***IWMI - ACIAR** Investing in Water Management to Improve Productivity of Rice-Based Farming Systems in Cambodia Project*. **Issue brief #3, June 2013**

Groundwater for Irrigation in Cambodia

IWMI is a member of the CGIAR Consortium and leads the: CGIAR Research Program on Water, Land and Ecosystems

International Water Management Institute

Australian Government
Australian Centre for International Agricultural Research

Groundwater for irrigation in Cambodia

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This issue brief is based on a review conducted by the International Water Management Institute (IWMI) on behalf of the Australian Centre for International Agricultural Research (ACIAR). The paper has been supplemented by discussions at a public workshop in Phnom Penh on 19 March 2013. IWMI gratefully acknowledges the input of workshop participants.

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There has been an increase in the use of shallow groundwater for agriculture in some areas of Cambodia over the past 15 years. However, uptake has been relatively limited compared to the rapid expansion of groundwater irrigation in much of the rest of Asia. Is groundwater an opportunity for Cambodia to "leap-frog" directly to an efficient model of small-scale irrigation, bypassing the need for the expensive infrastructure of formal surface-water irrigation with its attendant problems of operation and maintenance? Or is it inherently unsustainable, suitable only for limited applications?

Introduction

Groundwater is widely used for domestic water supply in Cambodia, and is increasingly being used for small-scale irrigation. In other parts of Asia, particularly India, Pakistan, and China, there has been a rapid expansion of individualistic groundwater irrigation, supplementing or even replacing large scale public systems and providing a significant boost to agricultural economies (Shah 2008, Mukherji et al 2011). In India, over 60% of irrigation now comes from groundwater.

Small-scale pump irrigation from groundwater can circumvent the large investments in storage and transmission infrastructure required for surface water irrigation. It can also provide farmers with water in a timely and reliable manner and give them direct control over water access. In some areas, however, problems such as groundwater depletion, deterioration of water quality, and high energy costs call into question the long-term sustainability of such an informal irrigation economy.

Is groundwater an opportunity for Cambodia to "leap-frog" directly to an efficient model of small-scale irrigation, bypassing the need for the expensive infrastructure of formal surface-water irrigation with its attendant problems of operation and maintenance? Or is it inherently unsustainable, suitable only for limited applications? In order to answer these questions, it is necessary to have a thorough understanding of the nature, extent, and sustainability of the groundwater resource.

Groundwater use in Cambodia

Groundwater for irrigation

Groundwater, along with surface water, has been used for irrigation and domestic purposes in Cambodia since ancient times (Phalla and Paradis, 2011). Shallow alluvial aquifers in the Mekong lowlands enable farmers to install shallow dug and tube wells to produce dry season crops. Areas where groundwater irrigation is known to take place include Siem Reap, Battambang, and Kampong Chhnang in the Tonle Sap region; Kampong Cham province in the Phnom Penh region; and Prey Veng, Svay Rieng, Takeo, and Kandal in the south (Pavelic, 2011). In Prey Veng, the number of tube wells used for irrigation grew from 1600 in 1996 (Briese 1996) to 25,000 by 2005 (iDE 2005). In 2012, Thuon (this study) reported one commune in Prey Veng where over 90% of farmers had installed tube wells.

Groundwater is used mainly to provide partial irrigation for either an early or late wet season crop grown in addition to the traditional wet season rice crop. It is also widely used for supplementary irrigation of the wet season rice crop and late-season recession rice. Access to groundwater is an important factor in increasing adoption of double cropping (Phaloeun et al 2004; Thuon, this study). Mechanized and treadle pumps are used for irrigation, rather than hand pumps (iDE 2005). Farmers usually develop their own wells, although there are reports of farmers buying water from a neighbor's tube well (Thuon, this study).

Groundwater for domestic supply

Around half (53%) of households access groundwater for domestic use in the dry season from shallow tube-wells or hand-dug wells. It is estimated that more than 270,000 tube-wells are currently in use for drinking water (Sok undated). Tube wells are commonly used with simple suction hand pumps, which can draw water from a maximum depth of around 6m. If the water table is below 6m, more expensive positive displacement or mechanized pumps capable of pumping from deeper levels are required (iDE 2009). A survey of groundwater use in Prey Veng and Svay Rieng found that 91% of almost 145,000 tube wells for domestic use were operated by hand pump (iDE 2005). Groundwater is also used for urban supplies in larger towns, using mechanized pumping to access deeper aquifers with higher yields. Industrial use is increasing, particularly in Phnom Penh and the surrounding areas where many industries drill their own wells (MOWRAM / CNMC 2003a).

Groundwater for ecosystems

Aquifers store water during the wet season and release it during the dry season to provide base flow for rivers, streams, and wetlands, thus providing an essential component of environmental flows (RAMSAR 2005). Floodplains are hydrologically complex, with a high degree of connectivity between surface and ground water systems. Over-extraction of groundwater can reduce dry season discharge and, if water levels drop significantly, surface water bodies may lose water to the aquifer system rather than gaining from it (IUCN 2011).

Hydrogeology of Cambodia

The Mekong lowland consists of thick alluvial deposits overlying shale, slate, and sandstone bedrock, featuring low hills and plateaus consisting of basalt, other igneous rocks, or limestone. The alluvial deposits are a complex pile of unconsolidated to semi-consolidated alluvial sediments, ranging in depth from a few meters to more than 160m along the rivers in the south. In Vietnam, eight major depositional sequences are distinguished on the basis of age from Miocene to the present (Landon 2012), hosting five main aquifers (IUCN 2011). However, in Cambodia, a simpler division is made: young alluvium (Holocene river and floodplain deposits) and old alluvium (Pleistocene to Miocene terrace and platform deposits).

In general, young alluvium is finer grained (clays and silts) and is a poor aquifer, although it can yield good ground water when it lenses with sand. Old alluvium comprises a thick pile of coarser textured sediments with high yielding aquifers and generally good quality water, although both yield and quality vary depending on location. Both confined and unconfined systems occur. Confined aquifers are pressurized and usually sub-artesian (do not flow naturally to the surface when tapped), so water levels are often only 1-5 m from the surface (JICA 2002, iDE 2009, Roberts 1998), although artesian groundwaters (which flow naturally to the surface when tapped) have been reported in Siem Reap and Kampong Thom provinces (Landon 2012).

Tertiary basalts (in eastern and central Cambodia) and Permian karsts (in Battambang and Kampot) may also have potential for significant irrigation. Groundwater irrigation in similar basalt terrains has supported the development of important coffee growing areas in the Central Highlands of Vietnam and the Bolavens Plateau in Lao PDR.

Water availability and sustainability

Groundwater is available in most areas of the lowland plains of Cambodia, but its sustainability as a resource is unclear, as are the number of aquifers able to provide flows adequate for agricultural purposes (Sok undated). The average (internal) recharge for Cambodia is estimated by FAO to be 17.6 km3/yr in volumetric terms or 97.2 mm/yr in effective terms. This represents just 5% of the country's average rainfall and probably underestimates the actual figure since all forms of surface water and groundwater exchange are not accounted for. The actual figure is typically around 10% of rainfall, compared to an estimated 9% for Thailand (AQUASTAT 2013).

JICA (2002) estimated that wells in the quaternary aquifers (mainly Old Alluvium) of Svay Rieng, Prey Veng, and southern Kandal provinces could yield 500 to 800 m^3 per day, sufficient to irrigate four to five hectares of rice per well. Roberts (1998) reports similar average pumping rates of 500 – 600 m3/day in Svay Rieng and Prey Veng. Yields from the Young Alluvium and the basement aquifers were much lower, generally making them unsuitable for irrigation (1.5 - 150 m3/day) (JICA 2002).

Sustainability of supply depends on the balance between recharge and withdrawals. There is a large range in estimates of recharge to the alluvial aquifers in Cambodia, from 3-15 mm/year (iDE 2009) to hundreds or even thousands of mm/year (JICA 2002, Kazama etal 2007). This range reflects the difficulty in deriving accurate estimates due to the spatial and temporal variability in recharge. Furthermore, there is a great deal of uncertainty about the relative importance of different recharge mechanisms, including direct recharge from rainfall and floodwater, indirect infiltration from distant recharge zones in the hills, and recharge from the main rivers. iDE (2009) argues that the young alluvium acts as an impermeable blanket preventing direct recharge of the old alluvium from the annual flood and that recharge from the Mekong River is mainly in the immediate vicinity of the river channel (see Figure 1, Page 7). Groundwater levels are observed to rise and fall with river level for a distance of up to 30 km from the river (Rickman and Sinath 2004).

Understanding recharge rates and processes is critical to determining the sustainability of the resource. If surface and ground waters are highly connected, with groundwater replenishment happening through yearly flooding, the system may be sustainable over the long term, even if groundwater is annually pumped out at local scales. However, seasonal drawdown jeopardizes water supply for crops; in Prey Veng, farmers complain that wells dry out at the end of the dry season (Try this study). Drawdown can compromise village water supplies, particularly if water levels drop more than 6m below ground surface level (the depth at which hand pumps are no longer useful). If extraction exceeds recharge, then long term declines in water level occur, with gradual increase in pumping costs and eventual system failure. iDE (2009) observed average water level declines of 14cm/year based on monthly water-level measurement in 49 wells in Prey Veng and Svey Rieng during 1996-2008, suggesting that over pumping may already be a problem in the area (Figure 2, Page 8). Declining groundwater levels have also been reported in Siem Reap (Landon 2012). While such trends can result from natural variation and are not necessarily evidence of man-made trends, promoting extensive groundwater use before the resource is better defined is not recommended.

In other parts of the world, managed aquifer recharge (MAR) is being promoted as a way to enhance groundwater storage and prevent long-term decline of groundwater levels. A range of approaches can be used: 'conjunctive' management of reservoir and canal seepage and return flows; flood spreading, check dams, and flood pits to increase infiltration to shallow aquifers; and injection of water into aquifers through boreholes (IWMI 2010).

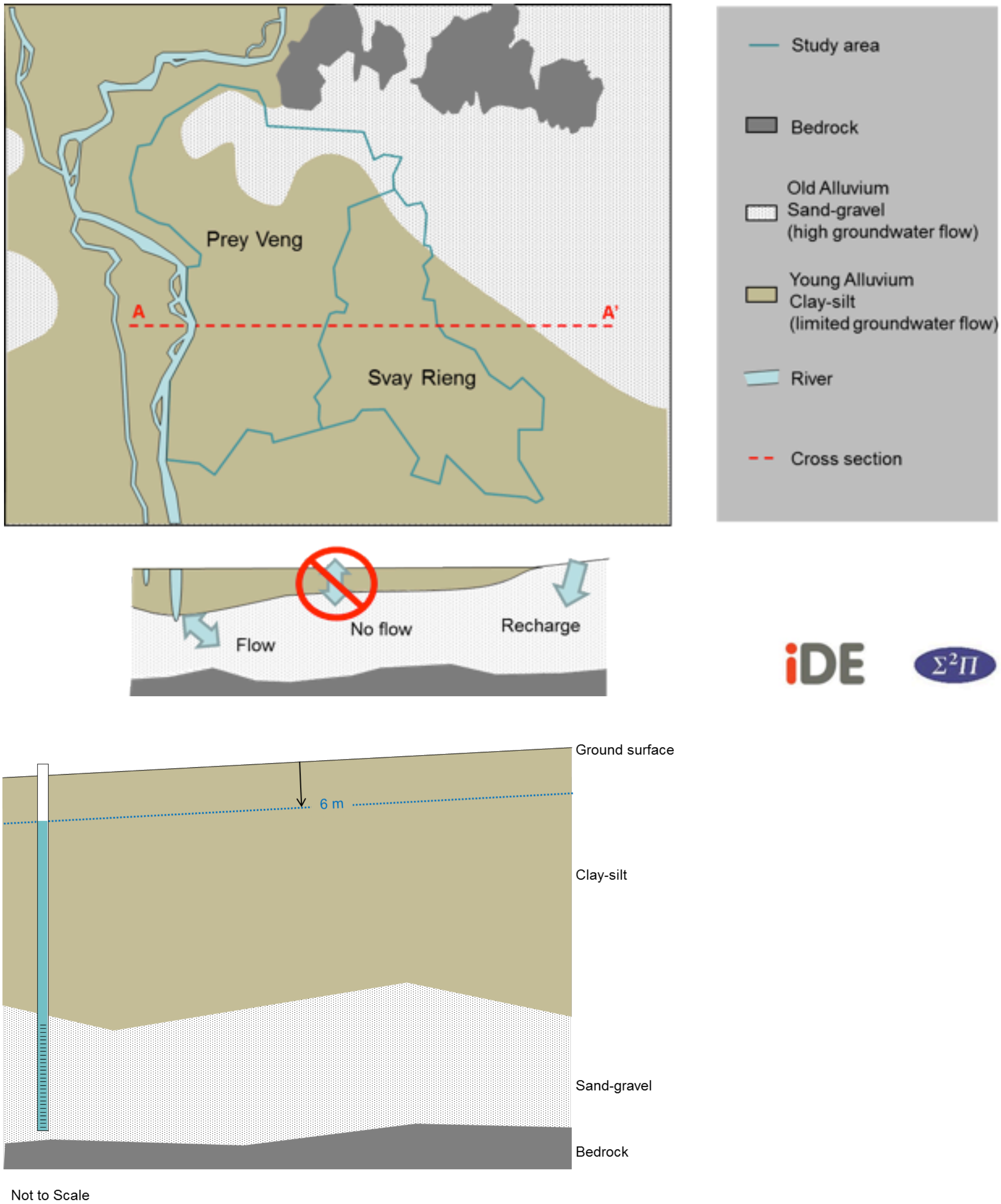

Figure 1: Schematic diagram of aquifers and groundwater recharge processes in Southern Cambodia. The Young Alluvium (with limited groundwater flow) acts as a confining layer, pressurizing groundwater in the productive Old Alluvium and restricting overland recharge. Diagram courtesy of Dr Mike Roberts, iDE

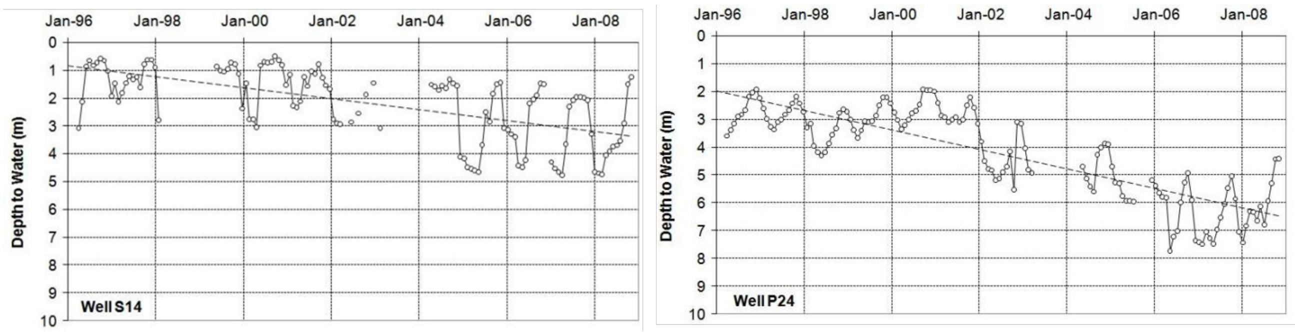

Figure 2: Groundwater levels in typical wells from Prey Veng and Svay Rieng 1996 – 2008, showing evidence of an overall decline in levels during 1996 – 2008.

Diagram courtesy of Dr Mike Roberts, iDE. http://bit.ly/12cG5lr

Water quality

Groundwater in Cambodia is generally of good quality and suitable for irrigation use. However, high levels of arsenic, iron, manganese, fluoride, and total dissolved solids (salinity) are observed in some areas, and many shallow wells are contaminated by fecal coliforms (JICA 2002, MRD 2004). Over 15% of wells tested nationally had arsenic above the provisional national limit of 50ug/l (MRD 2004)[1]. Irrigating with arsenic-contaminated water can result in elevated arsenic in rice and other crops (Santra and Samal 2013; FAO 2006). There is a strong geological control on arsenic levels: wells with high arsenic concentrations are almost always restricted to Holocene alluvium close to the main rivers, and maps have been produced of arsenic risk (Fredericks et al 2004). There are anecdotal reports that use of groundwater has reduced crop yields in some localities, and in extreme cases has harmed soil chemistry and structure, although data on groundwater quality does not suggest that this is likely to be a significant problem (MOWRAM/CNMC 2003).

Limitations and opportunities

Discussions at the IWMI/ACIAR workshop explored the question of why groundwater use for agriculture is limited, except in the southeast. A variety of possible reasons was put forward: pumping costs are limiting, particularly in areas where viable aquifers are deeper; returns are too low to justify drilling wells in locations with poor soil quality; the extent of the resource is not well known; and MOWRAM have not encouraged use of groundwater due to concerns about sustainability, except in areas where other sources are not available. However, there was a general consensus that in many cases, the reason groundwater is not being used is simply because the resource is not viable and that, if it was, it would be exploited.

This raised the question: under what conditions would groundwater be viable? An important consideration is how groundwater would be used. Possibilities include: supplementing surface water through conjunctive use to extend the cropping period at the beginning and end of the wet season, rather than as an alternative supply; insuring against drought during the wet season; and providing flexible, farmer-controlled access to water for high value crops such as vegetables. Given the widespread use of hand pumps, which can only draw from shallow levels, potential conflicts between agricultural and domestic use must also be considered.

[1] WHO limit for As in drinking water is 10ug/l

Conclusions

Since groundwater is widely used for domestic purposes, with more than 270,000 extant shallow wells, well-drillers operating in the provinces are likely to have a significant body of knowledge about the distribution, accessibility, and quality of shallow groundwater resources. iDE and ADB have both drawn on local knowledge of well-drillers in planning their programs. They suggest that a systematic national survey of well-drillers, supplemented by existing geological studies and well databases (held by MRD and Ministry of Health/UNICEF), would provide valuable insight into the viability of groundwater resources in different regions. The monitoring data collected in Prey Veng and Svay Rieng for 49 wells by iDE and MOWRAM between 1996 and 2008 provide a unique opportunity to assess the long-term impacts of groundwater use in the alluvial aquifers. Collection of even 1-2 years of additional data would confirm or deny long-term drawdown in this system.

This information, combined with an analysis of current patterns of irrigation demand, could provide the basis for identifying priority areas for groundwater development. In this process, it would be important to take into account the sustainability of withdrawals, as well as target specific uses and sectors, to ensure that the greatest value is derived from the resource.

What has already been done?

- On-going geologic mapping in Cambodia by the Cambodia Ministry of Industry, Mines, and Energy (MIME)
- Compilation of a well database with >60,000 records by Ministry of Rural Development (MRD) www.cambodiawellmap.com
- Groundwater study in 7 provinces (MRD – Sok undated)
- National hydrogeological reconnaissance study by USGS (Rasmussen and Bradford 1977), including 1100 test wells
- Detailed studies in Prey Veng and Svay Rieng (iDE 2009, Roberts 1998), including monitoring of 49 wells for 14 years up to 2008, and development of groundwater flow model (MODFLOW)
- Detailed study of hydrology in southern Cambodia (JICA 2002), including monitoring of 26 wells for 1 year
- Detailed study of hydrology in Kampong Cham and Kampong Chhnang (JICA/CMRD 2002), including monitoring of 55 test wells
- Groundwater flow models of southern and central Cambodia, largely based on data from the JICA/CMRD (2002a; 2002b) (Raksmey et al 2010)
- Extensive studies of arsenic in groundwater by UNICEF and others (see for example Polizzotto et al 2008; MRD 2004)
    - Arsenic database (UNICEF / MRD / Ministry of Health)
- Ongoing MRC initiatives:
    - Rapid appraisal of agricultural water use, including safe yield map using MODFLOW (MRC 2012)
    - USGS – comprehensive groundwater monitoring program proposed for LMB (Landon 2011)

Questions for further research

Resource assessment

- Where is there greatest potential for groundwater development?
- What are the sustainable limits to extraction from the major known aquifers? What are the main recharge processes for each aquifer, and how do they operate spatially?
- What are the interactions between groundwater and surface water systems, particularly in the floodplain? How does groundwater serve the environment/ecosystems?
- Could managed aquifer recharge enhance supply, particularly for seasonal groundwater shortfalls?
- Where are water quality issues (natural or anthropogenic) likely to limit groundwater irrigation? Can these be mitigated or managed?

Resource use and management

- Why has groundwater use for agriculture flourished in some areas and not others – is it simply about the resource, or is it about access to inputs, land tenure arrangements, credit, costs of drilling, and access to markets?
- How has the existing level of groundwater use impacted poverty and the environment?
- How do patterns of surface water use affect groundwater demand (and recharge)?
- What are the opportunities for conjunctive use? Can 'infilling' with groundwater within large irrigation systems overcome head-tail inequalities?
- What are the key challenges for management of groundwater use? What institutional arrangements are needed to support sustainable groundwater use?

Acknowledgements

We gratefully acknowledge the input of Dr. Mike Roberts and iDE Cambodia to this discussion and paper, including diagrams in Figures 1 and 2.

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