of modern karst sciences, including both understanding of the basic processes at work forming and regulating karst systems and identification of solutions to resource and environmental problems in karst regions related water access and quality, ecological protection, landscape stability, and relations to global carbon cycling.

During the last 20 years, more than 200 scientists from more than 40 countries, including many developing nations (quantified as low and middle income countries based on World Bank criteria) have directly participated in these projects. As a direct result of communication through IGCP, many bilateral and multilateral cooperative efforts have been established among scientists in China, USA, Slovenia, Austria, Switzerland, Indonesia, Vietnam, Italy, Germany, France, and other nations. The cooperative efforts have leveraged enormous financial, technical and human resources, and a significant effort in the project proposed herein is to better quantify this leveraging to provide a solid example that can be used to support the effectiveness of UNESCO/IUGS in supporting cost sharing of research programs, especially those with limited support from individual sources by themselves.

There are still critical unresolved questions concerning karst water environments and the capacities of karst watersheds, including their epikarstic zones, responding to climate change and especially to extreme climate events. The proposed project will move the study of karst hydrological processes and their relations with environmental change forward, and improve the technology and methods for karst environmental investigations and groundwater vulnerability assessments for water resource protection.

Karst water resources are very important for urban development and ecological reconstruction in many karst-rich countries and regions, with variations in attitudes on the relative importance of exploitation and environmental protection, and many relevant laws and regulations have been established for water resources management. However, extensive and widespread problems remain, which can be ameliorated through training and educating local people, disseminating karst knowledge, communicating with government officials at different levels, and increasing awareness of karst water resources and environment protection.

The main purposes of this project are to significantly enhance the research on karst hydrological processes, as well as to promote international cooperation and technology sharing on water environment protection, education and training. As the first UNESCO Category II institution in the Geosciences, the newly founded International Research Center on Karst still needs to work closely with IGCP, in turn become a major international cooperation and research platform in keeping with the mission of IGCP "Geoscience in the Service of Society".

Karst systems are very sensitive to environmental change, which is to say that karst hydrogeological processes are easily impacted by climate change and disturbance through human activities. This has in many cases led to catastrophic of water resource and other environmental problems. For example, rainfall seasonal variation and over

exploitation of ground water both can result in the movement of groundwater basin divides; urbanization, agriculture activities, mining and other land uses can rapidly and seriously contaminate ground water quality, in turn influencing sources of drinking water for large number of people.

From November 2009 to April 2010, for example, an extreme long drought event hit the southwest China karst area and cause a severe drinking water difficulty of more than eighteen million local people. In northern China karst area ground water circulation has been remarkably influenced owing to urban expansion and extensive coal mining during past 30 years. Discharge of up to 80% of the largest springs has been attenuated in different degrees, and 30% have become significantly drier. Accordingly, to better understanding of karst hydrology and water resources process, it is not enough to reveal karst aquifer responses to storm and seasonal events, it is also necessary to study vulnerability differences of karst aquifers in different geological and climatic conditions, aquifer regulating capacity and their relation to vegetation, climate change, human activities, and resilience of karst systems to environmental change.

8.3. Present state of activities in the field of the proposed project

Describe the present state of activities in the field of the proposed project. Include the names of relevant institutions and persons in charge. This should be precisely stated since it reflects the proposer's awareness of the general state of the proposed research field. Maximum length: 2,000 words.

While there are numerous individual scientists around the world at universities, governmental agencies and environmental consulting firms that undertake research in karst-related topics, and the number is rapidly increasing, there are a few key laboratories/research groups that in many cases play a leading role in advancing the field. Many of these individuals and laboratories have participated in the past four projects and would contribute to the proposed one, if approved.

1.) International Research Center on Karst (IRCK) under the auspices of UNESCO in Guilin, China. Established in 2008 the mission of IRCK is to spread and promote the understanding of karst dynamics around the world, establish a base for karst research innovation, create a platform for international exchange of karst scientists and ideas, and provide consultation and training services for economic and socially sustainable development in the world's karst areas.

2) Karst Research Institute ZRC SAZU, *Postojna, Slovenia*. Karst is a landmark of Slovenia. Almost half of the country is karstic with about 10,000 caves registered. More than half of the population is supplied by karst waters. An international term KARST is derived from the name of Slovenian region Kras, an area also regarded as the cradle of scientific discipline - karstology. Karstology has become a complex multidisciplinary science, covering wide range of earth sciences related to karst. Long tradition of excellent research and unique position in the center of classical karst have established the Institute as one of the most recognized karstological centers in the world.

Karst is in the focus of the Institute's research, including study of hydrology, geology, morphology, ecology, microbiology and speleology as well as history of the science. The Institute's researchers come from various backgrounds including geology, geography, physics, chemistry, biology and microbiology, thus enabling a multidisciplinary approach. Research includes field studies, laboratory investigations and numerical modeling. We conduct basic studies and applied studies. The Institute hosts a karstological library, one of the most complete of its kind, laboratory specialized in water chemistry, geological laboratory, and the Institute's researchers are enrolled as lecturers at the Postgraduate study of karstology at University of Nova Gorica.

3) National Cave and Karst Research Institute, Carlsbad New Mexico USA. The goals of the National Cave and Karst Research Institute are to 1) advance cave and karst science by conducting, coordinating, and facilitating research, 2) serve as a repository for and provide analysis and synthesis of speleological (cave related) information, 3) foster partnerships and cooperation in cave and karst research, education, and management programs, 4) promote and conduct cave and karst educational programs, 5) promote national and international cooperative programs that further cave and karst research, education, and stewardship, and to 5) develop and promote environmentally sound and sustainable cave and karst management practices.

4) Ukrainian Institute of Speleology and Karstology (UISK) Simferopol, Crimea. The Institute conduct research in karst hydrogeology, karst geomorphology, geospeleology, speleogenesis, high mountain karst, gypsum karst, environmental problems in karst, cave survey, cartography and visualization, and cave management.

5) Hoffman Environmental Research Institute, Bowling Green, Kentucky USA The mission of the Hoffman Environmental Research Institute is to be a leader in basic and applied research that aims to better understand landscape/atmosphere/water/human interactions. The Institute involves post-doctoral, graduate, and undergraduate students in all aspects of this work to increase their critical thinking skills and technical expertise in the environmental discipline, and in combination with extensive international ties, to prepare these students for success in a global society.

6) The Centre of Hydrogeology at the University of Malaga (CEHIUMA), Spain, develop wide activity on research in karst media. Besides it offers relevant master studies and continuing education courses, and organises international conferences and workshops focusing on karst hydrogeology, often in close cooperation with the IAH Karst Commission.

The following list describes the major recent and upcoming international conferences and training programs to give a sense of the current dimensions of international research and related communication in the karst sciences.

1. The International Training Course on Karst Hydrogeology and Karst Ecosystems, sponsored by China's Ministry of Commerce and organized by IRCK jointly with the Institute of Karst Geology (IKG), was held in Guilin, China, from November 8 to December

5, 2009. Seventeen students and scientists from eight countries participated in this course, including Vietnam, India, Indonesia, Kenya, Uganda, Ethiopia, Romania, and Peru. Twenty-five invited instructors gave lectures, including ten instructors from eight countries outside China including Australia, USA, Austria, and Canada. A four-day excursion to the Stone Forest (Shilin-World Natural Heritage Site, UNESCO) in Yunnan Province also was carried out during the course. At the end of the course every trainee was required to give a presentation on karst features and relevant environmental problems in his or her own country in order to assess impacts of the training course on their understanding of key concepts.

The main topics included discussion of karst dynamic systems, karst hydrogeology and karst ecosystems, including the concepts, structure and function of karst dynamic systems, karst landscape and formation, karst groundwater tracing techniques, quality and quantity of karst groundwater; karst groundwater monitoring and resource evaluation; and application of isotopes in karst hydrology.

Some of participants strongly expressed their willingness to cooperate with IRCK and to be involved in subsequent karst related IGCP projects. Two new Memoranda of Agreements for international cooperation were signed, with cooperative efforts to include karst water chemistry, trans-boundary aquifer monitoring and management, carbon cycle monitoring and carbon sink estimation. The IRCK is thus shown not only to be a platform for training professionals from developing countries, but also an effective way to initiate and complement international (both bilateral and multilateral) cooperation.

2. 4th International Symposium on Karst (27-30 April 2010, Málaga, Spain)

The symposia on karst that have been held periodically in Málaga since 1992 are intended to be an international forum for scientific debate on the progress made in research into karst environments. Karst is highly fragile and the exploitation of its resources or inappropriate land uses give rise to environmental problems (water pollution, subsidence, flooding, and changes in the subterranean environment). The threshold of the second decade of the 21st century seems a good time to reflect on the progress made in recent times and to set out some of the lines of research to pursue in the near future. This was the aim of this 4th International Symposium on Karst (ISKA-2010) organized by the Centre of Hydrogeology at the University of Málaga and the Spanish Geological Survey (IGME).

The following themes were to be addressed in the framework of this Symposium:

- 1) Water and karst: karst hydrogeology, investigation and protection of water resources in karst
- 2) Karst and natural heritage: karst landscapes, karst ecosystems, importance of groundwater in the environment
- 3) Relationships between humans and karst: tourism and karst, caves frequented by tourists, water in the unsaturated zone, environmental impacts and associated risks in karst

In the framework of 4th International Symposium on Karst was organized the 4th edition of

the annual Training Course on Karst Hydrogeology (HYDROKARST) under the auspicious of UNESCO. In this case the topic was Groundwater recharge assessment and contamination vulnerability mapping in carbonate aquifers.

Detailed information on these activities can be found in the web site <http://www.cehiuma.uma.es/>

3. International Karstological School “Classical karst” (14-20 June 2009, Postojna, Slovenia)

From June 14 to 20, 2009, the 17th International Karstological School “Classical karst” was held at the Karst Research Institute at ZRC SAZU in Postojna, Slovenia. This was the fifth school carried out in the frame of the 7th FP, Marie Curie Actions project »SMART-KARST: International KARSTological School: Sustainable MAnagement of Natural Resources on karst«.

The main topic “Cave climate” was first introduced by 4 keynote lecturers. Additional lectures were given by 15 invited experts and 16 selected participants, and in poster session 51 posters were displayed. Altogether 128 karstologists from 31 countries participated at the event. Field work was organised in 1 evening, 1 half-day and 2 whole-day excursions. Additional to this a visit to the Postojna Cave was arranged. The booklet with programme, field-trip guide and abstracts was published and supplemented by the CD with a selection of short scientific papers. Some of the authors were invited to prepare a full scientific paper for the karstological journal *Acta carsologica*.

4. The XXXVIII International Association of Hydrogeologists (IAH) Congress (12-17 September, 2010, Krakow Poland).

This conference was hosted by The Polish Chapter of IAH, AGH University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection and Jagiellonian University, and the Institute of Geography and Spatial Management. Since the Congress was held in Europe, the leading theme, *Groundwater quality and sustainability*, is linked with implementation of the EU Water Framework Directive. The year 2010 is the time when the formulation of programmes aimed at preventing further deterioration of groundwater quality in EU Member States must be completed.

The Congress provided the venues for the annual meetings of IGCP 513 and the IAH Karst Commission (affiliated with IGCP 513) The Congress was aimed at scientists, researchers, students, engineers, water resources specialists, consultants, officials, government administrators and educators, and those interested in groundwater and the environment. It will enable them to exchange ideas, knowledge, experience, techniques and the know-how in studies, investigations and practical applications related to groundwater issues. An important task of the Congress will be to communicate more effectively with the general public and non-groundwater specialists.

5. Training Course on Karst Hydrogeology and Karst Carbon Cycle Monitoring (29 November to 10 December, 2010) Guilin, China (organized by IRCK)

The Training Course on Karst Hydrogeology and Karst Carbon Cycle Monitoring aims to fully realize the functions of IRCK, enhance research cooperation and academic exchange

in both China and other countries, and to spread and disseminate past successful Chinese experience in karst scientific research. The course will exchange information on the latest research advances in karst-related fields, discuss methodologies for karst environmental protection work, and work to strengthen and deepen bilateral and multilateral collaboration and communication. Key topics include Karst of China and IGCP programmes, assessment and management of karst groundwater resources, and assessment techniques and methods for karst carbon cycle monitoring.

6. Asian Transdisciplinary Karst Conference (7-10 January 2011). Yogyakarta, Indonesia. This meeting is organized and hosted by the Geography Faculty, Gadjah Mada University. Conference Topics include the carbon cycle in karst, the climate change archive from karst systems, cave and karst management, hydrogeological engineering work in karst, water resource management in karst, education citizens about living in karst, and karst hydrology/hydrogeology.

7. International Conference on Karst Hydrogeology and Ecosystems (8-10 June, 2011) Bowling Green and Mammoth Cave, Kentucky. This will be followed by a week of karst training courses. With a location in the midst of one of the world's great karst landscapes, Western Kentucky University has a rich history of karst scientific research and has been pleased to host a series of international karst conferences over the last several decades including the 8th International Congress of Speleology in 1981 and joint conferences of international karst commissions in 1998, 2003, and 2007. In addition of course of sharing recent scientific accomplishments, the primary purpose of the meeting is to foster communication and cooperation between the various international groups coordinating karst research, including IGCP, IRCK, and the Karst Commissions of IAH, the International Geographical Union, and the Union Internationale de Spéléologie.

8.4 Workplan (items by year)

The work schedule should be prepared bearing in mind that, as a rule, projects will be accepted for a duration of five years maximum. The work schedule should include field and laboratory work, meetings, field trips, conferences, etc. Maximum length: 1,500 words.

Plans are of course less detailed at this point for the later years of the project.

Year One, 2011.

The websites <http://www.karst.edu.cn> and <http://www.irck.edu.cn> will be continuously used for public relations, communication between project participants, and dissemination of Project results. Using the web site and communication at appropriate scientific conferences and other outlets, additional Project participants and laboratories will be recruited. We will also try to recruit a listserv coordinator.

A plan for the next five years will be prepared using electronic communication, as well as a

formal planning workshop at the Karst Hydrogeology and Ecosystems in Bowling Green Kentucky, USA in 8-10 June (<http://hoffman.wku.edu/k2011.html>). It will include a selection of participants and karst field sites with different hydrogeological, climatic, and cultural conditions for understanding the relationships between environmental conditions and ecological function, water supply challenges, other karst environmental problems, and aquifer function and genesis. A working group meeting of the new IGCP project will be held.

19-21 September, Pretoria, SOUTH AFRICA. Groundwater: Our source of security in an uncertain future. GSSA/IAH Conference. Organised by Groundwater Division of GSSA and IAH. INFO: Email: confplan@iafrica.com Web: <http://www.gwd.org.za>

5-7 October, Kalavrita, GREECE. 9th International Hydrogeological Congress of Hellas. Organised by Hellenic Committee of Hydrogeology (Hellenic Chapter of IAH) and Association of Geologists & Mining Engineers of Cyprus. The Congress is aimed at scientists, students, governmental officials and specialists dealing with groundwater and the environment. Its main goal is the exchange of ideas, knowledge and experience in terms of a sustainable aquatic environment. It will be followed by a one-day field trip (October 8). INFO: Email: nlambrakis@upatras.gr Web: <http://www.hydrogeocongress.gr>

28 Nov-2 December

A working group meeting will be held in conjunction with the training course on karst hydrogeology and karst carbon sink organized by the International Research Center on Karst under the auspices of UNESCO, sponsored by the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and China Geological Survey. CCOP is an intergovernmental organization with the purpose of carrying out joint applied geoscience programmes for sustainable development in East and Southeast Asia. CCOP has 11 member countries; Cambodia, China, Indonesia, Japan, Malaysia, Papua New Guinea, The Philippines, Republic of Korea, Singapore, Thailand and Vietnam. CCOP is being supported by 14 cooperating countries and 13 international organizations.

Year Two, 2012.

The primary meeting for the year will be in Guilin China within the framework of a working project from China Geological Survey on karst carbon sink potential, July 25-28, with field excursions in the vicinity of Guilin as well as the Yunnan Province and Chongqing Municipality, and a working group meeting of the karst IGCP Project. This should provide an excellent opportunity for Project participants to discuss strategies for the protection of karst environments with a backdrop of the Chinese efforts to develop modelling schemes to identify contribution of carbonate rock weathering to the atmospheric CO₂ sink.

At a minimum there will be Working Group meetings in Brisbane, Australia, and at the annual karst commission meeting in Canada during the 40th IAH Congress.

34th International Geological Congress (IGC), in Brisbane, Australia, 2-10 August. In conjunction with one of symposia of Groundwater: Innovative methods for mapping of groundwater and salinity; Groundwater modelling; Water management in mineral and

energy resource production; Groundwater resources development & management

Confronting Global Change. 40th IAH Congress. 16-23 Sep. Niagara Falls, CANADA.

Organised by IAH Canada. INFO: Email: info@iah2012.org

Web: <http://www.iah2012.org/>

Project participants beginning at the end of year two will be strongly encouraged to prepare and submit papers from Project work, as appropriate, in high-quality, international peer-reviewed journals.

Year Three, 2013.

A working group meeting and field seminar will be in Brno Czech Republic during the 16th International Congress of Speleology, 21-28 July.

e-mail: speleo2013@speleo.cz

Web: <http://www.speleo2013.com>

In June, in conjunction with the 21st International Karstological School "Classical Karst" organized by Karst Research Institute at ZRC SAZU

E-mail: izr@zrc-sazu.si

Web page: <http://kras.zrc-sazu.si>

At a minimum there will be two additional Working Group meetings, with one at the annual Geological Society of America meeting on 2013 - Denver, Colorado, USA: 27–30 October. The project will continue to encourage, and assist with, the publication of Project results in peer-reviewed journals.

Year Four, 2014.

There will be a primary Working Group meeting and field seminar at either Málaga University, Spain (in the frame of the V International Symposium on Karst) or Brazilian Karst Research Institute, Belo Horizonte, or both. The interactions between human activities, karst environment and water resources will be investigated in the field. A tentative summary of the Project up to that point will be made.

At a minimum there will be two additional Working Group meetings, with one at the annual Geological Society of America meeting on 19–22 October Vancouver, British Columbia, Canada, and tentatively in Indonesia. Most communication will continue to take place electronically, and a goal will be to define the scope, and organize production, of the final report. The project will continue to encourage, and assist with, the publication of Project results in peer-reviewed journals.

Year Five, 2015.

The major goal of the year will be to prepare the final report, which will summarize the results of progress on all the four objectives of the project. Major Project contributions and advances will be synthesized at a final workshop and field excursion.

8.5 Results expected

Results expected should be specified as precisely as possible in respect of theoretical and applied science (including general applications where these are foreseen), as well as anticipated societal benefits. Outcomes should include both those expected at the end of the project as well as those to be achieved at the end of each year for which funding is requested. Meetings and conferences are not considered as results. Maximum length: 2,000 words.

a) in basic sciences

b) in applied sciences and technology

c) in respect of benefit to society

General expected results from the Project

1. A better understanding of the hydrological and geochemical behavior of a wide range of karst dynamic systems in the context of karst aquifer evolution, the carbon cycle, the hydrologic cycle and element migration as bases for more reasonable and sustainable land use in karst areas.
2. A better understanding of particular water supply and other environmental problems associated with human interaction with karst landscapes and aquifers, and using and sharing this information to synthesize new and cost effective solutions.
3. A better understanding of the relationships between water movement and behavior in karst systems and its relationship to ecological behaviors and health.
4. Widespread dissemination of the information obtained in the Project.
5. Beneficiate the Society with the results of the investigations on karst media in term of climate changes and water resources.

Specific Annual Goals are outlines below:

Year One, 2011. 1) Design and implementation of basic Project website and listserv, 2) communication to and addition of Project participants, 3) beginning of associated research efforts, 4) Project planning workshop and field excursions at the International Conference on Karst Hydrogeology and Ecosystems, Western Kentucky University and Mammoth Cave National Park, Kentucky, USA, June.

Year Two, 2012. 1) Continued individual project research and dissemination, 2) Communication among participants via website, as well as conferences in Guilin China, Brisbane, Australia, and Niagara Falls, Canada, 4) summary of CGS Karst Carbon Sink Project, 5) work on geological carbon cycle special issue of Journal of Environmental Earth Science or Acta Carsologica, 6) establishment of Groundwater Vulnerability and

Karst Disturbance Index communication network

Year Three, 2013. 1) Continued individual project research and dissemination, 2) Communication among participants via website, as well as joint international Karst Commission Conference of the 16th International Congress of Speleology in Brno Czech Republic, 3) Mid-project reports, submission and editing of peer-reviewed journal manuscripts. 4) publication of geological carbon cycle special issue of Journal of Environmental Earth Science or Acta Carsologica, 5) Groundwater Vulnerability and Karst Disturbance Index symposium

Year Four, 2014. 1) Continued individual project research and dissemination, 2) Communication among participants via website, as well as conferences/workshops and field excursions, potentially in Spain, Brazil, and/or Indonesia, 3) Planning for scope and outline of Project final report, 4) submission and editing of peer-reviewed journal manuscripts. 5) Groundwater Vulnerability and Karst Disturbance Index publication

Year Five, 2015. 1) Continued individual project research and dissemination, 2) Communication among participants via website and listserv, as well as the Final Project conference/workshop and field excursions, 3) editing and submission of peer-review journal manuscripts, 4) final Project report.

8.6 Participation

Provide a list of contributors to the project and the areas to which they will contribute. Applicants should note that an important aim of this program is to encourage involvement of scientists from the developing countries.

a) countries or institutions (or individuals) which have already agreed to co-operate

*This implies a **formal commitment** supported by written confirmation. Names and addresses should be listed.*

We have *written* endorsements and email communication for proposed project from scientists and resource managers living or working in the following countries.

All countries that have expressed interest have been invited to join and are included on our current list of 37 countries. Of course additional countries have karst water resources and will be welcome to join as communication of the project continues to expand.

- | | | |
|--------------|---------------|---------------------------|
| 1. Albania | 14. Greece | 27. Serbia and Montenegro |
| 2. Argentina | 15. Hungary | 28. Slovenia |
| 3. Austria | 16. Indonesia | 29. South Africa |
| 4. Australia | 17. Iran | 30. South Korea |
| 5. Brazil | 18. Italy | 31. Spain |

- | | | |
|-------------|-----------------|--------------------|
| 6. Bulgaria | 19. Japan | 32. Switzerland |
| 7. Canada | 20. Lithuania | 33. Turkey |
| 8. China | 21. Malaysia | 34. Ukraine |
| 9. Croatia | 22. Mexico | 35. United Kingdom |
| 10. Cuba | 23. Netherlands | 36. United States |
| 11. Egypt | 24. New Zealand | 37. Vietnam |
| 12. France | 25. Poland | |
| 13. Germany | 26. Romania | |

b) Countries likely to participate

Estimate the range of participation of those countries who have shown interest in the project but whose written commitment is still awaited.

1. Armenia
2. Bolivia
3. Costa Rica
4. Czech Republic
5. Egypt
6. Iceland
7. Ireland
8. Israel
9. Jordan
10. Lebanon
11. Luxembourg
12. Morocco
13. Namibia
14. Norway
15. Philippines
16. Puerto Rico
17. Slovakia
18. Syria
19. Venezuela

8.7 Location of major field activities

State the principal locations of any planned field investigations.

The two scales of field activities are the individual research projects that will be occurring throughout the list of 50+ countries above, and the locations of conferences/workshops for which there will be field correlation excursions. Although additional excursions will very likely be added as the project evolves, currently planned ones include the karst areas of Australia; Serbia; Poland; Guangxi, Guizhou, Yunnan, Chongqing (China); Kentucky, Tennessee(US); Spain; and/or Indonesia, Vietnam, Switzerland.

8.8 Location of major laboratory research (assured co-operation of laboratories)

*State names and locations of laboratories that **have agreed** to conduct laboratory work.*

The majority of the research work done in this project will be by individual scientists or small research groups, as opposed to highly developed laboratories. However, key laboratories and institutes that have provided confirmation or are anticipated to include:

Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green USA

Karst Dynamics Laboratory of the Institute of Karst Geology of China, Guilin China
Institute of Karst Environment and Rock Desertification Rehabilitation, Southwest University, Chongqing China

Karst Research Institute ZRC SAZU, Postojna, Slovenia

Karst Research Group, Dept. of Geography and Environmental Science, Gadjah Mada University, Yogyakarta INDONESIA

School of Geographical Sciences, Southwest University, Chongqing China

Centre d'Hydrogeologie, Universite de Neuchatel, Switzerland

Centre of Hydrogeology of the University of Malaga

8.9 Budget

Outline how the IGCP funds will be spent over the proposed duration of the project. Be sure to specify specific IGCP expenditures (see allowable items in "Guidelines" section 7). List other potential sources of funds and how IGCP funds may help in leveraging funds from other organizations. Provide a realistic estimate of the total cost (including non-IGCP sources) of the project, itemizing expenditures such as fieldwork expenses, laboratory costs, meetings, etc. (even though such costs may not be charged to IGCP).

All of the requested funds (except for up to 10% for secretariate use) for the proposed project will be spent on travel to support participation in meetings and training workshops, especially for participants from developing countries (low and middle economies based on World Bank criteria).