# Development of Groundwater Management Strategy in Cambodia:

***Institutional Assessment, Capacity Building Plan and Proposed Key Components of Ground Water Management in Cambodia***

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**Department of Water Supply and Sanitation, Ministry of Water Resources and Meteorology**
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**Strengthening Climate Information and Early Warning Systems to Support Climate-Resilient Development in Cambodia**

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## *Institutional Assessment, Capacity Building Plan and Proposed Key Components of Groundwater Management in Cambodia*

**Author: Dr. Chantha Oeurng,** ***Consultant***

**Technical Advisor:**
**Muhibuddin Usamah,** ***EWS Project Manager, UNDP Cambodia***
**Sem Samnang,** ***Department of Water Supply and Sanitation, Ministry of Water Resources and Meteorology***

**Edited by:**
**Muhibuddin Usamah,** ***EWS Project Manager, UNDP Cambodia***
**Kelsea Clingeleffer,** ***Monitoring and Evaluation Consultant, UNDP Cambodia***
**Sem Samnang,** ***Department of Water Supply and Sanitation, Ministry of Water Resources and Meteorology***
**Raksa Pen,** ***Department of Water Supply and Sanitation, Ministry of Water Resources and Meteorology***

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## List of Abbreviations

| | |
|---|---|
| ADB | Asian Development Bank |
| BDS | Basin Development Strategy |
| CCCSP | Cambodia Climate Change Strategic Plan |
| CCDM | Commune Committee for Disaster Management |
| CDRI | Cambodia Development Resource Institute |
| CIAP | Cambodia-IRRI-Australia Project |
| CNMC | Comisión Nacional de los Mercados y la Competencia |
| CNMC | Cambodian National Mekong Committee |
| CRC | Cambodia Red Cross |
| D&D | Decentralization and Deconcentration |
| DCDM | District Committee for Disaster Management |
| DNR | Department of Natural Resources |
| DPWS | Department of Potable Water Supply |
| DRWS | Department of Rural Water Supply |
| DWSS | Department of Water Supply and Sanitation |
| EIA | Environmental Impacts Assessment |
| EMP | Environmental Management Planning |
| EWS | Early Warning Systems |
| FA | Forestry Administration |
| FAO | Food and Agriculture Organization of the United Nations |
| FiA | Fishery Administration |
| GDANCP | General Department of Administration for Nature Conservation |
| IDE | International Development Enterprises |
| IEC | Information Education and Communication |
| ITC | Institute of Technology of Cambodia |
| IUCN | International Union for the Conservation of Nature |
| IWMI | International Water Management Institute |
| IWRM | Integrated Water Resource Management |
| JICA | Japan International Cooperation Agency |
| KII | Key Informant Interview |
| LMB | Lower Mekong Basin |
| LU/LC | Land Use/Land Cover |
| M&E | Monitoring and Evaluation |
| MAFF | Ministry of Agriculture, Forestry and Fisheries |
| MEF | Ministry of Economy and Finance |
| MIH | Ministry of Industry and Handicrafts |
| MIME | Ministry of Industry, Mines and Energy |
| MLMUPC | Ministry of Land Management, Urban Planning and Construction |
| MoE | Ministry of Environment |
| MoH | Ministry of Health |
| MoME | Ministry of Mines and Energy |
| MoWRAM | Ministry of Water Resources and Meteorology |
| MPWT | Ministry of Public Works and Transport |
| MRC | Mekong River Commission |
| MRD | Ministry of Rural Development |

| | |
|---|---|
| MRS | Magnetic Resonance Sounding |
| NCDM | National Committee for Disaster Management |
| NIS | National Institute of Statistics |
| NSDP | National Strategic Development Plan |
| O&M | Operation and Maintenance |
| ODC | Open Development Cambodia |
| PCDM | Provincial Committee for Disaster Management |
| PDoWRAM | Provincial Department of Water Resources and Meteorology |
| PDRD | Provincial Department of Rural Development |
| QA | Quality Assurance |
| QC | Quality Control |
| RDIC | Resource and Development International Cambodia |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation |
| RGC | Royal Government of Cambodia |
| RWSSH | Rural Water Supply, Sanitation and Hygiene |
| SAW | Strategy on Agriculture and Water |
| UNCDF | United Nations Capital Development Fund |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UN-REDD | United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation |
| USAID | United States Agency for International Development |
| VDMG | Village Disaster Management Group |
| WB | World Bank |
| WEPA | Water Environment Partnership in Asia |
| WHO | World Health Organization |

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# Desk Study on Groundwater Situational Analysis in Cambodia

## 1. General Information Related to Groundwater in Cambodia

Water in Cambodia is mostly associated with the Mekong River, Tonle Sap system and the annual flooding process; as a result, surface water is widely perceived as the sole water resource (MOWRAM, 2014). However, groundwater is an important resource across the country and is used particularly for rural drinking water supply, urban water supply, water for industry (in urban areas), and irrigation purposes.

Cambodia relies heavily on its groundwater resources to overcome water shortages during the dry season. At a certain depth, the ground is saturated with water, and the upper surface of this saturated zone is called the water table. An aquifer is the water below the water table. Water is contained in porous rocks and sediments and may flow depending on rock porosity. Groundwater refers to all the water below the water table, or the sum of aquifers (USGS, 2016).

The current status of groundwater in Cambodia should be discussed in order to fully understand the level of water security and resources available in the country (UNESCO, 2015). Cambodia is considered one of the most water-abundant countries in the region and has an economy highly dependent on water. Rivers, streams, lakes, aquifers and marine water are important sources for national economic development in many sectors such as agriculture, manufacturing and small-scale industries, hydropower, navigation, tourism, environmental protection, as well as in daily life (UNESCO, 2015). The maximum quantity of annual water consumption is estimated to be 750 million $m^3$ (10% of the country's total available water), of which 95% (710 million $m^3$) in used for irrigated agriculture (UNESCO, 2015). No reliable data exist regarding water quantity used for other purposes. The importance of water for food production, rural livelihoods and economic development is recognized in the Government's *Rectangular Strategy on Growth, Employment, Equity and Efficiency* (2018), the *National Strategic Development Plan* update (2009-2013), and *Strategy on Agriculture and Water* (SAW 2009-2013).

Groundwater is available almost everywhere in the plains area, except for the dry zone in the central and north-western regions. Cambodia has a total of 61,707 wells recorded in WellMap (see https://cambodiawellmap.com). The data associated with these can be used to provide an understanding of groundwater resources across the country. However, extracting information from these sources has not been undertaken, meaning that a clear evaluation of Cambodia's groundwater resources is not available. It is recognized that most untreated surface water in Cambodia is potentially contaminated (Ben, 2016); groundwater is generally less contaminated and provides an essential resource when surface water runs short.


Figure 1: Maps of recorded wells in Cambodia

Source: Ministry of Rural Development (2019)

### 1.1 Groundwater for domestic supply

Groundwater is a major source of the drinking water supply in Cambodia. Groundwater supplies over half of the population's drinking water in the dry season and this proportion increases in rural areas (ADB, 2013; National institute of Statistics, 2008; Sok, 2018). Approximately 270,000 tube-wells with hand pumps are functioning for drinking water purposes nationwide. 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). 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).

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, 2003). In 2017, about 65% of the households in Cambodia had access to a "safe/improved water source" , commonly via tube/piped well or borehole for the households; this figure is approximately 17% in the other urban areas and 35% in other rural areas (NIS, 2018).

Table 1: Estimation of potential groundwater per capital and by province in 1997

| Province | No. of Holes | Productive Wells | % | Yield (l/m) Range | Productive Depth (m) |
|---|---|---|---|---|---|
| Kg. Thom | 404 | 314 | 77.7 | 10-200 | 4-86 |
| Preah Vihear | 64 | 27 | 42 | 18-120 | 4.9-17 |
| Siem Reap | 71 | 62 | 87 | 15-1330 | 7-39 |
| Battambang | 4 | 3 | 75 | 0-50 | 30-57 |
| Kg. Chhnang | 22 | 11 | 50 | 49-200 | 18-80 |
| Pursat | 1 | 0 | 0 | - | - |
| Pailin | No data | No data | No data | No data | No data |

Source: Rasmussen et al (1997)

Table 2: Potential groundwater resources by province

| Province | No. Productive Wells | Avg. Yield (l/s) | Avg. Productive Depth (m) | Estimated Avg. Water Volume Available (l) | Estimated Population in 2002 in Tonle Sap | Avg. Potential Groundwater Available per Capita (l) |
|---|---|---|---|---|---|---|
| Kg. Thom | 314 | 105 | 45 | 1,483,650 | 672,788 | 2.2 |
| Preah Vihear | 27 | 69 | 11 | 20,493 | 150,495 | 0.13 |
| Siem Reap | 62 | 672.5 | 23 | 958,985 | 842,979 | 1.14 |
| Battambang | 3 | 25 | 43.5 | 3,262 | 993,196 | 0.003 |
| Kg. Chhnang | 11 | 124.5 | 49 | 67,105 | 501,551 | 0.13 |
| Pursat | 0 | No Data | No Data | No Data | 438,728 | No Data |

Source: Mekong River Commission

Table 3: Access to safe drinking water in rural areas by province

| Province | Main Source of Drinking Water (% Of Total) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Piped Water | Tube/Pipe Well | Dug Well | Spring/River Stream, Lake/ Pond, Rain | Purchased | Other | Total Access to Safe Drinking Water |
| Banteay Meanchey | 1 | 7.8 | 27.4 | 47.9 | 5.4 | 10.5 | 14.2 |
| Battambang | 1.3 | 8.4 | 41 | 43.1 | 4.5 | 1.7 | 15.2 |
| Kampong Cham | 3.7 | 8.9 | 65.6 | 14.1 | 5.4 | 2.3 | 18 |
| Kampong Chhnang | 0.6 | 15.1 | 55.5 | 24.7 | 0.5 | 3.6 | 16.2 |
| Kampong Speu | 1.4 | 17.3 | 35.3 | 44 | 1.8 | 0.2 | 20.5 |
| Kampong Thom | 1 | 0.8 | 81.6 | 14.2 | 0.3 | 2.1 | 2.1 |
| Kampot | 1 | 5.4 | 45.1 | 45.6 | 2.6 | 0.3 | 9 |
| Kandal | 4.1 | 11.9 | 11.6 | 54 | 18 | 0.4 | 34 |
| Koh Kong | 0.8 | 1.3 | 62 | 6.5 | 28.8 | 0.6 | 30.9 |
| Kratie | 1.8 | 14.5 | 33.1 | 39.4 | 10.7 | 0.5 | 27 |
| Mondulkiri | 0.6 | 0.4 | 16.5 | 75.8 | 5.3 | 1.4 | 6.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Phnom Penh | 19 | 9.2 | 9.4 | 21 | 41.1 | 0.3 | 69.3 |
| Preah Vihear | 1.5 | 7.5 | 32 | 38.9 | 0.1 | 20 | 9.1 |
| Prey Veng | 2 | 51.3 | 28.7 | 15.2 | 0.6 | 2.2 | 53.9 |
| Pursat | 1.3 | 4 | 57.5 | 28 | 3 | 6.2 | 8.3 |
| Ratanakiri | 0.3 | 2.1 | 27.1 | 69.3 | 0.6 | 0.6 | 3 |
| Siem Reap | 0.4 | 5.8 | 76 | 11.6 | 0.6 | 5.6 | 6.8 |
| Sihanoukville | - | - | - | - | - | - | - |
| Stung Treng | 0.6 | 11.2 | 3.7 | 84.3 | 0.2 | - | 12 |
| Svay Rieng | 0.6 | 47.4 | 47.2 | 1.5 | 0.2 | 3.1 | 48.2 |
| Takeo | 0.5 | 10.5 | 37.1 | 49.9 | 0.9 | 1.1 | 11.9 |
| Oddar Meanchey | 0.1 | 0.8 | 18.4 | 80.2 | 0.5 | - | 1.4 |
| Kep | - | - | - | - | - | - | - |
| Pailin | - | - | - | - | - | - | - |
| **Average for Cambodia** | **2.5** | **15.1** | **43.4** | **30.4** | **6.1** | **2.5** | **23.7** |

Source: National Institute of Statistics (1998)

Table 4: Main sources of drinking water by season and geographical domain in 2017

| Water Sources | Cambodia | Phnom Penh | Other Urban | Other Rural |
|---|---|---|---|---|
| **Improved** | 64.8 | 97.6 | 78.5 | 58.3 |
| Piped in dwelling or on premises | 29.2 | 96.1 | 56.6 | 16 |
| Public tap | 1 | 0.3 | 0.8 | 1.1 |
| Tube/piped well or borehole | 29 | 0.5 | 16.8 | 34.6 |
| Protected dug well | 5.3 | 0.6 | 3.7 | 6.2 |
| Improved rainwater collection | 0.3 | - | 0.7 | 0.3 |
| **Unimproved** | 35.2 | 2.4 | 21.5 | 41.7 |
| Unprotected dug well | 6.2 | - | 3.1 | 7.6 |
| Pond, river or stream | 11.2 | 0.4 | 2.2 | 13.9 |
| Unimproved rainwater collection | 7.3 | - | 5.7 | 8.5 |
| Vendor-provided water/tanker truck provision of water | 7.8 | 1.6 | 3.5 | 9.3 |
| Bottled water | 2.4 | 0.4 | 6.9 | 2 |
| Other | 0.4 | - | - | 0.4 |
| **Total** | **100** | **100** | **100** | **100** |
| Number of households | 3,438,000 | 377,000 | 372,000 | 2,689,000 |

Note: all number are in percentage (%)

Source: National Institute of Statistics (2018)

In 2006, total water withdrawal was about 2.184 km$^3$, of which 2.053 km$^3$ (94%) was for agriculture, 0.98 km3 (4.5%) for municipalities and 0.33 km$^3$ (1.5%) for industries (Table 5 and Figure 2).

Table 5: Water sources and use

| **Water withdrawal** | | | |
|---|---|---|---|
| Total water withdrawal | 2006 | 2 184 | million m$^3$/yr |
| - irrigation + livestock | 2006 | 2 053 | million m$^3$/yr |
| - municipalities | 2006 | 98 | million m$^3$/yr |
| - industry | 2006 | 33 | million m$^3$/yr |
| • per inhabitant | 2006 | 162 | m$^3$/yr |
| Surface water and groundwater withdrawal | 2006 | 2 184 | million m$^3$/yr |
| • as % of total actual renewable water resources | 2006 | 0.5 | % |
| **Non-conventional sources of water** | | | |
| Produced wastewater | | - | million m$^3$/yr |
| Treated wastewater | 1994 | 0.157 | million m$^3$/yr |
| Reused treated wastewater | | - | million m$^3$/yr |
| Desalinated water produced | | - | million m$^3$/yr |
| Reused agricultural drainage water | | - | million m$^3$/yr |

Source: Food and Agricultural Organization (2011)

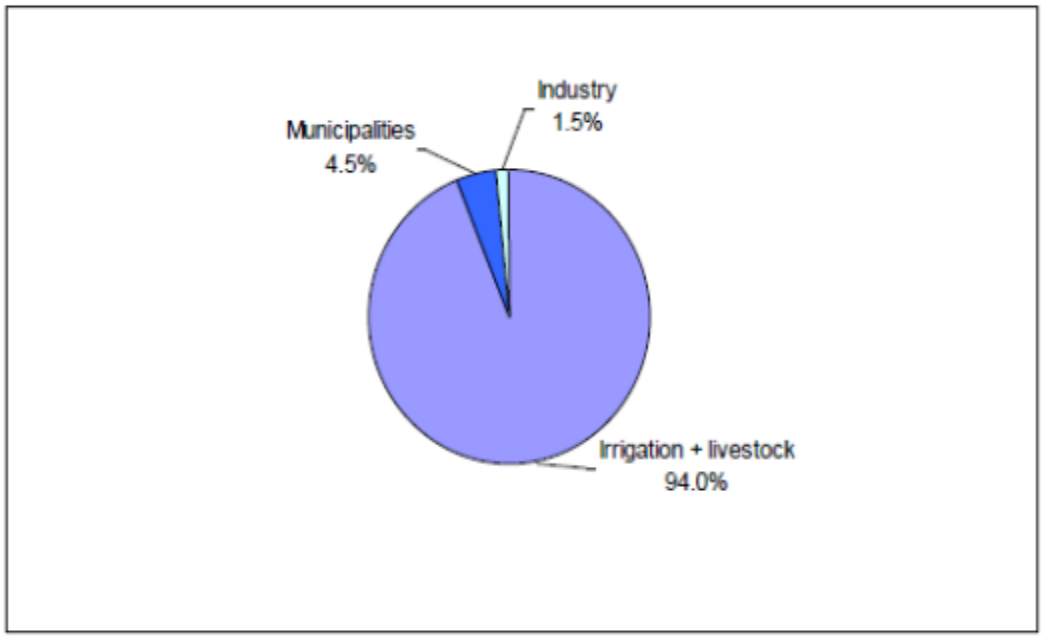


Figure 2: Water withdrawal by sector (total 2.184 km$^3$ in 2006)

## 1.2 Groundwater for irrigation

Groundwater, along with surface water, has been used for irrigation and domestic purposes in Cambodia since ancient times (Phalla & Paradis, 2011). Groundwater is used mainly to provide partial irrigation in

late dry season, and for complementary irrigation of wet season rice crops. In some parts of the country that are far from water sources and irrigation systems, people rely heavily on groundwater to cultivate land. 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). Thuon (2013) reported one commune in Prey Veng where over 90% of farmers had installed tube-wells by 2012.

Cambodia irrigates just 10% of its rice crop, most of which are grown during the wet season (May to November) (MRC, 2010). Though dry season irrigation capacity is certainly not the only factor limiting Cambodian rice production, it is a fundamental one undergoing rapid change. Irrigation using groundwater is on the rise in Cambodia and may outpace increases in access to surface water sources. Planned surface water infrastructure initiatives and upgrades are expected to increase the planted area of dry season crop by 45% over the next 20 years (MRC, 2009). Meanwhile, installation of motorized-pump irrigation wells has already increased at a rate of 20% per year over the period between 1996 and 2005 (IDE, 2005). As mentioned by Johnston et al (2013), the limited use of groundwater for irrigation in many areas of Cambodia is attributed to several reasons such as poor knowledge of the resource and its sustainability.

Results of the current study show a widespread exploitation of groundwater for irrigation crop production in Cambodia. Numbers of tube-wells actively used for rice production in Cambodia are shown in Table 1. There were 7 provinces (Battambang, Kampong Cham, Kampong Chhnang, Kandal, Prey Veng, Siem Reap, and Takeo) out of the 14 surveyed provinces that used tube-wells. Farmers in the remaining provinces did not use groundwater for irrigation even though earlier studies showed that the availability of groundwater existed with some degree of potential for irrigation (Rasmussen & Bradford, 1977; Briese, 1996; JICA, 1999). The current cultivated paddy area in Cambodia is approximately 2.37 Mha, of which approximately 1.36 Mha (57%) belongs to the 7 provinces using tube-wells to extract groundwater for irrigation. The total irrigated area of these provinces account for about 73% of the country's total irrigated area in 2001; about 9% was covered by groundwater tube-wells.

Table 6: Number of active tube-wells and related irrigated areas in 7 Cambodian provinces

| Province | Number of Tube-Wells | Number of Tube-Wells with Coordinate | Irrigated Area by Tube-Wells (ha) | Irrigated Area Per Tube-Wells (ha) | Cultivated Area (ha)[A] | Actual Irrigated Area (ha)[B] |
|---|---|---|---|---|---|---|
| Prey Veng | 9,038 | 26 | 13,557.00 | 1.5 | 276,899 | 25,360 |
| Kampong Cham | 1,258 | 51 | 2,401.82 | 1.91 | 214,339 | 16,870 |
| Takeo | 1,253 | 34 | 2,753.00 | 2.2 | 233,405 | 48,716 |
| Kandal | 347 | 11 | 372.00 | 1.07 | 96,603 | 34,768 |

| Province | Number of Tube-Wells | Number of Tube-Wells with Coordinate | Irrigated Area by Tube-Wells (ha) | Irrigated Area Per Tube-Wells (ha) | Cultivated Area (ha)[A] | Actual Irrigated Area (ha)[B] |
|---|---|---|---|---|---|---|
| Siem Reap | 92 | 10 | 109.50 | 1.19 | 187,305 | 48,195 |
| Battambang | 35 | 8 | 22.00 | 0.63 | 235,730 | 23,990 |
| Kampong Chhnang | 1 | 1 | 1.00 | 1 | 116,980 | 9,622 |
| Total | 12,023 | 141 | 19,215.32 | 1.6 | 1,361,261 | 207,521 |
| | | | | Country total | 2,374,175 | 284,172 |

Source: [a]MAFF (2005); [b]FAO (2001)

## 2. Previous Groundwater Studies in Cambodia

Groundwater in Cambodia has been poorly assessed and understood. The information for this profile was compiled from the works of Rasmussen (1977), geological maps published by ESCAP (1993), geology maps by the Office of Mapping in the Department of Geology in Ministry of Industry, Mines and Energy (MIME) (1997), geological landform maps by JICA (2005), and well data collected from various organizations and projects such as the ADB-financed Tonle Sap Rural Water Supply and Sanitation Project, RDIC water quality database, UNICEF-administered well database and arsenic database, and World Vision International well database. Much of this data was compiled in a sector study undertaken for ADB (2014).

In order to describe the availability of groundwater in Cambodia, Rasmussen (1977) studied the subsurface geology of Cambodia by examining drillers' logs and constructing geologic cross sections. The description and evaluation were based on test-drilling data and well records obtained by the Public Health Division of the United States Agency for International Development (USAID) Mission to Cambodia during a rural water-well development program in 1960-63.

Kazama et al (2007) evaluated groundwater resources in wide inundation areas of the Mekong River basin. This study determined the variation of groundwater resources caused by flooding over inundated areas located in lower parts of the Mekong River basin using numerical modeling and field observation; inundation calculations were evaluated using satellite image outputs. Kazama et al found that while flood control activities are vital to reduce negative impacts in the Mekong River basin, they also negatively impact groundwater resources in the area. Moreover, the Mekong River basin is located in a geological context whose potential groundwater has rarely been investigated (e.g. Erban & Gorelick, 2016; Rasmussen & Bradford, 1977), since most of the published works focuses on groundwater resources that are vulnerable to extraction for irrigation in agricultural (e.g. IWMI-ACIAR, 2013). In addition, groundwater for irrigation in Cambodia has primarily used groundwater flow models of southern and central Cambodia, largely based on data from the JICA/CMRD (2002a; 2002b; Raksmey et al, 2010).

A preliminary compilation and review of information on groundwater potential for both drinking-water supply and supplementary irrigation in Oddar Meanchey province was completed by Vouillamoz et al

(2016). The study was implemented over a 4-year period using hydrogeological techniques e.g. water-table mapping, drilling boreholes, setting up pumping tests, monitoring groundwater levels and rainfall, and analysis of water isotopes together with the geophysical magnetic resonance sounding (MRS) method. Simulations of pumping indicated that the aquifer can easily supply 100L of drinking water per capita daily, even considering the estimated population in 2030. However, the shallow aquifer c generally not deliver enough water to irrigate paddy fields of several hectares during a 2-month delay in the onset of the monsoon season.

Sokuntheara (2016) estimated sustainable rates of groundwater withdrawal for irrigation in Prey Veng and Svay Rieng provinces. To achieve this, a three-dimensional numerical groundwater flow model was constructed using the MODFLOW software package and calibrated to ensure a close match with observed water levels. Rough estimates of groundwater use for domestic and agricultural purposes in 2005 suggested that 53% of the sustainable withdrawal was being used at that time.

## 3. Hydrogeological Map Description

While this study must consider Cambodia as a whole, it must consider the 5 sub river basins - Coastal Zone sub river basin, Northeastern sub river basin, Upper Mekong sub river basin, Tonle Sap sub river basin and Mekong Delta sub river basin (MOWRAM, 2014). In order to study groundwater resources in Cambodia, geology formations must be considered – these have been classified and divided into two main rock formation types: quaternary alluvium, and other formations (see Table 7). The quaternary alluvium class comprises of 3 sub-classes: (i) alluvium, (ii) basalt and (iii) post-Triassic sandstone and conglomerate. The other formation class also comprises of 3 sub-classes: (i) limestone and (ii) Triassic metamorphic rock (iii) other igneous rock. The geological formations in the Coastal Zone sub river basin are predominantly post-Triassic sandstone and conglomerate, including clay stone, shale, sandstone and conglomerate; this makes up 67% of the total area. Recent alluvium is the second most extensive geological formation and is found in the valleys of the Cardamom mountainous ranges and in coastal areas. These formations make up 27% of the total. In the Northeastern sub river basin, the geological formations are mostly of the lower-middle Jurassic formation. This formation is sometimes called the Terrain Rouge, and covers large areas of Mondulkiri and Ratanakiri provinces, extending westward into Stung Treng and Preah Vihear provinces, and diminishing progressively toward the west and appearing as isolated outcrops north and west of Pursat. These post-Triassic sandstone and conglomerate make up 25% of the area. There are also old alluvium formations occurring on floodplains along rivers and drainage lines, making up 20% of the total area. The geological formations in the Upper Mekong sub river basin are predominantly Triassic metamorphic rock, making up 46% of the total area. These is sedimentary rock in the Triassic series and lower to middle Jurassic formations (Terrain Rouge). The second most dominant formation is alluvium (old and recent) that occurs in the north, along the Mekong River's meandering floodplain and in the valleys of the Terrains Rouges Plateau. This makes up 23% of the total area. Post-Triassic sandstone and conglomerate make up 16%. Geologically, the Tonle Sap sub river basin is dominated by the quaternary sediment formation consisting of old alluvium and extending everywhere up to the foothills of the surrounding mountain ranges (Cardamom and the Dangrek Range), overlaid by recent alluvium in the area below until the permanent lake area. The topography of the lake and its surrounding area is very flat.

There are very few investigations of the geology and geohydrology in the Tonle Sap Lake areas. The dominant geological formation is alluvium (recent and old) comprising 86% of the total area. These occur in central parts of this Basin Group, around the Tonle Sap Great Lake.

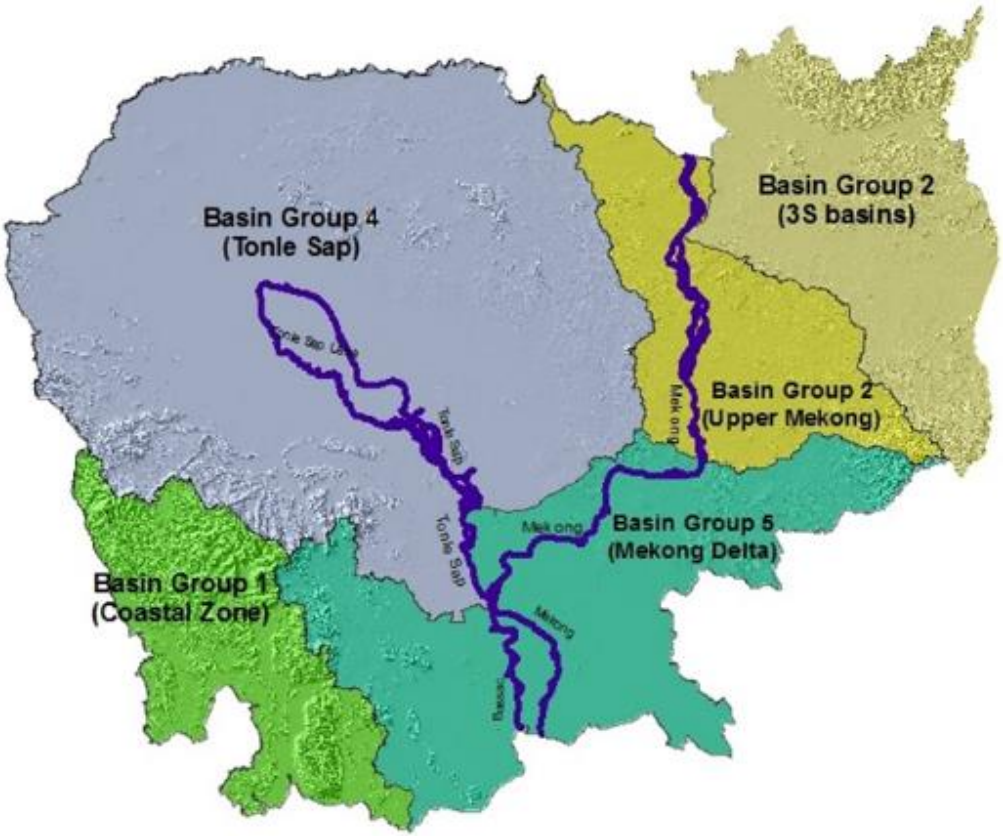


Figure 3: Basin groups in Cambodia

Source: Ministry of Water Resources and Meteorology (2014)

In the Mekong Delta Basin Group, the dominant geological formation is alluvium, including recent alluvium, old alluvium, and laterite, making up 84% of the total area. The second most common geological unit is basalt and volcanic rock, comprising 5% of the area and found in the east. The general geology of Cambodia was compiled by the Office of Mapping in the Department of Geology in Ministry of Industry, Mines and Energy (MIME) in 1997 using hard copies of geological maps, which were originally compiled by BRGM France in the 1960's as source maps and information from *Atlas of Mineral Resources of ESCAP Region, Vol. 10, Cambodia* (ESCAP, 1993).

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 based on 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).

"Young" and "older" sediments of the lowland agricultural areas offer the greatest potential for groundwater development. In general, young alluvium is finer grained (clays and silts) and is a poor aquifer, although it can yield good groundwater 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. The older alluvium, which probably underlies more recent alluvium in all areas, has less clay and more clean silt or sand, and is therefore more permeable with higher groundwater storage potential (ADB, 2014). The outcrop mostly has occurred in the northern, northeast and southwest Cambodia. The alluvium has very low hydraulic conductivity and yield (0.2 L/sec) except sandy beds and lenses where yields are higher (1 L/sec) (Peng & Pin, 2000). 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 groundwater (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 Bolaven Plateau in Lao PDR.

Table 7: Classification of geology formations for groundwater study in Cambodia

| Main Classes | Sub Classes | Description |
|---|---|---|
| Quaternary Alluvium | Alluvium | Alluvial formations include recent alluvium, alluvial sand, laterite and lateritic crust, and old alluvium |
| | Basalt | All Basalt including Quaternary basalt and Pleistocene basalt |
| | Post-Triassic Sandstone and Conglomerate | Includes Jurassic Cretaceous clay stone, sandstone, and conglomerate |
| Other Formation | Other Igneous Rock | All magmatic rock excluding basalt |
| | Limestone | All limestone and calcareous rock |
| | Triassic Metamorphic Rock | Triassic or older sedimentary rock and metamorphic rock |

The areas of the main geological formations in the basin groups are provided in Table 6 and are shown graphically in Figure 4. In Cambodia, the alluvium geological formations dominate, making up approximately 70% of the total area. The young alluvium and old alluvium occur in central part of Cambodia, around Tonle Sap Lake, and extend to the delta area (ADB, 2014).

Table 8: Area of geological formations in river basin groups

| River Basin Group | Total Number | Quaternary Alluvium | | | Other Formations | | |
|---|---|---|---|---|---|---|---|
| | | Alluvium | Basalt | Post Triassic Sandstone and Conglome-Rate | Other Igneous Rock | Limestone | Triassic Metamorphic Rock |
| Coastal | 18,046 | 5,081 | 369 | 11,983 | 157 | 7 | 243 |
| Northeastern | 25,965 | 5,144 | 4,608 | 32 | 3,391 | 0 | 12,435 |
| Upper Mekong | 19,522 | 6,176 | 1,172 | 367 | 1,215 | 11 | 10,204 |
| Tonle Sap | 81,663 | 58,392 | 1,732 | 4,284 | 5,349 | 230 | 8,742 |
| Mekong Delta | 35,839 | 27,079 | 3,574 | 343 | 2,639 | 17 | 1,350 |
| **Total** | **181,035** | **101,872** | **11,455** | **17,009** | **12,751** | **258** | **32,975** |

Source: Geo-Landform Map (Compiled in 2001-2003)

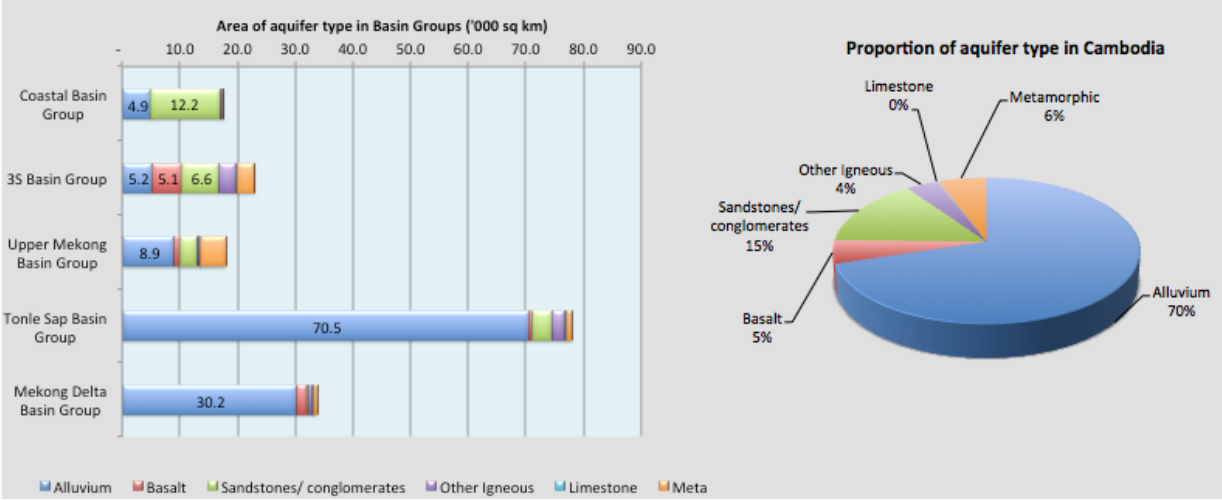


Figure 4. Areas of aquifer type per basin group

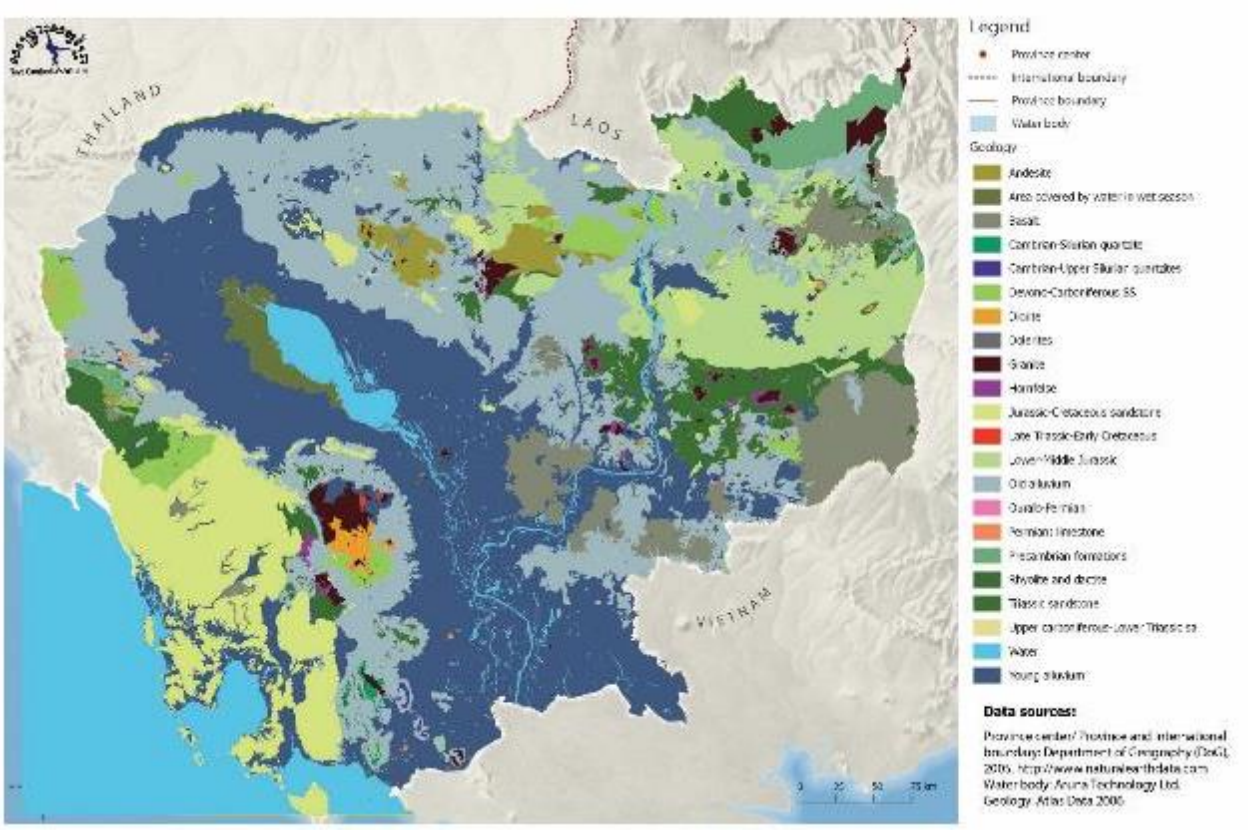


Figure 5: Simplified geological map of Cambodia

Source: Open Development Cambodia (2006)

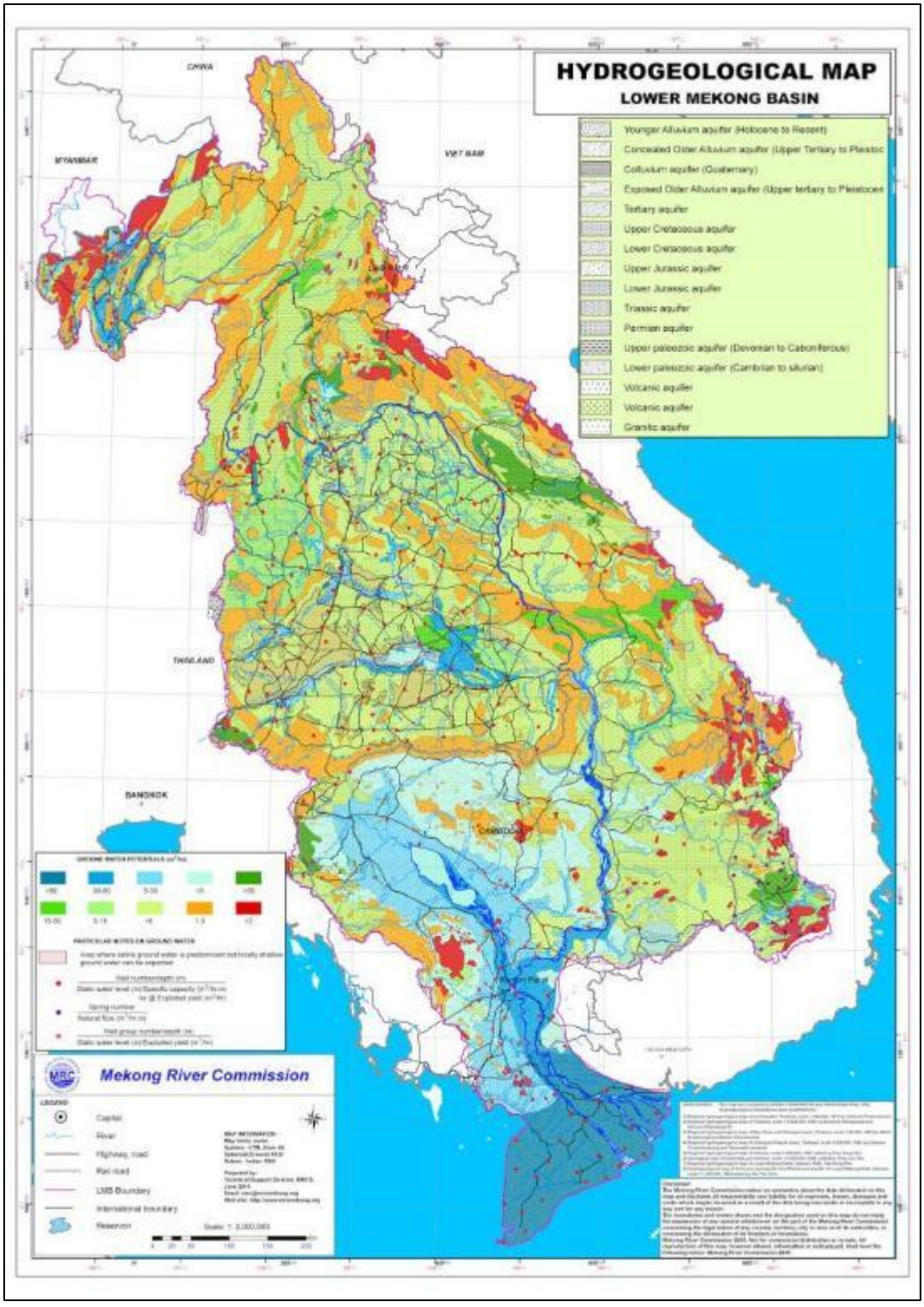


Figure 6: Overview of hydrogeologic setting of the Lower Mekong Basin

Source: Mekong River Commission (1978)

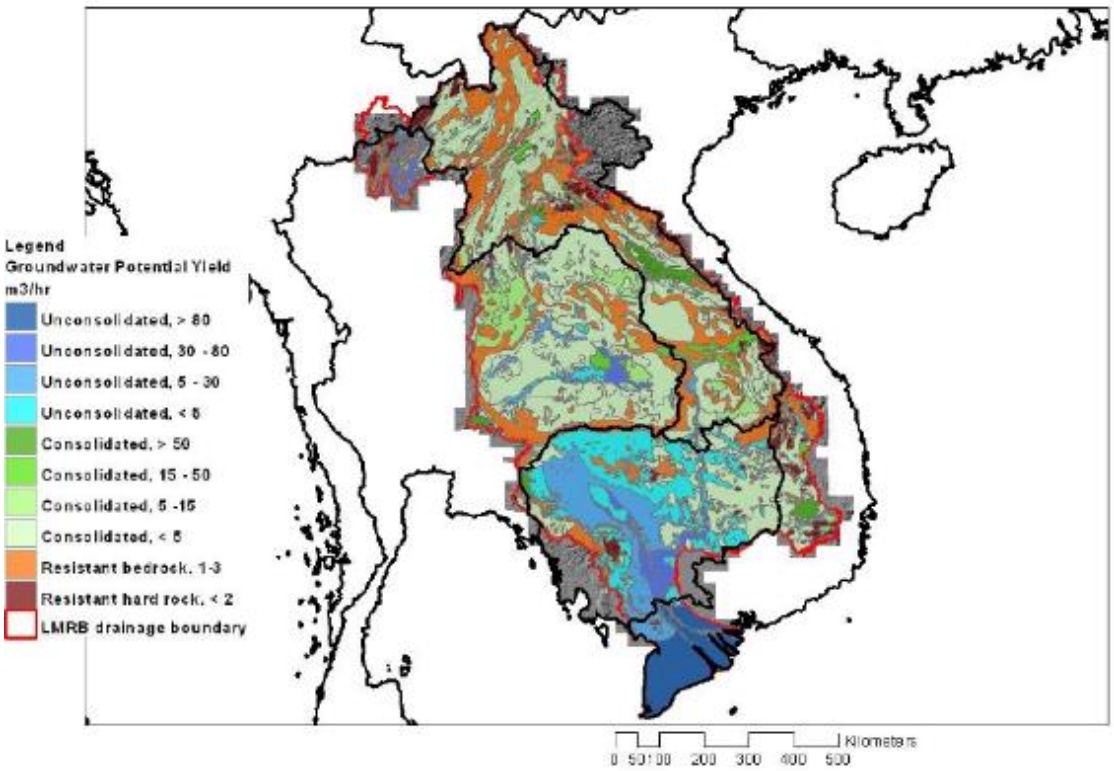


Figure 7: Groundwater yield map of the Lower Mekong Basin

Source: Mekong River Commission (2014)

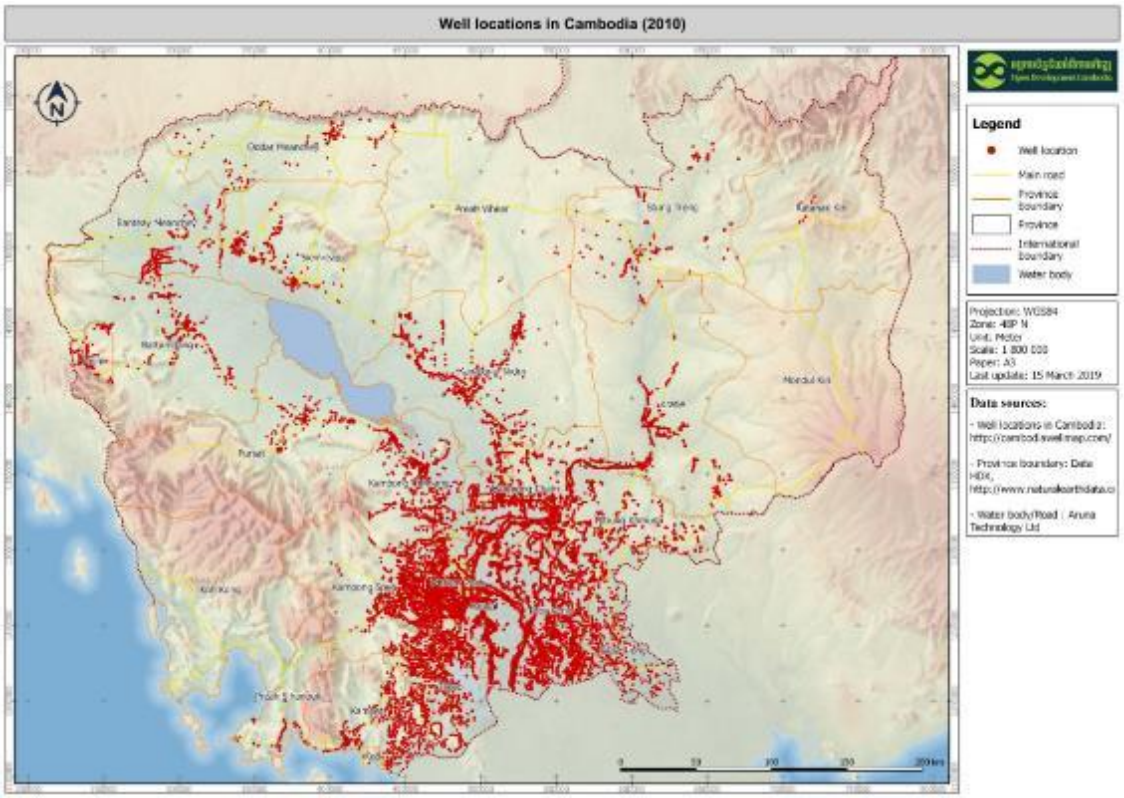


Figure 8: Well locations in Cambodia

Source: Open Development Cambodia (2010)

## 4. Groundwater Quantity

Cambodia can be divided into three regions based on landforms, geology and occurrence of groundwater. These regions are the Mekong lowlands; south-western highlands; and Coastal Plain of south-western Cambodia.

Since there has not been a comprehensive national disclosure of information on groundwater resources to date, key stakeholders lack information, knowledge and understanding of this natural resource. However, estimations by the Ministry of Water Resources and Meteorology show the amount of groundwater resources at 17.6 billion $m^3$ (WEPA, N.D.). The alluvial deposits in the Tonle Sap and Mekong floodplain/delta are believed to be excellent shallow aquifers, with high recharge rates and a water table generally within five to ten meters of the surface water. Shallow wells could be used in an estimated 48,000 $km^2$ of the country (WEPA, N.D.).

Over 50% of Cambodians rely on groundwater for drinking in the dry season. Note that in the wet season most rural Cambodians begin harvesting and drinking rainwater, but as you can see, most do not store enough water to last through the dry season (less than 1%). While groundwater is often separated from animal and human feces and disturbances at the surface, chemicals such as arsenic, fluoride, nitrate, and manganese may be present in groundwater which can cause health problems.

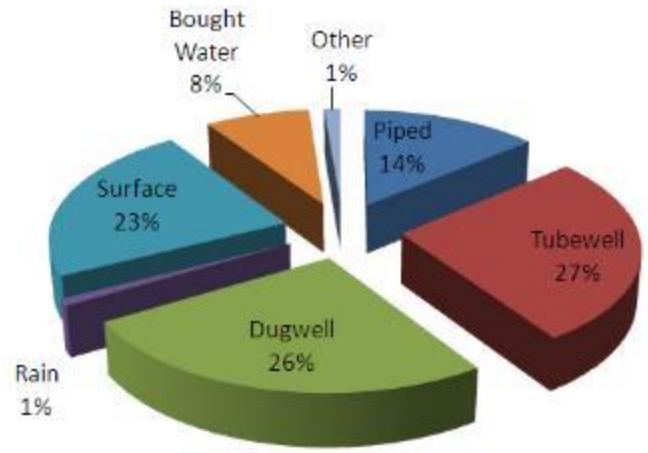


Figure 9: Water utilized in rural Cambodia

Source: Resource and Development International Cambodia (2000)

### 4.1 Groundwater exploitation in Cambodia

There are estimates of over 6,000 wells drilled post-1980 in the Mekong delta for domestic water supply and small-scale irrigation of vegetables and fruit trees. Groundwater use has increased from 120,000 $m^3$/day in 1997 to 290,000 $m^3$/day in 2000 (Hoanh et al, 2003). According to Seng et al (2006) over 12,000 tube-wells in Siem Reap, Battambang and Kampong Chhnang provinces of the Tonle Sap region; Kampong Cham province of the Phnom Penh region; and Prey Veng, Takeo, and Kandal provinces of the Border region of Cambodia have been used to abstract groundwater for irrigation. The area irrigated by these wells was around 19,000 ha. The average area served by each tube-well was approximately 1.6 ha. The fresh shallow aquifers that exist around the Tonle Sap Lake and beside the Bassac (central parts of Border region) and Mekong Rivers in Cambodia have strong interactions with these surface water bodies. Water levels up to 30 km each side of the Bassac River closely follow stage heights in the river (CIAP, 1999) indicating a continuous recharge from the river. Farmers along the Bassac River have installed shallow tube-wells for irrigating 1 to 2 ha of dry season crops. Due to relatively low recharge rates the farmers in some intensively irrigated areas run short of water during peak periods.

Erban et al (2016) found that groundwater use in Cambodia is rising by 10% each year. The study found that growing dependence on groundwater could drop the water table below the level at which conventional suction pumps can operate within 15 years. Besides its use for domestic consumption and farming, groundwater is increasingly exploited by the industrial sector. With high consumption of groundwater for agro-industrial purposes, sustainability of the resource may be threatened by over-extraction. There are issues around groundwater depletion, deterioration of water quality and the high cost of irrigation water.

All the Angkor temples are built on sand layers, whose strength depends on their degree of water saturation; if the sand layers are not saturated, they are less able to resist pressure. Currently, groundwater is being extensively pumped to meet the rising demand of hotels, guesthouses and residents

in the suburb of the Siem Reap City. The high level of water abstraction represents a great threat for stability of the world heritage–listed Angkor temples (ADB, 2014).

Table 9: Summary of groundwater exploitation in Cambodia based on previous studies

| Groundwater Exploitation | | Reported by |
|---|---|---|
| Post-1980 in the Mekong Delta | Over 6,000 wells | Hoanh et al (2003) |
| 1997 in the Mekong Delta | 120,000 m3/day | Hoanh et al (2003) |
| 2000 in the Mekong Delta | 290,000 m3/day | Hoanh et al (2003) |
| Siem Reap, Battambang and Kampong Chhnang provinces of the Tonle Sap region; Kampong Cham province of the Phnom Penh region; and Prey Veng, Takeo, and Kandal provinces for irrigation | 12,000 tube-wells | Seng et al (2006) |
| Private user in Siem Reap city | 18,000 m3 /day | MoWRAM & ADB (2014) |
| Well field south of the West Baray | 16,000 m3 /day | MoWRAM & ADB (2014) |
| Groundwater use in Cambodia is rising | Increase 10% / year | Erban et al (2016) |

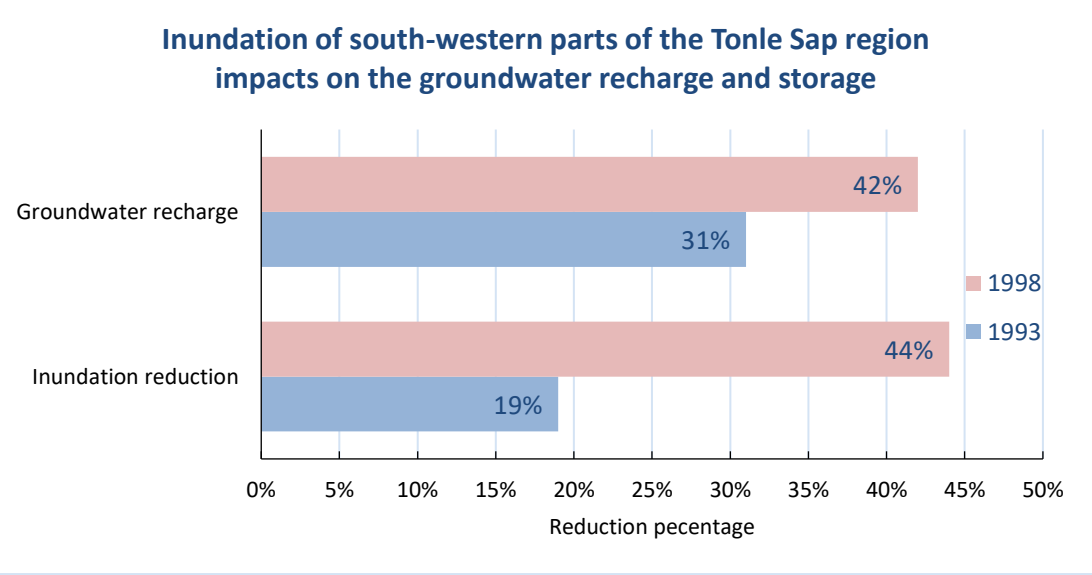


Figure 10: Inundation of south-western parts of the Tonle Sap region impacts on the groundwater recharge and storage

Source: adapted from Kazama et al (2007)

### 4.2 Groundwater extraction in Cambodia

There are two methods for groundwater extraction: dug wells (3–15 meters) and tube-wells (15–100 meters). Tube-wells are mostly used in Prey Veng and Svay Rieng (south-east Cambodia). Dug wells are commonly found in Kampong Thom province, as well as in central and north-east Cambodia (RDIC, N.D.). Well infrastructure depends on the depth at which water can be found underground. Deeper aquifers have been investigated in Kampong Thom Province though have not been utilized more widely (ADB, 2013). The two figures below show the percentage of the population drinking groundwater in the dry season, broken down by tube-wells and dug wells (National Institute of Statistics, 2008).

Figure 11: Groundwater extraction using a tube-well in northern Cambodia during dry season


Figure 12: Dry season tube-well map of Cambodia

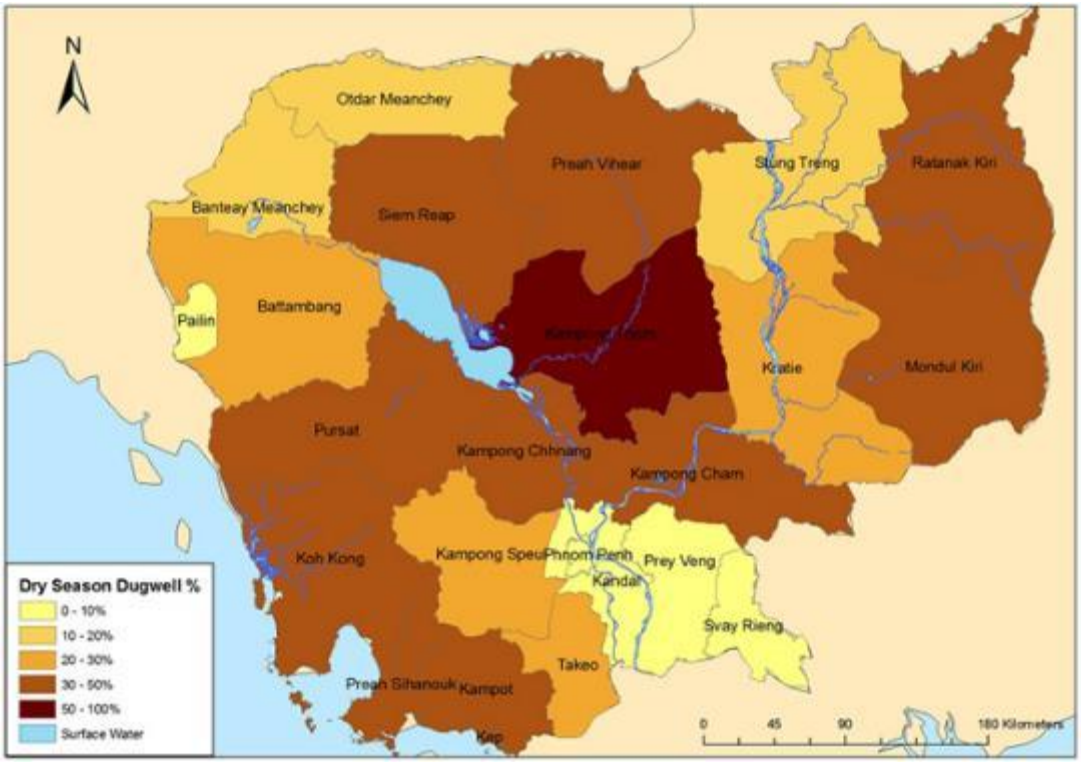


Figure 13: Dry season dug well map of Cambodia

### 4.3 Groundwater recharge in Cambodia

Groundwater recharge occurs through seepage from rainfall and areas inundated with flood waters during rainy season. Kazama et al (2007) conclude that the inundation areas in the Cambodian part (south-western parts of the Tonle Sap region) of the Mekong River have relatively large impacts on the groundwater recharge and storage. During 1993 the total area of inundation was around 5,200 km2 and the groundwater storage was estimated at 52 $km^3$. During 1997 a 19% reduction in the area of inundation due to low rainfall and flood waters in the Mekong River resulted in 31% reduction in the groundwater storage. During 1998 the inundation area was reduced to 44% of that during 1993 and it resulted in 42% reduction in the groundwater recharge.

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. Potential groundwater recharge during the wet season is more than adequate in most of Cambodia. Assuming that the average annual recharge to groundwater reservoirs is in the order of 150 mm a year, and that of this projected recharge, 100 mm is recoverable by properly spaced and developed wells, then the ultimate recovery from 175,630 $km^2$ could conceivably be about 17,600 million $m^3$ a year (Rasmussen, 1977). A study on groundwater recharge in Cambodia (ADB, 2014) showed that the recharge rate ranged from 14.9% to 22.1 % with a mean value of 18.5%.

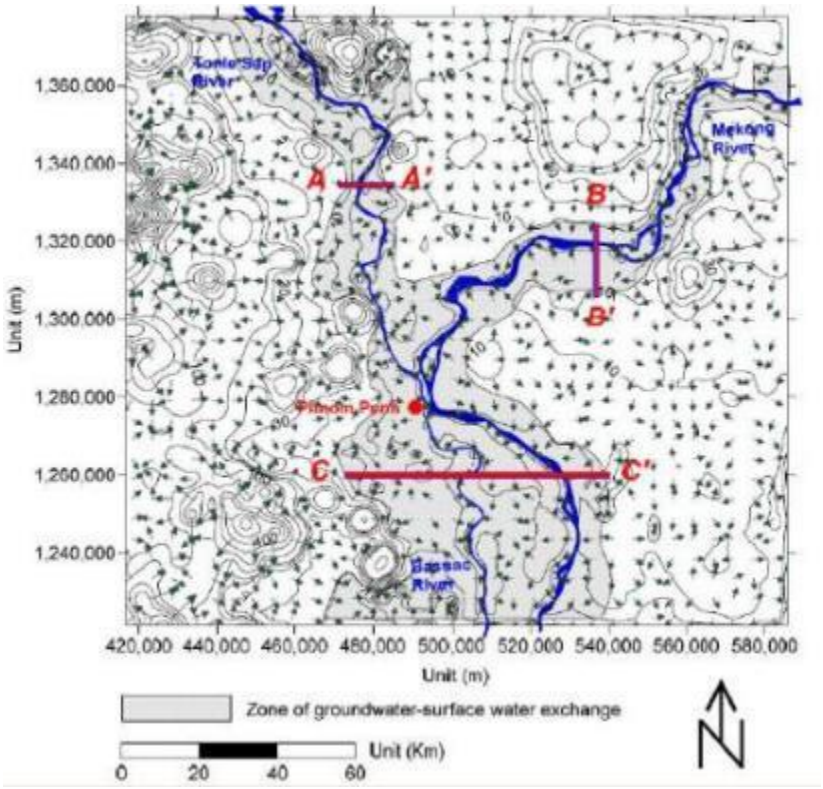


Figure 14: Countrywide groundwater recharge

Source: Asian Development Bank (2014)

### 4.4 Land use change impacts

Groundwater is intimately connected with the landscape and land use that it underlies, and most of the landscape and is vulnerable to the anthropogenic activities on the land surface above. Land use affects groundwater resources through changes in recharge and changing demands for water (Fan et al 2015; Lerner & Harris, 2009; Tetzlaff et al, 2007). Inappropriate land use, particularly poor land management, causes chronic groundwater quality problems.

In many places, including the Mekong Delta in Cambodia, growing population pressure and demand by agriculture and industry have resulted in the overuse of aquifers. In many places, water tables (the highest point of water saturation in the aquifer) have lowered, leaving wells dry. One study observed average water levels in wells decline by 14 cm/yr in Prey Veng and Svay Rieng between 1996 and 2008 (Johnson et al, 2013).

The 2016 forest cover assessment was produced by the national technical working group (GDANCP/MoE, FA/MAFF, FiA/MAFF) with technical supervision provided by FAO-UNREDD, JICA-CAMREDD and international universities. Forest cover for the 1965 to 2016 period declined by 24.9%. The results showed that the country's forest cover is 8 742 401 ha, equivalent to 48.14 % of the country's total area, and the average annual loss rate from 2014 to 2016 is about 0.67 %, equivalent to 121 328 ha.

The key to determining sustainable groundwater use is therefore understanding and influencing the effects of land use/land cover (LU/LC) changes and forest cover on groundwater recharge.

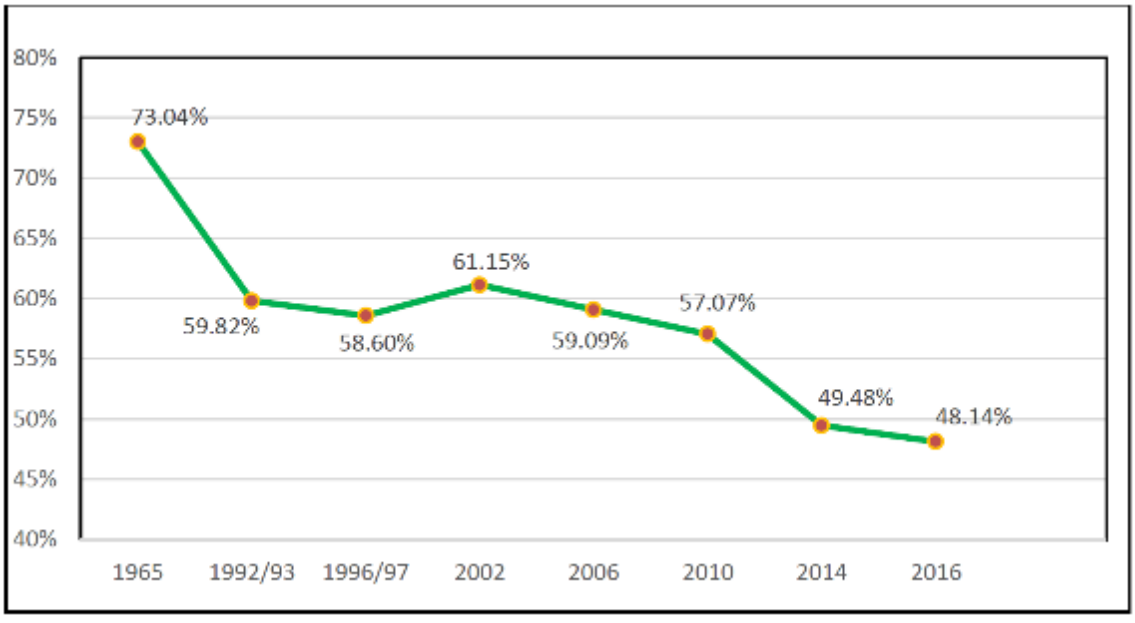


Figure 15: Rate of forest cover change statistics from 1965-2016

Source: Reducing Emissions from Deforestation and Forest Degradation (2018)

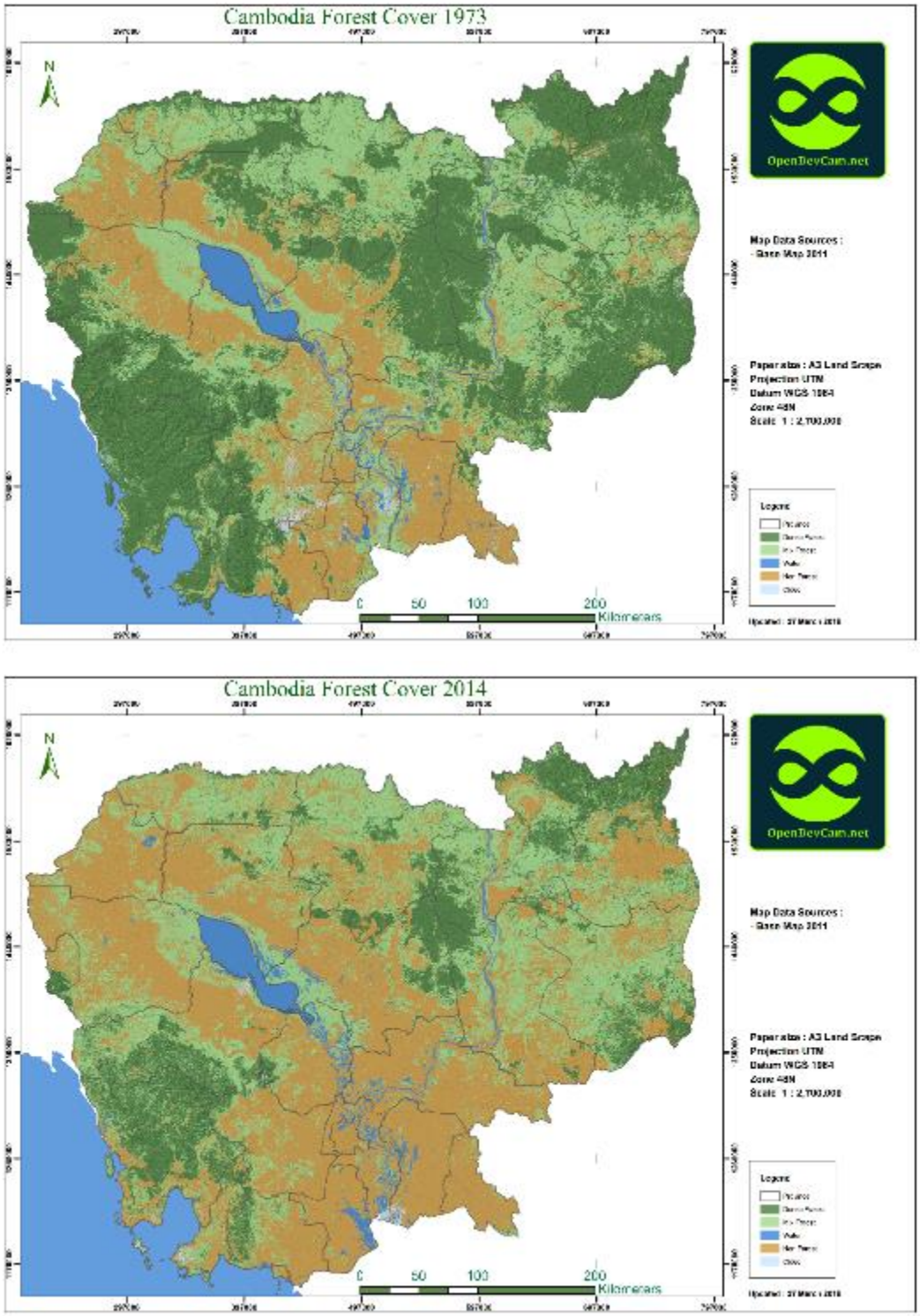


Figure 16 : Cambodia forest cover, 1973 and 2014

### 4.5 Climate change impacts

Few studies exist regarding the impact of climate change on groundwater; however, some general remarks may be made. In the Mekong Delta, future rainfall is projected to increase in wet season and decrease in dry season (Shrestha et al, 2016). Climate change may affect both the recharge to and the demand from aquifers. Since wet season rain is expected to increase, this may lead to greater recharge however overall groundwater recharge, and therefore groundwater levels and storage, is projected to decline. Future recharge in wet season at the end of 21$^{st}$ century is projected to remain at almost the same value of 28mm, however, in dry season it is expected to decrease by 2mm and 4mm under RCP4.5 and RCP8.5 scenarios, respectively. Overall, there is a clear decreasing trend in annual value of groundwater recharge from now to the end of the 21st century (Shrestha et al, 2016). For those aquifers along the rivers (in lower Cambodia especially) which are well connected to the rivers, the changed flow regime will presumably be reflected in changed aquifer levels.

## 5. Groundwater Quality

The quality of groundwater extracted from alluvium in Cambodia is generally good and fit for most purposes. Family-based groundwater wells have been becoming popular during the last 10 years in the Mekong Delta region due to bacterial diseases from using the surface water.

### 5.1 Groundwater contamination in Cambodia

Despite being of generally good quality across the country, high iron contents and increasing salinity levels of groundwater have been noted in Svay Rieng and southern Prey Veng provinces (Pan et al, 2002). Other problems have been reported:

- **Arsenic:** Arsenic concentrations in Cambodia have been found to significantly exceed WHO and Cambodian drinking water quality standards of 10 ppb and 50 ppb respectively. Areas where arsenic has been observed to be elevated in the groundwater include Kandal, Prey Veng, and Kampong Cham provinces. Note that most of the highest arsenic concentrations exist within 10 km from the Mekong River, its tributaries and ancient buried riverbeds.
- **Manganese:** The Cambodian and WHO drinking water standard for Manganese is 0.4 mg/l. Heightened tube-well groundwater levels of manganese have been found in Kandal, Prey Veng, and Kampong Cham provinces, with very high levels throughout Kean Svay district in Kandal.
- **Fluoride:** The Cambodian and WHO drinking water quality standards for fluoride are 1.5 mg/l. Concentrations greater than 4 mg/l can cause skeletal fluorosis, which can cause very serious health effects. Areas where fluoride has been observed to be elevated in groundwater include Kandal, Prey Veng, and Kampong Cham provinces.
- **Nitrate:** Tube-well groundwater nitrate has been found in Kandal, Prey Veng, and Kampong Cham provinces. Pockets of aquifer contamination have been found in Sithor Kandal district, Prey Veng province. This condition is present because of a combination of factors; there are many tube-wells in the villages, nearly all are very shallow (10 to 20 m), population density is high, cows and pigs are commonly raised under houses, and waste management practices are poor.

- **Iron:** Iron concentrations are generally very high in the groundwaters of Cambodia. Iron is naturally occurring but has no health effects when consumed through drinking water. Iron can cause the water to look cloudy, taste poor, and can stain laundry or discolor rice. The drinking water quality standard for iron is 0.3 mg/l based on aesthetic effects, but this is often exceeded in groundwater.

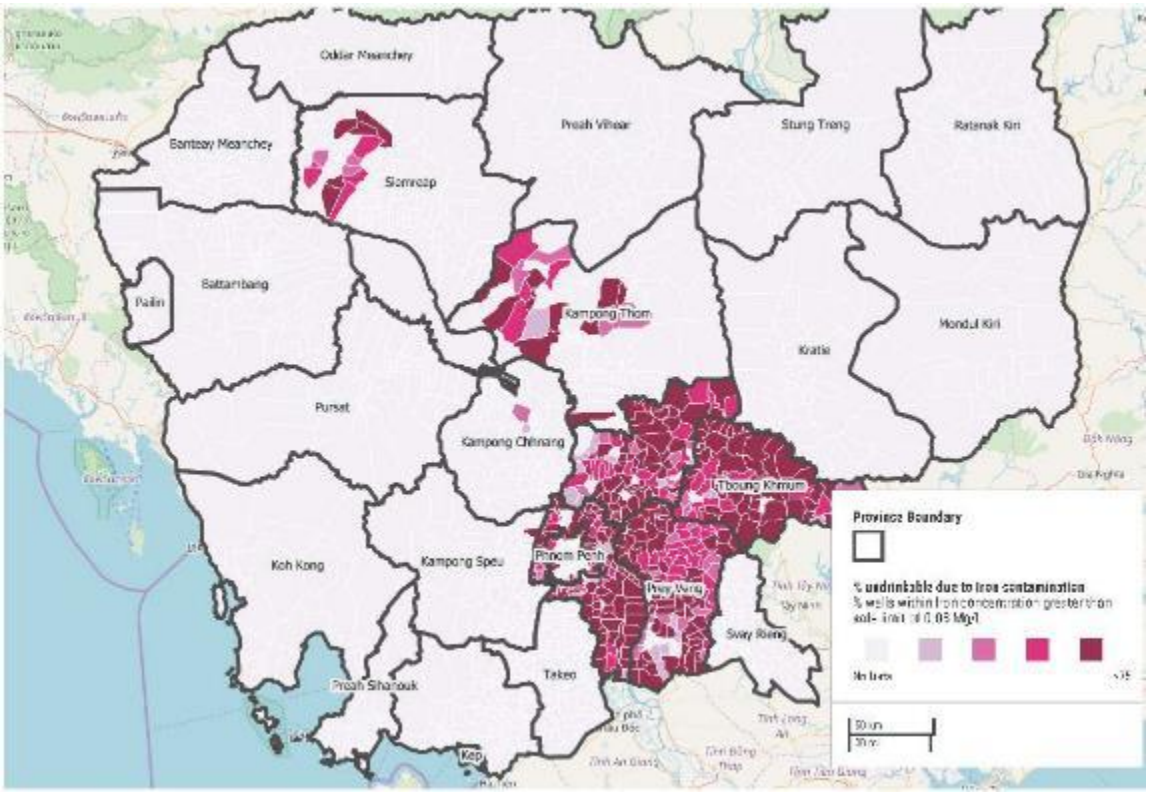


Figure 17: Well with undrinkable water by commune in Cambodia due to iron concentration

Source: Ministry of Rural Development (2019)

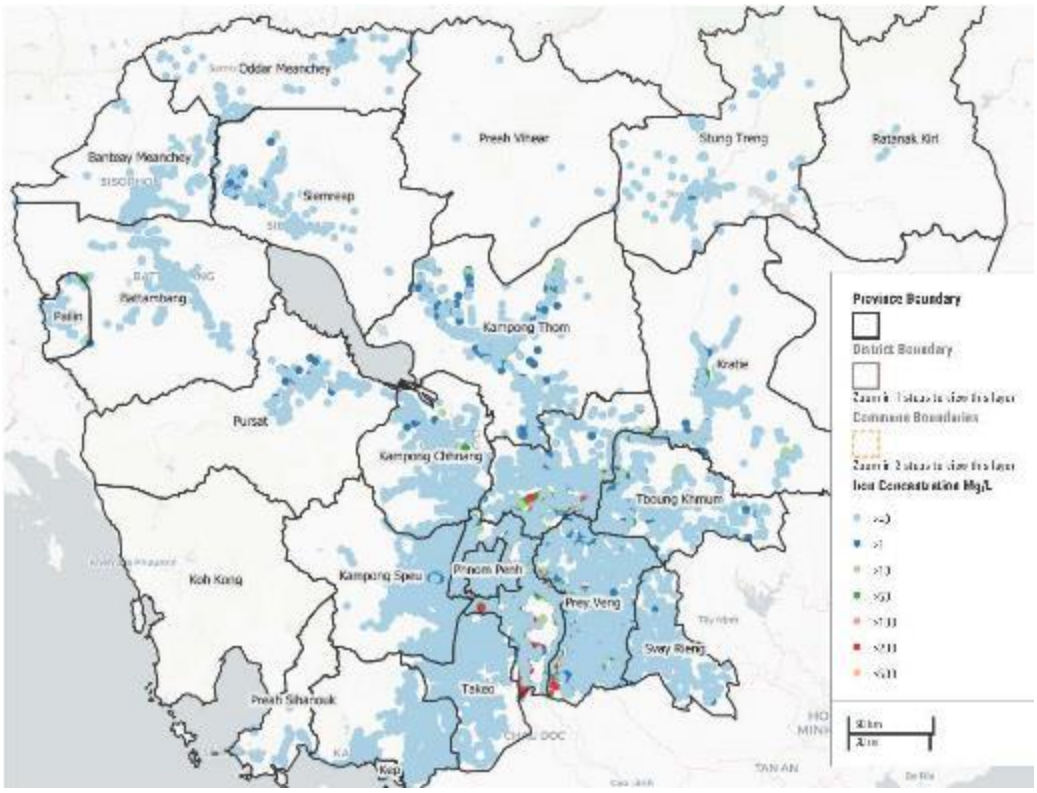


Figure 18: Iron concentration by well for 59,000 recorded wells

Source: Ministry of Rural Development (2019)

### 5.2 An arsenic problem in Cambodia

Arsenic contamination is a significant threat to safe drinking water in Cambodia, especially in the rural regions where hundreds of thousands of peoples rely primarily on groundwater for their drinking water needs. A study commissioned by the Ministry of Rural Development (MRD) and UNICEF to test the water from 16,000+ tube-wells for arsenic in 7 central provinces bordering the Mekong and Bassac rivers (Kandal, Kampong Cham, Kratie, Kampong Chhnang, Kampong Thom, Prey Veng and peri-urban Phnom Penh provinces) found that an estimated 320,000 people in 1,600 villages are at risk. A study by the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) reported arsenic concentration as high as 1,300 mg/l, which is 26 times higher than the Cambodian standard of 50 mg/l (MIME, 2004) in the Mekong delta south of Phnom Penh (Buschmann et al, 2007).

Arsenic contamination of groundwater Mekong delta was first identified in 2000 by Feldman et al (2001). Later it was found that there is a wide spread arsenic contamination of groundwater resources in the Mekong flood plain or Delta where some 100,000 family-based wells exist for drinking water supply (Polya et al, 2003; Polya et al, 2005; Stanger et al, 2005; Trang et al, 2005). Buschmann et al (2007) conducted a comprehensive survey in an area of 3700 $km^2$ in the Mekong River floodplain and found wide-spread arsenic contamination ranging from 1 to 1340 µg/L (average 163 µg/L) with 48% exceeding 10 µg/L. Around 350 people per $km^2$ are potentially exposed to chronic arsenic poisoning. These elevated levels of

arsenic are sharply restricted to the Bassac and Mekong riverbanks and the alluvium braided by these rivers.

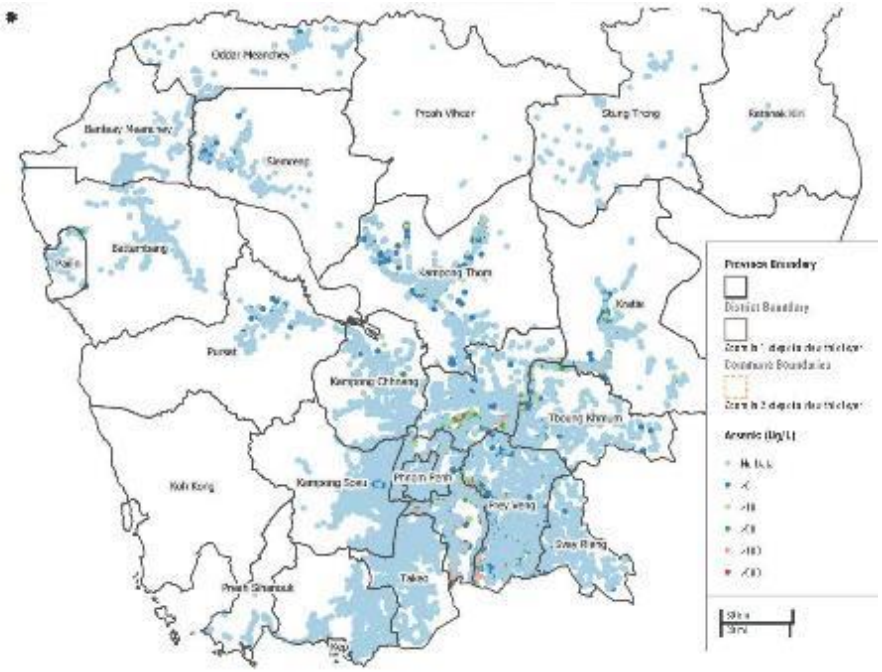


Figure 19: Arsenic contamination by well for 59,000 recorded wells

Source: Ministry of Rural Development (2019)

The elevated arsenic concentrations were observed in wells located near major watercourses such as the Mekong River and its tributaries and distributaries, and in areas where the surgical geology comprised sediments of Quaternary age. Areas along the Mekong and Bassac rivers to the south and southeast of Phnom Penh (in neighboring Kandal Province) appeared to have the highest concentrations in the study area (Pan et al, 2002).

## 6. Management Challenges

There are several major issues and challenges at management level that threaten sustainable management of groundwater resources. Firstly, there is no data record of those who use excessive groundwater for irrigation, industries and livestock, as well as no clear regulations on how much water can be extracted for irrigation or industry. Groundwater management is only partially included in *the Law on Water Resource Management* (2007) and is only managed by government agencies in a fragmented manner. There are also groundwater quality problems with high arsenic and iron (Fe) contents in Mekong and Tonle Sap river basin (along the rivers); as industrial zones are expanding in Cambodia there could be potential problems of groundwater contamination from untreated industrial waste. A proper monitoring program is required to gather database information for research and development. Groundwater

assessment, management and development programs (i.e. groundwater recharge, geochemical studies, integration with surface water, modelling studies, etc.) require experienced and knowledgeable people in both the public institutions and private practice. However, human resources are still lacking.

# Capacity and Institutional Assessment on Groundwater Management in Cambodia

## 1. Introduction

Cambodia is facing mounting development challenges due to climate change. Longer dry seasons and shorter, more intense rainy seasons have become a common observation in Cambodia – an issue for a country dependent on agriculture. The lack of institutional capacity for comprehensive groundwater management and groundwater monitoring systems is noted in Cambodia (ADB, 2014). Strengthening capacity of relevant government institutions and key stakeholders working on groundwater issues is very important for effective groundwater management.

This report will assess institutional capacity of relevant government agencies, particularly the Department of Water Supply and Sanitation in the Ministry of Water Resources and Meteorology (DWSS/ MOWRAM) as the main agency mandated to manage groundwater monitoring and assessment and long-term capacity building.

Objectives

The objectives of this capacity and institutional assessment on groundwater management in Cambodia are:

- To identify relevant groundwater related laws/regulations such as water resource management laws, disaster management laws, and other related strategic plans;
- To identify the roles and responsibilities of relevant government institutions working in the groundwater sector;
- To assess the capacity of relevant government institutions on groundwater management;
- To propose capacity needs for sustainable groundwater management in Cambodia.

## 2. Methodology and Process of the Institutional Capacity Assessment

**Desk Review:** Information regarding legal frameworks and institutional structures, roles and responsibilities of relevant government agencies working on groundwater was collected from websites, recent research or study reports and relevant government agencies such as MoWRAM, CNMC, MRC, MRD, MIH, MoE, and NCDM.

**Key Informant Interviews (KII):** were used to understand the organizational structure, roles and responsibilities of each institution working on groundwater and how they coordinate and cooperate with each other, as well as understand institutional capacity gaps and needs of each agency regarding groundwater management in Cambodia. KII's were specifically used to deeply understand the way key government agencies coordinate to deal with groundwater stresses, disasters (droughts), and groundwater monitoring based on their existing knowledge, technical skills, and practical experience at national and sub-national level. At this stage, it was also important to gather initial ideas regarding the long-term capacity building program for groundwater management as one part of the groundwater management strategic plan in Cambodia. Three main ministries were interviewed: DWSS of MOWRAM, DRWS of MRD, and DPWS of MIH.

**Analyzing and Reporting:** All information and results from the desk review and KII were used to analyze the real capacity gaps and needs of relevant institutions regarding groundwater management. Drawing from these results, recommendations for a long-term capacity building program on groundwater management in Cambodia were developed, with input from UNDP as the instigator of this research.

**Presentation of the result**: The key results of the capacity and institutional assessment will be presented to key stakeholders to collect wider comments before finalizing the report.

# 3. Desk Review

## 3.1 Related laws, regulations, and strategic plans

There are no specific laws or regulations regarding the groundwater sector, however it is highlighted in certain related legal frameworks and strategic plan (Table 10):

Table 10: Related laws and regulation frameworks for groundwater

| Related Laws/Regulations/Strategic Plan | Description |
|---|---|
| *Law on Water Resource Management 2007* (MoWRAM) | Every person has the right to use water resources (including groundwater) for his/her vital human needs including drinking, washing, bathing and other domestic purposes including watering for animal husbandry, fishing and irrigation of domestic gardens and orchards (article 11). This use is not subject to licensing but if diversion, abstraction and use of water resources is for purposes other than those mentioned in article 11, it is subject to a license or permit (article 12)<br>It is mandatory to report to MoWRAM when groundwater is discovered in the course of mining, drilling or other activities (articles 20 and 21) |
| *Sub-decree on River Basin Management 2015* (MoWRAM) | To establish a river basin management committee to manage, conserve, and develop a river basin development plan in an efficient and sustainable manner in accordance with the *Law on Water Resource Management.* The responsible agencies are also required to design and implement a groundwater management plan in the river basin boundary areas |
| *Sub-Decree on Water Pollution Control 1999* (MoE) | The storage or disposal of solid waste or any garbage and hazardous substances that leads to pollution of public water areas shall be strictly prohibited (article 8). The owner of storage places or landfill of hazardous waste shall make quarterly |

| | |
|---|---|
| | reports on the hazardous waste and forward this to the Ministry of Environment (MoE) (article 18) |
| *Cambodia Drinking Water Standard 2004* (MIME) | This standard describes satisfactory groundwater quality required for drinking water |
| *Law on Environmental Protection and Natural Resource Management 1996* (MoE) | Water (including groundwater) "shall be preserved, developed and managed to use in a rational and sustainable manner" |
| *National Strategy on Rural Water Supply, Sanitation and Hygiene 2011-2025* (MRD) | This strategy is to strengthen institutions and identifies responsibilities of relevant agencies at both national and sub-national levels to improve water supply service and water quality |
| *National Constitution 1993* | Water is the state's ownership (article 58) and the task of planning management of water resources is assigned to the state (article 59) |
| *Disaster Management Law 2015* | Relevant due to the interrelated nature of groundwater depletion and potential for drought. The three main goals of this law are:<br>(i) Prevention, adaptation and mitigation in the pre-disaster period, due to natural or human-made causes;<br>(ii) Emergency response during disaster;<br>(iii) Recovery in the post-disaster period |
| *National Policy and Strategic Plan for Green Growth 2013-2030* (MoE) | To promote a national economy with growth stability, reduction and prevention of environmental pollution, safe ecosystem, poverty reduction, and promotion of public health service, as well as sustainable land use and water resource management. |
| *Cambodian Climate Change Strategic Plan 2014-2023* (MoE) | To reduce vulnerability of those most affected by climate change impacts (including changes to groundwater resources) and promote low-carbon development and technologies, as well as to promote awareness and participation of public in climate change response actions. |

## 3.2 Roles and responsibilities of relevant institutions

Generally, there are many government and non-government institutions at all levels involved in groundwater/water related issues (Table 11):

Table 11: Related institutions and their responsibilities

| Institutions | Responsibilities |
|---|---|
| **Government** | |
| Parliament | Develop, adopt, endorse, amend, monitor and enforce laws and legislation frameworks |
| Royal Government | Lead, manage, monitor and evaluation decision making and policy guidelines<br>Coordinate among line ministries |
| National | Develop policy and strategy, and provide policy guidelines<br>Provide regulation and technical services<br>Monitor |
| Province | Management and coordination role<br>Develop, monitor and evaluation provincial plans<br>Seek funds for development<br>Intervention |
| Local Authority | Community Development Plans to reduce poverty through use of the commune/Sangkat fund<br>Security<br>Administration<br>Empower local communities |
| **Users** | |
| Communities | Participate<br>Utilization and management<br>Operation and Maintenance (O&M)<br>Elections |
| Private sector | Participate<br>Provide funding for research and development<br>Investment |
| **Supporters** | |

| | |
|---|---|
| Universities/Research Institutes | Provide guideline documents<br>Research and development<br>Academic study<br>Technical support and extensions<br>Training |
| Non-Government Organizations (NGO)/ Development Partners (DP) | Help seek funding<br>Clear priorities and good participation in projects/programs |

Source: MoWRAM (2005)

The three main government agencies working on groundwater in Cambodia are Ministry of Water Resources and Meteorology (MoWRAM), Ministry of Industry and Handicraft (MIH), and Ministry of Rural Development (MRD). The most relevant departments working on groundwater are Department of Water Supply and Sanitation (DWSS) in MoWRAM, Department of Potable Water Supply (DPWS) in MIH, and Department of Rural Water Supply (DRWS) in MRD (see Annex 1).

**Ministry of Water Resources and Meteorology**

This agency has been in operation since 1999. MoWRAM's mandate is to:

- Carry out scientific research on the potential of underground and surface water resources to establish scientific knowledge on the topic;
- Set short-, medium- and long-term direction and roadmaps with respect to water consumption to fulfill the country's development and industry needs and preserve urban and rural populations;
- Control and monitor all activities consuming water to mitigate incurred risks;
- Prepare and draft laws and regulations linked to the use of water and control procedures, gather documents and build technical data about climate and hydrology regarding water use nationally and abroad, and find return on investment for the scientific research;
- Raise awareness and provide advice to industries, NGOs, civilian communities and populations regarding development and exploitation of water resources;
- Communicate and seek innovative techniques with respect to water use and its treatments;
- Collaborate and participate in the management of the Mekong Basin through the Cambodia National Mekong Committee (CNMC), considering both the management of water resources and meteorology;
- Issue licenses and permits for water use.

Specifically, DWSS/MoWRAM are responsible for:

- Conducting research on surface and groundwater sources;

- Completing research, evaluation and preparation for short, medium, and long-term plans for development of water sources to serve the production of potable water, and perform monitoring and evaluation on implementation;
- Preparation of short, medium, and long-term plans for the development of wastewater discharge from cities, municipalities, towns and public gathering places; and completing regular monitoring and inspection on implementation;
- Conduct research studies and monitoring and evaluation on water quality for both underground and surface water.

Source: Toch (2014); ODC (2016); DWSS/MoWRAM (2019)

Currently, DWSS/MoWRAM is responsible for developing a nation-wide groundwater management strategy and long-term capacity building program on groundwater management in Cambodia (UNDP, 2019).

**Ministry of Industry and Handicraft**

DPWS of Ministry of Industry, Mine, and Energy (MIME) (now known as MIH) has been in operation since 1996. This department is responsible for development of the water supply sector in urban areas, policy development and implementation, and regulation enforcement. The role of DPWS includes resource inventories, monitoring, legal work (rules, regulations, standards, licensing), policy and strategy development in water resource management, but is not limited to groundwater (ADB, 2014). According to the *Cambodia Drinking Water Standard 2004,* this agency shall regularly follow up and monitor water quality of drinking water sources, operational facilities, and public water supply systems in order to assess the production process of water supply (MIME, 2004).

Important roles of DPWS are:

- Controlling and managing production and utilization of safe water throughout the country;
- Collecting information and developing an inventory on the potential production of water supplies (both surface water and groundwater);
- Developing policies, rules, and regulations to manage water supply and sanitation in accordance with actual geographical areas;
- Preparing and installing specific laboratories to control water quality based on the national drinking standard;
- Issuing a license to persons in charge of operating clean water supply and sanitation facilities in compliance with ministry guidelines and principles.

**Ministry of Rural Development**

DRWS of MRD has been in operation since 1996. MRD is the agency responsible for development, coordination, implementation, and monitoring and evaluation of the implementation of the national policy and strategy on rural water supply and sanitation to achieve the common goal of achieving country-wide access to water and sanitation by 2025 (RGC, 2011). MRD's mandate is to:

- Coordinate, cooperate, implement, monitor and evaluate rural development projects and programs (including related groundwater projects);
- Coordinate the operational efforts of various line ministries and assistance programs;

- Undertake independent research initiatives to practically develop rural areas of Cambodia by assessing likely needs and investigating possible solutions that would maximize identified opportunities.

While not within the three major ministries related to groundwater management, the National Committee for Disaster Management (NCDM) is important in disaster risk management. NCDM was established in 1995 to lead and coordinate disaster management in Cambodia. It consists of 22 members from different ministries, Cambodia Armed Forces, Civil Aviation Authority, and Cambodia Red Cross (CRC). As part of decentralization process, disaster management institutions such as Provincial Committee for Disaster Management (PCDM), District Committee for Disaster Management (DCDM), and Commune Committee for Disaster Management (CCDM) have been set up to lead disaster management at their administration level respectively. Village Disaster Management Groups (VDMG) are also in place as the lowest level body for disaster management (NCDM, 2014). Related to groundwater management, this institution has worked with their line agencies, particularly at the sub-national level, on early warning systems and information sharing related to temperature, weather, rainfall, and water levels in order to alert citizens about drought/flood risks. It should be noted that related meteorology/hydrology information is sourced from PDoWRAM/MoWRAM (see Annex 1).

The Cambodian National Mekong Committee (CNMC) is also an important agency responsible for coordination for Mekong River Basin management and development, including groundwater issues and drought management, and international agreement implementation among signatory countries. They have a role in liaising between the Mekong River Committee (MRC) and Cambodian government agencies. This agency is under the administration of MoWRAM (see Annex 1).

Other relevant ministries are:

- The Ministry of Mines and Energy (MoME) is responsible for hydropower development which relies on both surface and groundwater resources for operation;
- The Ministry of Public Works and Transport (MPWT) is responsible for water supply and sanitation in Phnom Penh and districts, along with the Water Supply Authority. Groundwater is the main resource for domestic water supply;
- The Ministry of Environment (MoE) is responsible for protecting water resources, including groundwater;
- The Ministry of Agriculture, Forests and Fisheries (MAFF) is responsible for policy implementation related to the use of groundwater and surface water (irrigation and catchments) for agricultural purpose;
- The Ministry of Health (MoH) is responsible for controlling the quality of water used for public water supply;
- The Ministry of Economy and Finance (MEF) is responsible for harmonizing the diverse proposals on water management, while matching the Government's priority (ODC, 2016).

In total, no less than 9 ministries are directly or indirectly involved with water/groundwater management in Cambodia (CDRI, 2016).

# 4. Institutional Capacity Assessment

## 4.1 Capacity of relevant government institutions

Implementation of groundwater management requires a suitable technical capacity and professional skill to coordinate and cooperate with relevant agencies and stakeholders both at national and sub-national level. Technical knowledge, particularly of the aquifer system, is often limited at the level at which management response is required (FAO, 2003). Groundwater management in Cambodia is fragmented by overlapping government institutions. At this point, there has been no nationwide groundwater management strategic plan and strong coordination and cooperation among relevant agencies to work on groundwater issues – they work individually based on funding provided by development partners and/or private sectors.

Generally, the related government agencies still have low individual, organizational, programmatic capacity to work on groundwater sector in Cambodia. According to Pradhananga and Davenport (2013), "***individual capacity*** includes an individual's actions, beliefs, concerns, sense of responsibility, and ability to take action. ***Organizational capacity*** includes organizational leadership and development, partnerships, and collaborative decision-making processes. ***Programmatic capacity*** includes stakeholder engagement, assessment, outcomes evaluation, and adaptation."

**Individual Capacity**

Within the three main departments of MoWRAM (DWSS), MIH (DPWS), and MRD (DRWS), there is a lack of technical and management skills required for development and enforcement of a proper groundwater management plan that would ensure sustainable water use in Cambodia. Most staff have limited knowledge and skills in hydrogeology, water resources engineering, GIS mapping, and groundwater monitoring and modeling assessment capacity (both water quantity and quality). They are more concerned about equipment than scientific/technical knowledge, suggesting that "if their departments were to have enough financial resources, the well-trained staff would be able to perform their work efficiently" (Seng et al, 2013). Other capacity gaps include knowledge on water pollution control in wells, capacity to analyze data and estimate groundwater availability, land use change impacts assessment on groundwater and so on. Beside technical knowledge gaps, there is difficulty accessing land use planning information and the ratio of groundwater quantity that has been abstracted and used by private companies and for domestic water supply.

Regarding management skill, there is still a lack of a sufficient groundwater management database. Data/information on groundwater quantity and quality issues are very important – land use change resulting from conversion of forest or wetland areas to agricultural and urban zone and overuse of groundwater due to increasing populations, factories and infrastructure development plan in the urban areas bring challenges that need to be addressed. Moreover, officers of key government agencies find it challenging to identify types of information and data required for long-term groundwater management. Data and information required includes:

- Hydrogeological data
- Detailed aquifer characteristics
- Detailed groundwater yield map
- Groundwater recharge data and projected groundwater use trends
- Changes in static levels at different development zones such as urban and industrial
- Land-use maps for agricultural, industrial, or other infrastructure projects

- Forest cover maps showing forest loss areas
- Well-maps and groundwater source maps
- Groundwater quality at different aquifers
- Groundwater quantity extracted from industrial zones
- Disaster areas, particularly drought prone areas
- Climate change information, etc.

It should be noted that data and information filed within government agencies is only available internally within their individual agency and is difficult to access across ministries.

**Organizational Capacity**

Organizational capacity is still very limited, particularly within DWSS of MoWRAM. The DWSS has been established since the beginning of MoWRAM in 1999, but it has not been well-functioning to work both at national and sub-national level. To this point, there had not been a master or long-term strategic plan for protection of groundwater, and there is a lack of clarity regarding a clear structure of staff expertise and roles or duties. Between 2013 to 2017, there were no outputs of DWSS mentioned in MoWRAM's strategy and development plan (DWSS/MoWRAM, 2019). Also, the two groundwater monitoring and data collection proposals raised by DWSS since 2010 have not yet been funded by any development partner (ibid). Related groundwater projects such as water supply and sanitation are mostly funded under the responsibility of MIH and MRD, who have more involvement with private sectors and sub-national administrations. Moreover, DPWS issue water use licenses, but have limited capacity to conduct detailed studies on the impacts on groundwater quality and quality. This has resulted in adverse impacts on the sustainability of groundwater use by the agriculture and industrial sectors.

To avoid this problem, internal organizational improvement of DWSS and resourcing are needed to improve functioning of this agency to fulfill its mandate regarding groundwater. For example, the name of DWSS should be revised to Department of Groundwater Management, which focuses primarily on groundwater monitoring and assessment. Also needed is a clear structure of roles and responsibilities for each line-unit of DWSS, as well as a focus on improving staff capacity. The EWS project funded by UNDP supports MOWRAM in developing a groundwater management strategy and long-term capacity building program, which provides a good first step in holistically shaping the main objectives for DWSS/MoWRAM and other ministries and stakeholders involved with groundwater management.

**Programmatic Capacity**

Programmatic capacity is strongly linked to individual and organizational capacity – once there is lack of individual proficiency and poor organizational capacity, it is hard to say that an agency is good at programmatic capacity. Programmatic capacity in this context would involve engaging relevant stakeholders including technical staff of relevant agencies, experts, local authorities, communities, private sectors, and development partners to be involved in all stages of development of a short-, medium-, or long-term groundwater management plan or program. This includes engaging stakeholders in defining groundwater problems and identifying priority actions by assigning roles and responsibilities of each involved agency based on expertise and experience, and then implementing and monitoring the actions and outcomes of the program, and finally applying what has been recommended for sustainable groundwater use and ecosystem protection. Both financial and technical support is necessary.

## 4.2 Proposed capacity needs

For individual staff capacity, the following various skills and knowledge should be developed:

- Groundwater hydrology;
- Groundwater data collection, management and analysis;
- Groundwater recharge and pollution;
- Groundwater resources mapping;
- Groundwater pumping, monitoring and modelling;
- Groundwater use and management for a sustainable agricultural sector;
- Groundwater impact by land use change and climate change;
- Groundwater policy and governance.

For institutional capacity, the following various skills should be developed:

- Staff capacity in hydrogeology and water resources planning and management;
- Organizational capacity to avoid overlapping tasks, roles, and responsibilities;
- Coordination, cooperation, and information and data sharing capacity among relevant government agencies to develop long-term groundwater management strategic plan;
- Groundwater development and management planning capacity, particularly on Integrated Water Resource Management (IWRM) at local level through building individuals' sense of responsibility to protect groundwater (local planning) and promoting groundwater protection to ensure drinking water quality;
- Improve institutional capacity in disaster response, risk reduction, monitoring and evaluation (M&E), and EWS, particularly in the NCDM, PCDM, and CCDM;
- Enhance university and ministry cooperation for research capacity development on the importance of sustainable groundwater management;
- Improve donor-driven capacity for groundwater management project funding from development partners such as joint-proposal development among relevant government agencies.

# Groundwater Management Strategy in Cambodia

## 1. Introduction

Cambodia is considered as one of the most water-abundant countries in the region. Rivers and streams, lakes, aquifers and marine water are important sources for national economic development in daily life as well as many sectors including agriculture, manufacturing and small-scale industries, hydropower, navigation, tourism and environmental protection (UNESCO, 2015). Groundwater resources are crucial for sustaining water security and as a major source of Cambodia's drinking water supply; over half of household drinking water comes from groundwater sources in the dry season (Sok, 2018). Groundwater is available almost everywhere in the plains area, except for the dry zone in the central and north-western regions. However, people still face challenges in accessing groundwater for domestic water supply and related groundwater business purposes, as some wells have dried out due to overuse and climate change impacts, and some groundwater sources have been polluted by human activities and contaminated with mineral substances in the aquifer itself.

To achieve sustainable groundwater resource management, there is urgent need for appropriate groundwater resource governance, including capacitated local participative resource management, enabled and supported by a coordinated national and sub-national government working with groundwater users and extractors, and technical guidance from experts and financial support from development partners and/or charities. At this point in Cambodia, there are many institutions related to the groundwater sector both directly and indirectly yet there is no groundwater management strategy.

By seeing the importance of groundwater resources and the lack of legal frameworks and documents on groundwater management, under the financial support of the UNDP, this groundwater management strategy in Cambodia has been proposed by the Department of Water Supply and Sanitation (DWSS) of Ministry of Water Resources And Meteorology (MoWRAM) in order to ensure sustainable use and prevention of groundwater in Cambodia.

This proposed document is the first strategy for the government of Cambodia to consider as a long-term groundwater strategy for use by relevant government agencies. It is believed that this strategy would contribute to further sustainable groundwater development and management action plans in order to enhance the effectiveness and sustainability of groundwater utilization and preservation for the next generation.

## 2. Legal Framework on Groundwater in Cambodia

In Cambodia, there is no specific law or regulation regarding only groundwater sector, however, it has been highlighted in related legal frameworks including:

- *Constitution of the Kingdom of Cambodia* (1993), New Articles 58 and 59 (January 1995);
- *Law on Water Resource Management* (2007);
- *Law on Environmental Protection and Natural Resource Management* (1996);
- *Disaster Management Law* (2015);
- *Sub-decree on River Basin Management* (2015);
- *Sub-decree on Water Pollution Control* (1999);

- *Cambodia Drinking Water Standard* (2004);
- *National Strategy on Rural Water Supply, Sanitation and Hygiene* (RWSSH) (2011-2025);
- *National Policy and Strategic Plan for Green Growth* (2013-2030);
- *Cambodian Climate Change Strategic Plan* (2014-2023).

Key government institutions working on groundwater are found in Table 12:

Table 12: Government agencies and their mandates

| | **Key Agency** | **Mandate** |
|---|---|---|
| 1. | Ministry of Water Resources and Meteorology (MoWRAM) | Water resources (including groundwater) management, development and conservation, irrigation, meteorology systems |
| 2. | Ministry of Industry and Handicrafts (MIH) | Water supply provision to provincial towns |
| 3. | Ministry of Rural Development (MRD) | Provision of wells and water sanitation such as potable water systems and drainage in rural areas |
| 4. | National Disaster Management Committee (NCDM) | Coordination for pre-, during-, and post disaster management and rehabilitation |
| 5. | Cambodia National Mekong Committee (CNMC) | Coordination for Mekong River Basin management and development, and international agreement implementation among signatory countries. Liaise between MRC and Cambodia government agencies. |
| 6. | Ministry of Mine and Energy (MoME) | Plan industrial water use including groundwater for hydropower plant operation |
| 7. | Ministry of Public Work and Transport (MPWT) | Land drainage and sewerage in Phnom Penh and provincial towns – study, survey, construction and maintenance of water supply equipment and related infrastructure |
| 8. | Ministry of Environment (MoE) | Water pollution control, Social and Environmental Impact Assessment (EIA) and licensing, Ramsar sites and Tonle Sap Biosphere Reserve development and management |
| 9. | Ministry of Agriculture, Forestry and Fisheries (MAFF) | Water for agriculture, livestock, and joint *Strategy on Agriculture and Water* (SAW 2009-2013) implementation |
| 10. | Ministry of Health (MoH) | Control of the quality of water used for public water supply |
| 11. | Ministry of Economy and Finance (MEF) | Responsible for financial preparation of water management while matching with government priority |

# 3. Vision / Mission

The vision and mission is to manage groundwater use effectively and sustainably, and to monitor and respond in a timely manner within the development pressures of Cambodia.

# 4. Goal

The GOAL of the groundwater management strategy is to fulfill all groundwater preservation and utilization activities through strengthening groundwater governance, technical capacity, cooperation, and resource mobilization to implement groundwater management and development for sustainable use in Cambodia.

# 5. Strategic Objectives

To achieve the goal, six strategic objectives are as follows:

1. Strengthen relevant government institutions and related law enforcement to maximize sustainable groundwater management and utilization;
2. Increase and improve scientific and governance capacity in the groundwater sector;
3. Improve groundwater information and data management and sharing;
4. Strengthen coordination and cooperation of relevant government agencies, research institutions, and stakeholders;
5. Raise awareness with relevant stakeholders including public and private sectors on the importance of groundwater resources to ensure sustainable water use in Cambodia;
6. Develop sustainable financial systems partnering with private sectors and development partners on groundwater resource management in Cambodia.

# 6. Proposed Groundwater Management Strategy

## 6.1 Strategy 1: Strengthening institutional arrangements and law enforcement

### 6.1.1 Background and key challenges

In Cambodia, there are many related policies and regulations addressing water resources, however, none specific to the groundwater sector. The Royal Government of Cambodia (RGC) issued the *Sub-decree on Water Pollution Control* (1999) and *Law on Water Resource Management* (2007) with clear objectives that covered principles on management, monitoring, utilization and protection of water resources to ensure their effective development, and to provide guidelines for efficient and effective water resources management, socio-economic development and welfare of population within a sustainable environment (MoE, 2009). The implementation of these regulations and legal frameworks is still limited, particularly regarding groundwater utilization for both domestic and commercial consumption. Reasons include the lack of institutional arrangements or national groundwater management strategy and action plan from

relevant government agencies. It is difficult for MoWRAM, MIH, and MRD to work together on water supply and sanitation as well as other groundwater uses for agriculture and industry purposes across the country as they have not yet shared roles and responsibilities clearly among each other.

Every person has the right to use water resources (including groundwater) for his/her basic needs including drinking, washing, bathing, and other domestic purposes such as watering for animal husbandry, fishing, and agricultural irrigation. Any diversion, abstraction and use outside of these basic needs requires licensing, according to the *Law on Water Resource Management* (2007). Under this law, MIH and MRD[1] have provided many licenses to water supply service providers in order to meet the RGC's strategy that "everyone must have access to water supply and live in a hygienic environment by 2025" (*National Strategy on Rural Water Supply, Sanitation and Hygiene 2011-2025*). The licensing approval should be based on a clear information and data on the quantity of water, however this information is limited and the lack of groundwater management strategy means that knowing how much should be extracted and how much should be kept in the aquifer to maintain ecological system and the balance between surface and groundwater resources is not yet known. MoWRAM has responsibility to conduct groundwater research and distribute these results to relevant agencies for the purpose of sustainable use and conservation of both surface and groundwater. Lack of human and financial resources have resulted in unsustainable use for domestic water supply as well as illegal groundwater extraction for irrigation, industries, livestock, etc. Therefore, improving the coordination of relevant government agencies working in the groundwater sector as well as laws/regulations enforcement is a great need in Cambodia.

### 6.1.2 Main actions

In response to the challenges above, main actions to strengthen institutional arrangements and regulation and law enforcement are proposed as follows:

- Set up clear roles and responsibilities of each relevant government agencies to avoid overlapping tasks when working on the groundwater sector. A sub-decree on the organization and functioning of the Department of Water Supply and Sanitation (DWSS) of MoWRAM, Department of Potable Water Supply (DPWS) of MIH, and Department of Rural Water Supply (DWP) of MRD should be considered to establish how to share important duties regarding groundwater efficiently and effectively;
- Strengthen regulations and laws enforcement related to the groundwater sector, mainly on licensing and water extraction by private sector participants who work on extracting groundwater for domestic water supply, irrigation, and industry sectors;
- Improve groundwater resource management law and regulation implementation that ensures sustainable groundwater use from the aquifer and protects ecosystems, social and cultural values;
- Prohibit all construction projects that severely impact groundwater and ecosystems; and take necessary measures to ban any illegal groundwater extraction and water pollutions of all forms

[1] MRD provide licenses to water supply service providers in rural areas of less than 500 households' water supply consumption.

such as groundwater for irrigation and for the industry sector, pesticide use in the agricultural sectors, chemical substance use in mining activities, etc.;

- Examine effectiveness of existing penalties for violations of groundwater-related permit conditions and recommend necessary improvements to the central government;
- Develop a consistent evaluation process for groundwater appropriation permit applications that effectively incorporates recommendations to avoid groundwater use conflicts (domestic, agriculture and industry) and well interference, evaluates cumulative impacts, stays within sustainability thresholds for water levels, addresses ecosystem concerns and water quality concerns, and provides water conservation technical guidelines;
- Develop and apply procedures for social and environmental restoration and mitigation regarding groundwater use and recharge.

## 6.2 Strategy 2: Human resource development

### 6.2.1 Background and key challenges

Groundwater assessment, management and development programs (i.e. groundwater recharge, geochemical studies, integration with surface water, modelling studies, etc.) require experienced and knowledgeable people in both public institutions and private practice. Related to groundwater management in Cambodia, both public and private sector have limited technical capacity in hydrogeology, hydrogeochemistry, and groundwater analysis and modelling. This shortage brings negative effects regarding the ability for groundwater development and management in Cambodia.

Government officials of national and sub-national level - Department of Water Supply and Sanitation (DWSS) of MoWRAM and Provincial Department of Water Resources and Meteorology (PDoWRAM) (MoWRAM, 2012), Department of Potable Water Supply (DPWS) of the Ministry of Industry and Handicrafts (MIH), and Provincial Department of Rural Development (PDRD) of the Ministry of Rural Development (MRD) - are generally limited in groundwater knowledge and the link to climate change issue. Some departments can contract out a considerable proportion of technical groundwater work to the private sector or consultants, but there remains a requirement for technical expertise within the departments to evaluate the quality of work being done. This function demands experience as well as technical knowledge on both groundwater and climate change issues.

The alignment of a groundwater management strategy and program and integration into a water resource management framework assumes adequate capacity in local authority (provincial, district and commune level). Yet, the capacity of local government to work on related groundwater issues is still low. Therefore, it is critical for sufficient internal capacity to be developed within local government. Staff and technical practitioners with hydrogeological or hydrological training background should be appointed by municipalities to ensure more effective and sustainable groundwater management, particularly as groundwater becomes increasingly relied on for municipal water supply.

While the private water operator sector is growing, challenges remain concerning their technical and managerial performance (WB, 2015). Groundwater in Cambodia is being exploited to an increasing extent, particularly by shallow tube-wells used for community and household water supply and irrigation

(MOWRAM, 2001). Moreover, private activities such as land use change for the agricultural sector and other infrastructure and economic development projects have brought more concern to the groundwater as forest cover has been lost on a daily basis. Hence, technical capacity and water climate change related knowledge is vital for the private sector to take into consideration sustainable use of groundwater to maximize their benefit whilst protecting the ecosystem.

### 6.2.2 Main actions

In response to the challenges above, main actions for human resource development in the groundwater sector are proposed as follows:

- Improve management of professional service providers by building capacity at various levels there is a need to develop adequate capacity to fulfil the groundwater functions. Furthermore, there is a need to mobilize private sector support where necessary to capacitate ministerial and local level and implement practical, in-service training courses on priority aspects (e.g. licensing process, the reserve, groundwater monitoring) for staff;
- Improve groundwater expertise at sub-national level. Staff at sub-national level and technical practitioners with hydrogeological background should be appointed/allocated to the provincial department level to ensure more effective and sustainable groundwater management. Training focal persons at provincial and district level must be implemented to develop local hydrogeologists – this may be enhanced by mobilizing support from the private sector. In order to do this, there is a need to develop and implement a national and sub-national capacity building strategy that includes implementing practical, in-service training courses on priority aspects such as groundwater knowledge, Integrated Water Resource Management (IWRM), licensing process, groundwater monitoring, etc.;
- Build capacity for local authorities and private sectors. It is preferred to have cooperation that ensures both vertical integration between the national level (ministry level and inter-ministry level) and local level (local authority and local private sector including water vendors, users and drillers) as groundwater is essentially a local resource. Capacity building requirements for local authorities and private sectors shall include groundwater exploration technologies, monitoring network and database management system; suitable and locally available groundwater development technology choice; and groundwater monitoring system maintenance for focal persons;
- Topics for training and capacity building on groundwater management must be designed based on the understanding of groundwater and the significance of the peer group (farming community, local focal person, provincial department staff, ministry and inter-ministry) in creating learning opportunities and optimizing the output for groundwater management in Cambodia. The training method and capacity building methods could include in-service courses, seminars, and workshops.

## 6.3 Strategy 3: Information and data management

### 6.3.1 Background and key challenges

Groundwater data such as water levels and groundwater quality are the foundation of groundwater management. A lack of reliable groundwater data in Cambodia makes it difficult to make accurate assessments of the availability (i.e. quantity and quality) and abstraction (i.e. rates, quantities and drawdown levels) of groundwater for research, investment in operation, maintenance activities and development strategy.

Lack of data combined with lack of skill at provincial and ministry level results in poor information for decision making and management of the groundwater resources. Poor management is manifested in over-abstraction, lack of monitoring, groundwater pollution and a lack of policing. Adequate investment in the maintenance of infrastructure, data collection and interpretation are likely to repay themselves many times over as more effective use of local resources (i.e. limit reliance on distant surface water supplies). To achieve success in groundwater management strategy and program and integration into a water resource management framework, adequate information and data at the various levels (provincial level, district and commune level) must be accomplished.

In 2004, a FAO study recorded the amount of groundwater resources. Since then, most research on Cambodia's groundwater have been conducted based on Cambodia's well databases (ODC, 2016a). WellMap is an initiative of the MRD, piloted with financial support under World Bank's Water and Sanitation Program. In March 2010, the system came online with data contributed by a large number of projects and organizations active in Cambodia's rural water supply sub-sector (MRD, N.D.). However, key stakeholders working on groundwater sectors still find it difficult to access comprehensive and updated national disclosure of information and understanding relating to groundwater resources, as research results and recently constructed groundwater wells have not been included in the database.

### 6.3.2 Main actions

In response to the challenges above, main actions for information and data management in the groundwater sector are proposed as follows:

- Collect data and information required for groundwater management in Cambodia. The groundwater data management in Cambodia shall consider quantity of groundwater data including systematic national hydrogeological mapping, well records, time series of groundwater levels, groundwater quality analyses and other related research datasets. The compilation of existing data and new proposed monitoring data shall be done by various government agency levels (sub-national level including community, commune, district and provincial level). A comprehensive database shall include information on hydrology, geomorphology, geology, hydrogeology, borehole drilling, geophysical findings, hydrochemistry, groundwater use, groundwater contamination, and vulnerability to groundwater quantity and quality. The types of data required for groundwater management are detailed in Table 13;

Table 13: Summary of technical data and information in groundwater management in Cambodia

| Data and Information | Targeted Relevant Groups | Output and Information from the Data |
|---|---|---|
| Aquifer properties data | Inter-ministries<br>Provincial department | Data on physical properties (transmissivity, storage coefficient, porosity and permeability) |
| Geophysical logs | Ministry level<br>Provincial department | Detailed record of geologic formations penetrated by a borehole. |
| Groundwater levels<br>(in different spatial scales) | Provincial department<br>Community | Indication of how humans and climate have impacted amount of water stored underneath<br>Groundwater levels in response to seasonal climatic fluctuations<br>Seasonal patterns of groundwater levels<br>Groundwater level trends<br>Amount of water in storage in the monitored aquifer. When recharge exceeds natural discharge plus abstraction, groundwater levels rise |
| Hydrogeological maps<br>(including groundwater recharge information) | Inter-ministries<br>Provincial department<br>Commune focal persons | Basic geological information + data on hydraulic and hydrochemical characteristics of the rocks and their usefulness for groundwater supply<br>Information on groundwater resources, reserves, quality, flow |
| International (country) data collections and maps | Inter-ministries<br>Provincial department | Understanding of the dynamic interactions between transboundary groundwater resources |
| Groundwater level information (contour information) | Inter-ministries<br>Provincial department | Depth information is represented in meters below the ground surface<br>Groundwater flow direction |
| Groundwater use and abstraction | Ministry level<br>Provincial department<br>Commune focal persons | Abstraction rate, percentage of groundwater using compared to surface water<br>Maintain groundwater level |
| Water quality baseline data<br>(based on Cambodia Water Quality) | Ministry level<br>Provincial department<br>Commune focal persons | Summary data on baseline parameters, including quality, for each site/location/area<br>Designated monitoring stations<br>Detect any deterioration of water quality if occur |
| Well records/Well inventory | Inter-ministries | Collection of available data for various use and open access |

| | | |
|---|---|---|
| | Provincial department staff | Different types of wells studied to record yielding capacities, main aquifers contributing to yield, etc. |

Data must be frequently updated to allow accurate understandings, and to enable development of history of data and past/future trends.

- **Factors to consider in data storage and information management:**
  - **Information storage and processing:** an important element of a monitoring database is quality control of the data. There is a need to decide on the level and methods of processing and quality control required to produce the desired information. Key guidelines for a Quality Control (QC) and Quality Assurance (QA) system are:
    - ✓ Train the observer: cross checks in the field;
    - ✓ Guidelines: follow procedures (e.g. for sampling);
    - ✓ Keep copy of field readings;
    - ✓ QA on groundwater quality analysis;
    - ✓ QC procedures for data entry in the data base; QC control in data processing.
  - **For information sharing and dissemination:** it is important to consider how to disseminate information and in what form to support decision-making, keep stakeholders informed, provide timely prior warning information and trusted data, and consider all possible risks to groundwater caused by weather, climate, and human activities. The choice of methods will depend on resources available and the target audience (Table 14).
  - **Information types and characteristics:** There is a wide range of information types that can be selected and used for different purposes. Table 15 demonstrates the classification of data types in Cambodia at national and sub-national level.

Table 14: Information sharing and dissemination strategy

| Targeted Group | Information Outputs Required | Dissemination Methods/Channels |
|---|---|---|
| Ministry level<br>Provincial department | Quantity and quality of groundwater available for allocation<br>List of groundwater users and permit holders<br>List of non-compliance by water permit users and actions taken<br>Location and yield of well fields/boreholes | Shared database (e.g. national well database or well inventory) |
| Civil society<br>NGOs<br>Universities | General situation and information regarding water use and quality | Website (e.g. Cambodia well database) |
| Political stakeholders such as government officials<br>Inter-ministries | Summarized information on status of groundwater management and allocation | Regular status reports such as a leaflet/newsletter<br>Half-yearly or annual report |

Table 15: Wide range data required for groundwater management for national level

| Type of Data | Static Data<br>No significant variation with time<br>(from archives) | Dynamic Data<br>Variation with time<br>(from field stations) |
|---|---|---|
| Groundwater occurrence and aquifer properties | Water well records (hydrogeological logs, initial groundwater levels and quality)<br>Well and aquifer pumping tests | Groundwater level monitoring<br>Groundwater quality monitoring |
| Groundwater use | Water well pump installations<br>Water use inventories<br>Population registers and forecasts<br>Energy consumption for irrigation | Water well abstraction monitoring (direct or indirect)<br>Groundwater level variations at well |
| Supporting information | Climatic data<br>Land use inventories<br>Geological maps/sections | River flow gauging<br>Meteorological observations<br>Satellite land use surveys |

**Notes:**

- Data collection by regional offices, and submission of the data to head office, needs to be reviewed.
- Data collection is closely related to sufficient human capacity.
- Privately held data by private sector, research projects and sub-national level needs to be incorporated into national, accessible databases.
- Private drilling contractors need to be registered to allow the data that they collect to be made publicly available.
- Current groundwater databases need more funding and attention and need to be verified and combined. In particular, the future of the national groundwater archive needs to be specified.

## 6.4 Strategy 4: Enhancing coordination mechanisms and cooperation strategies

### 6.4.1 Background and key challenges

To develop a groundwater management program or project, there is great need to engage relevant stakeholders including technical staff of relevant agencies, experts, local authorities, communities, private sectors, and development partners. However, in Cambodia, there are still limited coordination mechanisms. Each agency works independently to meet their organization's objectives or purposes by conducting related groundwater studies and/or using groundwater resources without a clear collaborative approach.

Some research/activities related to groundwater have been conducted by individual agencies, including:

- Groundwater data collection conducted by the Japan International Cooperation Agency (JICA) in 2002 (U.S. Geological Survey, 2011);
- Groundwater data collection conducted by the International Development Enterprises (IDE) in 2008 (U.S. Geological Survey, 2011);
- Investigation to develop an arsenic strategy was conducted by MRD and Institute of Technology of Cambodia (ITC) to prevent health problems related to consumption of arsenic-contaminated water (ODC, 2016a);
- Joint program among MoWRAM, MRD, and the World Bank on groundwater quality mapping (WEPA, N.D);
    - Groundwater maps have been produced by MRD for 8 provinces in Cambodia (Svay Rieng, Prey Veng, Kandal, Takeo, Kampong Speu, Kampong Chhnang, and Kampong Cham) and a suburb in Phnom Penh capital (NSDP, 2014-2018);
    - National groundwater resource assessment conducted by Asian Development Bank under the "Supporting Policy and Institutional Reforms and Capacity Development in the Cambodian Water Sector" project (ADB, 2014);

- Groundwater study was conducted by MoWRAM with 7 provinces out of 25 covered (UNESCO, 2015);
- Country report on groundwater issues and hydrogeological survey of the Mekong River Basin in Cambodia conducted by Research and Development Center, National Polytechnic Institute of Cambodia and Department of Geology, General Department of Mines Resource in 2015 (UNESCO, 2015).

At the sub-national level, there is still limited, if any, initiative ideas on protection and monitoring the use of quality and quantity of groundwater from local authorities, private sectors, and public groundwater users. Some NGOs and private sectors working on water supply and sanitation focus solely on water delivery to the consumer with less consideration of groundwater recharge, ecological balance and water balance between surface and groundwater in the region. Some well-drillers only work to drill the wells for their clients without any clear information and data on groundwater location and its hydrological conditions, etc. Therefore, improving coordination and coordination mechanisms among relevant agencies working on groundwater is vital to ensure the sustainable and efficient use of groundwater in Cambodia.

### 6.4.2 Main actions

To ensure the strategic objective of this plan are met, strengthening collaboration among relevant government agencies and with other stakeholders is crucial. Specific main actions include:

- Improve coordination among relevant ministries working in the groundwater sector, particularly DWSS of MoWRAM, DPWS of MIH, and DRWS of MRD. For example, this draft groundwater management strategy in Cambodia should be distributed to these agencies, who should then be called upon for cooperation in setting up and implementing a joint action plan;
- Promote cooperation between universities (e.g.: Institute of Technology of Cambodia) and relevant ministries for scientific study and development on related groundwater issues such as identifying sources, quantity, and quality, as well as the availability and security of groundwater to be extracted for domestic use to ensure people have access to water supplies, sanitation and sustainable groundwater management;
- Engage more private sectors, well drillers, domestic water supply service providers, and other private groundwater users to develop a groundwater management action plan that ensures sustainable use of groundwater and protection of the ecosystem;
- Coordinate, cooperate, and share information and data to relevant government agencies and stakeholders for development of long-term strategic plans;
- Improve donor-driven capacity for groundwater management project funding, using approaches such as joint-proposal development among relevant government agencies;
- Develop and implement a communication plan to increase understanding of groundwater resources and issues among government agencies, local authorities, communities, private sectors, development partners and funding providers;

- Continue to work with national and international NGOs to ensure sustainable use and conservation of groundwater;
- More actively engage all relevant stakeholders to discuss groundwater management and conservation for sustainable utilization both currently and in the future;
- Work with Ministry of Land Management, Urban Planning and Construction (MLMUPC) and MAFF on agricultural land use preparation, and other relevant agencies to adopt policies, practices and procedures that preserve groundwater recharge areas and minimize risk of groundwater contamination;
- Establish at least three pilot Groundwater Management Areas for application of related groundwater law or regulation enforcement, public awareness raising, and study.

## 6.5 Strategy 5: Knowledge and awareness raising

### 6.5.1 Background and key challenges

Groundwater resources are crucial for sustaining water security. Groundwater systems are complex in nature and largely unseen, unlike lakes and rivers – water passing through aquifers may travel slowly, per day, whereas rivers may travel much faster, per second (DNR, 2013). Due to this challenge, ongoing stakeholder knowledge and awareness raising on groundwater issues can take long periods of time.

In Cambodia, generally, awareness raising programs on groundwater issues are limited. NGOs and government agencies mainly provide general knowledge related to water and environment such as the impacts of water pollution on human health, environment, fish and other aquatic resources (MoE, 2009).

### 6.5.2 Main actions

Main strategic actions to improve knowledge and awareness raising on groundwater sector in Cambodia should be considered as follows:

- Improve public and private knowledge on groundwater development and management planning, particularly on Integrated Water Resource Management (IWRM), at local level through building local individuals' sense of responsibility to protect groundwater (local planning) and promoting groundwater protection to ensure drinking water quality;
- Improve the distribution and utility of groundwater data and information in order to increase understanding of aquifers and hydrogeology among public and private users, and other relevant stakeholders;
- Support local NGOs and private sectors working in groundwater to do public awareness campaigns, workshops, social media releases, and produce other Information Education Communication (IEC) materials on the importance of groundwater preservation;
- Study exchange or peer-peer knowledge exchange among successful groundwater management projects (national or international project) should be conducted so that both public and private sectors and other relevant stakeholders can improve their knowledge and capacity on groundwater development and management projects in Cambodia;

- Provide a public forum for discussion and knowledge sharing among relevant stakeholders on how to sustain the use of groundwater for present time and next generation;
- Promote personal willingness to contribute and pay for water fee and save water.

## 6.6 Strategy 6: Financial resource mobilization

### 6.6.1 Background and key challenges

Financial sustainability is a key theme for groundwater management in Cambodia. There are three kinds of financial sources, including national budget of the government, grant or loan of development partners, and private sector investment cost. At the present time, annual investment in groundwater resources management and development is limited. There is no internal revenue due to inefficient operations in the water supply and sanitation sector in Cambodia (ADB, 2012). Funds available for monitoring, rehabilitation, operation and maintenance of hydraulic infrastructure, meteorological forecasting systems, and hydrological monitoring systems are also limited (MoWRAM, 2012).

Major funding from development partners and government focuses primarily on diverting and extracting groundwater and surface water supplies for sanitation, daily livelihood and economic demands. According to ADB, approximately US$49.6 million was committed for investment in rural water supply and sanitation including infrastructure, capacity development, and administration and management for 2008-2015 (ADB, 2012). By November 2019, ADB and the MEF signed two agreements worth $89 million to boost rural areas' access to water supply and sanitation services and improve the country's financial sector development efforts (Newsroom, 2019). Nevertheless, there is limited consideration of groundwater conservation.

At sub-national level, district and commune investment funds primarily focus on road and irrigation construction and rehabilitation, with less consideration of the groundwater sector. Approximately 35% of investment aimed at improving transport systems, especially during the rainy season, followed by approximately 20% (per focus) being invested into strengthening agricultural systems and improving the availability of potable and safe water (UNCDF, 2014).

According to ADB's 2012 assessment on the water and sanitation sector in Cambodia, private participation is a main agency involved in the construction of water facilities (ADB, 2012). Private participation has invested in groundwater for domestic water supply, for irrigation, and other industry sectors however still has less involvement in groundwater studies and monitoring.

Therefore, financial mobilization from relevant stakeholders is very important to ensure groundwater resources in Cambodia are protected and used effectively and sustainably.

### 6.6.2 Main actions

Main actions to ensure the increase of groundwater management project funding are:

- Privatize RGC owned water supply systems through leases or contract-management, established through an open bidding process – this is part of decentralization approach in which

government monitors and manages groundwater use as a whole, and private sector does so in a specific location (based on the contract agreement);

- "Polluter pays principle"– users must pay water fee. This includes public and private sectors such as domestic water users, agricultural and industrial companies using groundwater for business, mining companies that pollute surface and groundwater, etc.;
- Coordinate donor funds while increasing national budget for groundwater resource management and development;
- Encourage public people and communities to contribute and pay water fees for groundwater protection and ecological conservation.

# 7. Monitoring, Evaluation and Reporting

Monitoring outcomes and impacts is a necessary component for long term groundwater resource management; there must be a regularly review of the strategic plan to make sure measures are implemented and goals are realistic and are being accomplished. As part of the monitoring process, key indicators of the six strategies of groundwater management strategy will be evaluated. Internal monitoring of implementation performance and efficiency at the activity/output level shall be undertaken. Also, external evaluation by independent consultant shall be required in order to ensure transparency and accountability of the action plan implementation from beginning to the end of the project. Internal and external financial monitoring and auditing should be developed as a standardized task.

Below are the performance measures to track progress against the six strategic objectives:

1. **Strengthen relevant government institutions and related law enforcement to maximize sustainable groundwater management and utilization:**
    a. Clear roles and responsibilities among relevant government agencies have been defined and stated in the sub-decree for effective institutional functioning and implemented to ensure sustainable groundwater management;
    b. Number of good performance private sectors that received water licensing (for those who permit related groundwater regulations/laws)
    c. Number of illegal groundwater extractors that have been prohibited and fined by the government;
    d. Procedures for EIA and mitigation on groundwater use have been set up and implemented.
2. **Increase and improve scientific and governance capacity in the groundwater sector:**
    a. Capacity of related government agencies, both at national and sub-national level, has increased (e.g.: number of staff attended the training and practice what has been learned in their daily work);
    b. Number of trainings provided.

3. **Improve groundwater information and data management and sharing:**
    a. Groundwater information and data have been shared to relevant agencies to ease the monitoring of groundwater use and protect groundwater sources.
4. **Strengthen coordination and cooperation of related government agencies, research institutions, and relevant stakeholders:**
    a. Number of agencies involved with MoWRAM to develop groundwater management strategy and action plan, and joint implementation;
    b. Number of research studies conducted by research institutions/universities under cooperation with MoWRAM and related agencies.
5. **Raise awareness with relevant stakeholders including public and private sectors on the importance of groundwater resources to ensure sustainable water use in Cambodia:**
    a. Number of workshops, campaigns, and media coverage related to groundwater and the environment;
    b. Number of IEC materials produced and shared to public and private sectors.
6. **Develop sustainable financial systems partnering with private sectors and development partners on groundwater resource management in Cambodia:**
    a. Number of private sectors and development partners involved with government agencies to improve groundwater management in Cambodia;
    b. Funding amounts from government, private sector, and development partners have increased to use for groundwater management projects/programs.

# Recommendations for Capacity Development Plan for Groundwater Management in Cambodia

## 1. Background

### 1.1 Groundwater development and use in Cambodia

The current status of the groundwater environment in Cambodia should be discussed in order to fully understand the level of water security and resources available in the country (UNESCO, 2015). Cambodia is considered one of the most water-abundant countries in the region. Rivers and streams, lakes, aquifers and marine water are important sources for both daily life and national economic development in many sectors such as agriculture, manufacturing and small-scale industries, hydropower, navigation, tourism, and environmental protection (UNESCO, 2015). The maximum quantity of annual water consumption is estimated to be 750 million $m^3$ (10% of the country's total available water), of which 95% (710 million $m^3$) in used for irrigated agriculture (UNESCO, 2015).

Drinking water is supplied substantially from groundwater resources: over half of the population's drinking water in the dry season is from groundwater and this proportion increases in rural areas (ADB, 2013; National institute of Statistics, 2008). Groundwater is mostly used in rural Cambodia. It is generally less contaminated than surface water and provides an essential resource when surface water runs short. It is recognized that most untreated surface water in Cambodia is potentially contaminated (Ben, 2016).

Cambodia irrigates just 10% of its rice crop (MRC, 2010), most of which is grown during the wet season of the monsoon (May to November). Though dry season irrigation capacity is certainly not the only factor limiting Cambodian rice production, it is a fundamental one undergoing rapid change. Irrigation with groundwater is on the rise in Cambodia and may outpace increases in access to surface water sources. Planned surface water infrastructure initiatives and upgrades are expected to increase the planted area of the dry season crop by 45% over the next 20 years (MRC, 2009). Meanwhile, installation of motorized-pump irrigation wells has already increased at a rate of 20% per year over the period between 1996 and 2005 (IDE, 2005). As mentioned by Johnston et al (2013), the limited use of groundwater for irrigation in many areas of Cambodia is attributed to reasons such as poor knowledge of the resource and its sustainability.

### 1.2 Groundwater management issues

Groundwater in Cambodia is poorly assessed and understood. The Ministry of Water Resources and Meteorology (MoWRAM) in collaboration with development organizations has started groundwater level monitoring in at-risk provinces, however, several recent reports have highlighted the lack of a comprehensive groundwater monitoring system for all 25 provinces in Cambodia. Reasons for this could include constraints in human and financial resources. Some of these reports also indicate receding groundwater levels in Cambodia's southern provinces due to over pumping.

Implementation of groundwater management requires suitable technical capacity and professional skill, alongside a high level of interest, to coordinate and cooperate with relevant agencies and stakeholders at

national and sub-national level to ensure the quality and quantity of groundwater. Generally, the related government agencies (MoWRAM (DWSS), MIH (DPWS), and MRD (DRWS)) still have low individual, organizational, programmatic capacity to develop a groundwater management plan that ensures the sustainability of the groundwater use and groundwater preservation in Cambodia.

There is a lack of relevant technical backgrounds among staff, as well as a general lack of using data and information to develop a good groundwater management database. Data/information on groundwater quantity and quality issues are very important – land use change resulting from conversion of forest or wetland areas to agricultural and urban zone and overuse of groundwater due to increasing populations, factories and infrastructure development plans in urban areas bring challenges that need to be addressed. Moreover, officers of key government agencies find it challenging to identify types of information and data required for long-term groundwater management.

# 2. Recommendations

A Capacity Development Plan for groundwater management in Cambodia is essential to the long-term sustainability of water sector programs and projects. Integrated Water Resource Management (IWRM) is the key approach to set up a priority capacity development plan for groundwater management. Based on the assessment of capacity needs and gaps of deliverable 2 and the groundwater management strategy of deliverable 3, three main components are recommended for the capacity development plan:

- ✓ **Component 1:** Groundwater governance capacity
- ✓ **Component 2:** Operational management capacity
- ✓ **Component 3:** Analytical tools capacity

## 2.1 Groundwater governance capacity: policy, institutional, law and regulations

According to Tafesse and Wickremage (1991), strengthening institutions at all levels and creating a favorable policy environment and legal framework is vital to deal more effectively and efficiently with all aspects of sustainable water resource development (including the groundwater sector). The coordination of functions from grass roots to central level is an important element in achieving IWRM. Local level institutions need to be involved, with a proper mandate that is comprehensive, relevant and unique to them. Clear programs and plans with objectives, targets, and monitoring and evaluation (M&E) systems should be established for all levels.

Governance capacity is the important soft component for improving management efficiency and sustainability of groundwater use. Recommended capacity building actions to strengthen institutional and develop an enabling environment for sustainable groundwater management are as follows:

- Develop appropriate institutional frameworks for groundwater management from national to sub-national level (with a decentralization and deconcentration (D&D) focus), with particular attention paid to provincial, district, and commune levels. Organizational capacity must be established to avoid overlapping roles and responsibilities among agencies;

- Provide training workshops on relevant legislative frameworks and legal requirements for groundwater allocation, evaluation and assessment of groundwater permit applications, groundwater resource assessment for use in permitting (recharge assessment, determination of exploitable groundwater etc.), enforcement of groundwater permit conditions, effective groundwater monitoring as part of compliance monitoring, and coordination and cooperation approaches for addressing emerging challenges of climate change and environment sustainability;
- Provide training to national government agencies on developing a guideline for groundwater extraction and groundwater extraction certification;
- Provide training to relevant national and sub-national staff, private sector, and communities on integrated groundwater management including use, protection, and conservation. The IWRM concept is needed for this training;
- Provide training workshops to relevant stakeholders (particularly MoWRAM, MIH, and MRD) on how to develop a groundwater strategy and joint action plan (including M&E) under the cost-effective approach for sustainable groundwater development.

## 2.2 Operational management capacity: operations and maintenance (O&M)

Technical capacity is vital to improve operational management of groundwater in Cambodia and to ensure the productive and sustainable utilization of groundwater resources. It is recommended to work directly with different sectors, particularly with local government staff and the private sectors (well drillers, groundwater extractor for agriculture and industry, etc.) to provide related groundwater skills for O&M operators. Operational management instruments including concrete activities, regulation, economic instruments, community and awareness raising, and capacity building are needed in this sector.

Ministry staff, sub-national governments and private sector working in the groundwater management sector should be recommended to undertake a training program in order to strengthen their technical capacity. Recommended capacity actions to improve operational management are as follows:

- Provide training for managerial and administrative staff on integrated groundwater basin plans to improve and support operational management;
- Strengthen national and district capacity through provision of laboratory and office equipment for use at national and local government level and later at groundwater source sites as part of D&D;
- Build capacity of local authorities, private operators, pump mechanics, well drillers, and some community members on methodological O&M of both rural and urban water supply installations and groundwater extraction for agriculture and industry sector. Particular focus should be on refresher training on pump installation and maintenance, determination of optimum pump installation depths, pump servicing and optimum pump selection;
- Build capacity to identify and monitor potential threats to groundwater due to poor sanitation and waste discharge. Specifically, capacity for regulation of both point and non-point source pollution needs to be built;

- Build capacity in terms of equipment used for pumping tests, groundwater data collection including water level, quality and quantity, and groundwater exploration technologies including mapping of groundwater sources;
- Improve public knowledge and awareness on policy, regulation, and the importance of population involvement for groundwater protection;
- Provide training on groundwater and IWRM tools, groundwater use efficiency, demand, groundwater management planning, and water as an economic good that should be priced in regards with equity and efficiency principles;
- Improve capacity in disaster response, risk reduction, and EWS, as well as increasing understanding on climate change threats to groundwater depletion;
- Provide technical skills to national and sub-national staff on hydrogeological and hydrological capacity as well as land use mapping.

### 2.3 Analytical tools capacity: resource exploration, assessment, and prediction

Analytical support tools are important to carry out IWRM in an effective and efficient way and to help government and decision makers to make the right decisions for sustainable use and protection of the groundwater resources. The tools can address challenges and be used to assess the present and predicted future situation of groundwater resources, which is crucial in operational and strategic decision-making and development processes.

In Cambodia, collaboration between universities specialized in groundwater research and development (such as the Institute of Technology of Cambodia) and relevant government staff should be enhanced. Joint research will provide more opportunity for government staff to have an adequate understanding of hydrogeologic settings. A lack of geologic, physical, and chemical process understanding make it difficult for the water resource industry, agriculture, and regulatory and planning agencies to effectively address issues in the future.

Key capacity on analytical tools are as follows:

- Provide training on groundwater assessment – geophysical exploration methods, monitoring network design, data management (data collection from ground or remote-sensed sources, data analysis and interpretation and groundwater data presentation using GIS tools);
- Provide regular refresher trainings on groundwater development, well site selection and well testing;
- Provide training on groundwater quality and quantity analysis;
- Provide knowledge on groundwater occurrence and movement to national and sub-national staff;
- Provide training on hydrodynamics, hydrogeological modelling, IWRM principles, and groundwater monitoring;
- Cooperate with universities to conduct groundwater research and develop pilot projects for groundwater monitoring and protection, groundwater data collection and data management;

- Establish a country-wide groundwater database for use in capacity building and groundwater development projects;
- Build capacity through regular short courses targeting working professionals on topics such as groundwater exploration, development, monitoring, assessment, groundwater hydraulics and computational methods, and regulation;
- Build capacity for Environmental impacts Assessment (EIA) and Environmental Management Planning (EMP).

## 3. Proposed Training Needed

Main training topics for groundwater management capacity development plan in Cambodia are proposed in Table 16:

Table 16: Training needed for each component

| Training Topics | Targeted Groups | Training Output | Plan (2020-2023) | Related Components |
|---|---|---|---|---|
| Groundwater governance and regulations, licensing processes and best practice in groundwater use | Department management | Improve knowledge on policy, roles, administrative responsibilities and regulations of groundwater use and protection<br>Understand the legal requirement for groundwater allocation, evaluation and assessment of groundwater permit applications | Annually | 1 |
| Role of stakeholder participation and communication in groundwater management | Department management and technical staff | Identify main stakeholders in groundwater management<br>Improve knowledge of institutional mechanisms for stakeholder participation in groundwater management (including D&D on groundwater development project)<br>Prepare communication and coordination strategy for groundwater management | Annually | 1 |
| IWRM (including *The Dublin Statement on Water and* | National, sub-national and local agencies, plus related public, private, | Improve knowledge on how to develop a joint action plan on groundwater management and why groundwater is important for river basin management (including Tonle Sap and Mekong River Basin) | Twice annually | 1, 2, and 3 |

| | | | | |
|---|---|---|---|---|
| *Sustainable Development*) | and community agencies | Establish cooperation approaches between different technical agencies | | |
| Special training on developing a guideline on groundwater extraction and groundwater extraction certification | Department management, technical and administration staff, including staff with background in legal sector | Understand ways of developing a guideline on groundwater extraction to ensure effective processes for groundwater management and conservation<br>Understand how to set up curriculum or main points for groundwater extraction certification development | Only when government is ready to develop such guideline and groundwater extraction certification | 1 |
| O&M methodologies for rural and urban water supply installations | Technical staff (particularly at sub-national level), local authorities, private operators, pump mechanics, well drillers, and communities | Understand ways to operate and maintain related groundwater equipment<br>Improve knowledge on:<br>- drilling operations and technologies<br>- well construction and pump installation<br>- installing monitoring wells for discharge, level and quality sampling<br>- monitoring for compliance to permit conditions<br>- use of information and communication technology for groundwater data handling – data collection and use of databases for processing, quality control, and reporting | Annually | 2 |
| Groundwater hydrology | Technical staff from provincial to ministry level | Understand water availability and distribution<br>Understand groundwater flow and aquifers<br>Understand how groundwater processes interact with surface water, and approaches/tools for sustainable management of water resources | Annually | 2 and 3 |

| | | | | |
|---|---|---|---|---|
| Groundwater monitoring and information management | Inter-ministries<br>Provincial department staff<br>Commune focal persons | Be able to prepare the groundwater resources monitoring program<br>Understand data storage and information management, benefits and cost effectiveness of monitoring, and access and exchange of national data | Annually | 2 and 3 |
| Groundwater recharge and safe yield | Inter-ministries<br>Provincial department staff | Understand factors related to groundwater recharge<br>Understand general information about groundwater recharge in Cambodia<br>Understand factors threatening groundwater recharge<br>Improve aquifer storage recovery operations<br>Understand groundwater levels and quantity | Annually | 2 and 3 |
| Groundwater quality and contamination | Relevant ministerial staff<br>Provincial department staff<br>Commune focal persons | Address groundwater quality in natural state<br>Understand general information and status of groundwater quality in Cambodia and standard of groundwater quality for domestic use<br>Understand sources and types of groundwater contamination and pollution<br>Improve mechanism for groundwater pollution prevention and protection | Annually | 2 and 3 |
| Groundwater modeling and mapping (including remote sensing and GIS application to groundwater exploration) | Technical staff | Build capacity to support decision-making<br>Understand quantitative framework for synthesizing field information and conceptualizing hydrogeological processes for research and development<br>Predict and simulate groundwater use scenarios | Annually | 2 and 3 |

| | | | | |
|---|---|---|---|---|
| Sustainable groundwater use under land use, climate change and other hazards | Relevant ministry staff<br>Provincial department staff | Inventory/baseline information compiled in spreadsheet format covering the components of groundwater use and IWRM<br>Investigate water use and ground-water extraction within the context of IWRM, with consideration of social and economic relevance, and impacts of land use and climate change<br>Assessment of groundwater pollution, aquifer vulnerability and over-exploitation | Annually | 2 and 3 |
| Disaster response preparedness | Relevant ministry staff (NCDM)<br>Provincial department staff (PCDM)<br>Commune focal persons (CCDM)<br>Community representative | Improve knowledge on how to response to disaster (particularly drought) and climate change impacts on groundwater resources | Annually | 2 and 3 |
| Project development (proposal writing) and Monitoring and Evaluation (M&E) | Management and technical staff at all levels | Improve knowledge on how to develop, monitor, and evaluate the relevance, effectiveness, and sustainability of groundwater development projects<br>Draw from M&E results to set up future strategy and/or continuing action plan | Annually | 1, 2, and 3 |

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## Annex 1: Structures of Government Agencies Working on Groundwater

### Ministry of Water Resources and Meteorology (MoWRAM)

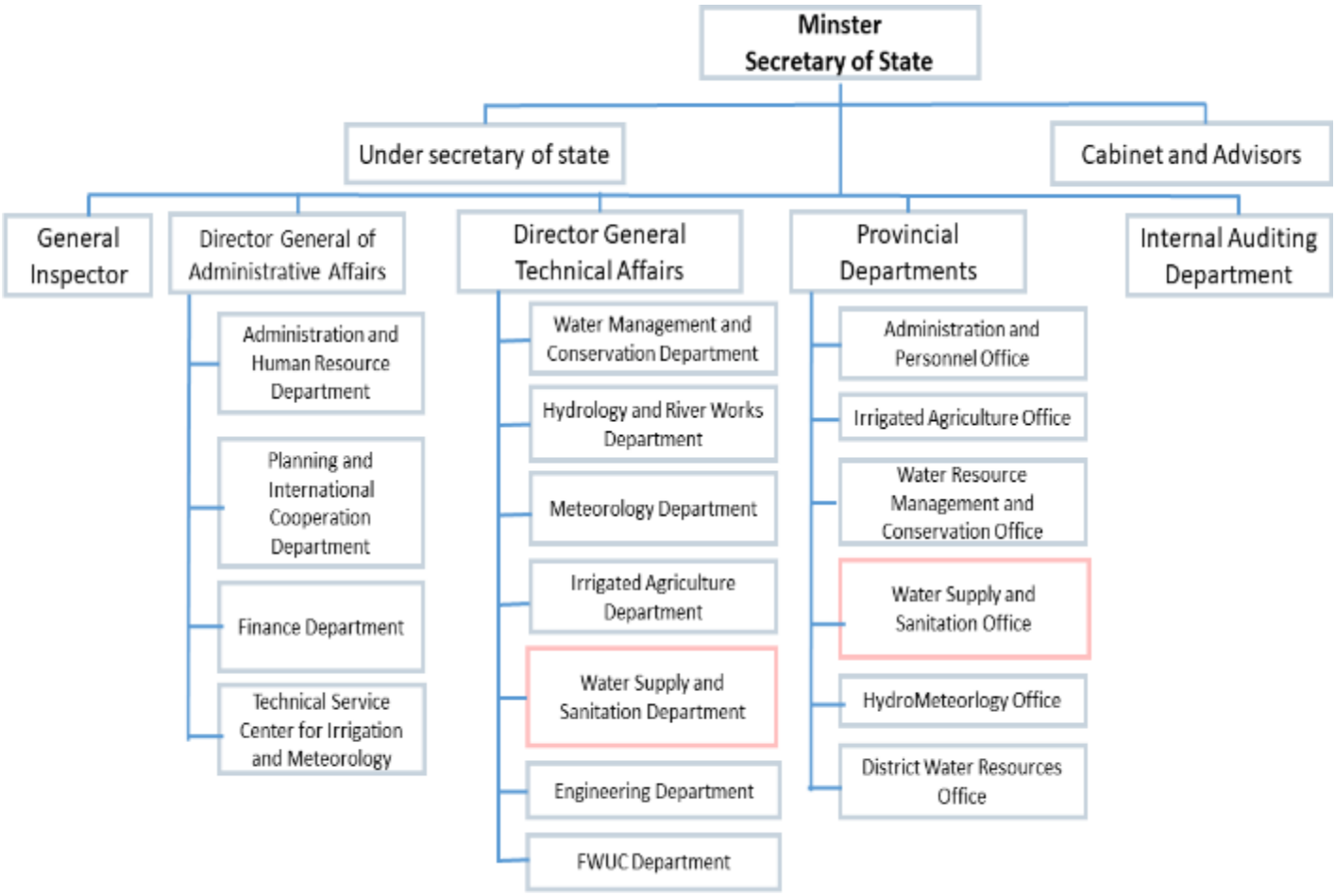


Figure 20: Structure of Ministry of Water Resources and Meteorology

Source: Ministry of Water Resources and Meteorology (2019)

**Ministry of Industry and Handicrafts**

**(Only General Directorate of Industry)**

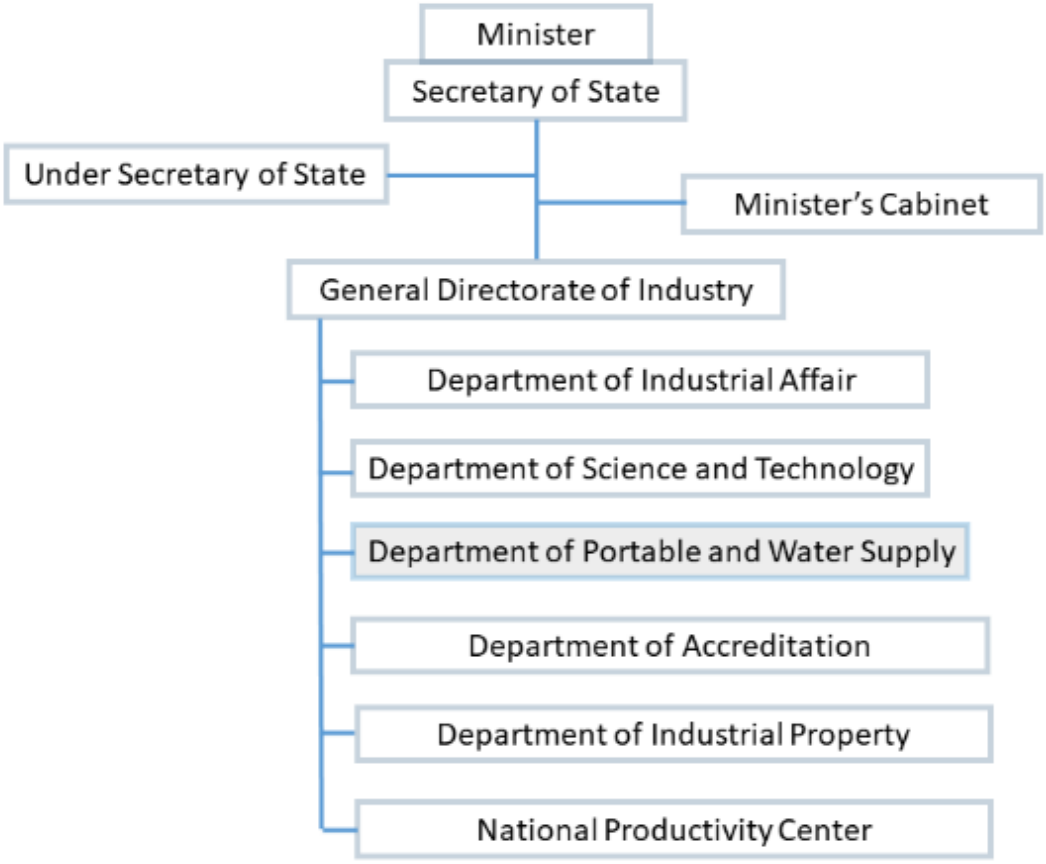


Figure 21: Structure of General Directorate of Industry, Ministry of Industry and Handicraft

Source: Ministry of Industry and Handicraft (2013)[2]

[2] Unofficial translation from the Sub-Decree of the Organization and Functioning of Ministry of Industry and Handicrafts (2013)

## Ministry of Rural Development (MRD)

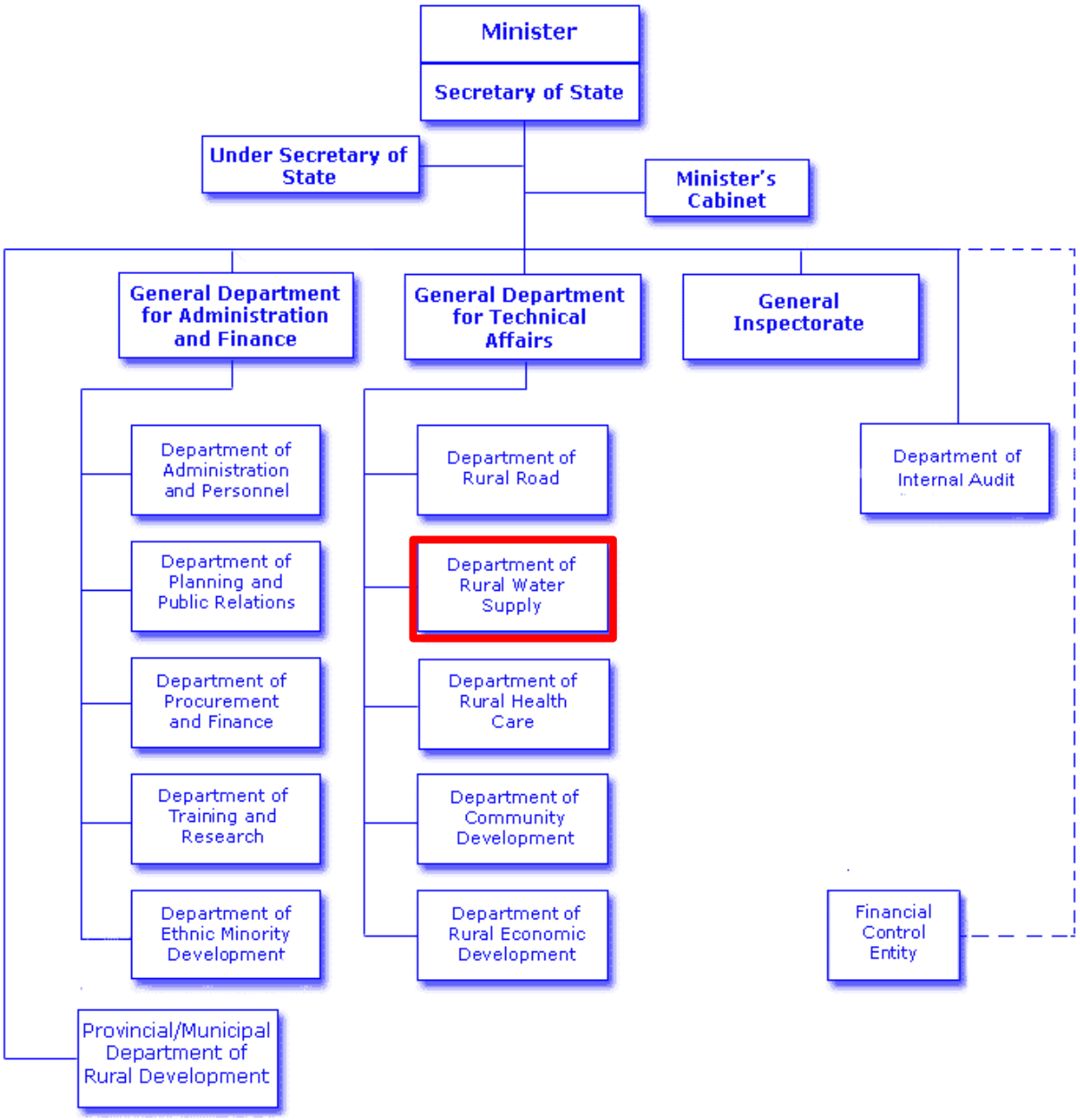


Figure 22: Structure of Ministry of Rural Development

## National Committee for Disaster Management

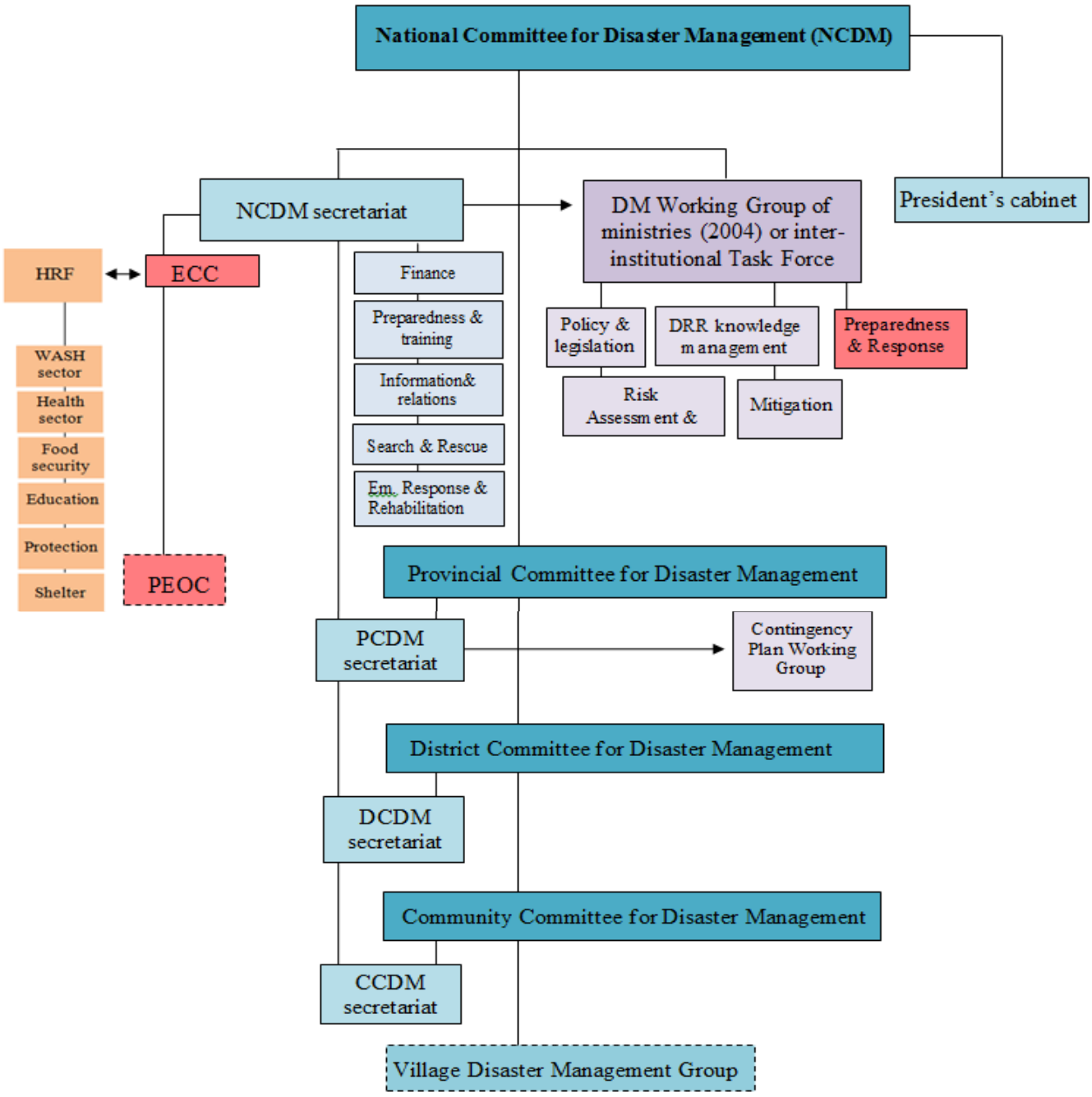


Figure 23: Structure of National Committee for Disaster Management

Source: National Committee for Disaster Management (2015)

**Provincial Committee for Disaster Management in the Operational Taskforces**

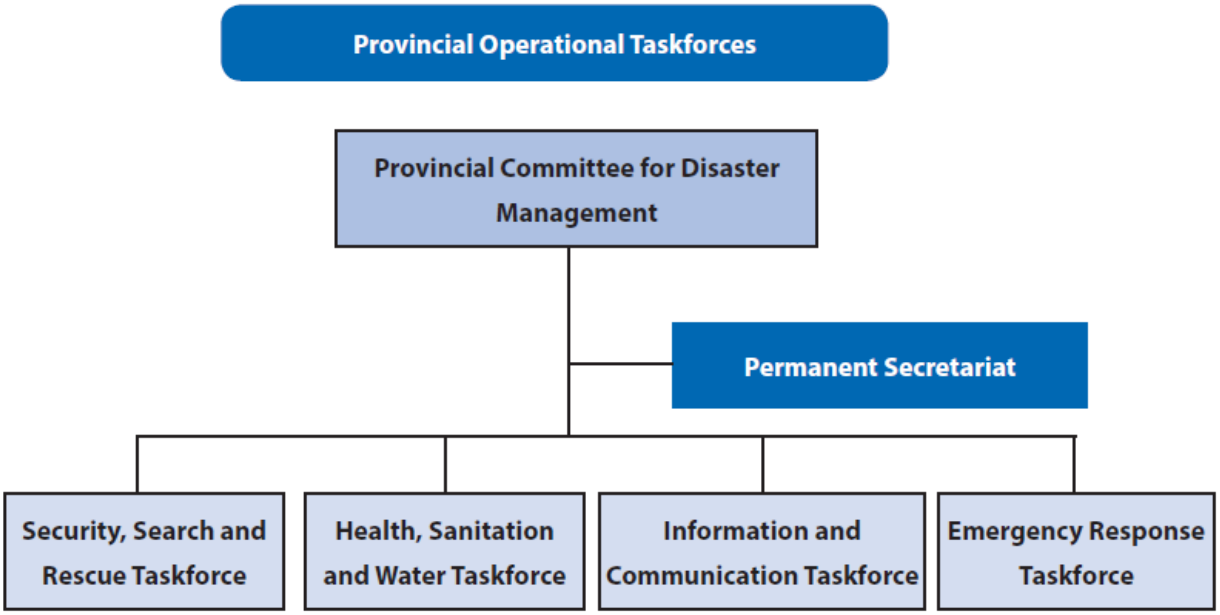


Figure 24: Structure of Provincial Committee for Disaster Management

Source: National Committee for Disaster Management & United Nations Development Programme (2014)

**District Committee for Disaster Management in the Operational Taskforces**

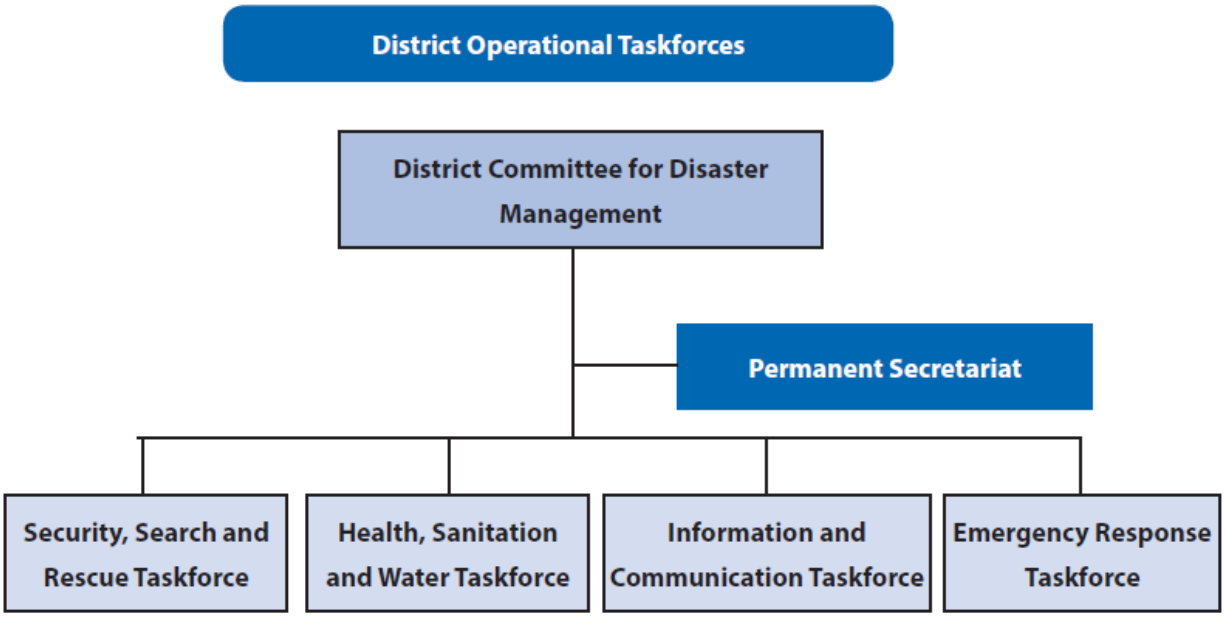


Figure 25: Structure of District Committee for Disaster Management

Source: National Committee for Disaster Management & United Nations Development Programme (2014)

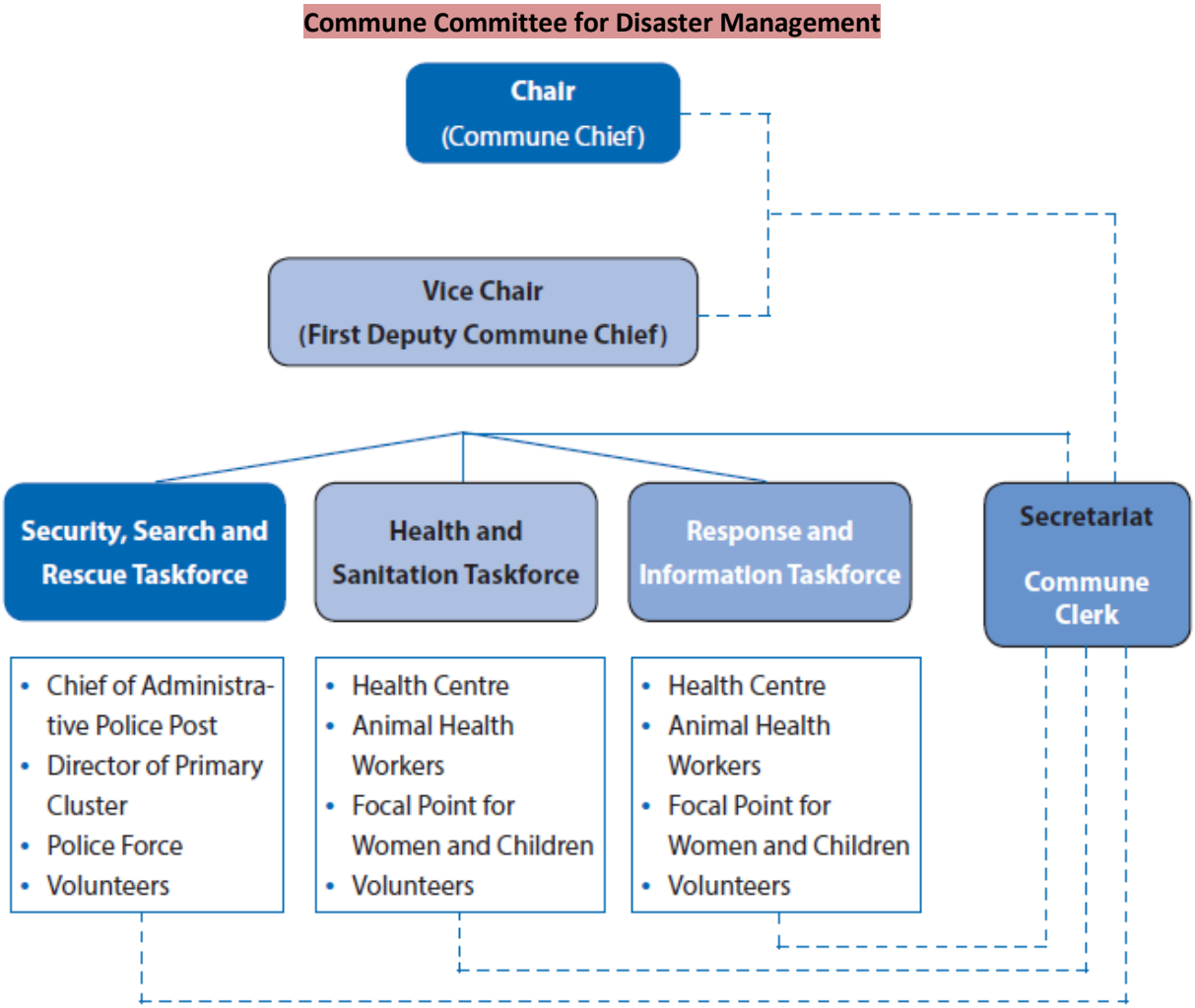


Figure 26: Structure of Commune Committee for Disaster Management

Source: National Committee for Disaster Management & United Nations Development Programme (2014)

**Cambodia National Mekong Committee**


Figure 27: Structure of Cambodia National Mekong Committee

## Annex 2: Questionnaire

1. What are the related laws/regulations/strategies/action plans on groundwater management?
   □ Water Resources Management Law (2007)
   □ Law on Environmental Protection and Natural Resource Management (1996)
   □ Sub-Decree on River Basin Management (2015)
   □ Sub-Decree on Water Pollution Control (1999)
   □ Other:……

2. Is there any ministry at national level and line ministries at local level working on groundwater issue and disaster risk management (drought/flood) in Cambodia? Who are they?

| **National Level** | **Sub-National Level** |
|---|---|
| □ MoWRAM<br>- Dept. of Water Supply and Sanitation of Ministry of Water Resources and Meteorology (DWSS)<br>- Others:…… | □ PDoWRAM<br>- ……<br>- …… |
| □ MIH<br>- Dept. of Potable Water Supply (DPWS)<br>- …… | □ PDIH<br>- ……<br>- …… |
| □ MRD<br>- Dept. of Rural Water Supply (DRWS) | □ PDRD<br>- Rural Water Supply Office |
| □ NCDM | □ PCDM<br>□ DCDM<br>□ CCDM |

3. What are the roles and responsibilities of your agencies in response to groundwater management at National and Sub-National level?
- At National Level: …….
- At Sub-national level: …….
4. How do you work with local authority in dealing with groundwater issue and disaster risk management (DRM)?
- Groundwater:
- DRM:
5. What are your existing knowledge and capacity to work on groundwater issue?
- Basic capacity:
- Technical Capacity:
6. What are your capacity gaps and capacity needs to improve your ability and skills to work on groundwater management in Cambodia? (list 5 priority and rank from most important to less important)

| **No.** | **Capacity Gaps** | **Rank** | **Capacity Needs** | **Rank** |
|---|---|---|---|---|
| 1 | | 1 2 3 4 5 | | 1 2 3 4 5 |
| 2 | | 1 2 3 4 5 | | 1 2 3 4 5 |
| 3 | | 1 2 3 4 5 | | 1 2 3 4 5 |

| | | | | |
|---|---|---|---|---|
| 4 | | 1 2 3 4 5 | | 1 2 3 4 5 |
| 5 | | 1 2 3 4 5 | | 1 2 3 4 5 |

7. List 3 main training courses that you think are important to be provided to relevant government agencies and stakeholders who are working on groundwater issue in Cambodia? Which one is the main priority to train first (circle it)?
- Basic knowledge on groundwater management
- IWRM
- Technical skills (what are they?)
- Financial management
- others……
8. What are your 3 main recommendations for improving groundwater management in Cambodia? Which one is the main priority (circle it)?
- Institutional capacity: ……..
- Financial support: ……

Technical Support: