



Dr. Philip LaMoreaux (left), honored as the Father of Groundwater in Thailand.

# **Groundwater Science: Issues and Research Trends**

---

**Presented at**

**THA 2022 International Conference on  
Moving Towards Sustainable Water and  
Climate Change Management After  
COVID-19**

**January 26 – 28, 2022**

**by Dr. James W. LaMoreaux**

**Editor Discover Water**

**Chairman P.E. LaMoreaux & Associates, Inc.**

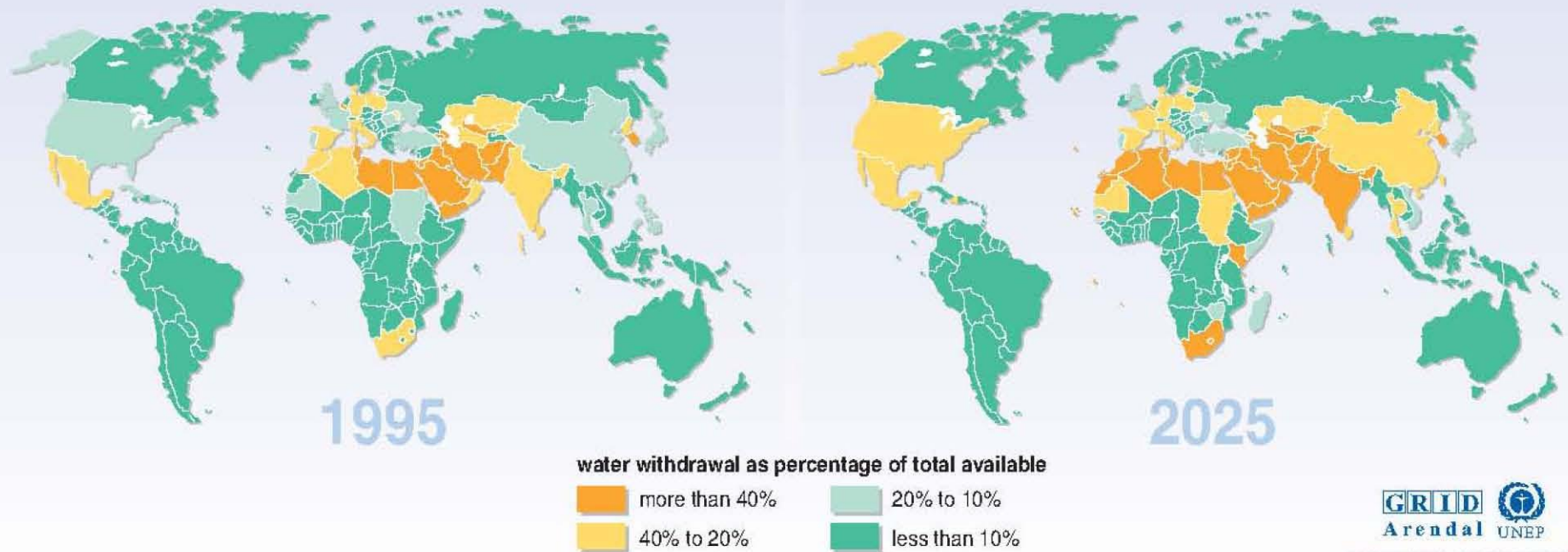


- **Hydrogeology plays major role in all aspects of environmental planning, execution and implementation.**
- **Without a safe sustainable water supply, life cannot exist and hopes for prosperity are limited.**
- **Much of future world demands will be made up of groundwater component.**

- **United Nations has identified water resources as a top priority.**
- **Attention is particularly drawn to freshwater stress which relates water withdrawal to percentage of water available.**
- **Based on current rate of usage, UN is not optimistic about the global water outlook.**

# Global Water Outlook Not Optimistic

## Freshwater stress



Source: Global environment outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

**AP** Associated Press 1/25/2008

## UN calls water top priority

**To address this issue, mankind needs to embrace sustainable water development (SWD). SWD is “the development of water in a manner in which [an] adequate supply of good quality water is sustained and the watercourse ecosystem is maintained for the uses of future generations.”**

Source: Pichyakorn, 2002



**Water quantity and water quality are inextricably linked; therefore there needs to be rapid movement towards SWD in developed and developing countries.**





## **SWD includes five specific elements:**

- (1) The right to use water;**
- (2) The protection of water resources and prevention of water degradation;**
- (3) The maintenance of water flow;**
- (4) An ecosystem related approach; and**
- (5) The procedural elements to achieve sustainable development.**

- **Right to use water involves comprehensive permitting with continuing review; strategic counseling, crisis management, creative dispute resolution; and enhanced relations with stakeholder and community groups.**
- **Protection of water resources and prevention of water degradation includes addressing non- point sources of pollution on a national, regional and local basis; land use controls; integration of water and land management; and regulation of interbasin transfers.**

- **Maintenance of water flow involves instream flows and environmental flows and may require appropriate controls.**
- **An ecosystem related approach should not be limited only to watercourse mainstream or tributaries; it should also incorporate terrestrial and marine environment interaction; promote health of the entire ecosystem; and actively involve watershed management authorities.**

**To move toward SWD, freshwater should be managed in a holistic manner, or in other words - an ecosystem approach.**

**“Management of water resources is holistic when it is done on a catchment or drainage basin basis. This includes both land and water resources, since land use can have significant impacts on freshwater and related ecosystems.... Thus water legislation should provide for a holistic, ecosystem approach to the management of water....”**

Steve McCaffrey and Greg Weber – **GUIDEBOOK FOR POLICY AND LEGISLATIVE DEVELOPMENT ON CONSERVATION AND SUSTAINABLE USE OF FRESHWATER RESOURCES (2005)**



# **UN Sustainable Development Goal 6:**

## **Access to Water and Sanitation**

- **Clean, accessible water for all is an essential need of the world. There is sufficient fresh water on earth to achieve this. Due to bad economics or poor infrastructure, millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene.**
- **Water scarcity, poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families. Drought afflicts some of the world's poorest countries, worsening hunger and malnutrition.**
- **By 2050 one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water.**



# **Research Trends in Selected Prominent Journals**



# **Sustainable Water Resources Management (SWAM)**



# **Aims and Scope: SWAM**

- **This peer-reviewed journal explores wide-ranging developments and challenges in pursuit of practical, sustainable water resource management; and**
- **Addresses a broad range of topics in water resources management;**
- **Covers geopolitical and socio-economic effects and constraints;**
- **Includes such topics as natural and man-induced contamination of water resources, surface and ground water interaction, managed aquifer recharge and storage ;**
- **Addresses water resources management, sustainability of water resources, ground and surface water quality and quantity, water use and reuse, surface and ground water interaction, aquifer recharge, storage and more.**

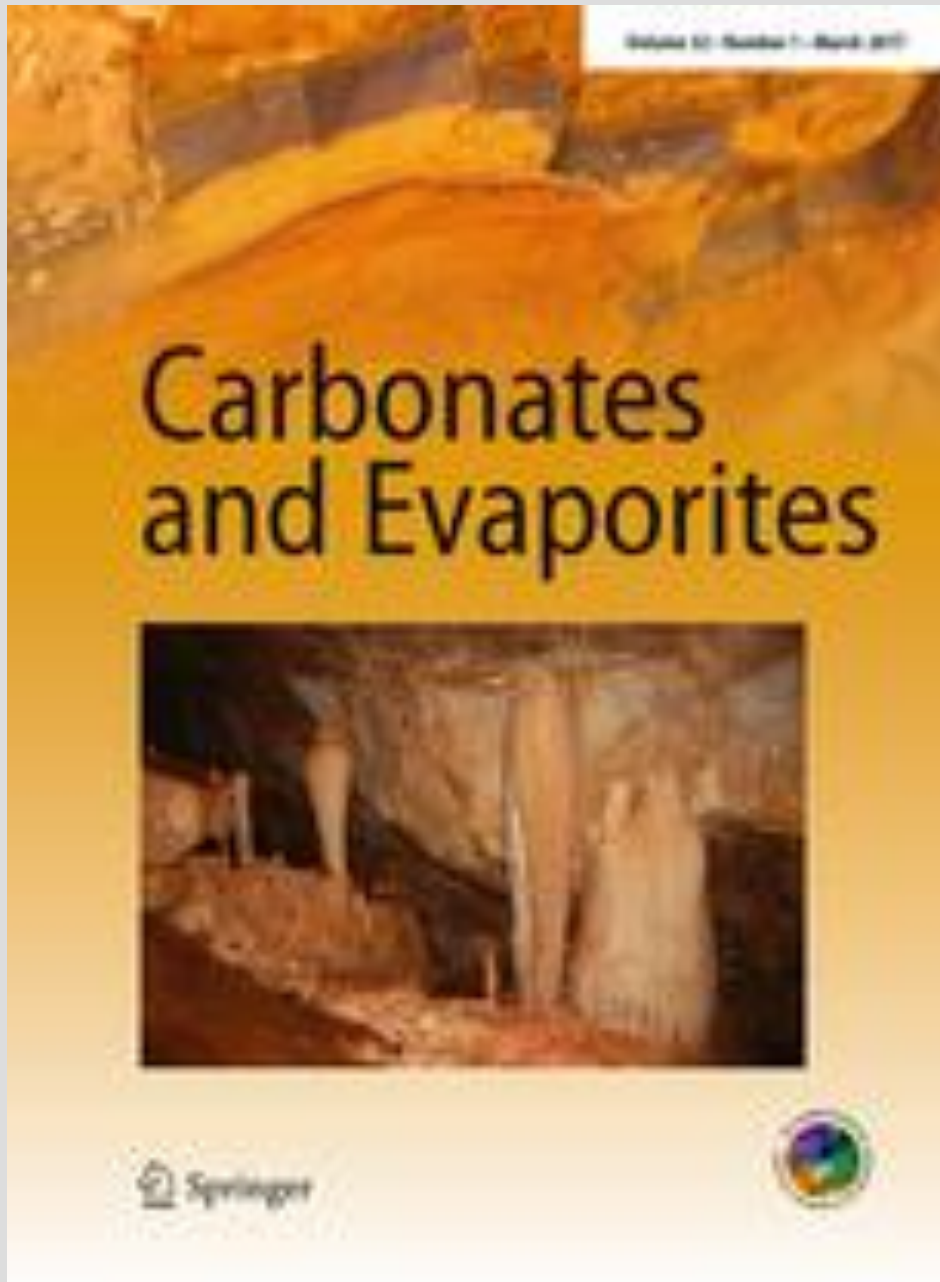




## 4.2 Top 10 Full-Text Article Requests 2017 (all publication years)

Title	Author	Article Type	Volume	Issue	Year	Article Requests 2017
Water quality assessment of lake water: a review	Rachna Bhateria et al.	Original Paper	2	2	2016	3,476
An overview to flood vulnerability assessment methods <span>Open Access</span>	Hajar Nasiri et al.	Original Paper	2	3	2016	3,409
Development of an analytical function for optimizing the capacity of spring water storage structure	A. K. Vashisht	Original Paper	2	4	2016	2,097
Removal of iron and manganese from drinking water supply	G. K. Khadse et al.	Original Paper	1	2	2015	2,058
Environmental challenges of trans-boundary water resources management: the case of Bangladesh	Mohammed Abdul Baten et al.	Original Paper	2	1	2016	1,795
A review: dew water collection from radiative passive collectors to recent developments of active collectors	B. Khalil et al.	Original Paper	2	1	2016	1,788
Assessment of water scarcity and its impacts on sustainable development in Awash basin, Ethiopia	Dereje Adeba et al.	Original Paper	1	1	2015	1,149
Domestic wastewater treatment performance using constructed wetland	J. S. Sudarsan et al.	Original Paper	1	2	2015	1,123
WEAP modeling of surface water resources allocation in Didessa Sub-Basin, West Ethiopia	Tena Bekele Adgolign et al.	Original Paper	2	1	2016	1,029
Hydropower for sustainable water and energy development in Ethiopia	Dagmawi Mulugeta Degefu et al.	Original Paper	1	4	2015	1,024

This slide excludes articles with unexplained peaks in downloads during the reporting period.  
Source: COUNTER Reporting / Business Warehouse.



# **Carbonates and Evaporites (CAEV)**



# **Aims and Scope - CAEV**

- **Examines and provides a forum for all aspects of carbonate and evaporite geology;**
- **Provides a forum for the exchanges of ideas on all aspects of carbonate and evaporite geology;**
- **Includes origin and stratigraphy of carbonate and evaporite rocks and issues unique to these rock types;**
- **Karst weathering phenomena, engineering and environmental issues, mining and minerals extraction, and caves and permeability.**

## 4.2 Top 10 Full-Text Article Requests 2017 (all publication years)

Title	Author	Article Type	Volume	Issue	Year	Article Requests 2017
Tectonic evolution and paleokarstification of carbonate rocks in the Paleozoic Tarim Basin <a href="#">Open Access</a>	Xuhui Xu et al.	Original Paper	32	4	2017	567
Carbonate phases rich in magnesium in the Triassic limestones of the eastern part of the Germanic Basin <a href="#">Open Access</a>	Katarzyna J. Stanienda	Original Paper	31	4	2016	334
Ultrasonic investigations of marble columns of historical structures built in two different periods	Ali Erden Babacan et al.	Original Paper	30	3	2015	286
Special topical issue: karst waters of Europe	James W. LaMoreaux	Editorial Notes	31	4	2016	280
Carbonate diagenetic products and processes from various diagenetic environments in Permian paleokarst reservoirs: a case study of the limestone strat	Xuesong Tian et al.	Original Paper	32	2	2017	275
Sedimentology and sequence stratigraphy of evaporites in the Middle Jurassic Buqu Formation of the Qiangtang Basin, Tibet, China	Xiaoqun Yang et al.	Original Paper	32	3	2017	259
Synthesis of precipitated calcium carbonate: a review	Onimisi A. Jimoh et al.	Original Paper	#	#	2017	257
A qualitative and quantitative model for climate-driven lake formation on carbonate platforms based on examples from the Bahamian archipelago <a href="#">Open Access</a>	Lisa E. Park Boush et al.	Original Paper	29	4	2014	253
Laboratory simulation experiment on dissolution of limestone under hydrodynamic pressure <a href="#">Open Access</a>	Qj Liu et al.	Original Paper	28	1-2	2013	251
Depositional environment characteristics of Uluk la Evaporites, Central Anatolia, Turkey	Şeref Keskin et al.	Original Paper	32	2	2017	243

This slide excludes articles with unexplained peaks in downloads during the reporting period.  
Source: COUNTER Reporting / Business Warehouse.

## Top ranking highest cited 2015-2016 articles for IF Year 2017 (Cont.)

Title	Author	Publication Type	Publication Date	DOI	Volume	Issue	Total Citations*	Citations for IF 2017
The importance of microbial mats for dolomite formation in the Dohat Faishakh sabkha, Qatar	Brauchli, Marisa; McKenzie, Judith A.; Strohmenger, Christian J.; Sadooni, Fadhil; Vasconcelos, Crisogono; Bontognali, Tomaso R. R.	Article	01-09-2016	10.1007/s13146-015-0275-0	31	3	5	2
The characteristics of dolomite reservoir in saline lacustrine Basin, Qaidam, China	Huang, Chenggang; Zhao, Fan; Yuan, Jianying; Wu, Lirong; Chen Gengxin	Article	01-09-2016	10.1007/s13146-015-0267-0	31	3	4	2
Facies analysis and depositional environment study of the mixed carbonate-evaporite Asmari Formation (Oligo-Miocene) in the sequence stratigraphic framework, NW Zagros, Iran	Daraei, Mehdi; Amini, Abdolhossein; Ansari, Morteza	Article	01-09-2015	10.1007/s13146-014-0207-4	30	3	4	2
Microstructures of consolidated Kaolin clay at different depths in centrifuge model tests	Cui, Zhen-Dong; Zhao, Ling-Zi; Yuan, Li	Article	01-03-2016	10.1007/s13146-015-0252-7	31	1	3	2
Identification of Neogene mixed lacustrine carbonate in western Qaidam basin	Zhao, Fan	Article	01-09-2015	10.1007/s13146-014-0210-9	30	3	3	2
Acid fluids reconstruction clastic reservoir experiment in Qaidam saline lacustrine Basin, China	Huang, Chenggang; Zhao, Fan; Yuan, Jianying; Sun, Ping; Zhang, Shiming	Article	01-09-2016	10.1007/s13146-015-0273-2	31	3	2	2

## 6.2 Altmetric Top 10 - 2017

How is the Altmetric score calculated? The score is a weighted count

The score is a weighted count of the different sources (newspaper stories, tweets, blog posts, comments) that mention the paper.

Why is it weighted? To reflect the relative importance of each type of source. It's easy to imagine that the average newspaper story is more likely to bring attention to the paper than the average tweet. This is reflected in the default weightings.

News	Blogs	Q&A forums	Twitter	Google+	Facebook
8	5	2.5	1	1	0.25

Score	Article DOI	Title	Author(s)	Publication Date
11	10.1007/bf03175407	Blue holes: Definition and genesis	JOHN E. MYLROIE, JAMES L. CAREW, AUDRA I. MOORE	01-09-1995
8	10.1007/s13146-017-0402-1	Methods for reconstruction of paleo-seawater pH based on boron isotopes in evaporative depositional sequences: case study using the Cambrian–Lower Ordovician evaporite sequence in the Tarim Block, NW China	JUNFENG YANG, YUNFENG ZHANG, YONGQUAN CHEN, LIJUAN ZHANG, CHANGJIAN ZHU, ZHENYU WANG	03-11-2017
3	10.1007/s13146-017-0337-6	Mathematical modeling of karstogenesis: an approach based on fracturing and hydrogeological processes	ANTOINE LAFARE, HERVÉ JOURDE, VÉRONIQUE LÉONARDI, SÉVERIN PISTRE, NATHALIE DÖRFLIGER	07-03-2017
2	10.1007/s13146-017-0341-x	Synthesis of precipitated calcium carbonate: a review	ONIMISI A. JIMOH, KAMAR SHAH ARIFFIN, HASHIM BIN HUSSIN, ADESUJI E. TEMITOPE	09-03-2017
2	10.1007/s13146-016-0311-8	Messinian evaporites in the Msaoria Basin, North Cyprus: facies and environmental interpretations	BAKI VAROL, CAVIT ATALAR	16-07-2016

Score	Article DOI	Title	Author(s)	Publication Date
2	10.1007/s13146-016-0307-4	Tectonic evolution and paleokarstification of carbonate rocks in the Paleozoic Tarim Basin	XUHUI XU, QIANGLU CHEN, CHENGLIN CHU, GUORONG LI, CUNGE LIU, ZHENG SHI	14-07-2016
2	10.1007/s13146-017-0333-x	Using stable isotopes and major ions to identify hydrogeochemical characteristics of karst groundwater in Xide country, Sichuan Province	JIANFEI YUAN, FEN XU, GUOSHI DENG, YEQI TANG	14-02-2017
2	10.1007/s13146-017-0360-7	Genesis of Paleocene and Lower Eocene shallow-water nodular limestone of South Tibet (China)	MICHAELA M. KAHSNITZ, HELMUT WILLEMS	30-06-2017
2	10.1007/s13146-017-0345-6	Micropalaeontology and sedimentology of an inter-evaporite Arab-C carbonate exposure, Riyadh, Saudi Arabia	G. WYN HUGHES, R. F. LINDSAY	18-03-2017
2	10.1007/s13146-017-0340-y	Evaporation stage of paleo-saline lake in North Shaanxi salt basin China: insight from fluid inclusions in halite	TING DING	11-03-2017





# Environmental Earth Sciences (EES)





# **Aims and Scope (EES)**

- **Environmental Earth Sciences is concerned with interaction between humans, natural resources, ecosystems, special climates or unique geographic zones, and the earth.**
- **Major disciplines include: hydrogeology, hydrochemistry, geochemistry, geophysics, engineering geology, remediation science, natural resources management, environmental climatology and biota, environmental geography, soil science and geomicrobiology.**



- **Water and soil contamination caused by waste management and disposal practices;**
- **Environmental problems associated with transportation by land, air, or water;**
- **Geological processes that may impact biosystems or humans;**
- **Man-made or naturally occurring geological or hydrological hazards;**
- **Environmental problems associated with the recovery of materials from the earth;**
- **Environmental problems caused by extraction of minerals, coal, and ores, oil and gas, water and alternative energy sources;**
- **Environmental impacts of exploration and recultivation – Environmental impacts of hazardous materials;**
- **Management of environmental data and information in data banks and information systems;**
- **Dissemination of knowledge on techniques, methods, approaches and experiences to improve and remediate the environment.**



## 4 Usage

### 4.2 Top 10 Full-Text Article Requests 2017 (all publication years)

Title	Author	Article Type	Volume	Issue	Year	Article Requests 2017
Anthropogenic contamination of groundwater with nitrate in arid region: case study of southern Hodna (Algeria) <a href="#">Open Access</a>	Salah Abdesselam et al.	Original Paper	70	5	2013	2,337
Mineralogical and geochemical analysis of Fe-phases in drill-cores from the Triassic Stuttgart Formation at Ketzin CO2 storage site before CO2 arrival <a href="#">Open Access</a>	Monika Kasina et al.	Original Paper	76	4	2017	2,045
Environmental degradation assessment in arid areas: a case study from Basra Province, southern Iraq <a href="#">Open Access</a>	Mushtak T. Jabbar et al.	Original Paper	70	5	2013	1,653
Energy storage in the geological subsurface: dimensioning, risk analysis and spatial planning: the ANGUS+ project <a href="#">Open Access</a>	Alina Kabuth et al.	Original Paper	76	1	2017	1,630
Hydraulic fracturing: a toxicological threat for groundwater and drinking-water?	Birgit C. Gordalla et al.	Original Paper	70	8	2013	1,326
Impacts of climate change on stream flow and hydro power generation in the Alpine region <a href="#">Open Access</a>	T. Wagner et al.	Original Paper	76	1	2017	1,265
Physical weathering of building stones induced by freeze–thaw action: a laboratory long-term study <a href="#">Open Access</a>	J. Ruedrich et al.	Original Paper	63	7-8	2011	1,193
Aquatic effects of peat extraction and peatland forest drainage: a comparative sediment study of two adjacent lakes in Central Finland <a href="#">Open Access</a>	T. Kauppila et al.	Original Paper	75	23	2016	1,069
Optimized extraction of dimension stone blocks <a href="#">Open Access</a>	S. Mosch et al.	Original Paper	63	7-8	2011	1,060
Analysis of changes in climate and river discharge with focus on seasonal runoff predictability in the Aksu River Basin <a href="#">Open Access</a>	Z. W. Kundzewicz et al.	Original Paper	73	2	2015	1,011

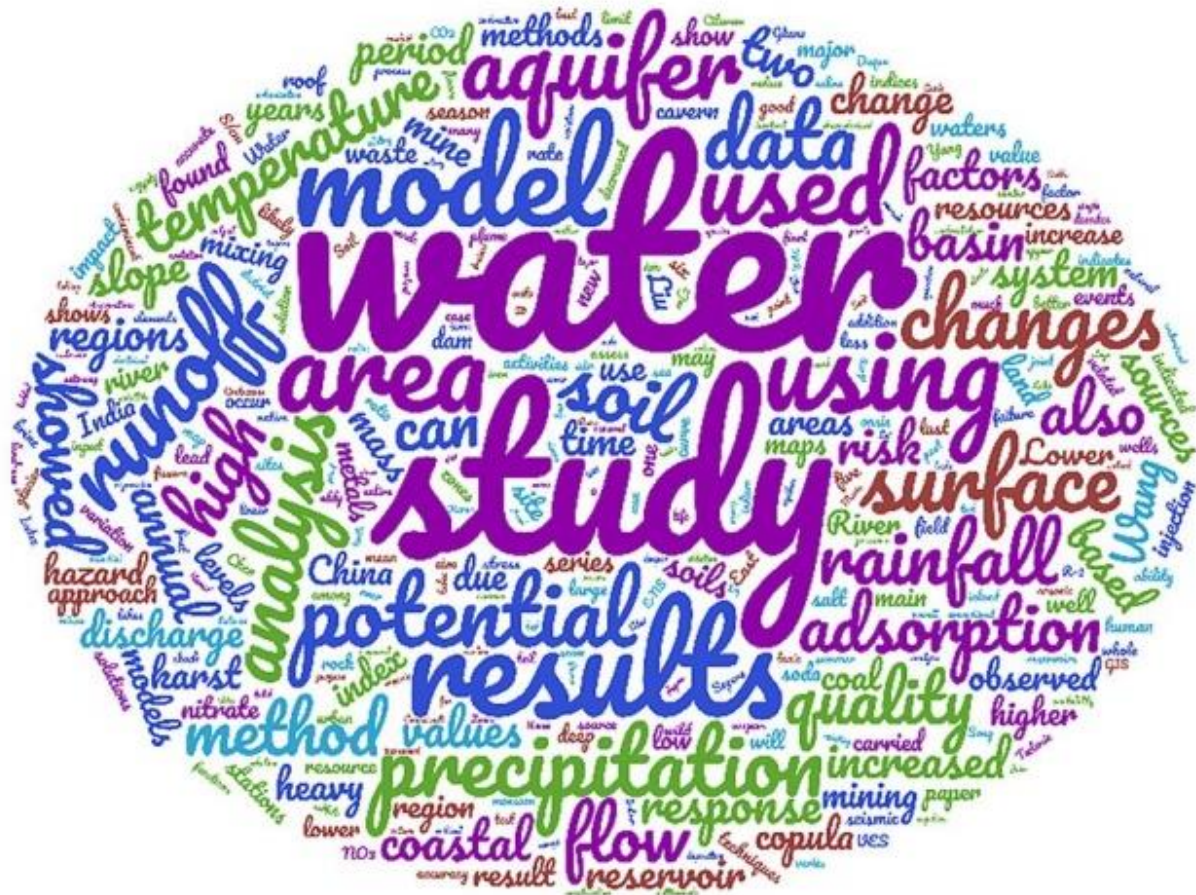
This slide excludes articles with unexplained peaks in downloads during the reporting period.  
Source: COUNTER Reporting / Business Warehouse.

## 4 Usage

### 4.2 Top 10 Full-Text Article Requests 2017 (publication years 2015–2017)

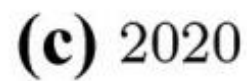
Title	Author	Article Type	Volume	Issue	Year	Article Requests 2017
Mineralogical and geochemical analysis of Fe-phases in drill-cores from the Triassic Stuttgart Formation at Ketzin CO2 storage site before CO2 arrival <a href="#">Open Access</a>	Monika Kasina et al.	Original Paper	76	4	2017	2,045
Energy storage in the geological subsurface: dimensioning, risk analysis and spatial planning: the ANGUS+ project <a href="#">Open Access</a>	Alina Kabuth et al.	Original Paper	76	1	2017	1,630
Impacts of climate change on stream flow and hydro power generation in the Alpine region <a href="#">Open Access</a>	T. Wagner et al.	Original Paper	76	1	2017	1,265
Aquatic effects of peat extraction and peatland forest drainage: a comparative sediment study of two adjacent lakes in Central Finland <a href="#">Open Access</a>	T. Kauppila et al.	Original Paper	75	23	2016	1,069
Analysis of changes in climate and river discharge with focus on seasonal runoff predictability in the Aksu River Basin <a href="#">Open Access</a>	Z. W. Kundzewicz et al.	Original Paper	73	2	2015	1,011
GIS-based assessment of combined AHP and SAW methods for selecting suitable sites for landfill in Al-Musayib Qadhaa, Babylon, Iraq <a href="#">Open Access</a>	Ali Jalil Chabuk et al.	Original Paper	76	5	2017	959
Developing a groundwater vulnerability map for unconventional oil and gas extraction: a case study from South Africa <a href="#">Open Access</a>	Surina Esterhuyse	Original Paper	76	17	2017	952
Field spectroscopy and radiative transfer modelling to assess impacts of petroleum pollution on biophysical and biochemical parameters of the Amazon r <a href="#">Open Access</a>	Paul Arellano et al.	Original Paper	76	5	2017	947
The future Aral Sea: hope and despair	Philip Micklin	Original Paper	75	9	2016	935
Forensic hydrology: what function tells about structure in complex settings <a href="#">Open Access</a>	Gunnar Lischeid et al.	Original Paper	76	1	2017	864

This slide excludes articles with unexplained peaks in downloads during the reporting period.  
Source: COUNTER Reporting / Business Warehouse.











# 100 most cited papers from all years since 2009 (using Wordle<sup>TM</sup>)





# 15 Most Cited Articles 2015-16

- **Abdullaev I, Rakhmatullaev S (2015) Transformation of water management in central Asia: from state-centric, hydraulic mission to socio-political control.**
- **Aishan T, Halik U, Kurban A et al (2015) Eco-morphological response of floodplain forests (*Populus euphratica* Oliv.) to water diversion in the lower Tarim River, northwest China.**
- **Azarnivand A, Hashemi-Madani FS, Banihabib ME (2015) Extended fuzzy analytic hierarchy process approach in water and environmental management (case study: Lake Urmia Basin, Iran).**
- **Belletti B, Rinaldi M, Buijse AD et al (2015) A review of assessment methods for river hydromorphology.**
- **Beskese A, Demir HH, Ozcan HK, Okten HE (2015) Landfill site selection using fuzzy ahp and fuzzy topsis: a case study for Istanbul.**
- **Chalov S, Jarsjo J, Kasimov NS et al (2015) Spatio-temporal variation of sediment transport in the Selenga River Basin, Mongolia and Russia.**
- **Gordalla BC, Ewers U, Frimmel FH (2013) Hydraulic fracturing: a toxicological threat for groundwater and drinking-water?**
- **Hajihassani M, Armaghani DJ, Monjezi M, Mohamad ET, Marto A (2015) Blast-induced air and ground vibration prediction: a particle swarm optimization-based artificial neural network approach.**
- **Karthe D, Chalov S, Borchardt D (2015) Water resources and their management in central Asia in the early twenty first century: status, challenges and future prospects.**



# 15 Most Cited Articles, continued

- **Kim H-S, Kim K-R, Kim H-J, Yoon J-H, Yang JE, Ok YS, Owens G, Kim K-H (2015) Effect of biochar on heavy metal immobilization and uptake by lettuce (*Lactuca sativa* L.) in agricultural soil.**
- **Li P, Qian H, Howard KWF, Wu J (2015) Building a new and sustainable “silk road economic belt”.**
- **Lim LBL, Priyantha N, Mansor NHM (2015) *Artocarpus altilis* (breadfruit) skin as a potential low-cost biosorbent for the removal of crystal violet dye: equilibrium, thermodynamics and kinetics studies.**
- **Ren F, Wu X, Zhang K, Niu R (2015) Application of wavelet analysis and a particle swarm-optimized support vector machine to predict the displacement of the shuping landslide in the three gorges, China.**
- **Wu J, Li P, Qian H (2015) Hydrochemical characterization of drinking groundwater with special reference to fluoride in an arid area of China and the control of aquifer leakage on its concentrations.**
- **Youssef AM, Pradhan B, Jebur MN, El-Harbi HM (2015) Landslide susceptibility mapping using ensemble bivariate and multivariate statistical models in Fayfa area, Saudi Arabia.**
- **Zhang J, Zhang Q, Sun Q, Gao R, Germain D, Abro S (2015) Surface subsidence control theory and application to backfill coal mining technology.**



Discover Water  
(DW)



# Aims and Scope

*Discover Water* is part of the Discover journal series committed to providing a streamlined submission process, rapid review and publication, and a high level of author service at every stage. It is an open access, community-focussed journal publishing research from across all fields relevant to water research.

*Discover Water* is a broad, open access journal publishing research from across all fields relevant to the science and technology of water research and management. *Discover Water* covers not only research on water as a resource, for example for drinking, agriculture and sanitation, but also the impact of society on water, such as the effect of human activities on water availability and pollution. As such it looks at the overall role of water at a global level, including physical, chemical, biological, and ecological processes, and social, policy, and public health implications. It is also included that articles published in *Discover Water* may help to support and accelerate United Nations Sustainable Development Goal 6: ‘Clean water and sanitation’.



# **Research Trends**

## **International Societies**

### **International Association of Hydrogeologists**

- **Scientists, engineers, water managers and other professionals;**
- **Groundwater research, management and protection;**
- **Has 4,000 members worldwide in 40 countries;**
- **Worldwide networking;**
- **Eight specialized research commissions.**



# **IAH Specialized Commissions**

- **Commission on Groundwater and Climate Change;**
- **Commission on Groundwater and Energy;**
- **Commission on Groundwater Outreach;**
- **Commission on Karst Hydrogeology;**
- **Commission on Managing Aquifer Recharge ;**
- **Commission on Mineral and Thermal Waters ;**
- **Commission on Regional Groundwater Flow ;**
- **Commission on Transboundary Aquifers.**

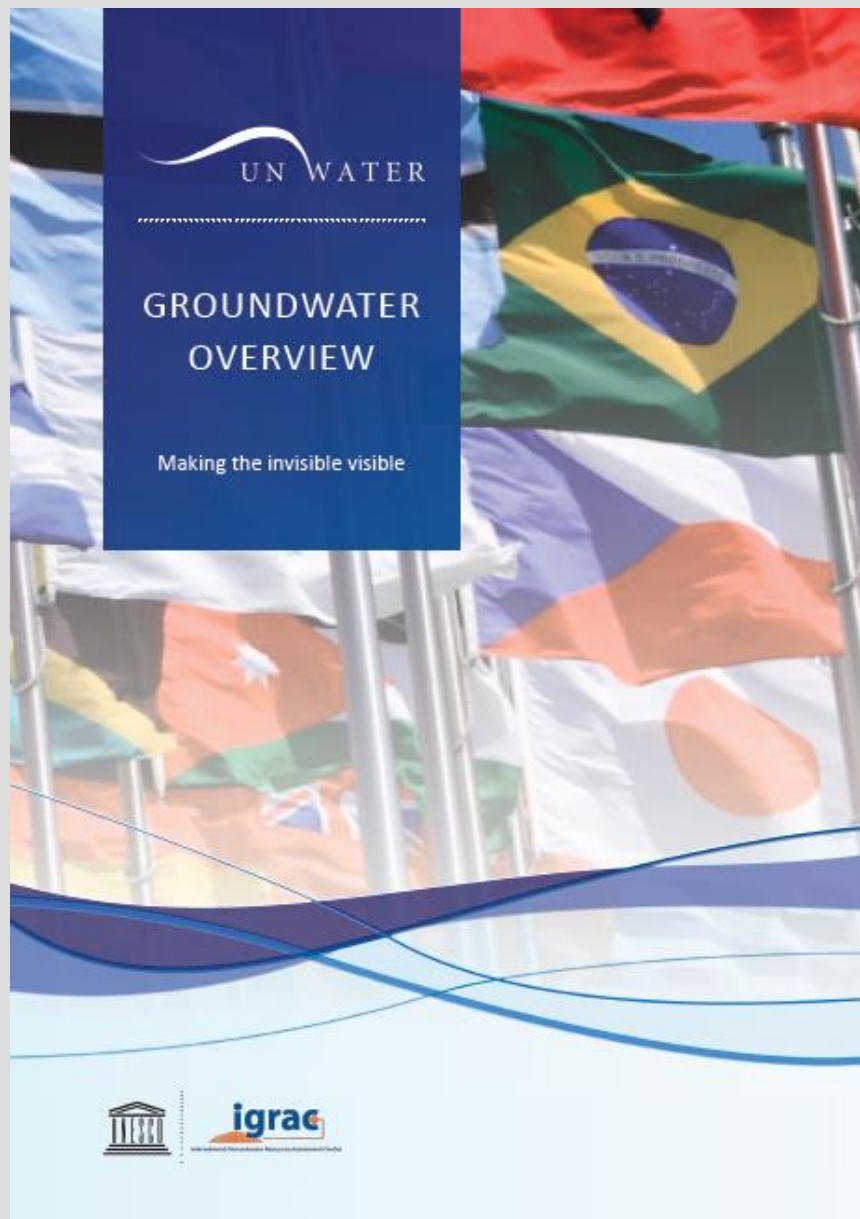


# UN Water Partners

**Global groundwater resources are under increasing pressure due to human activities and climate change. The UNESCO/IGRAC Groundwater Overview -**

- **Showcases the essential issues of groundwater,**
- **Informs about groundwater-related activities,**
- **Enhances knowledge exchange and collaboration, and**
- **Raises awareness about our most important hidden resource: GROUNDWATER.**







# Climate Variability

**As the world's largest distributed store of fresh water, groundwater plays a central part in sustaining ecosystems and enabling human adaptation to climate variability and change. Aquifers have a buffering capacity and they are naturally more resistant to external impact than surface waters. Since variability of surface water availability is increasing due to climate change, strategic importance of aquifers for water and food security is clearly growing. (UNESCO/IGRAC)**



# Natural Disasters, Conflicts and Human Rights

**Aquifers can substitute affected drinking water supplies in time after catastrophic events, such as tsunamis. Relief organisations need to know about availability of groundwater for water supply when settling displaced communities (after natural disasters and/or conflicts). Groundwater is often a possible solution for the people without access to safe drinking water - still more than 600 million. (UNESCO/IGRAC)**



# Governance, Law, and Transboundary Issues

- **Groundwater is a common-pool resource and is often utilized at an individual level regardless of overall impact on the aquifer because neither use nor impact are necessarily immediately visible.**
- **This becomes even more complex when aquifers cross state or national borders (transboundary). Aquifers need to be governed through a process of shared responsibility and participation, information availability and transparency, and rule of law.**  
**(UNESCO/IGRAC)**



# Groundwater and the Environment

**Various kinds of ecosystems depend on groundwater:**

- **Aquatic - wetlands, rivers and lakes receiving groundwater.**
- **Terrestrial - phreatophyte vegetation, either shallow-rooted in alluvial settings or deep-rooted in arid zones .**
- **Subterranean - limestone formations with karstic caverns.**
- **Accordingly, groundwater is an essential part of any ecosystem-based adaptation measure, green infrastructure or a nature-based solution.**

**(UNESCO/IGRAC)**



# Groundwater in Settlements

**Groundwater is the main source of water supply in many cities around the world and increasingly under pressure due to continuous urbanisation, climate change and inadequate water management. Groundwater depletion and land subsidence are serious problems. The pumping rates in the megacities may be reduced and compensated by urban rainwater harvesting, rural-urban water transfers, aquifer recharge with wastewater and similar measures. (UNESCO/IGRAC)**



# **Sanitation, Health and Pollution**

- **Water-related disease remains one of the major health concerns in the world. The improvement of groundwater quality control, in conjunction with improvement in sanitation and personal hygiene, is the main strategy to reduce water-related disease.**
- **Groundwater can be polluted from agriculture, sanitation, industry and mining, landfills and waste disposals, traffic and transport and also from chemical processes within geological environments.**
- **Regular groundwater monitoring, vulnerability assessment, protection from point-source and diffuse pollution, and pollutant removal, are some of necessary actions in preserving and improving groundwater quality and health.**  
**(UNESCO/IGRAC)**





# Food and Energy

- **About 2/3 of all abstracted groundwater is used in agriculture. Global food production increasingly relies on groundwater over-abstraction. Groundwater depletion eventually leads to decline of food production.**
- **About 1/4 of the energy used globally is spent on food production and supply, including groundwater pumping.**
- **Deep aquifers, as a potential source and a sink for heat, can play a much more prominent role in the provision of renewable geothermal energy.**



# Economics

- **Groundwater resources are extensively used in production processes by large international companies all over the world. Accordingly, international investors are being encouraged to share broader societal and environmental costs of groundwater.**
- **Understanding the value of groundwater would be an additional incentive for investors and asset managers to participate, leading eventually to investment risk reduction.**





# Summary of Research Trends

- **Remote sensing increasingly used for aquifer management.**
- **Satellite data interpretation for drought and long-term weather forecasting.**
- **Bringing more real-time reporting data online via web.**
- **Cross-disciplinary training.**
- **Regional, national and international emphasis on improving water use agreements and best practices.**
- **More collaborative studies among consortium universities or corporations.**
- **Water as an economic commodity or as a natural right.**

