United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

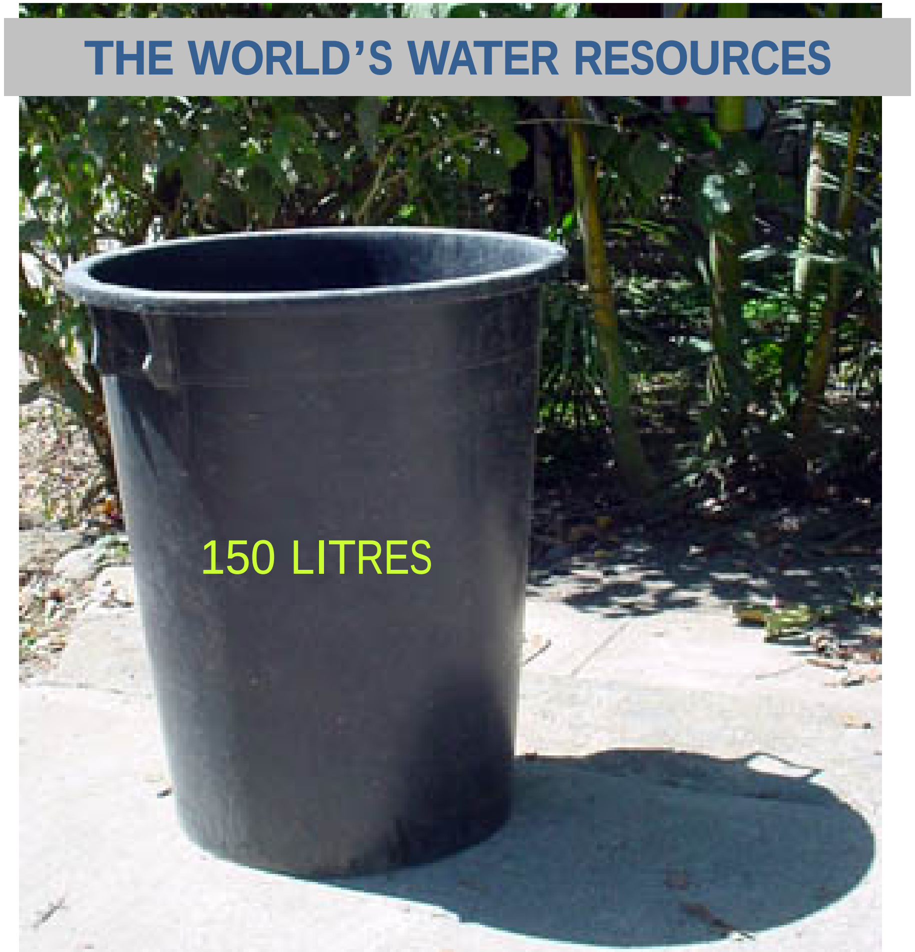
GROUNDWATER FOR CLIMATE CHANGE ADAPTATION

Tales Carvalho Resende

International Hydrological Programme

GRAPHIC

The importance of groundwater



Imagine:

All the water on the planet =

150 litre container

BUT JUST 4 LITRES ARE FRESH !!

The remaining 146 litres are SEAWATER

Source: Prof Ken Howard, Osaka Cut, 2003

The importance of groundwater

Out of these 4 litres:

3 litres are frozen (earth's ice caps, permafrost regions)

… leaving one lonely litre of freshwater

… and 99% the lonely litre of freshwat
is GROUNDWATER !!

It is essential that we protect and manage groundwater resources effectively!

Source: Prof Ken Howard, Osaka Cut, 2003

The importance of groundwater

UNESCO estimated people living in water stressed situation:

- **0.5 billion in 2000**
- **2.8 billion in 2025**
- **4.0 billion in 2050**

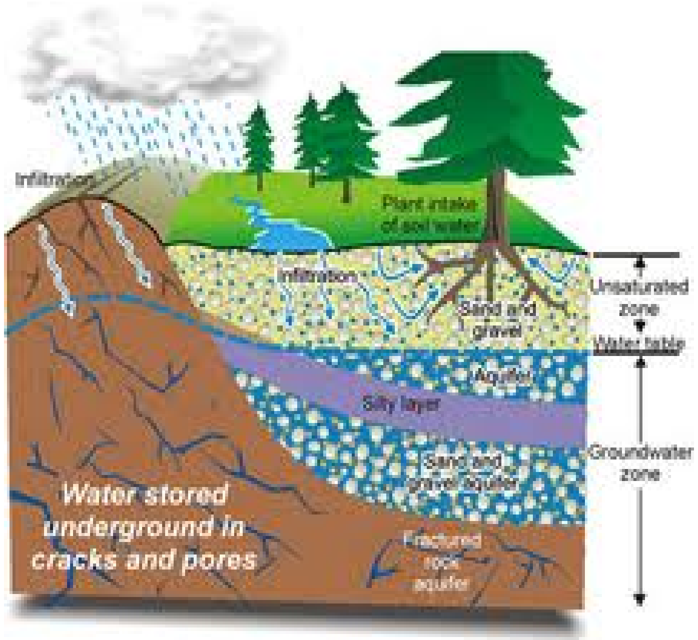
Community well in Gujarat, India (2003): water table declining 3 m/yr

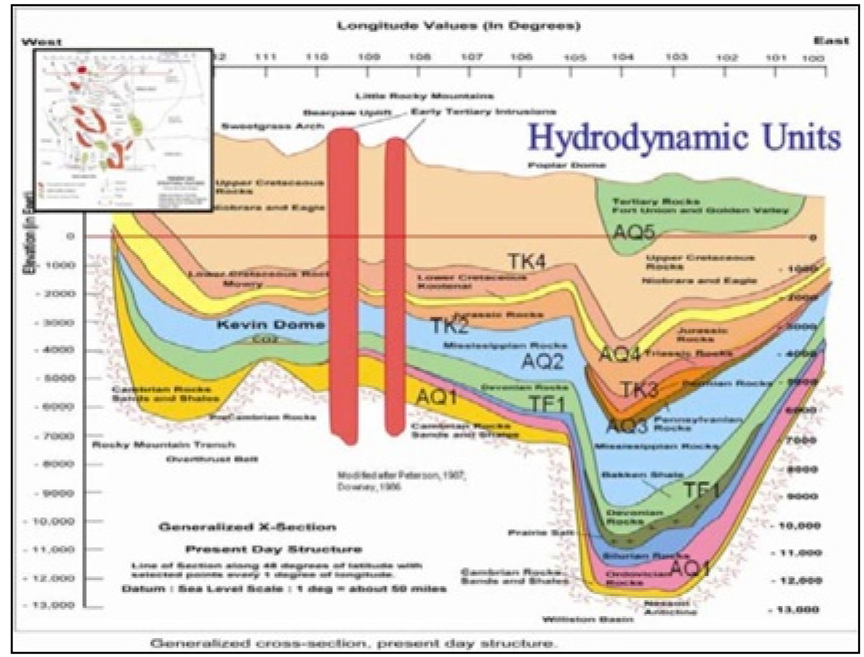
Photo: Amit Dave, Reuters

Groundwater will help meet the growing demand for water supplies under growing global population and the uncertain effects of climate variability and change.

United Nations Educational, Scientific and Cultural Organization · International Hydrological Programme · GRAPHIC

Challenges





Groundwater studies: art of studying and informing about what we cannot see

Stationary is dead

Lack of data

Lack of governance

Motivation for GRAPHIC

GRAPHIC

GLOBAL COMMITMENT TO GROUNDWATER AND CLIMATE CHANGE

To better understand the effects of climate change on global groundwater resources, the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) International Hydrological Programme (IHP) initiated the GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change) project in 2004[1].

Motivation for GRAPHIC

Vision of GRAPHIC:

- advance sustainable groundwater management considering projected climate change and linked human effects.

Mission of GRAPHIC:

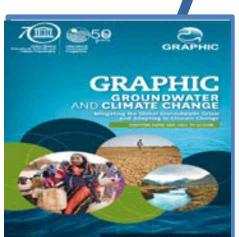
- provide a platform for exchange of information through case studies, thematic working groups, scientific research, and communication.
- serve the global community through providing scientifically based and policy-relevant recommendations.
- use regional and global networks to improve the capacity to manage groundwater resources.

How do we do it?

Networking

Research (case studies, information, maps, etc.)

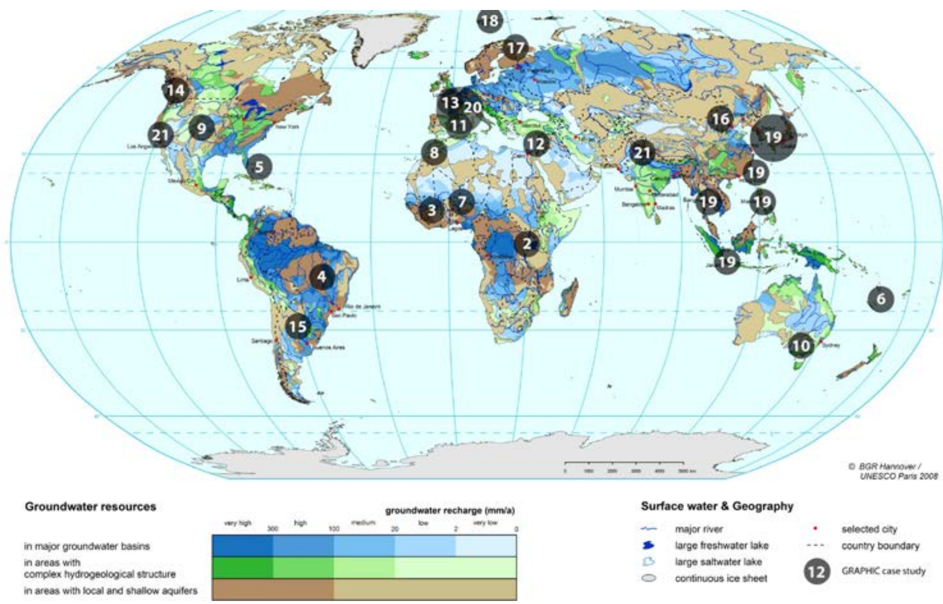
Capacity building



Outreach and communication

GRAPHIC: A global network with many partners

- **More than 100 members from different regions**
- **<u>Partners:</u> academia, geological surveys (USGS, …), research centres (NASA, IGRAC, …)**
- **Annual meetings**
- **GRAPHIC has regional studies in Africa, Asia and Oceania, Europe, Latin America, and the Caribbean, and North America**
- **More than 20 flag case studies**



<u>Flag Basins</u>:

- North West Sahara (Africa)
- Iullemmeden Basin (Africa)
- High Plains (North America)
- Guarani (South America)
- North China Plains (Asia)
- Baltic Artesian Basin (Northern Europe)
- Great Artesian Basin (Oceania)

Several addition study aquifers.

GRAPHIC: Leader in research

nature climate change
REVIEW ARTICLE
PUBLISHED ONLINE: 25 NOVEMBER 2012 | DOI: 10.1038/NCLIMATE1744

Ground water and climate change

Richard G. Taylor *et al.**

As the world's largest distributed store of fresh water, ground water plays a central part in sustaining ecosystems and enabling human adaptation to climate variability and change. The strategic importance of ground water for global water and food security will probably intensify under climate change as more frequent and intense climate extremes (droughts and floods) increase variability in precipitation, soil moisture and surface water. Here we critically review recent research assessing the impacts of climate on ground water through natural and human-induced processes as well as through groundwater-driven feedbacks on the climate system. Furthermore, we examine the possible opportunities and challenges of using and sustaining groundwater resources in climate adaptation strategies, and highlight the lack of groundwater observations, which, at present, limits our understanding of the dynamic relationship between ground water and climate.

Ground water is an almost ubiquitous source of generally high-quality fresh water. These characteristics promote its widespread development, which can be scaled and localized to demand, obviating the need for substantial infrastructure[1]. Globally, ground water is the source of one third of all freshwater withdrawals, supplying an estimated 36%, 42% and 27% of the water used for domestic, agricultural and industrial purposes, respectively[2]. In many environments, natural groundwater discharges sustain baseflow to rivers, lakes and wetlands during periods of low or no rainfall. Despite these vital contributions to human welfare and aquatic ecosystems, a paucity of studies on the relationship between climate and ground water severely restricted the ability of the Intergovernmental Panel on Climate Change (IPCC) to assess interactions between ground water and climate change in both its third[3] and fourth[4] assessment reports. There has since been a marked rise in published research[5–8] applying local- to global-scale modelling, as well as ground-based and satellite monitoring, which has considerably enhanced our understanding of interactions between ground water and climate. Here we build on an earlier broad-based overview[8] of the topic, and examine substantial recent advances. These include emerging knowledge of the direct and indirect (through groundwater use) effects of climate forcing — including climate extremes — on groundwater resources, as well as feedbacks between ground water and climate, such as the contribution of groundwater depletion to global sea-level rise. Furthermore, we identify critical gaps in our understanding of the interactions between ground water and climate.

Influence of climate on groundwater systems
Climate variability and change influences groundwater systems both directly through replenishment by recharge and indirectly through changes in groundwater use. These impacts can be modified by human activity such as land-use change (LUC).

Palaeohydrological evidence. The long-term responses of ground water to climate forcing, largely independent of human activity, can be detected from palaeohydrological evidence from regional aquifer systems in semi-arid and arid parts of the world (Fig. 1). Much of the ground water flowing in large sedimentary aquifers of the central United States (High Plains aquifer), Australia (Great Artesian basin), southern Africa (Kalahari sands) and North Africa (Nubian sandstone aquifer system) was recharged by precipitation thousands of years ago[10–13]. As evaporation and plant transpiration consume soil moisture but leave chloride behind, substantial

accumulations of chloride in unsaturated soil profiles within these basins indicate that little (≤5 mm yr^{-1}) or no recharge has since taken place[14]; which is the case across many of the basins. Stable isotopes of oxygen and hydrogen, together with concentrations of noble gases, suggest that recharge occurred under cooler climates (≥5 °C cooler) before and occasionally during Late Pleistocene
glaciation, w…
Ground wate…
the Late Pleis…
monly referr…
recharge rate…
groundwater…
than recharg…
mined by th…
able storage…
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climate varia…
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*A full list of author names and their affiliations appears at the end of the review article.

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Review papers

Beneath the surface of global change: Impacts of climate change on groundwater

Timothy R. Green [a,*], Makoto Taniguchi [b], Henk Kooi [c], Jason J. Gurdak [d,1], Diana M. Allen [e], Kevin M. Hiscock [f], Holger Treidel [g], Alice Aureli [g]
[a] USDA, Agricultural Research Service (ARS), Fort Collins, CO, USA
[b] Research Institute for Humanity and Nature (RIHN), Kyoto, Japan
[c] VU University, Amsterdam, The Netherlands
[d] San Francisco State University, CA, USA
[e] Simon Fraser University, Burnaby, BC, Canada
[f] University of East Anglia, Norwich, UK
[g] UNESCO, International Hydrological Programme (IHP), Paris, France

…A R Y
…e encompasses changes in the characteristics of inter-related climate variables in space and …rived changes in terrestrial processes, including human activities that affect the environ-…h, projected global change includes groundwater systems. Here, groundwater is defined as …e water including soil water, deeper vadose zone water, and unconfined and confined aquifer …tial effects of climate change combined with land and water management on surface waters …udied in some detail. Equivalent studies of groundwater systems have lagged behind these …research and broader interest in projected climate effects on groundwater have been accel-…ent years. In this paper, we provide an overview and synthesis of the key aspects of subsur-…y, including water quantity and quality, related to global change.
…to global change must include prudent management of groundwater as a renewable, but …k resource in most cases. Groundwater storage is already over-tapped in many regions, …subsurface storage may be a key to meeting the combined demands of agriculture, industry, …d domestic water supply, and ecosystems during times of shortage. The future intensity and …dry periods combined with warming trends need to be addressed in the context of ground-…es, even though projections in space and time are fraught with uncertainty. Finally, poten-…f groundwater on the global climate system are largely unknown. Research to improve our …g of the joint behaviors of climate and groundwater is needed, and spin-off benefits on each …likely.
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Rate of papers addressing groundwater and climate change:

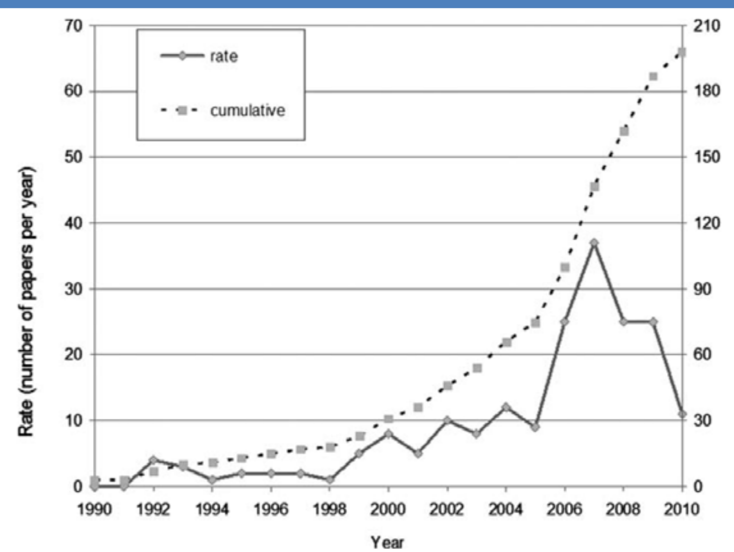

Figure 1.1. Rate of peer-reviewed journal paper publications addressing groundwater and climate change from 1990 to 2010. A total of 198 papers addressing subsurface water and climate change are included. Final references were compiled in February 2011, so some papers published late in 2010 may be missing (modified from Green et al. 2011).

More than 100 scientific papers since GRAPHIC was launched in 2004

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International Hydrological Programme
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GRAPHIC: Capacity building

Training workshops for students and early-career scientists

- Longterm groundwater dynamics – Tunisia, Nov 2010, with INQUA
- Groundwater as a key for adaptation to changing climate and society – Japan, Nov 2010
- Methods for Assessing the Impacts of Climate Change and Human Activities on Groundwater Resources – Focus on Asia, China, Oct/Nov 2011 (IAH, Sun Yatsen University)
- Mozambique, Nov 2013 – with INQUA and G@GPS
- Guangdong Province, China, Dec 8-13 2014 – with INQUA and G@GPS
- Tallinn, Estonia July 5-9, 2015, with G@GPS


G@GPS Project International workshop 2015

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- Programme
- Practical Info
- Links

G@GPS Project International workshop Tallinn, Estonia, July 5-9, 2015

We heartily invite you to participate in the G@GPS Project International workshop „Palaeogroundwater from past and present glaciated areas" and related mini-workshop on time series and spectral methods in the climate variability analysis as related to groundwater, to be held in Tallinn, Estonia, July 5-9, 2015. This is the main meeting of G@GPS in 2015.

The aim of the meeting is to present talks on progress within the G@GPS group in 2014-2015. Discussion of future activities, new ideas, meetings (e.g. INQUA Congress, Nagoya, 2015) proposals, and possible academic exchange of staff and students.
It gives an opportunity to meet G@GPS participants, to present relevant studies and discuss methods related to palaeogroundwater:

- Groundwater dating
- Links between recharge and climate
- Old seawater intrusion
- Mixture of modern and old groundwater
- Methods related to isotopes and noble gases
- Numerical modelling of palaeogroundwater systems

Presentation of G@GPS relevant case studies from groundwater basins

The training course in the field

G@GPS workshop at Zhanjiang Bureau of Hydrology

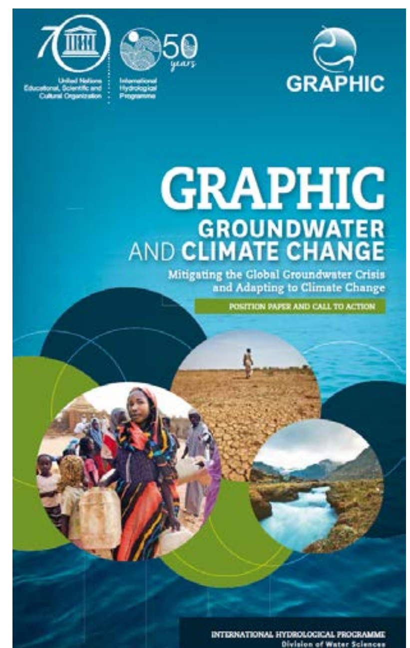
GRAPHIC: Outreach and communication

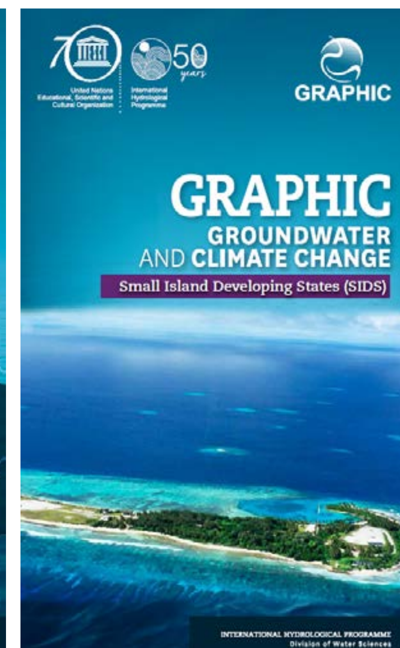
Translate our scientific findings into concrete actions for better management and outline policy relevant recommendations

GRAPHIC at COP21:

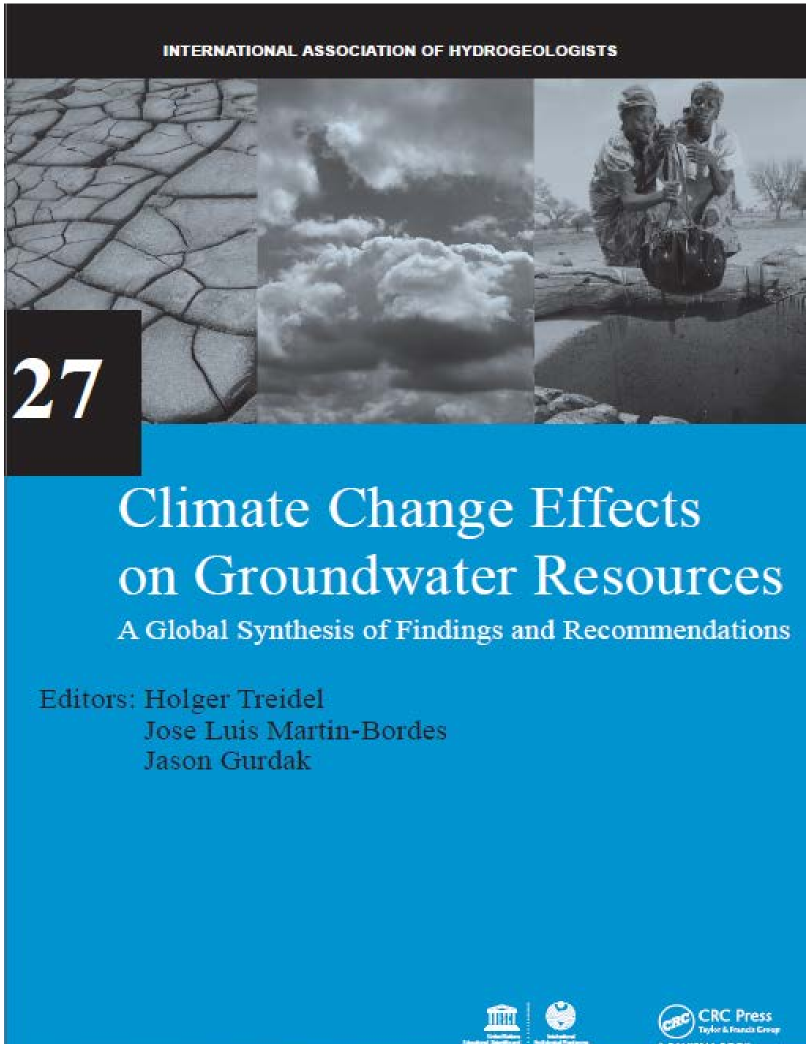
Launch of GRAPHIC position paper at the COP21

Official release of 2 position papers by GRAPHIC at COP21:





Scientific Findings and Policy Relevant Recommendations



Research in 30 countries; 60 authors

Research Themes & Topics:
(climate variability and change)

- **variety of settings: alpine, agricultural, island/coastal, urban**
- **land-use/land cover**
- **storm surge**
- **seawater intrusion**
- **land subsidence**
- **effects on recharge (17 of 20 studies)**
- **response to drought**
- **response to permafrost/glaciers melt**
- **dependent ecosystems (GDE)**
- **falling/rising water tables**
- **groundwater quality**
- **GRACE: GW depletion rates**
- **statistical downscaling; GCMs**
- **ENSO, NAO, PDO, AMO**

GRAPHIC

Scientific Findings and Policy Relevant Recommendations

>75 major scientific findings & policy/management recommendations

Need for interdisciplinary and multidisciplinary collaboration

Work on global/national monitoring and database programs

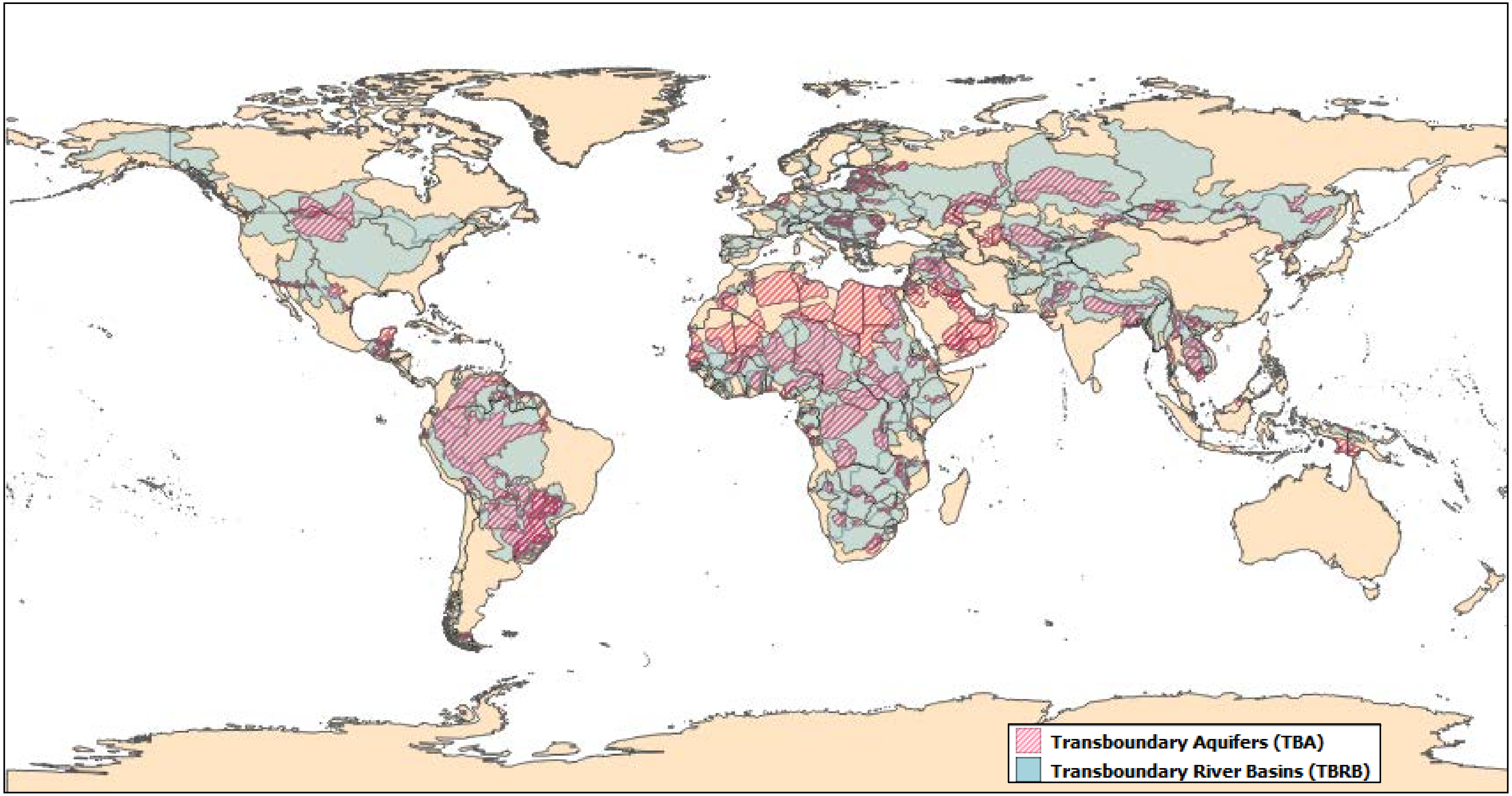
Temporal lags in responses to land-use change, climate, pollution

Improve understanding of recharge stories and how they improve adaptation/management

GW response to global-scale oceanic-atm. climate variability (ENSO, PDO, NAO, …)

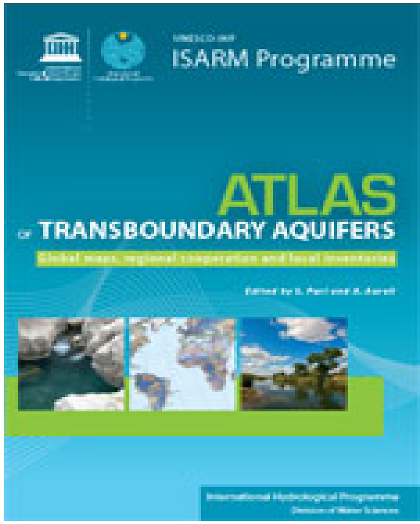
Need for strategic management and governance (domestic and transboundary level)

Transboundary aquifers and transboundary river basins



UNESCO's leading role in transboundary GW governance

- ISARM → TWAP → GGRETA

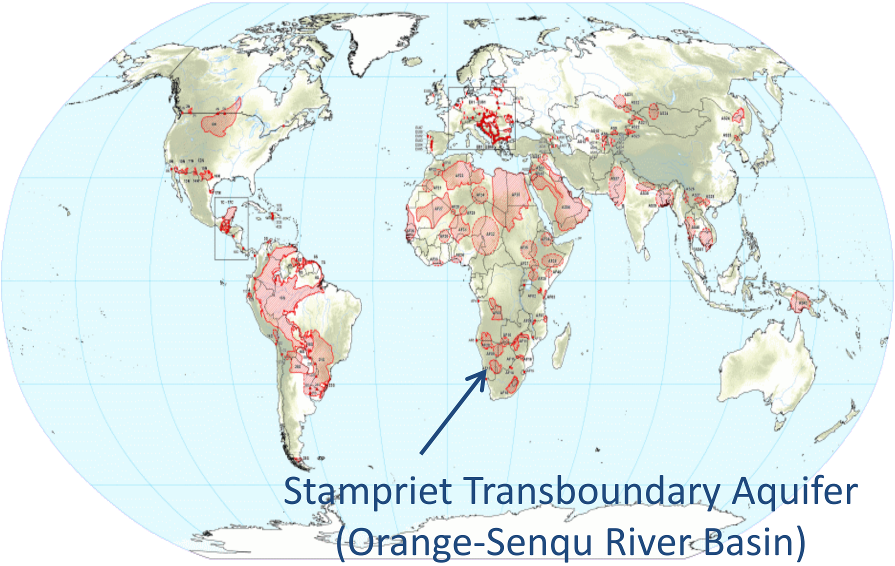


- **ISARM (2000-present):**
  - International Shared Aquifers Resources Management
  - Inventory of Transboundary Aquifers (TBAs)
- **TWAP (2013-2015):** gef
  - TB waters assessment program
  - Global assessment 166 TBAs

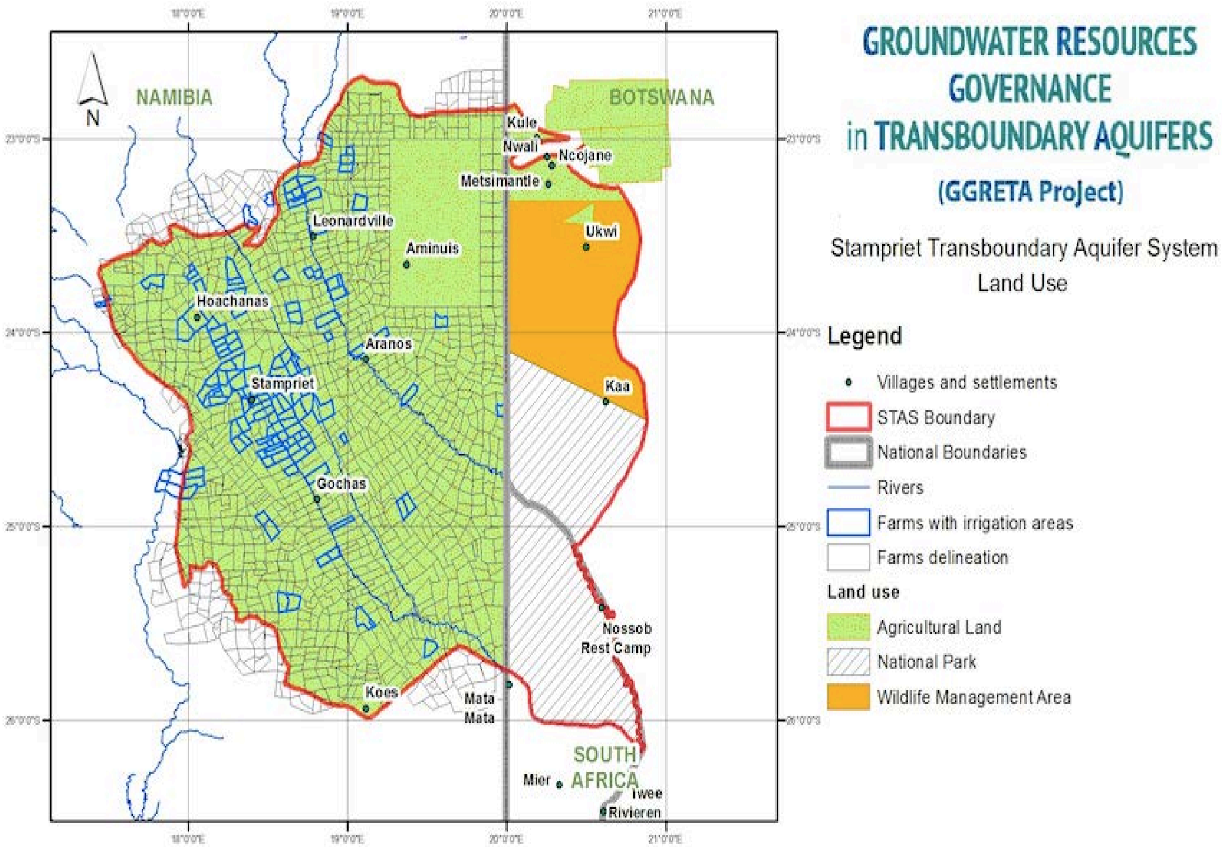
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

- **GGRETA (2013-2015):**
  - Governance of Groundwater Resources in Transboundary Aquifers
  - In-depth assessment of TBA case studies
  - Spatially differentiated information, maps



The Stampriet Transboundary Aquifer
(Botswana, Namibia, and South Africa)



Area: 86 000 km2

Rainfall: 150-300 mm/yr

Population: 50 000

Human dependency on groundwater: 100%

Increased interannual variability (more floods + more droughts)

<u>Main economic activity:</u>
Agriculture and livestock (highly climate change dependent)

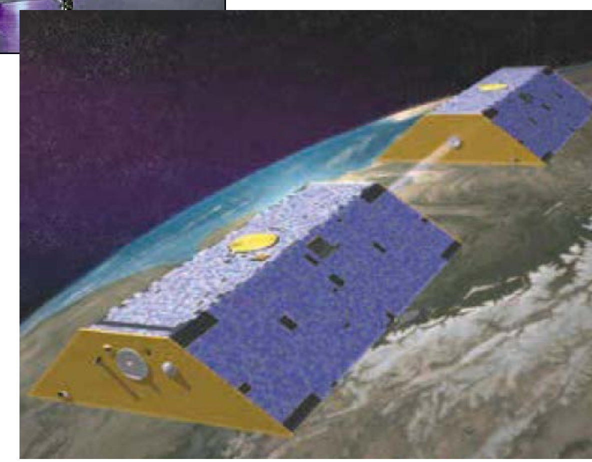
70% of abstraction occurs from shallow and highly vulnerable aquifers

Need to assess climate variability impact on shallow aquifers rehacrge

Climate Change Adaptation in the Stampriet aquifer

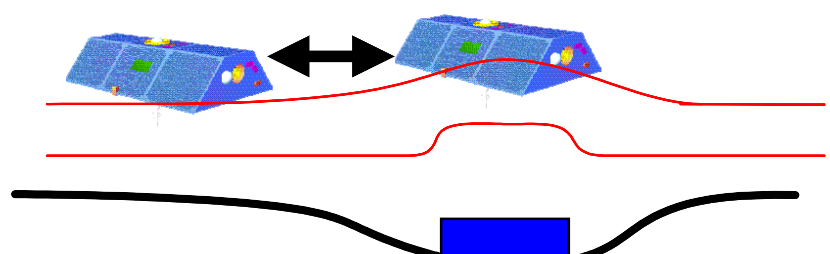
Objective:

Assess the impact of climate variability in recharge despite the lack of data to support sound management strategies



Methods:

- **Gravity Recovery and Climate Experiment (GRACE):**
  - *First satellite mission able to monitor total water-storage changes (including groundwater) remotely*
- **Global datasets for precipitation, runoff and evapotranspiration**
- **Simplified water balance models**
- **Limited water level / borehole data**



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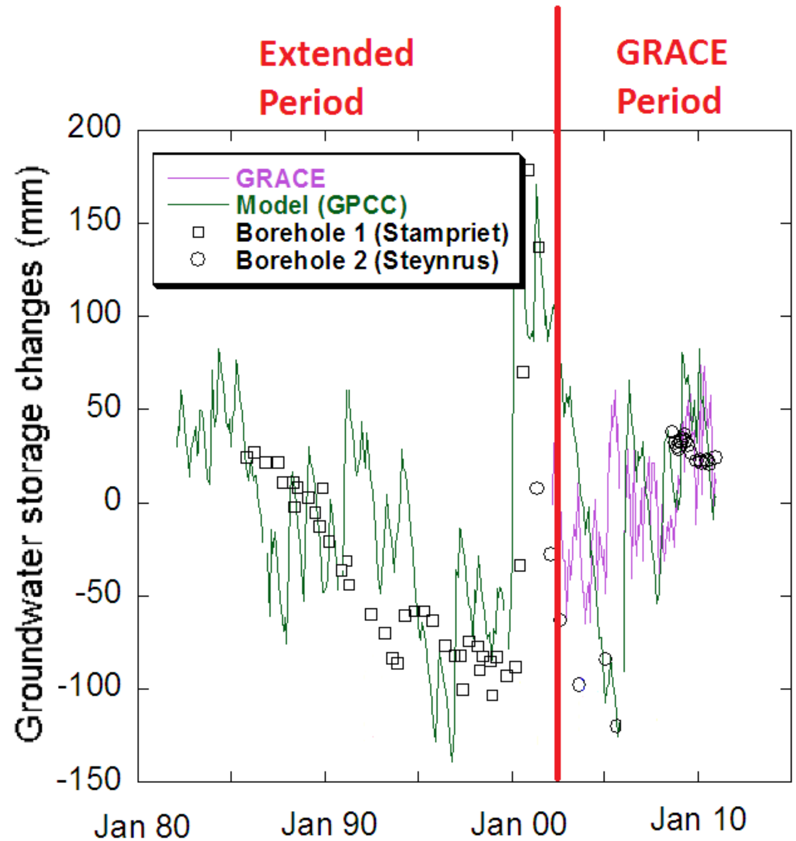
Climate Change Adaptation in the Stampriet aquifer

Challenge:

- GRACE's limited time scale (10 years)
- A better understanding on how natural climate variability (ENSO, etc…) affects precipitation and groundwater storage needs time scales > 10 years



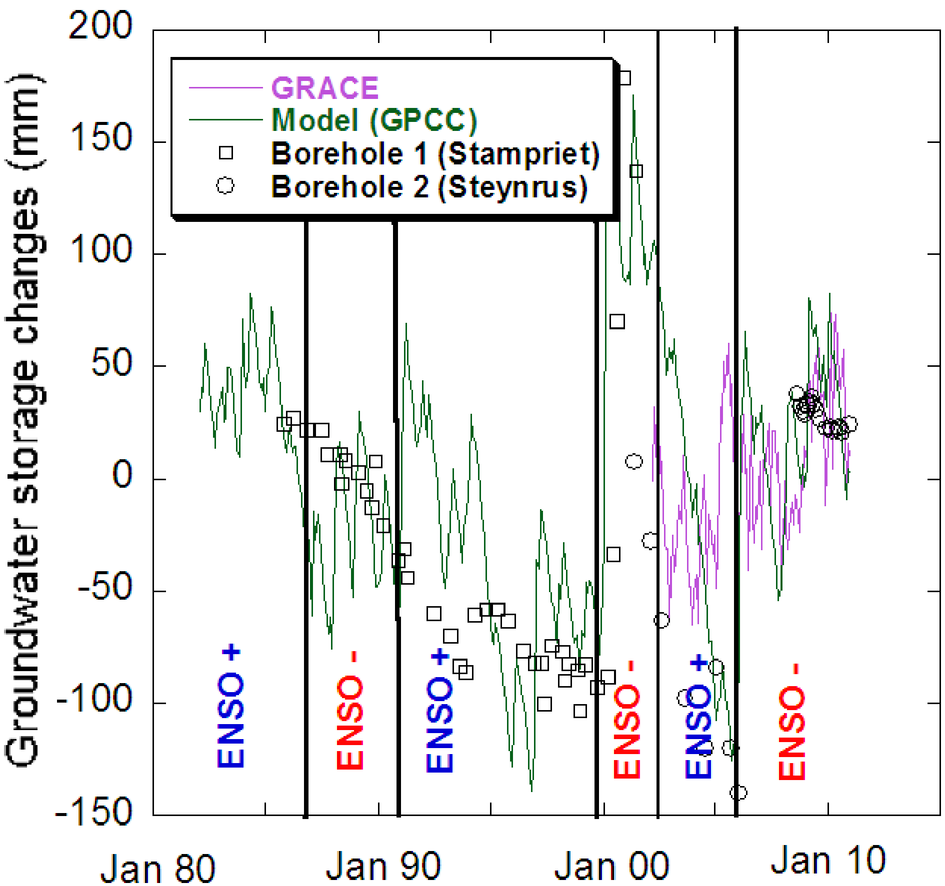
Solution:

"Extend" GRACE time frame to the past with adequate models to "reconstruct" groundwater level fluctuations

Climate Change Adaptation in the Stampriet aquifer

Main findings:

- Shallow aquifers are highly responsive to rainfall
- Strong correlation between ENSO and groundwater levels
- El Nino years (ENSO+): falling water table
- La Nina years (ENSO-): rising water table
- Need to strengthen links with metereological agencies
- Efficient CC adaptation strategies require stakeholder consultation from basin (ORASECOM) to local (farmers)
- Work will provide further guidelines for agriculture and livestock planning (especially during drought periods)



Become involved with GRAPHIC


GRAPHIC NEWS

GRAPHIC News n° 1 — January 2016

Dear GRAPHIC members,

Happy new year and best wishes for 2016!

Since its launch in 2004, the UNESCO International Hydrological Programme (IHP) GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Clima[illegible]ange) project (www.graphicnetwork.net) has provided water practitioners with [illegible] exchange information on groundwater and climate change through case stu[illegible] work[illegible] groups, scientific research, and communication.

The idea of a newsletter arise to meet [illegible] for informati[illegible] and exchange. Each quarter, GRAPHIC NEWS will give you an o[illegible] research publications, studies and projects related to groundwater [illegible] announce events that may be of interest to you.

This n[illegible] you to inform us concerning your activities, publications and projects, an[illegible] us [illegible]back about this newsletter.

Please, co[illegible]act and join us at email : t.carvalho-resende@unesco.org

THANK YOU!

Launch of GRAPHIC Position Paper at the COP21

In this edition:

- COP21 and groundwater
- Paris Pact
- GRAPHIC at COP21: Launch of the Position Paper
- GRAPHIC in the Press
- Recent publications and events by GRAPHIC members
- GRAPHIC upcoming events
- What's next?

Please sign up for our newsletter & mailing list: http://www.graphicnetwork.net/newsletter/

t.carvalho-resende@unesco.org

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