# *GroFutures:*

# Groundwater Futures in Sub-Saharan Africa:

***developing the scientific basis and participatory management processes by which groundwater resources can be used sustainably for poverty alleviation in Sub-Saharan Africa***

UCL

IDS Institute of Development Studies

Sokoine University of Agriculture

Addis Ababa University

IWMI International Water Management Institute

Université Abdou Moumouni

IRD Institut de recherche pour le développement

BGS British Geological Survey, Natural Environment Research Council

igrac

US University of Sussex

Université de Ngaoundéré

University of Maiduguri

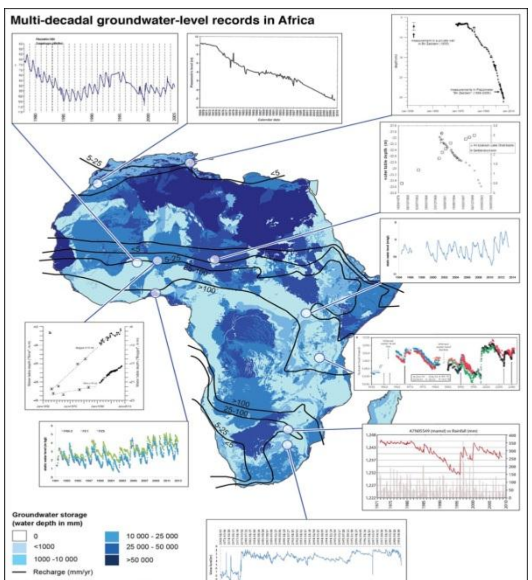
University of the Witwatersrand, Johannesburg

***UPGro Consortium Grant Kick-Off Meeting, London – 22 April 2015***

# *GroFutures – knowledge generation*

- *step change* in understanding of GW recharge & storage in SSA
- *new tools and data* to forecast available GW resources under changing climate, land-use and demand scenarios

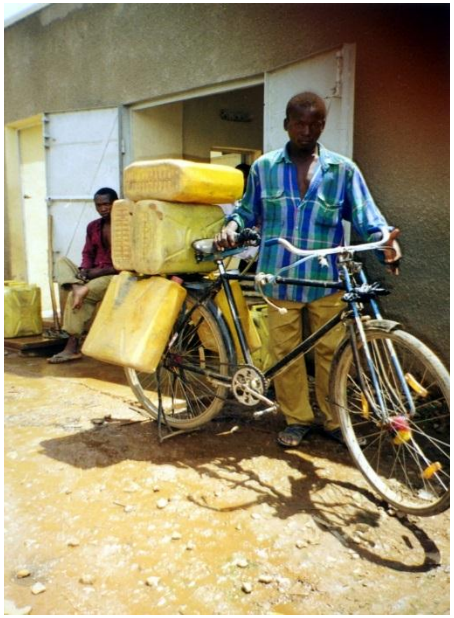
***Assess multi-decadal groundwater-level records***

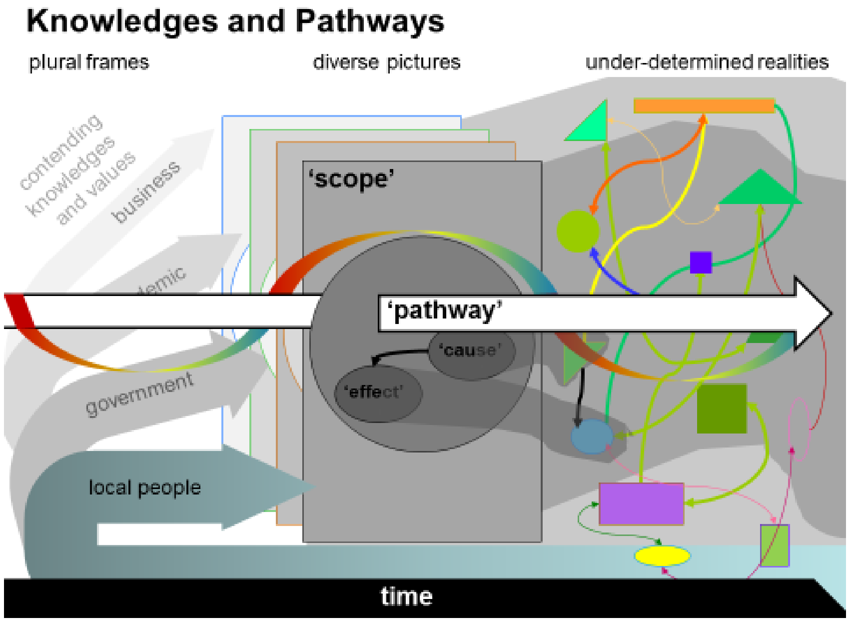



***Apply new in situ geophysical technique "MRS" (Magnetic Resonance Sounding) combined with detailed piezometry***

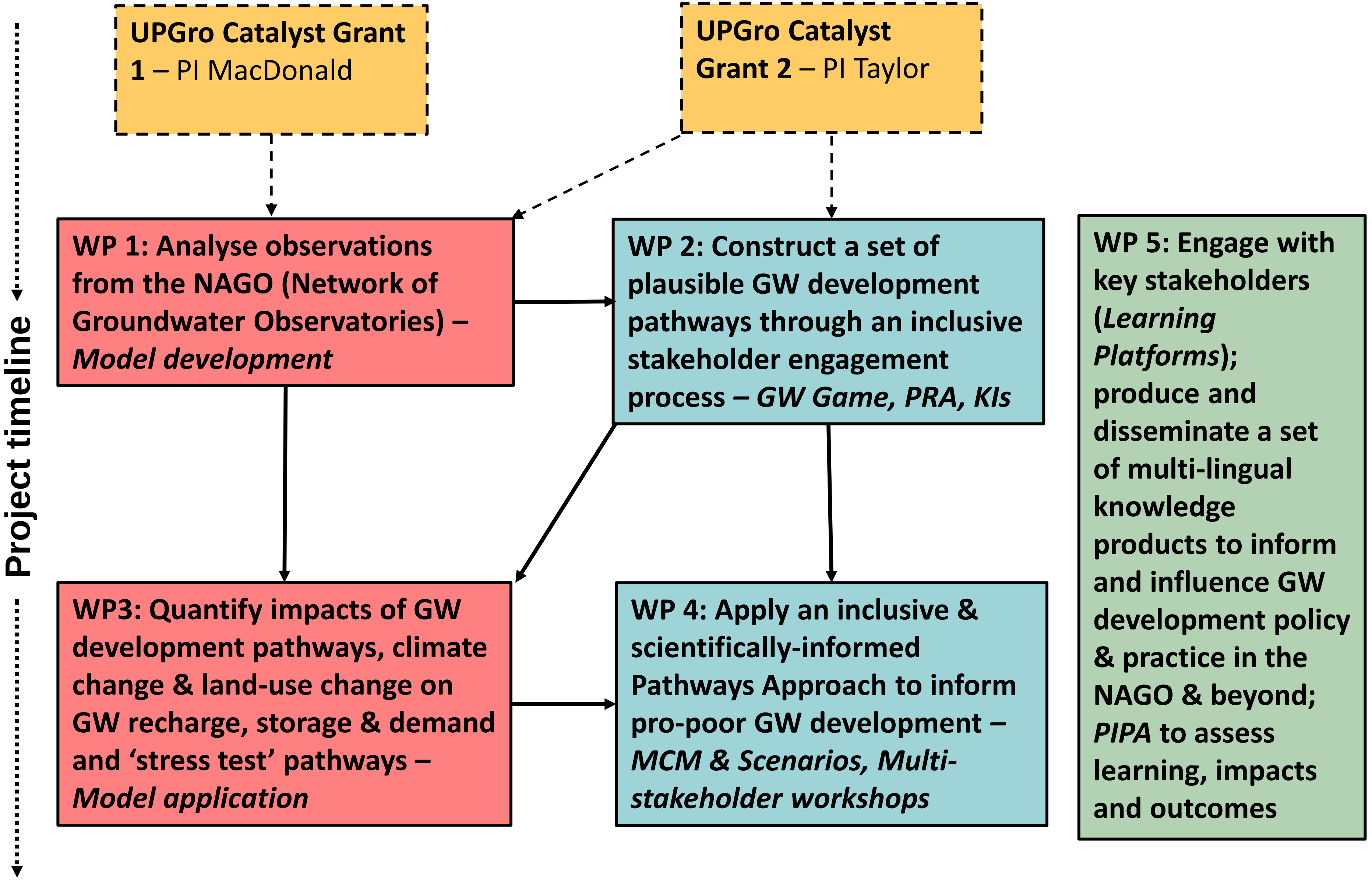
# *GroFutures – inclusive GW governance*

- *inclusive, participatory framework for GW governance* in which views of poor women and men and trade-offs associated with GW development are considered
- *novel tools and approaches for analysing GW development pathways from different stakeholder perspectives* – GW Game, Multi-Criteria Mapping, Pathways Approach…

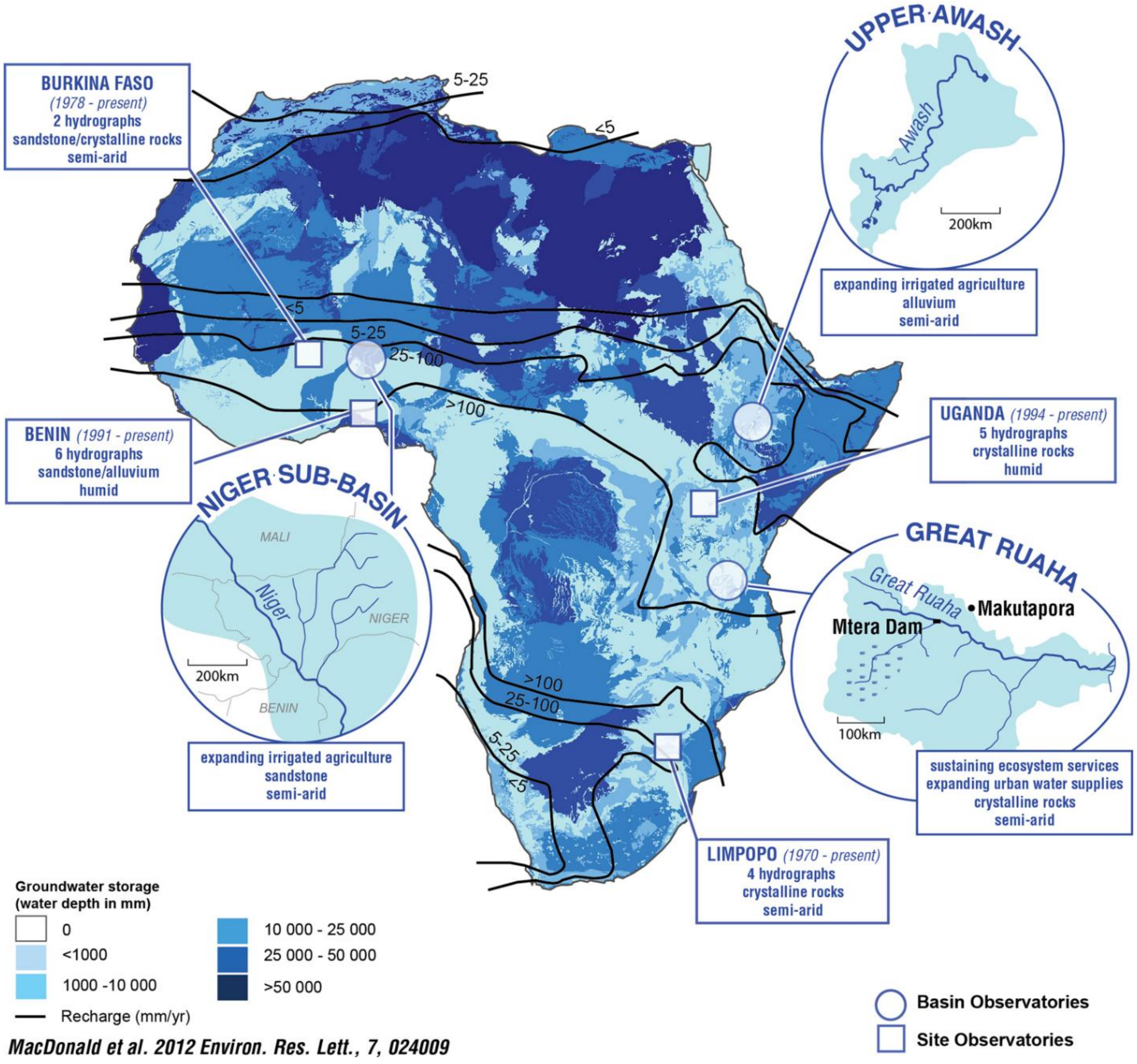


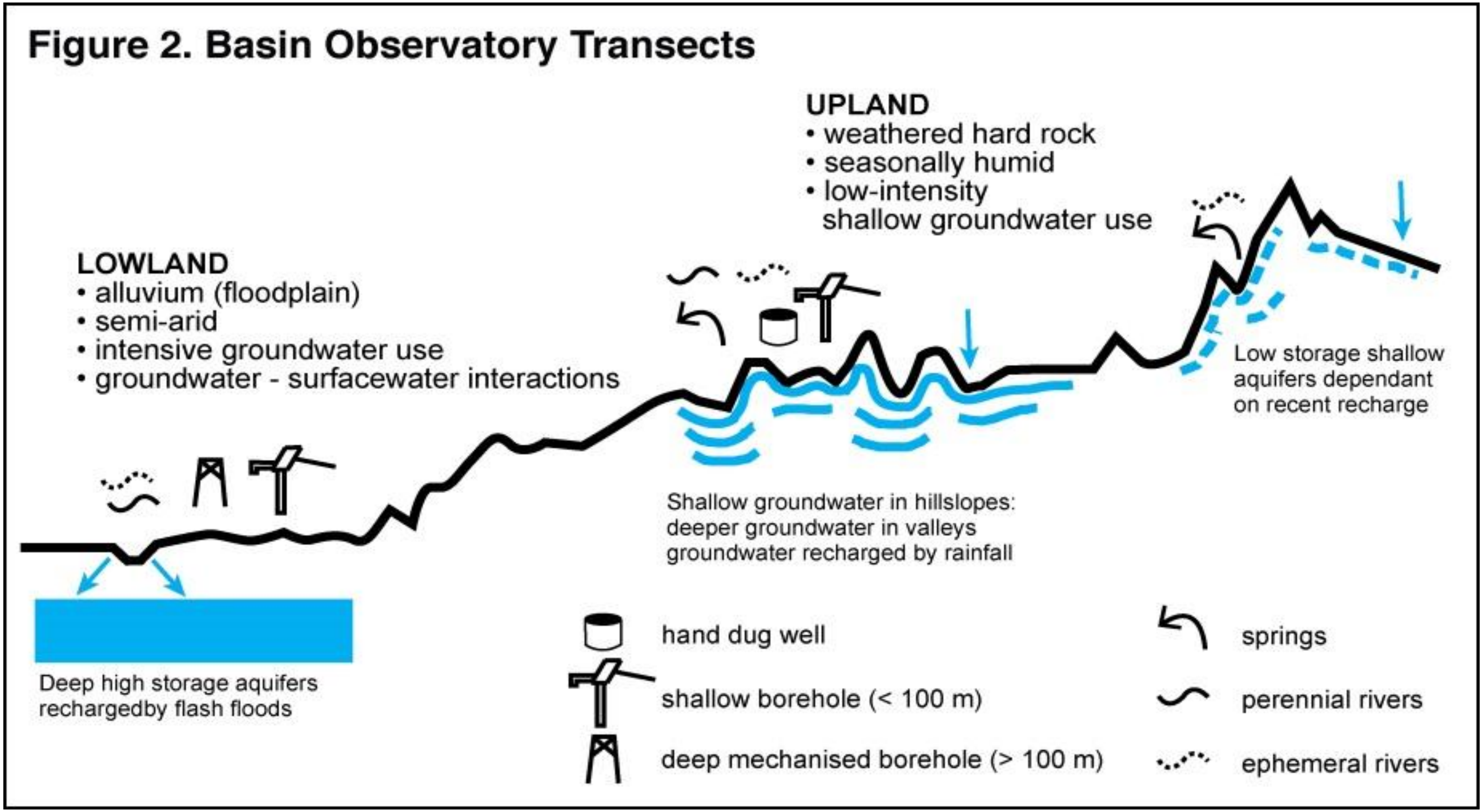



# *GroFutures* Methodology



# *GroFutures* NAGO
# Network of African Groundwater Observatories






- nested upland-lowland transects comprising different groundwater typologies within hydrologically interconnected basins
- stakeholder engagement at multiple scales from Water-User Associations to International Basin Organisations

# *GroFutures* (WP1, WP3)

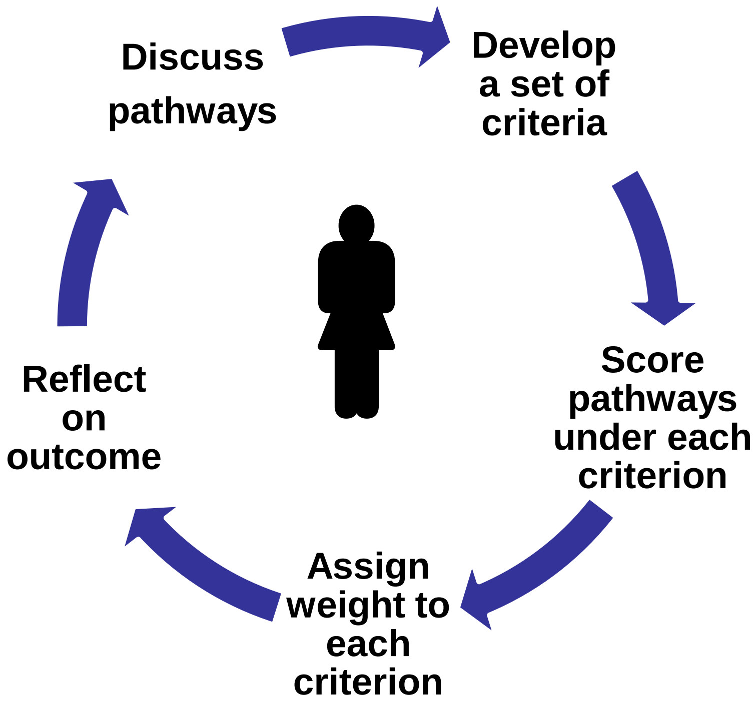
- **Develop and test rainfall-recharge-storage models** – from long-term and high-resolution NAGO data and experiments: 1D site and 2D basin-scale models
- **Synthesise ensemble climate projections to 2050** – from CMIP5 repository of IPCC AR5, bias corrected and transformed
- **Generate probabilistic ensembles of future scenarios of groundwater resources up to 2050** – Monte Carlo simulations
- **Evaluate and 'stress test' GW development pathways** – under future climate and land-use change projections

# *GroFutures* Pathways Approach (WP2 & WP4)

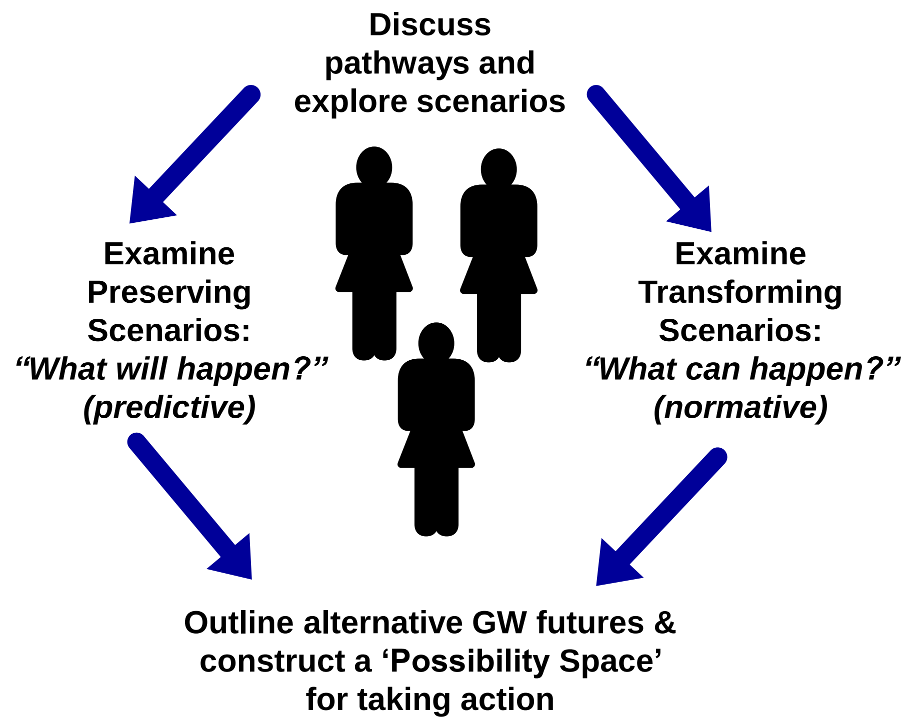
- ‘Open up’ range of GW development pathways: *bush paths/motorways*
- Evaluate viability and sustainability of identified pathways

# *GroFutures* Pathways Analysis

## Upper Awash
## Multi-Criteria Mapping




## Iullemmeden & Great Ruaha
## Scenario Analyses




- **Share MCM & Scenario findings at multi-stakeholder workshops**
- **Communicate lessons & recommendations to local communities (water users) & key decision makers**

# *GroFutures* Pathways to Impact

- ***Multi-lingual outputs and dissemination events***
- ***Learning Platforms:*** multi-stakeholder forums across NAGO where ideas on GW development pathways can be embedded in basin planning
- ***Website:*** [www.grofutures.org](http://www.grofutures.org) – access to all knowledge products, links to partners & *UPGro Knowledge Broker* website
- ***Participatory Impact Pathways Analysis (PIPA)*** – for M&E & learning

***High-impact science***

LETTERS
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nature climate change

Evidence of the dependence of groundwater resources on extreme rainfall in East Africa

Richard G. Taylor[1]*, Martin C. Todd[2], Lister Kongola[3], Louise Maurice[4], Emmanuel Nahozya[3], Hosea Sanga[3] and Alan M. MacDonald[4]

**Groundwater recharge sustains the groundwater resources on which there is global dependence for drinking water and irrigated agriculture[1]. For many communities, groundwater is the only perennial source of water. Here, we present a newly compiled 55-year record of groundwater-level observations in an aquifer of central Tanzania that reveals the highly episodic occurrence of recharge resulting from anomalously intense seasonal rainfall. Episodic recharge interrupts multiannual recessions in groundwater levels, maintaining the water security of the groundwater-dependent communities in this region. This long-term record of groundwater storage changes in the semi-arid tropics demonstrates a nonlinear relationship between rainfall and recharge wherein intense seasonal rainfall associated with the El Niño Southern Oscillation and the Indian Ocean Dipole mode of climate variability[2,3] contributes disproportionately to recharge. Analysis of the Intergovernmental Panel on Climate Change AR4 and AR5 multi-model ensembles for the twenty-first century indicates that projected increases in extreme monthly rainfall, responsible for observed recharge, are of much greater magnitude than changes to mean rainfall. Increased use of groundwater may therefore prove a potentially viable adaptation to enhanced variability in surface-water resources and soil moisture resulting from climate change[4–7]. Uncertainty in the projected behaviour of the El Niño Southern Oscillation and associated teleconnections remains, however, high[8].**

Groundwater is the world's largest accessible store of fresh water and supplies 36% of the world's drinking water and ~42% of the water used for irrigation[1]. Groundwater is the only reliable source of fresh water in many semi-arid and arid regions where surface waters are seasonally or perennially absent[9]. The long-term viability of groundwater resources as well as the ecosystems and livelihoods that they sustain, depends on replenishment of groundwater by recharge. Over the past 50 years, groundwater depletion has been estimated and observed in several aquifers throughout the tropics and sub-tropics[10–13]. Such depletion not only threatens ecosystem function and the livelihoods of groundwater-dependent communities in some of the world's poorest regions but is also estimated to contribute to sea-level rise[12,13]. A conceptual understanding of the relationship between rainfall and recharge is fundamental to the development of robust estimates and projections of not only groundwater recharge and depletion but of all components of the terrestrial water balance under changing climates and increasing freshwater demand.

Recharge results from effective precipitation (that is, precipitation minus losses from evapotranspiration) infiltrating the subsurface where hydraulic gradients are downward. Diffuse groundwater recharge occurs directly through the soil matrix in saturated soils and through soil macropores and fractures that bypass the soil matrix. Focused groundwater recharge takes place indirectly by way of leakage from runoff and surface-water sources including ephemeral streams and is often a critical source of recharge in semi-arid environments[14–16]. The magnitude of effective precipitation is highly sensitive to changes in precipitation and evapotranspiration, particularly in semi-arid environments where differences between these fluxes are small[16,17]. Soil-moisture balance modelling studies in the tropics[18–20] suggest a nonlinear relationship between rainfall and recharge in which recharge is biased to heavy rainfall events (>10 mm $d^{-1}$) that temporarily exceed high rates of prevailing evapotranspiration. A key uncertainty is whether soil infiltration capacities are able to transmit, in practice, modelled increases in recharge generated by heavy rainfall. Indeed, the relationship between precipitation and groundwater recharge remains poorly resolved in many regions owing to a lack of long-term observational data.

Here we present empirical evidence of the relationship between rainfall and groundwater recharge in semi-arid tropical East Africa from a recently compiled near-continuous, 55-year (1955–2010) record of coincidental, *in situ* groundwater-level observations (variable time step with gaps) and monthly rainfall (Fig. 1a,b). Observations derive from the Makutapora Wellfield (35° 45′ E, 5° 55′ S) in central Tanzania where groundwater is abstracted from an aquifer comprising deeply weathered granite overlain by alluvium. This unique time series, the longest observed record yet published for any location in the tropics, reveals the highly episodic nature of recharge events indicated by positive deflections in groundwater levels that result from anomalously intense rainfall during the austral summer monsoon (November–April). These recharge events interrupt multiannual recessions in groundwater levels. Rates of groundwater-level decline have increased substantially from ~0.5 m $yr^{-1}$ (1955–1979) to ~1.7 m $yr^{-1}$ since 1990. This change is a response to pronounced increases in monthly groundwater abstraction from 0.1 to 0.9 million $m^3$ to supply potable water to the national capital, Dodoma (Fig. 1c). Intensive groundwater abstraction is sustained by natural, inter-annual groundwater storage that is replenished on a decadal timescale by episodic recharge.

The observed relationship between seasonal rainfall and groundwater recharge is nonlinear (Fig. 2a) as recharge is largely restricted to anomalously intense seasonal rainfall. The cumulative recharge distribution (Fig. 2b) shows that the top 7 (11) seasons of rainfall account for 60% (75%) of the total recharge observed over 55 years from 1955 to 2010; remaining recharge is confined to seasons that

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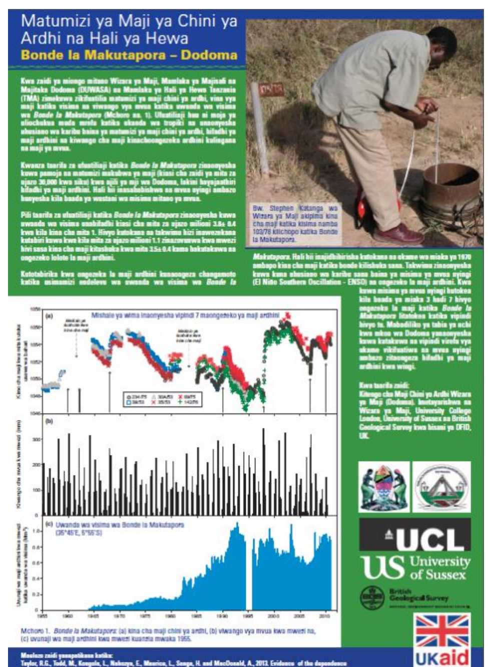
***Policy briefs***




***Radio (AgFax, RadioFrance)***

Agfax
Reporting Science in Africa

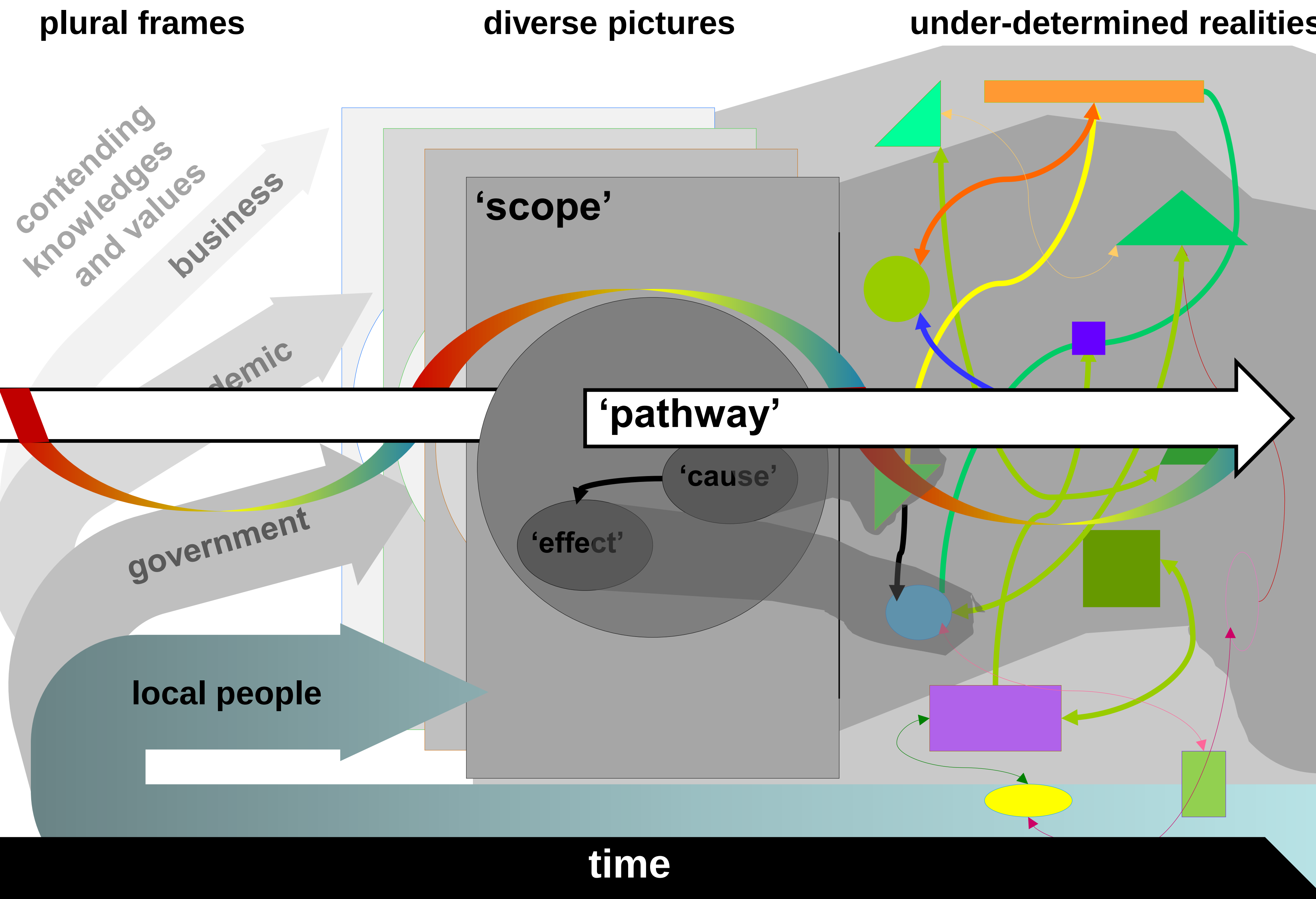
# *GroFutures* Summary

- ✓ Create a *pan-African Consortium* of GW experts with strong national and regional partnerships
- ✓ Establish a *Network of African Groundwater Observatories (NAGO)*
- ✓ Produce an extensive collection of *long-term datasets* and field observations on GW recharge & demand
- ✓ Assess and extend an *integrated set of GW modelling tools*
- ✓ Integrate and apply an *suite of social science tools* (*e.g.* GW Game, MCM, Learning Platforms)
- ✓ Link natural science with a *Pathways Approach* to analyse, inform and improve pro-poor GW development processes

# *GroFutures*

# Additional Slides for Reference

# Knowledges and Pathways



# Knowledges and Pathways

## CONTEXTS

**interacting processes**
**agencies and structures**
**social and material**
**subjects and objects!**

discourses

practices

imaginations

values

**'pathway'**

intentions
physical world

institutions

interests

technologies

ecologies

power relations

expectations

**a self-reinforcing**
**trajectory of change**
**(social, technological,**

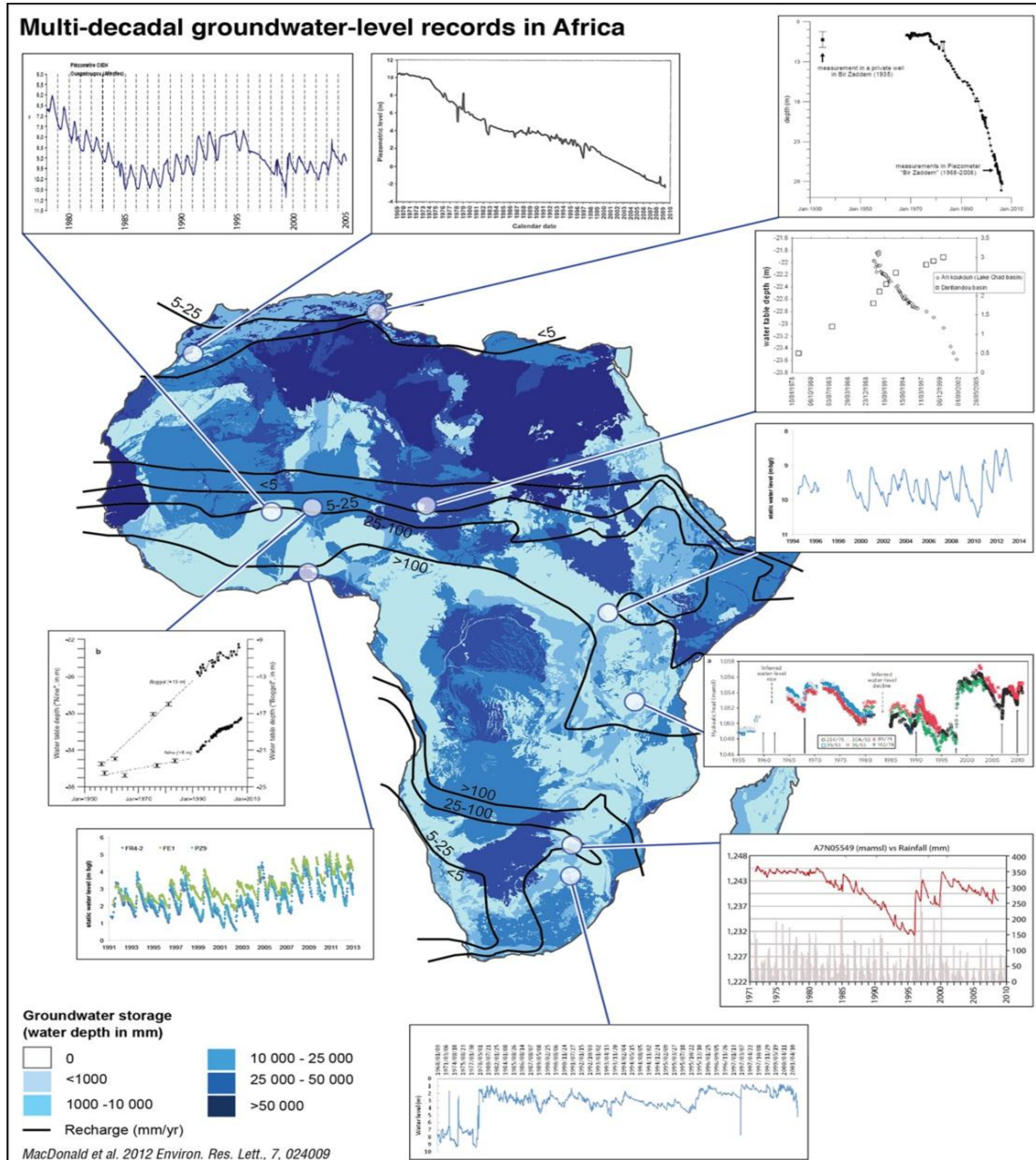
**time**

# GroFutures

Site Observatories established as:

***'The Chronicles Consortium'***

***www.un-igrac.org***



# *GroFutures* NAGO

Figure 2. Basin Observatory Transects

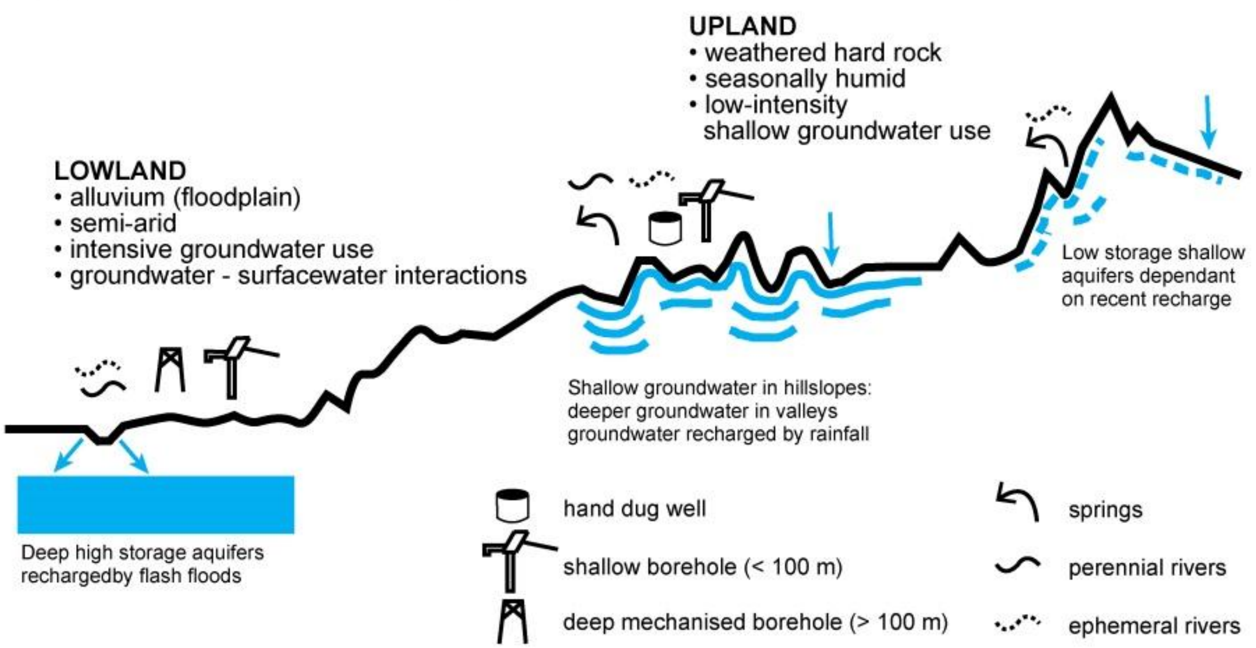



Figure 3. NAGO Basin Observatories