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Groundwater Assessment of the Southern Gobi Region

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Foreword

This report joins the series of reports that have been prepared by the World Bank, with the strong support of various partners—most notably the Government of the Netherlands through its NEMO program—on the Southern Gobi Region (SGR). This report focuses on one the most critical issues for the SGR: groundwater resources. This is a critical issue because rainfall and surface water availability are so severely limited and the demands are expected to increase rapidly with the development of mining and new population centers. Water is the fundamental constraint to development in the region and yet its distribution and quantity are poorly known.

The report looks critically at the water resources and the current and projected future water demands in the SGR using the widely dispersed data and information that are currently available. An important conclusion of the report is that almost all the significant sources of groundwater in the SGR are 'fossil' or 'non-renewable', meaning that they are finite resources which cannot be replenished. Not only that, but pumping water out of these fosil aquifers will tend to cause a drop in the groundwater levels above them. The report proposes practical steps by which water resources development and management could be managed to best serve economic and infrastructure development while giving attention to environmental protection and service to communities in the SGR.

The report also highlights the urgent need for more data. A more detailed picture of the distribution and quantity of the groundwater would give planners first, a better idea of both the limits to the growth of the SGR; and, second, of the future water demands, its spatial distribution, quality requirements, and the possibilities to increase water use efficiency and water re-use. Thus there is a need to bring all information and data together to form the basis for rational planning.

We hope to use the findings and recommendations of this report in the continued dialogue with the Government of Mongolia and a broad range of stakeholders. We also hope that this report will increase awareness of the need for any long-term development plans, especially for mines, to be undertaken in full knowledge of the peculiar characteristics of groundwater in the SGR.

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Acronyms and Abbreviations

ADB	Asian Development Bank
BGR	Bundesanstalt fur geo Wissenschaften
BOT	Build-operate-transfer
CWWTP	Central Waste Water Treatment Plant
EIA	Environmental Impact Assessment
GDP	Gross National Product
GIC	Geological Information Centre
GWMATE	Groundwater Management Advisory Team
IAH	International Association of Hydrogeologists
IGMR	Institute for Geology and Mineral Resources
IPPC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
IWER	Institute of Water Exploratory Research
JICA	Japan International Cooperation Agency
LCD	Liter per Capita per Day
MCUD	Ministry of Construction and Urban Development
MDG	Millennium Development Goals
MEGM	Ministry of Geology, Energy and Mining
mg/l	Milligram per Liter
MH	Ministry of Health
MNET	Ministry of Nature, Environment and Tourism (previously Ministry of Nature and Environment (MNE)
MoUB	Municipality of Ulaanbaatar
MOFE	Ministry of Fuel and Energy
MOI	Ministry of Infrastructure

MRTT	Ministry of Road, Transport, and Tourism
MW	Mega Watt
NEMO2	Netherlands-Mongolia Trust Fund for Environmental Reform
NWC	National Water Committee
PPM	Parts per million
REA	Regional Environmental Assessment
RDS	Regional; Development Strategy
SGR	Southern Gobi Region
SGRDP	Southern Gobi Regional Development Plan
TDEM	Time Domain Electro Magnetics
TDS	Total Dissolved Solids
ToR	Terms of References
Tpd	Tons per day
Tpy	Ton per year
USUG	Water Supply and Sewerage Authority
WA	Water Authority
WRM	Water Resources Management

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This report on Groundwater in the South Gobi Region is prepared as part of the World Bank support to the Regional Environmental Assessment (REA) for the Gobi Region and to provide inputs to the Government's Gobi Regional Development Strategy RDS and the Integrated South Gobi Regional Development Plan (SGRDP). The work was carried in 2008 and 2009 by Albert Tuinhof of Acacia Water /GWMATE and Dr. Buyankhishig Nemer of Ulaanbaatar University. Most of other work was carried out during two visits of Albert Tuinhof to Mongolia in 2008, including a 5 day field visit to South Gobi Region. They would like to express their sincere thanks Enkhtsetseg Ayur (Project Coordinator, NEMO-II), Erdene-Ochir Badarch and other staff of the World Bank Office in Ulaanbaatar for their hospitality and assistance throughout the missions, to Tony Whitten, Judith Schleicher and Neelesh Shrestha of the World Bank in Washington DC for their continuous efforts in editing and correcting this report, and to the various government and World Bank peer reviewers. We also would like to thank the many Mongolian experts and agencies for the fruitful and inspiring conservations and the data and information they made available to us. A special word of thank goes to Dr N. Jadambaa of Ulaanbaatar University who made ample time available to share with us his broad and in depth knowledge of the complex groundwater situation in the South Gobi Region.

Executive Summary

The Gobi Region is vast and sparsely populated with few transport links but with enormous mineral wealth, including large coal and major copper deposits. The economic development of the Southern Gobi Region (SGR) is a priority for the Government of Mongolia. The World Bank is providing support to the Gobi Regional Development Strategy (RDS) through the preparation of a Regional Environmental Assessment (REA) for the Gobi Region and an Integrated South Gobi Regional Development Plan (SGRDP). Water is one the important resources since rainfall and surface water availability are limited.

This report serves as a background document for the RDS, REA, and SGRDP and describes the current and future water resources and water demands in the Southern Gobi Region. It is based on available data and information and proposes a way forward to assure that water resources development and management can support the economic and infrastructural development and environmental protection.

Water resources development in the SGR is part of the national water resources strategy and its management is embedded in national legislation and regulation, institutional framework, and human resource capacity. The report therefore includes a section on the national water resources and water demand in Mongolia.

Water Demands in the SGR

The SGR occupies about 350,000 square kilometers (km^2) covering broadly the area of the three aimags of Dornogovi, Dundgovi, and Umnogovi and has a population of only 150,000 (2007 data). Livestock farming has been the main economic activity for a long time, but the economic development of the SGR is expected to grow rapidly in the near future, with its foundation being the planned development of coal and gold mines.

The current water demand for domestic uses (rural and urban) is approximately 10,000 cubic meters per day (m^3/day) and 32,000 m^3/day for livestock water supply. The main water use in the SGR is from the mining sector and in particular from the 4 main mining areas: Tsagaan Suvraga (copper), Oyu Tolgoi (copper/gold), Shivee Ovoo (coal), and the coal mines in the area around Dalanzadgad (Tavan Tolgoi, Ovoot Tolgoi, Nariin Sukhait/Ovoot Tolgoi). The current operational mines in Tsagaan Suvraga, Shivee Ovoo, and other coal mines around Dalanzadgad have an estimated water demand of 40,000 m^3/day. This demand is expected to grow sharply under ongoing and planned mining developments and may reach 300,000 m^3/day in 2020.

The main part of the mine water demand is for processing of the raw material (concentration of copper/gold and washing of coal), dust suppression, and power generation. These uses have variable water quality requirements, which are less strict than the smaller portion of the water that has to meet drinking water standards.

Mine development will trigger population increases and industrial, commercial, and agricultural development in the area around the mines that also contribute to an increased water demand. A reliable estimate of the future water demands is difficult to make given the uncertainties in the economic and demographic development planning. A preliminary estimate gives a total water demand in 2020 of 400,000–450,000 m^3/year of which 300,000 m^3/year goes for mining.

Estimated Groundwater Resources

Groundwater is the main source of water in the SGR. Almost all of this groundwater is fossil, which means that it receives little or zero recharge. The only recharge in the SGR comes from the limited rainfall—an average of 115–150 mm/year—and that recharge is estimated to be just 1 mm/year. Most of this water circulates in the upper streambed aquifers (0–20 meters) and a small portion percolates to the shallow aquifers (20–50 meters) and possibly to the deeper aquifers (below 50 meters).

The deeper aquifers are permeable (productive) rocks (mainly sandstones) surrounded and overlain by less permeable deposits and contain mainly fossil water. These local aquifers have a limited spatial (less than 500 km^2) and vertical (less than 50–100 meters) extension and are (semi) confined, which means that the groundwater is under pressure. Pumping from these fossil aquifers will drain the layers above the aquifer and cause a lowering of the groundwater table. If pumping further continues, the aquifer itself will start to be emptied. The groundwater potential in these aquifers is therefore directly linked to the selected time period (number of years) and an accepted lowering of the water table.

Estimates of the groundwater potential vary between 200–500 million m^3/per year assuming a 25–40-year period and a lowering of the groundwater of 50–100 meters. The lower range of 200 million m^3/year is equal to 550,000 m^3/day and leads to the conclusion that the groundwater potential for the SGR as whole is sufficient to cover the water demands in the next 10–12 years.

The main groundwater quality concern is the salinity along with the occasional occurrence of trace elements like arsenic and fluoride. Water for domestic purposes will generally need some form of treatment. Most of the water demand concerns industrial water, which has variable water quality requirements and a higher economic value, allowing for investments in treatment if needed.

Regional Groundwater Assessment

Meeting water demands with groundwater resources requires a more detailed picture of the spatial (and vertical) distribution of the groundwater (quantity and quality) and of the future water demands, its spatial distribution, quality requirements, and the possibilities to increase water use efficiency and water re-use.

A regional groundwater assessment study is needed to bring all information and data together, prepare an aggregated overview of the current groundwater potential, define information gaps, coordinate additional investigations and studies as the basis for regional groundwater development and management plans. Although needed for the whole Southern Gobi, this assessment study should initially focus on the area around Dalanzadgad where the main mining developments are planned. Additional groundwater resources may be confirmed in this area through the following:

- Review of groundwater assessment studies done in area in the last decades, providing a more accurate estimate of the potential of these aquifers;
- Exploration studies in potential new sites that can be explored for the presence of suitable aquifers, especially at a depth greater than 150 meters, and
- Detailed study of the recharge from rainfall to the streambed aquifers and shallow groundwa-

ter to explore ways to increase the utilization of this renewable resource.

Surface Water Conveyance

There are two existing plans to convey surface water to the SGR: the Herlen-Gobi Pipeline project and the Orhon-Gobi Pipeline project. The Herlen-Gobi Pipeline will convey 1,500 l/sec from the Herlen River through a 540 km-long pipeline to Shivee Ovoo, Sainshand, and Zamin-Udd with a side branch to Tsagaan Suvraga. The Orhon-Gobi Pipeline will pump 2500 l/sec from the Orhon River through a 740 km-long pipeline to Tavan Tolgoi and Oyo Tolgoi with side branches to Mandalgobi and Dalanzadgad. About 50 percent of the water is for mining and industrial clients and 30 percent for irrigated agriculture. The remaining water is for domestic and livestock water supply and for non specified environmental uses

The plan is still at pre-feasibility level and needs further study and analysis to answer some critical questions on the socio-economic, financial and environmental feasibility.

Comparing Surface and Groundwater

Comparing groundwater development and long-distance surface water conveyance is not a straightforward exercise because of the different nature between decentralized groundwater supply systems and a central surface water pipeline. It should further be noted that the surface water conveyance option is in fact a conjunctive use option since it will not replace current groundwater use, and further groundwater development would also be needed to supply the areas outside the reach of the pipelines or as a backup for the surface water system.

There is still a lack of information to conduct a conclusive feasibility study as a basis for decision-making. A comparative analysis is presented in this report showing the advantages and disadvantages of both options. A preliminary cost comparison shows that groundwater supply is about 50 percent cheaper than surface water supply but is likely to have some higher operation and maintenance costs.

Institutional, Regulatory, and Capacity Building Aspects

The study concludes that a Southern Gobi Groundwater Management and Information Center (SGR-GMIC) is needed to implement the SGR groundwater assessment study. The SGR-GMIC should operate under the Water Authority but be shared by the different ministries involved and other institutions in the country where groundwater knowledge and information is available.

This SGR-GMIC can act as the focal point for groundwater management, monitoring, and regulation and can coordinate studies and investigations that will be needed to update and refine the groundwater potential and to develop guidelines for its sustainable allocation and use. This will also ensure that groundwater is presented as a single resource and as such facilitate the process of further decision making on future water supply investments. A strong linkage with the national level and a human resources capacity-building component will be important factors for SGR-GMIC success.

Way forward: scenario approach

Given the uncertainties in demand projections and groundwater or surface supply options, the best way forward is to develop short- and medium-term scenarios for matching supply and demand and update them on a regular basis when new information becomes available.

1. Water Resources and Management in Mongolia

This report provides an overview of the water resources in the SGR and the options and conditions for its sustainable development and management. This report supported the preparation of the Regional Environmental Assessment (REA) (Walton, 2010) and the draft SGR Infrastructure Strategy (World Bank, 2009) intended to provide inputs to the Government of Mongolia's Gobi Regional Development Strategy (RDS), which is under preparation.

The intended audience is primarily Parliament and those government entities concerned with SGR development. The focus of the report is consistent with (a) the Government's 2003 Regional Development Strategy, which identified the Gobi Region as one of the priorities to ensure sustainability of the country's economic growth; (b) the second objective of the Mongolia Country Assistance Strategy 2004-2007 (World Bank, 2004), which states "addressing growing equity concerns and reducing rural and urban vulnerabilities through improved environmental governance and management, and analysis of viability of options to support regional development objectives", and (c) the Bank's planned Integrated Southern Gobi Regional Development Plan (SGRDP), which will cover the development impacts from mineral development. Water resources are one of the important issues addressed in the REA, RDS, and SGRDP.

This section is mainly derived from the first National Report on Water Resource, Use and Conservation. This 2008 report summarized the water resources in Mongolia, with Mongolian scientists and experts covering multiple topics including groundwater, surface water, water quality, land use, mining, pasture irrigation, and climate change. Published by the National Water Committee under the Ministry of Nature and Environment (MNET), this national report was produced during the inception phase of the project "Strengthening Integrated Water Resource Management in Mongolia", and funded by the Government of the Netherlands.

General Features

The Mongolia's Gobi Region is enormous, sparsely populated, richly endowed with mineral wealth, served by few transport links, home to many wide-ranging threatened species, and suffering from a decrease in rainfall and water availability.

Mongolia is located inland in Northeast Central Asia, between China and Russia. It forms the transition zone between the great Siberian taiga and the Central Asian desert. Forests cover is limited to the Khangai, Khuvsgul, and Khentii mountainous regions in the north, while bluffs are found in the Mongolian Altai and Gobi Altai mountains. High plateaus of the Gobi Desert and steppes cover the eastern and southern areas. The total territory of Mongolia is 1,564,000 km^2 and the average elevation is 1,580 meters above sea level with a maximum elevation of 4,000 above mean sea level in the Western mountain ranges (Figure 1).

Due to its inland location and mountainous surroundings, the Gobi Region has a climate described as continental-harsh and arid. Important characteristics of this climate are long winters, short summers, large fluctuations of (daily and seasonal) temperatures (Table 1), and low distributed precipitation with about 85 percent of it falling in the summer. The precipitation on average is about 300–350 millimeters (mm) in Khangai, Khentii, and Khuvsugul mountain ranges; 250–300 mm in Mongol Altai and forested areas, and 50–150 mm in Gobi Desert area.

Traditionally, the main type of land use has been semi- nomadic livestock husbandry in consequence of the low precipitation. Presently agriculture accounts for about 19 percent of the country's gross domestic product (GDP) and about 50 percent of the workforce is involved in agriculture. However, Mongolia also has extensive mineral

Figure 1. General location map

Table 1. High and low temperature for different regions (NWC, 2008)

Region	Average coldest month (January) (^0C)	Region	Average warmest month (July) (^0C)
Valleys between mountain ranges Altai, Khangai, Khentii and Khuvsgol	–30 to –34	Great lake valley, Orhon and Seleng basin, region between mountain ranges Altai, Khangai, Khentii and Khuvsgol	+15 to +20
High mountains	–25 to –30	Khangai, Khentii and Kvusgol mountains	+15
Steppe region	–20 to –25	Southern part of Dornod steppe and Gobi Desert	+20 to +25
Gobi Desert	–15 to –20	Steppe and desert	+ 25 to + 30

deposits: copper, coal, molybdenum, tin, tungsten, and gold. In the past few years the mining industry became the leading industry in the country.

Mongolia's population is around 2.6 million and the population density is only 1.8 persons per square kilometer. Much of the population, around 1 million, lives in Ulaanbaatar, the capital of Mongolia. Mongolia is a unitary state and divided administratively into 21 aimags (provinces) and a capital city (Figure 2). Aimags are subdivided into 340 soums, soums into bags, a capital into districts, and districts into khoroos.

Water Resources

Surface water

The surface water resources of Mongolia comprise rivers, lakes, and glaciers. Many studies and surveys on the surface water resources have been conducted since the end of the 19th century. One of the recent studies are those by J. Tserensodnom (2000) based on analyzing existing lake studies done in the 1970s. He estimated the total water resources of Mongolia—500 km^3 of which 410 km^3 is fresh water. According to the estimation of A.F. Krashnikov in 1975, the river water resources of Mongolia are 40.1 km^3, from this 29.2 km^3 is surface water and 10.9 km^3 is groundwater. His assessment slightly overestimated the water resources of Mongolia due to the lack of observation data and because the water balances were made over a large area. The book on surface water edited by Davaa and Myagmarjav1999, estimated that the total resources of Mongolia are 599 km^3 of which river water accounts for 34.6 km^3. A summary of estimates is given in Table 3.

The surface waters in Mongolia are unevenly distributed over the country since 380 km^3 of the total surface waters alone are stored in Lake Khuvsugul, which comprises 63 percent of the surface water of Mongolia and 75 percent of the fresh water. The high mountain ranges, which occupy 30 percent of the country's territory, are the source for 70 percent of the surface water resources of Mongolia (Table 2).

Groundwater

In 1958 the Russian scientist A.T. Ivanov estimated for the first time in Mongolia the groundwater resources over a total area of 1,000,000 km^2 showing 5.58 km^3 of water of which 0.6 km^3 was available for utilization. Next, the Institute of

Figure 2. Aimags of Mongolia

Water Exploratory Research (IWER) estimated the total groundwater resources in Mongolia at 12.93 km^3 in 1973 and 6.88 km^3 in 1975. Later, groundwater resources available for use were estimated at 6.28 km^3. More recently, Davaa and Myagmarjav (1999) estimated the groundwater resources of Mongolia at about 12.0 km^3. Jadambaa and Tserenjav (2003) estimated the groundwater resources that could be used for economic use of pastureland. Their estimation was based on a proposed distance between two water points of 5–7 km in the whole territory of the country, and it took into consideration different types of water bearing rock formations and possible rates

Table 2. Result of surface water state inventory (2003)

	Rivers, creeks		Spring		Mineral water		Lakes, ponds	
Name of aimag	**Total**	**Dried**	**Total**	**Dried**	**Total**	**Dried**	**Total**	**Dried**
Arkhangai	546	124	474	123	31	3	249	32
Bayan-Ulgii	293	17	736	42	13		1180	217
Bayankhongor	299	61	837	55	22		104	38
Bulgan	449	62	668	238	36		254	27
Gobi Altai	219	2	779	35			75	0
Gobi sumber	3	0	19	1	2		1	0
Darkhan Uul	21	4	27	13			4	2
Dornogovi	0	0	345	50	4		1	0
Dornod	156	39	354	121	24		515	233
Dundgovi	1	0	187	15	5		12	0
Zavkhan	217	19	444	18	15		118	2
Orkhon	5	0	28	7			4	1
Uberkhangai	294	51	530	97	37	3	110	20
Omnogovi	2	1	559	20	5		18	0
Sukhbaatar	35	22	368	41	6		55	4
Selenge	596	90	208	70	28	2	46	6
Tov	537	94	413	103	17	1	235	72
Ulaanbaatar	72	22	106	22	20	1	4	1
Uvs	183	0	493	31	16		121	6
Khovd	214	7	468	10	9		201	4
Khuvsugul	1233	70	969	193	78		642	30
Khenteii	246	17	588	179	6		247	65
Total country	**5565**	**683**	**9600**	**1484**	**374**	**10**	**4193**	**760**

of discharge They calculated the groundwater resources at about 10.79 km³. Table 3 (in Jadambaa and Buyanhishig, 2007b) shows a summary of the various surface water and groundwater resources assessment studies in Mongolia.

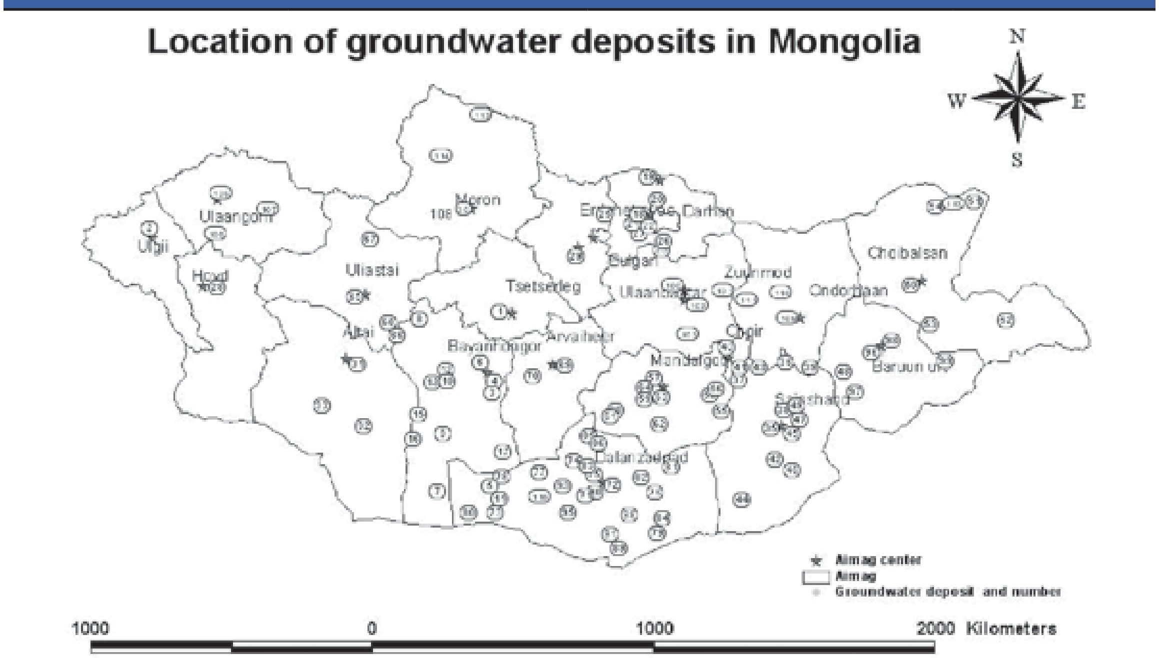
Hydro-geological research in Mongolia was developed in four main stages:

1. A hydro-geological map, which covered the whole territory of Mongolia, was drawn,

Table 3. Summary of water resources assessment studies (NWC, 2008)

	Groundwater resources (km^3)		Surface water resources (km^3)				
No	Total	Availability	Total	River	Lake	Ice, Glacier River	Source
1.	5.58	0.6	—	—	—	—	À.T. Ivanov, 1958
2.	12.9	—	—	—	—	—	IWER, 1973
3.	—	6.07	—	28.5	—	—	IWER, 1975
4.	—	—	—	40.1	—	—	À.Ph. Krashnikov, 1975
5.	6.88	6.28	—	—	—	—	N.À. Marinov, 1977
6.	12.0	5.6	599	34.6	500	62.9	G. Davaa, B. Myagmarjav, 1999
7.	—	—	—	—	500	—	J. Tserensodnom, 2000
8.	—	10.79	—	—	—	—	N. Jadambaa, G. Tserenjav, 2003

Figure 3. Location map of groundwater assessment studies



followed by maps for selected regions (e.g., Gobi and Ulaanbaatar).
2. Groundwater exploration was conducted to satisfy livestock, irrigated crop and herders' water demands and 125,000 boreholes were drilled and over 40,000 wells were constructed. Groundwater exploration was carried out to estimate the available groundwater resources for cities, towns, and industries, and for piped drinking water supply systems to towns and industries. Exploration has been carried out for 133 potential groundwater reserves. An estimated 1.5 million m^3/day of exploitable resources were identified in these studies (Figure 4).
3. There is on-going research on the dewatering of the mineral ore deposits and coal mines and for the water supply to existing and new mines such Tavan Tolgoi and Oyu Tolgoi.
4. A hydro-geological study of mineral springs was conducted. As a result of that research, five aquifers for hot spas and seven aquifers for cold spas were identified.

Water quality

Surface water quality per basin

Surface water quality in the mountainous regions of Mongolia is fresh and soft and classified as hydrocarbon calcium water. Studies and analyses by the IWER Central Hydro Chemical Laboratory and other sources have determined that the mineralization (total dissolved solids or TDS) of the river waters is 300–500 mg/l and is almost suitable for utilization by any economic sector of the country (Table 4).

The mineralization of the main lakes shows a much wider variation. For example, water in Uvs Lake, Khyargas Lake, Khar Lake, Boontsagaan Lake, Sangiin dalai Lake, Khukh Lake, and Oigon Lake has a mineralization of around 2,000–15,000 mg/l, while water in Khar Us Lake, Khuvsugul Lake, Buir Lake, Tolbo Lake, Terkhiin Tsagaan Lake, and Khoton Lake has a mineralization of 50–300 mg/l.

Groundwater quality per zone

Groundwater quality and chemical composition in Mongolia is generally classified into four physical-geographical zones (Table 5)

The groundwater mineralization is below 1,000 mg/l in most of country except for the Gobi Region where high TDS are found along with high levels of iron, arsenic, and other trace elements and heavy metals. Further details on the groundwater quality in the SGR are given in Chapter 2.

Water Use

The main water use sectors in Mongolia are (a) drinking water, (b) agricultural water demand (livestock and irrigation) and (c) industrial water. Minor water use sectors are tourism, urban, green areas, and the 'Green Wall'. Environmental water demands (base flow to rivers and wetlands, water

Table 4. Summary of surface water quality

		TDS		Hardness
Region	Rivers (+ tributaries)	Mg/l	pH	Mg-eke/l
Arctic Ocean Basin	Selenge, Sishged Huremteier	50–300	7.4–8.3	2.3
Pacific Ocean Basin	Onon, Ulz, Kherlen and Khalkh	120–300		2
Central Asian Internal Drainage Basin	Bulgan, Uench, Bodonch, Buyant, Khovd, Tsenkher, Tsagaan, Sagsai, and Sogoot	60–450		0.8–3.80

Table 5 Summary of average groundwater quality parameters (NWC, 2008)

		TDS	Hardness	Other
Region	**Features**	**Mg/l**	**Mg-ekv/l**	
Khangai–Khenti mountainous region	Mostly forest steppe	450	4.5	
Altai mountainous region	Mongol Altai, Siilhem, Kharhiraa, Turgen and Gobi-Altai mountains	640	4.8	
Mongolian Dornod steppe		950	5.6	High iron
Gobi region	Mainly steppes	1120	5.4	As, Fe, and others

for wildlife, and water for greenbelts) are important functions but difficult to estimate due to lack of data and information.

Drinking water supply

By 2004, 66 percent of the Mongolian population received water from a piped water supply system (30 percent from a house or yard connection and 36 percent from public standpipes). The remaining 34 percent got their water from non-piped water supply systems: 24 percent by water delivery trucks and 9 percent from natural springs, ponds, snow and rivers (Table 6). These percentages have changed over the past few years due to rapid urbanization and the building of over 10,000 apartments. The data in Table 6 show a large difference

Table 6. Total drinking water consumption in Mongolia, 2005 data (NWC, 2008)

#	Type and source of supply	Number of consumers (*1000)	Average consumption (l/day)	Total consumption (10^6 m^3/yr)	Involved areas
1	Central system	780	230	65.6	Apartments in central area
2	Water delivery unit (kiosks, trucks)	630	10	2.3	Ger districts in Ulaanbaatar city, centers of provinces and sub provinces
3	Water transportation service /track, pack animal/	917	9	3.0	Ger districts herders and local people
4	Rivers, springs, ponds and ice/snow water	233	5	0.4	Local people and herders
5	Total	2560		71.3	

1. The water consumption in the settlements in the central area has been estimated based on the appointment # 153 by the Minister of Nature and Environment in 1995. The consumption includes losses and leakages.
2. The source for the estimation of the daily water consumption in the settlements which is provided from the water delivery unit, rivers, springs, ice, snow, water and transportation water services is the "Access to water and sanitation services in Mongolia" (2004) joint study by the Government of Mongolia, UNDP, World Health Organization and UNICEF.

between the daily consumption from piped supply and from non-piped supply sources.

Agricultural water use

Groundwater, surface water, snow and glacier water are used for livestock water supply. By 2006 the livestock population was 34.9 million head and their total water use was estimated at around 80.0 million m^3/year.

Mongolia has always been a country of nomadic herders and pastureland. Nevertheless, crop irrigation has been present in all stages of its historical development. By 1990, crop irrigation was well developed. There were 45,000 hectares designated as irrigated areas, of which 16,000 hectares were irrigated with surface water. The estimated volume of water that was used to irrigate crops for the years 1989 to 2006, based on calculations of crop water use, shows an increase by 13–16 percent in recent years and a total use of about 51-million m^3 for the total irrigated area in 2006.

Industrial and energy water use

Previous estimates of the industrial water use give a range of 99–115-million m^3 in 1991–1993 of which 53 percent was used for the mining sector, 33 percent for the manufacturing industrial sector, and 14 percent for the construction sector. In 1995, the water use was estimated 108-million m^3 of which 55 percent was used for mining industries, 33 percent for manufacturing, and 12 percent for construction industries.

In 2006 the Water Authority gave permits to 143 mining companies to use a total of 143 million m^3 water of which 94 million m^3 was actually used. The amount of water extraction approved by permits is not well defined. The volume of water consumption per year is determined through internal discussions. Sufficient information about the technical condition of the mining processes, available water resources and quality, as well as current water use in the mining sector is missing, which makes it difficult to prepare reliable estimates. At the moment, the largest water users are the 117 placer gold mines, and other larger mining companies like Erdenet, Tomortei-Ovoo, Olon-Ovoot, and Boroo. According to the Water Law, the mining industries are also responsible for establishing the water supply system for new cities or towns (sometimes 30,000–60,000 dwellers) that accompany large-scale mining operations.

By 2006, the annual water use by power plants in Ulaanbaatar, Darkhan, and Erdenet cities was 27 million m^3 and about 80 million m^3 is used for hydropower generation. The total capacity of the power plants is 830 megawatts (MW), with 700 MW for Ulaanbaatar and 130 MW for regional centers. Of this total capacity, 176 MW are imported from Russia. The contribution from hydropower—6 plants totaling 3,428 kilowatts (kW)—is very low and marginal because the plants can be used only in the summer months.

Other water uses

Minor water demands come from tourism with 2 million m^3/year (2005) estimated from the number of tourists, their average stay, and their average water consumption.

More important, but largely unknown, are the environmental water demands. Environmental water demands are the water requirements to maintain nature and environmental functions such as the base flow to rivers, lakes, and wetlands, and water availability for natural vegetation, wildlife, and other ecological functions. These needs are not easy to define but are generally less than the water that is actually allocated to the environment. Also in the case of Mongolia, data and information on the environmental water demands and water use are lacking (MNE, 2007). The only reported environmental water allocation is water for the green areas of the main cities and for the Green Wall national program that plants trees in the transitional zone of the Gobi desert and the steppe.

Summary

Table 7 shows the total estimated water use for all sectors.

The summary report of inception phase for the Strengthening Integrated Water Resources Management in Mongolia Project (MNE, 2007) contains a summary table with all the water balance parameters derived from earlier studies, and provides a useful reference to the main water-related parameters in Mongolia. This summary can be found in Annex B.

Water Institutions and Regulation

Institutional framework

Water issues come under the jurisdiction of the Ministry of Nature, and Environment and Tourism (MNET). The Water Authority (under MNET) is the main implementing agency of the Water Law (2004). In addition, there is a National Resource and Environmental Policy Coordination Division within MNET.

At the central level is the National Water Committee (NWC). Established in 1999, the NWC co-ordinates between institutions in the water sector to implement the national water program (Figure 4). The NWC director is the government representative who is responsible for environmental issues. The NWC responsibilities and function are not clear due to lack of legislation.

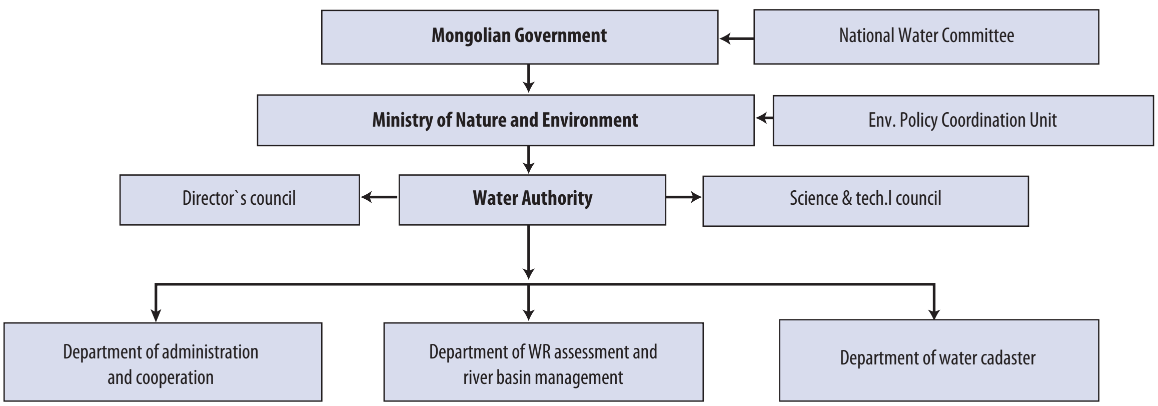
In the current institutional structure, many institutions are involved in the water sector. The central water supply organization is under the supervision of the Ministry of Construction and Urbanization. Irrigated crop, pastureland irrigation, and livestock water supply policy is made by the Ministry of Food, Agriculture and Light Industry. Hydropower policy is carried out by the Ministry of Fuel and Energy. And public health issues are in the scope of the Ministry of Health. An overview of the ministerial responsibilities is given in the Annex C.

In addition to the Government agencies engaged in water resources development and management, universities, scientific institutes, and the private sector (consultancy firms and contractors)

Table 7. Total annual water use of Mongolia, based on 2005/2006 data (NWC, 2008)

#	Sectors that use water		Total water use (million m^3)
1.	Drinking water supply		71
2.	Agricultural water supply	Livestock	80
		Crop irrigation	52
3.	Industrial water supply	Exploitation industry	36
		Extractive mining industry	94
		Energy production, Power plants	27
		Hydro Power Plant	80
4.	Tourism water supply (excl. spa resorts)		2
5.	Green area		<1
6.	Water for nature and environmental functions		p.m.
Total:			**443**

Figure 4. Structure of the key water management agencies



are resources for good knowledge on water-related issues.

Policies

Although the organizational responsibilities at the national level are formally established, a comprehensive policy on water issues is still lacking. Water resource management is the responsibility of MNET and the protection of water, water resources, and aquatic life leads the itinerary of government policy, aiming to meet the following objectives:

- Elaborate a national water resources management plan and to get approval from the government and provide its implementation;
- Develop a river basin management plan and to establish River Basin Councils for large river basins and appoint professional administration;
- Provide adequate water resources for drinking water use;
- Improve water supply for herders and livestock;
- Assess the existing groundwater resources;
- Intensify irrigated crop production;
- Assess the conjunctive use of groundwater and surface water;
- Increase the use of hydropower;
- Enhance water use technology for the mining sector, and
- Enhance capacity building in the water sector, to provide specialized training, and to strengthen the relevant institutions.

The main program in the water sector is the *National Water Program, 2000–2010,* which was adopted in 1999. Although the Government approved the program, the implementation is poor since the institutional structure is weak and adequate financial input is lacking. The program document is also not specific, and programming of activities is unclear.

The program was followed by an action plan —*Water Renovation–XXI which looked forward to 2025*. Adopted in 2004, the document is mainly an investment plan. It does not include an initial analysis that justifies the investment or an economic analysis for benefits and costs. The plan mainly focuses on reservoirs and irrigation measures while, for example, projections of demand and demand management are missing.

The new project *Strengthening Integrated Water Resource Management in Mongolia* will address these issues and support the Government of Mongolia through the Water Authority in the following ways:

- Capacity building in the field of integrated water resources management in Mongolia,

- Preparation of a National Water Management Plan, and
- Preparation of a River Basin Management Plan in a pilot basin.

Laws

By 2007, the following water laws (including adopted years) were regulating the water sector of Mongolia:

- Law on Environmental Protection, 1995 (with amendments in 1998, 2002, 2003, and 2005);
- Law on Water – revised and adopted in 2004;
- Law on Water Supply and Sewerage Network Use in Cities and Settlements – 2002 (with an amendment in January 2005).
- Law on Hydrology, Meteorology and Research Monitoring – 1997 (with amendment in January 2003);
- Law on Water and Mnieral Springs Use Fees, 1995 (with amendment in December 2004);
- Law on Mineral Springs, 2003;
- Law on Navigation, 2003 (with amendment in January 2005);
- Law on Amount of Expenditures for the Measures to Protect the Environment and to Restore the Natural Resources Out of the Funds, 2000.

Besides the above water laws, the Government has issued over 20 acts and regulations, and over 20 standards are in force in the water sector. The overall set of laws and acts covers most of regulatory issues related to water resources development and management, but some laws overlap and some terminology often differs between laws. A harmonization of current laws is considered an important objective.

The main constraint lies in the implementation and enforcement of the laws and regulation. One of the urgent needs is the development and adaptation of relevant mandatory penalty rates for pollution incidents or non-payment for water use.

Water Pricing

Water fees are regulated by two laws: the Law on Water and Mineral Springs Use Fees (1995, revised in 2004) and the Law on the Amount of Expenditure for the Measures to Protect the Environment and to Restore Natural Resources. These laws face difficulties with implementation and enforcement, but both provide the legal basis to charge a service fee for domestic water supply (Table 8) and a water use fee for industrial water supply (Table 9). Water use in the energy sector, for crop production, for livestock and herders water supply (outside the town centers), and for domestic water consumption are excepted from the water use fee.

Table 8. Service fee tariff (in togrogs/m^3) for drinking in Ulaanbaatar city (2007)

#	Type of service	Service fee	Note
1.	Piped water (Ulaanbaatar): • Office • Apartment/Houses	 367 189.0	 The appointment # 2 by the director of USUG /January 16, 2007/
3.	Water delivery kiosks and pipeline wells: • dwellers in ger districts • office buildings.	1000	The appointment # 90 by the director of USUG /April 12, 2007/
4.	Transportation of water to settlements	2000	
5.	Freshwater delivery to the summer camps	3000	

Table 9. Water use fee tariffs (in 2006)

Purpose of water use	Water use fee (togrogs/m^3 water use) Surface water	Water use fee (togrogs/m^3 water use) Groundwater
Heavy manufacturing	20.0	30.0
Manufacturing	10.0	30.0
Mining industry 1. Gold, pewter extractive industry 2. Natural oil and zinc, plumbum 3. Copper concentration, spar	 100 100 80	 120 120 120
Food and beverage industry	10.0	30.0
Other commercial use	10.0	30.0
	Water use fee (% of total market revenue)	
Water use for hydropower stations, navigation, ample fauna and flora breeding, water sports, etc.;	1.0 %	

Note: A water delivery identity collects water use fee from the firms, individuals, and organizations on behalf of the government.

2. The South Gobi Region

Physical Description

The SGR (Figure 5) occupies about 350,000 km^2 covering broadly the area of the aimags of Dornogovi, Dundgovi, and Umnogobi (Figure 2). The area is a region at relatively lower elevation. In the eastern part, the topography consists of the low elevations of the Gobi Mountains, which are separated by a broad shrub-dominated desert basin and steppes. In the western part, the topography is slightly higher with more rugged mountains and broader gravel plains (Sheely and others, in press).

The rainfall in the SGR has a considerable annual and seasonal variation. Annex D gives the annual rainfall, average monthly rainfall, and the monthly rainfall in July, August, and September for Dalanzadgad, Mandalgobi and Sainshand during the period 1970–2002. The annual average rainfall is 115–150 mm/year with the highest values in July and September and the lowest rainfall in the period December–March. Table 10 gives some typical figures for the three stations.

Also the temperature shows large fluctuations between the seasons with maximum values of 35–40°C in the summer and minus 30–40°C in winter.

Figure 5. South Gobi Region location map

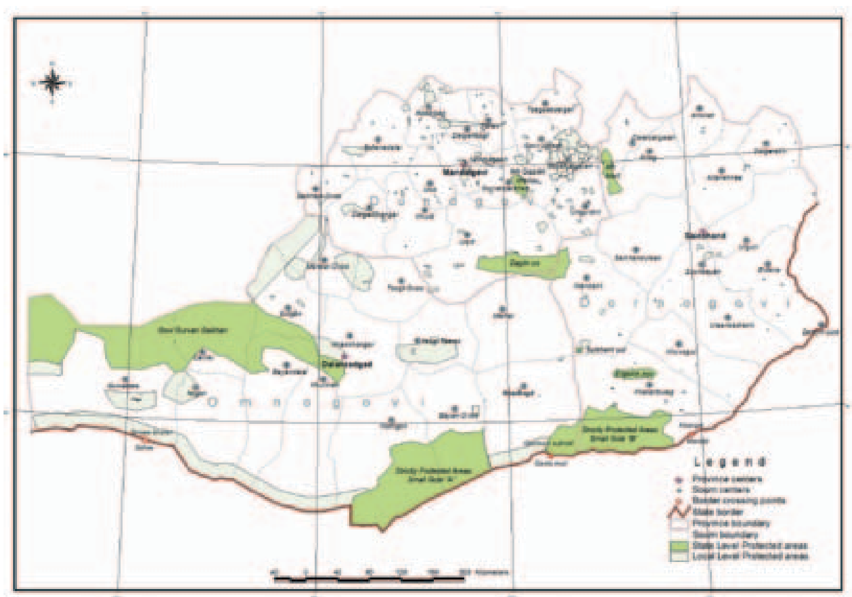


Table 10. Rainfall figures Dalanzadgad, Mandalgobi and Sainshand (1970–2002)

	Annual rainfall (mm)			Average monthly rainfall (mm)		Highest monthly rainfall (mm)		
	Average	Highest	Lowest	High	Low	Jul	Aug	Sep
Dalanzadgad	125	230	75	34	1	78	75	72
Mandalgobi	150	240	75	44	1	92	102	86
Sainshand	115	225	55	36	1	58	135	102

Demography and Economic Development

Population

In the SGR, the human population in Dornogovi and Omnogovi provinces has followed the national trend. Between 1985 and 2004, the human population in 13 soums of these two aimags increased 53 percent, from 41,072 to 62,735 persons. The most dramatic increase in human population occurred from 1985 to 1995 and was mostly due to urban growth in Sainshand (Dornogovi) and Dalanzadgad (Omnogovi) as a result of younger people from rural areas seeking jobs and opportunities. The current population of Dundgovi province is more dynamic as many herders have moved their livestock to other aimags to escape periods of drought.

The current (2007) total population in the three aimags is around 150,000 of whom about 60,000 live in towns, mainly the three aimag capitals Dalanzadgad, Mandalgobi, and Sainshand (Table 11).

Economic development

Livestock farming has been the main economic activity in the SGR for a long time, but the economic development of the SGR is expected to grow rapidly in the near future, based instead on the planned development of coal and gold mines. The infrastructure development for these mines will trigger the development of additional mines and associated industries along with expanding populations and urban development.

Table 11. Population figures 2004 and 2007

	Total Population		Towns	Rural
Aimag	2004	2007	2004	2007
Omnogovi	46,800	46,900	15,000	31,900
Dornogovi	52,500	55,600	30,000	25,600
Dundgovi	49,900	48,800	14,000	34,800
Total	**151,204**	**153,307**	**61,004**	**94,307**

Sheely and others (in press) summarized the main economic and infrastructure development activities that are planned for the Region as follows:

- Mongolia's primary transportation corridor (rail and highway) linking Ulaanbaatar with China which crosses the eastern section of the SGR.
- Large-scale infrastructure construction, including (a) development of a support and service infrastructure to facilitate exploitation of minerals, coal, and oil, and (b) enhancement and expansion of the existing transportation network (roads, rail lines, air service, and ancillary industries).
- Oasis and deep-well agriculture to produce crops and animal feed for small-scale, intensive livestock production near aimag capitals.
- An expanding tourism industry, including eco-tourism, requiring infrastructure development.
- Commercialization of the livestock industry accompanied by increasing demand for meat and livestock products throughout the Asia Region, especially from China.

Water Use and Water Supply

Current water demand and use

Water supply in the SGR is almost entirely from groundwater (and springs) as surface water sources are absent during large parts of the year (Table 2). The main water use was traditionally for domestic water supply and livestock farming. Locally in the SGR there is increasing water use by the mines and related economic developments.

The current demand for urban water supply to Dalanzadgad, Mandalgobi, and Sainshand is 6,500 m³/day (total population 55,000). The supply is from well fields with treatment where necessary to reach drinking water standards. Table 12 shows consumption figures of 100–130 liters per capita per day, which is in agreement with the figures in Table 6 assuming that half the population has house connections and half uses kiosks.

Rural water supply is mainly from individual water points (herders' wells) and from deep wells with a pipeline that supplies the soums. Water supply in the soums is mainly through kiosks, although some of the soums may have a limited number of house connections. The total rural water supply is estimated at 1,000–3,000 m³/day assuming a daily consumption of 10–30 liters per day for a rural population of 95,000. Livestock watering is calculated using the estimated number of livestock and daily water consumption figures (Table 13). The total water use for livestock water supply is around 32,000 m³/day.

Groundwater use for agriculture is limited and confined to subsistence farming in villages and hamlets. Irrigated agriculture is applied on a small scale with surface water from springs and stream flow during and after the rains. The present water demand for tourism and wildlife are also small compared with the mining, drinking, and livestock water demand.

Table 12. Water use in the Aimag capitals

		Yield	Abstraction capacity	Abstraction		Consumption
Name	Number wells	l/sec	m³/day	m³/day	Population	lit/cap/day
Dalanzadgad	10	1–15	4,000	2,000	15,000	133
Sainshand	18	0.4–27	5,000	3,200	29,000	110
Mandalgobi	15	1–10	3,500	1,000	10,000	100

Table 13. Animal water use

Livestock	Daily water consumtion (lit-day)				Number cattle (2003)	Water demand (m^3/day)
		Ref 2				
	Ref 1	Warm season	Cold season	Average		
Sheep-goat	4	5	3	4	3,400,000	13,600
Cow	22	40	30	35	100,000	3,500
Horse	20	40	30	35	260,000	9,100
Camel	35	55	40	45	120,000	5,400
				Total:	**3,880,000**	**31,600**

Ref 1: National Water Committee (2008); Ref 2: JICA (2003

Table 14. Mines water demands in the SGR (Jadambaa, 2007)

Mine	Type	Demand 2010 (m^3/day)	Groundwater source
Oyu Tolgoi	Gold and copper	67,000	Galbyn Gobi Gunii Hooloi
Tsagaan Suvarga	Copper	32,000	Tsagaan Tsav
Olon Ovoot	Gold	2,500	Bayan Hoshuu
Tavan Tolgoi	Coal	76,000	Balgasiin Ulaan Nuur Tavan Zag Tavan Ald Khurment Tsagaan Naimant
Nariyn Suhayt	Coal		
Host	Coal		
Shivee Ovoo	Coal	6.480	Jargalant Nuur Morit Spring
Odvog hudag	Coal	3.440	Morityn Bulag Morit spring
Tevsh Gobi	Coal		
Omnogovi Ovoo	Khoklmorit	950	Dugui Ulaan
Hamort	Lead	950	Dugui Ulaan
Urgun	Fluorspar	860	
Lugyn Gol	Rare earth	1,050	

The reported water demand of the mining industry in the SGR is around 190,000 m³/day (Jadambaa and Buyanhishig, 2007a) of which approximately 180,000 m³/day for the four main mines: Oyu Tolgoi (67,000 m³/day), Tavan Tolgoi (76,000 m³/day), Tsagaan Suvraga (32,000 m³/day), and Shivee-Ovoo (6,480 m³/day). There is still uncertainly about the accuracy of these figures (Table 14) and to what extent they include water demands for current or planned mining operations.

More detailed information on the water demand is only available for the Oyu Tolgoi mine which shows the following water demand requirements for a planned capacity of 110,000 tons per day:

Plant raw water demand

- Concentrator 670 l/sec

Infrastructure /mining water demand

- Domestic, washing, and heating water 16 l/sec
- Power plant 10 l/sec
- Dust suppression 59 l/sec
- Underground mine 30 l/sec

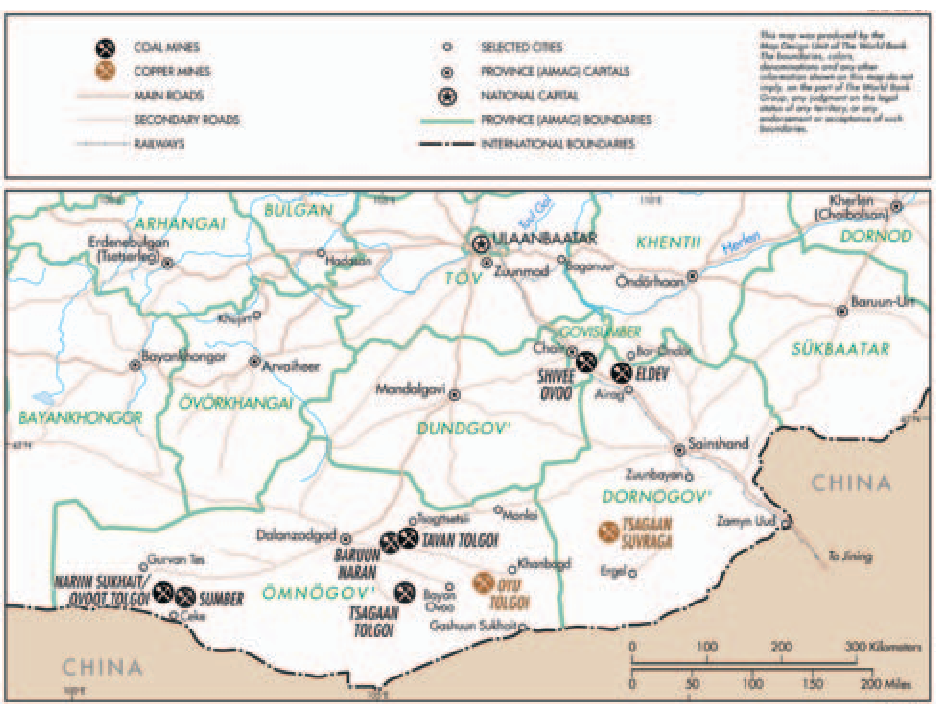
Total 785 l/sec

This is equivalent to 67,000 m³/day or 600 liters per ton of production. This capacity will be reached when the mine is in full operation, which is expected to occur in a few years.

The (open pit) copper mine in Tsagaan Suvarga has an annual planned extraction capacity of 20,000 tons per day (7.5 million tons/year and a reported water demand of 32,000 m³/per day. This indicates a water use of 1,600 liters per ton, which is much higher than Oyu Tolgoi (600 liters per ton). Applying the more reliable figure from Oyu Tolgoi, the Tsagaan Suvraga water demand is much lower (13,000 m³/day).

Information on water demands for coal mining is not readily available. Mining operations in the Tavan Tolgoi and Nariin Sukhait area (Figure 6) are still modest but given the enormous

Figure 6. Mining locations in Dalanzadgad region (Energy Economist, 2006)



coal reserves in the area, the mining production is expected to increase sharply in the coming years.

The coal reserves in the Tavan Tolgoi area alone are estimated at 5–6 billion tons and could sustain an annual production of 100 million tons for 50 years. Future production figures were found in scattered reports and articles and indicate that the coal production may rise from 11 million tons per year in 2008 to some 50 million tons per year in 2020 (Table 15).

Water use in coal mining varies according to the method of mining (underground or surface), equipment used, and the availability of water. Underground coal mining requires water but surface mines do not use water in actual mining. For processing of the coal, one can distinguish four water demand categories:

- Washing of the coal,
- Dust suppression,
- Use for plant operation and personnel, and
- Power supply.

Water is also needed if the coal is conveyed by pipeline (mineral conveyance) but this is not applicable in SGR.

Most coal mines in the SGR are open pits with no processing and shipment of the coal by truck or railroad. Under these conditions, the main water needs are for dust control and small uses. A senior mining expert met was of the opinion that this water demand is estimated at 100–200 liters per ton of coal produced. Washing of the coal will add 400–600 liters to this demand, depending on the process used and the level of re-use. Assuming that 300 liters of water are used for the current coal production of 11 tons per year, the total water use is 9,000 m^3/day, which is much less than figures in Table 14.

The reported total water demand for mining of 190,000 m^3/day seems to be on the high side. Given the fact that Oyu Tolgoi is not yet in operation, that the Tsagaan Suvarga mine consumes 12,000 m^3/day, and the current coal mine operations have a demand of 9,000 m^3/day, the total present water demand is more in the order of 40,000 m^3/day

As explained below, environmental water demands are not known and no quantitative data or estimates are available of the current environmental water use. Water for the Green Wall project

Table 15. Key figures on coal mining in the SGR

Mine	Company	Reserves (10^6 ton)	Production 2005/2008 (106 ton)	Processing	Future production
Eldev	MAK	50			?
Nariin Sukhait	MAK/Qing Hua	134	2	No	5 million tons in 2014
Ovoot Tolgoi (Nariin Sukhait)	SG Energy Resources	150.	1	No	Production 2012; 8 Mt
Tavan Tolgoi	Mongolian Government New concessions	6400	1	No	30 Mt during 30 years
Tsaagan Tovi	SG Energy Resources	36	–		?
Small mines	40 mines		7	No	?
Total			**11**		**45+**

in the SGR, as well as other small uses like for tourism, is negligible.

Water supply infrastructure

Groundwater is abstracted typically by four types of wells: traditional, shaft, shallow, and deep wells (Figure 7). Originally the shaft wells, traditional wells, and shallow wells were the main abstraction means. With the introduction of motorized pumps, many higher-yielding deep production wells have been drilled since the late 1970s.

After the transition, a large number of these wells have been abandoned due to lack of maintenance and unresolved ownership issues. Also many of the shallow wells and shaft wells are out of operation due to a variety of reasons (Table 16). Based on the estimated number of operational wells and typical abstraction rates (JICA, 2003), a total groundwater abstraction for rural, urban, and livestock water supply is estimated to be around 50,000 m^3/day (Table 16). This amount is in agreement with the calculated water use in the next chapter.

Most of the rural water supply is taken straight from the wells. In the soums and the ger districts of the aimag capitals, the water is mainly supplied through kiosks (from individual deep wells or from the piped system).

The three aimag capitals also have a distribution system with connections mainly serving apartment blocks and offices. The aimag capitals are in the process of upgrading the water supply systems through the ADB-financed Basic Urban Services in Provincial Towns project. The figures in Table 12 show that this upgrading is not needed for the groundwater availability since the current abstraction is only half of the installed capacity

Mining water supply is mainly from high-yielding deep production wells and piped to the points of use. In the case of the Oyu Tolgoi mine, a 75-km pipeline is under construction to bring the water from the well-field to the mining site.

Future water demands

Future water demands depend on economic and infrastructure development; but it is evident that mine development will be the most important water consumer and the trigger for population increase (township development) and additional industrial and commercial development.

Mining water demand will depend on the number of new mines, rate of expansion, and the type of technologies used. An attempt is made to estimate the 2015 water demands of the four main mining areas based on the currently known expansion plans:

- ***Oyu Tolgoi***. Planned extraction of 110,00 tons per day will be reached in the next 4–6 years with a corresponding water demand of 70,000 m^3/day.
- ***Tsagaan Suvarga***. Planned extraction capacity is 7.5 million tons per year which would require 13,000 m^3/day (using the Oyu Tolgoi unit figures).
- ***Nariin Sukhait/Ovoot Tolgoi***. 15 million tons per year of which 50 percent is processed (average demand 600 liters/ton), giving a water demand of 25,000 m^3/day.
- ***Tavan Tolgoi.*** 30 million tons per year using 600 liters/ton, giving 50,000 m^3/day.
- ***Other mines***. 20,000 m^3/day.

Assuming an annual increase of 10 percent in the period 2015–2020, the 2020 water demand would reach 300,000 m^3/day in 2020.

Urban water supply will grow around the mines and in the aimag capitals. The Ministry of Construction and Urban Development (MCUD) expects a population increase in the vicinity of the main mines of 110,000 by 2020 (see accounts of the SGR workshop in May 2008 in Dalanzadgad —see www.worldbank.org/southgobi). Assuming an overall increase of the urban population to 200,000 in 2020, the urban water supply demand will reach 25,000 m^3/day.

Increased demands for water of the other economic activities such as additional industrial

Figure 7. Typical design of abstraction wells

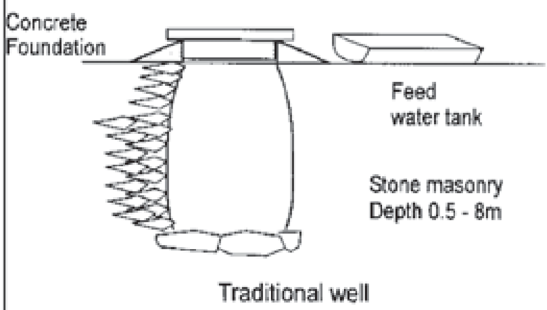


Fig. 2.5.24 General Map of Traditional Well

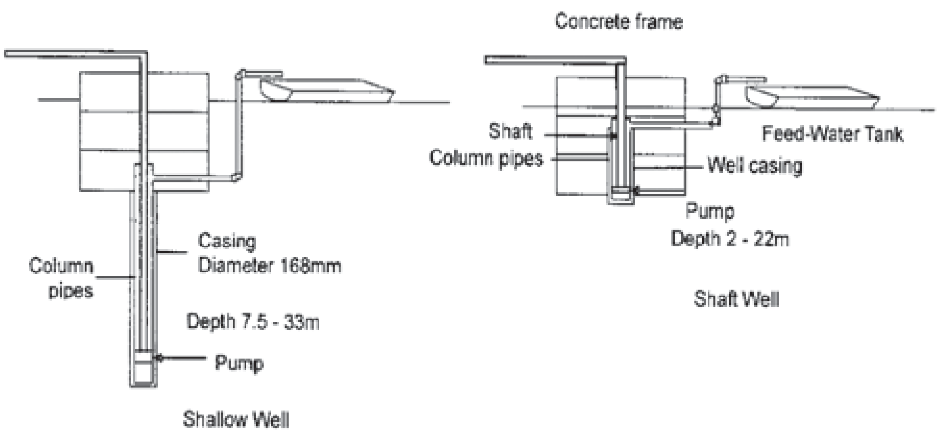


Fig. 2.5.23 General Map of Shallow and Shaft Wells

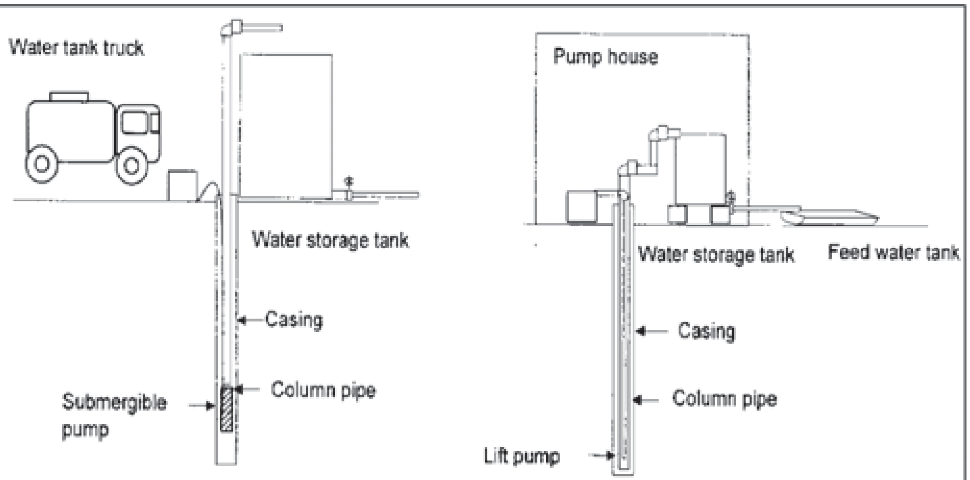


Fig. 2.5.22 General Map of Production Well Facilities

Source: JICA, 2003.

development, deep-well agriculture to produce specialty crops and animal feed, more intensive livestock production near provincial cities, and tourism development are also difficult to estimate without further details on the size of these activities and more details on the development planning. Like for urban water supply, these future water demands are also expected to be located in

Table 16. Type and number of wells and estimated abstraction rates (JICA, 2003)

			Aimag			Well yield	Total abstraction
Type of well		**Dornogovi**	**Dundgovi**	**Omnogovi**	**No operational wells**	**m^3/day**	
Production wells							
Total number		321	437	357			
Operational	%	18	16	24	213	60	12,803
Depth range	m below groundsurface	30–190	20–220	30–240			
Yield range	1–15 l/sec submersible or						
Pump	Engine driven lift pump						
Shallow wells							
Total number		85	285	469			
Operational	%	8	8	23	137	25	3,437
Depth range	m below groundsurface	10–100	10–100	10–100			
Yield range	0.3–1 l/sec hand operated						
Pump	Rotary pumps						
Shaft wells							
Total number		1100	1500	900			
Operational		35	80	20	1,765	15	26,475
Depth range	m below groundsurface	2–20	1–20	2–22			
Yield range	0.2–0.4 l/sec hand operated						
Pump	Rotary pumps						
Traditional wells							
Total number		1300	1500	2000	5,000	2	10,000
Operational							
Depth range	m below groundsurface	1–10	1–10	1–20			
Yield range							
Total							**52,715**

Table 17. Estimated current and future water demands

Sector	Water demand (m^3/day) 2005/10	Trends	2020
Mines	40,000	Some main mines coming into operation in the next 5 years. Annual increase 2015–2020: 10%	300,000
Industry / Commerce	Small	Increase expected around mining areas	12,500
Urban water supply	6,500	Urbanization around mining areas will increase with 100,000 in 2020 (MC&UD)	12.500
Rural water supply	3,000	Annual increase of 5%	5,000
Live stock water supply	32,000	Annual increase of 5%	50,000
Irrigated agriculture	small	Vegetable production around urban centers. Assumption: 1000 ha @ 10,000 m^3/yr	30,000
Tourism /environment	small	Remains small and localized	15,000
Total	**85,000**		**425,000**

the area of mining activities and around the aimag capitals

Environmental water demands should be mapped in order to define the future water needs to sustain environmental and ecological values in the SGR. Table 17 gives the summary of the current and future water demand estimates and shows a total demand in the order of 425,000 m^3/day in 2020.

3. Groundwater Occurrence and Potential

Groundwater Occurrence: Explanation and Terminology

Aquifers

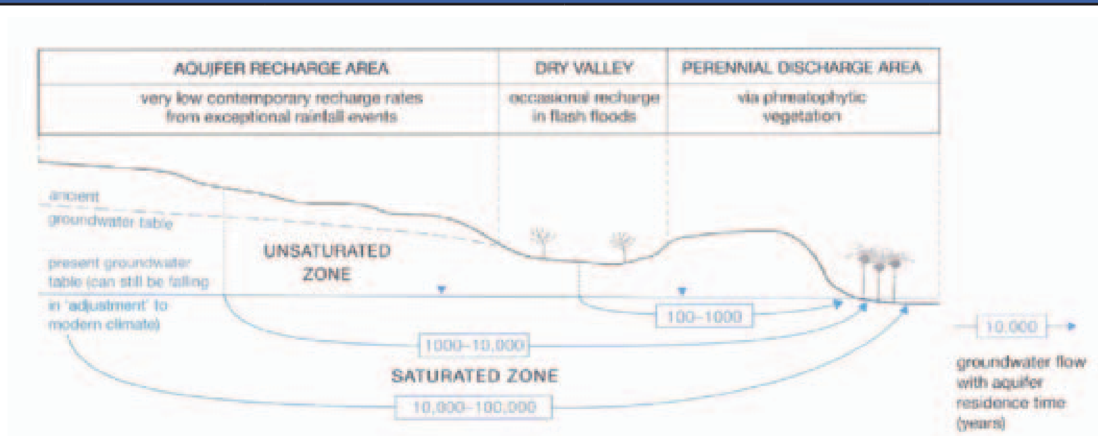
Aquifers are layers of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) through which groundwater can flow and from which groundwater can be usefully extracted using a water well.

The occurrence of groundwater (and its quality) in the aquifers and its movement depends not only on type of formation but also on the recharge mechanisms. All groundwater must have had a source of recharge. This is normally rainfall but can also be seepage from rivers, canals, or lakes. Infiltrating water percolates to the water table and flows from the points of recharge to the points of discharge. The aquifer flow regime depends on the hydraulic characteristics of the rocks (media) and the hydraulic gradient and may vary widely with the geology and the recharge conditions.

Groundwater systems are dynamic with groundwater continuously in slow motion from zones of recharge to zones of discharge. Tens, hundreds, or even thousands of years may elapse, especially in arid and semi-arid regions (Figure 8)

All aquifers have two fundamental characteristics: a capacity for groundwater storage (productivity) and a capacity for groundwater flow (continuity). Productive aquifers have good hydraulic characteristics and usually a distinction is made between highly, moderate, and low

Figure 8. Typical groundwater cycle in arid region underlain by major aquifers



productive to classify the aquifers in a region. Continuous aquifers (such as in Figure 8) have a regional extension and are usually referred as major aquifers. Aquifers with a smaller extension (like in the SGR) are called minor aquifers or local aquifers.

A summary of the characterization of groundwater systems is given in GWMATE (2006).

Fossil or non-renewable groundwater

In some cases aquifers are cut off from their source of recharge due to geological events or climatic changes. These are called *fossil* (or *non-renewable)* aquifers. For fresh groundwater abstraction, the term non-renewable can be interpreted in two ways, quantitatively and qualitatively:

- *Quantitatively* – when fresh groundwater is not replenished which results in a continued decline of the water level (both in the pumping well and regionally).
- *Qualitatively* – when fresh groundwater is (partly) replenished by more brackish or saline groundwater resulting in increased salinity.

Fossil groundwater needs special care in its exploitation as it concerns a one-time reserve, which is not replenished. Scenarios for development and management of non-renewable groundwater are summarized in GWMATE (2006).

A planned depletion scenario described in Box 1 means that a period of time is defined during which a certain quantity of water is abstracted from the aquifer and expressed in a certain lowering of the groundwater table (or groundwater head).

Geology

The geology of Mongolia is described in various reports and publications including the Explanatory Note to the Hydrogeological Map of Mongolia, Scale 1: 1,000,000 (Jadambaa and others, 2003) and the report on groundwater prepared for the inception phase of Strengthening Integrated Water Resources Management in Mongolia project (MNE, 2007). Specific information on the geology and hydrogeology of the SGR is available in JICA (2003) and in the background document for this study, Groundwater Assessment of the Southern Gobi (Jadambaa and Buyanhishig, 2007b).

The geology of Mongolia reflects the development of Central Asia between the cartons formed at the end of the Archean: the Siberian craton in the North and the Tarim, North China, and Sino-Korean craton in the South. The whole territory of Mongolia was consolidated and belonged to the Late Paleozoic Pangean supra-continent. Further development from the Mesozoic to Cenozoic is characterized be orogenesis, magmatism, and sedimentation, particularly in southern and eastern Mongolia.

No good quality study exists of the plate tectonic development although attempts have been made in the recent past. Tumurtogoo (2002) differentiates among three megablocks (the northern, central, and southern megablocks) and six supraterrains and numerous terrains (Figure 9), and describes the geodynamic position as well as the petrology of single structures.

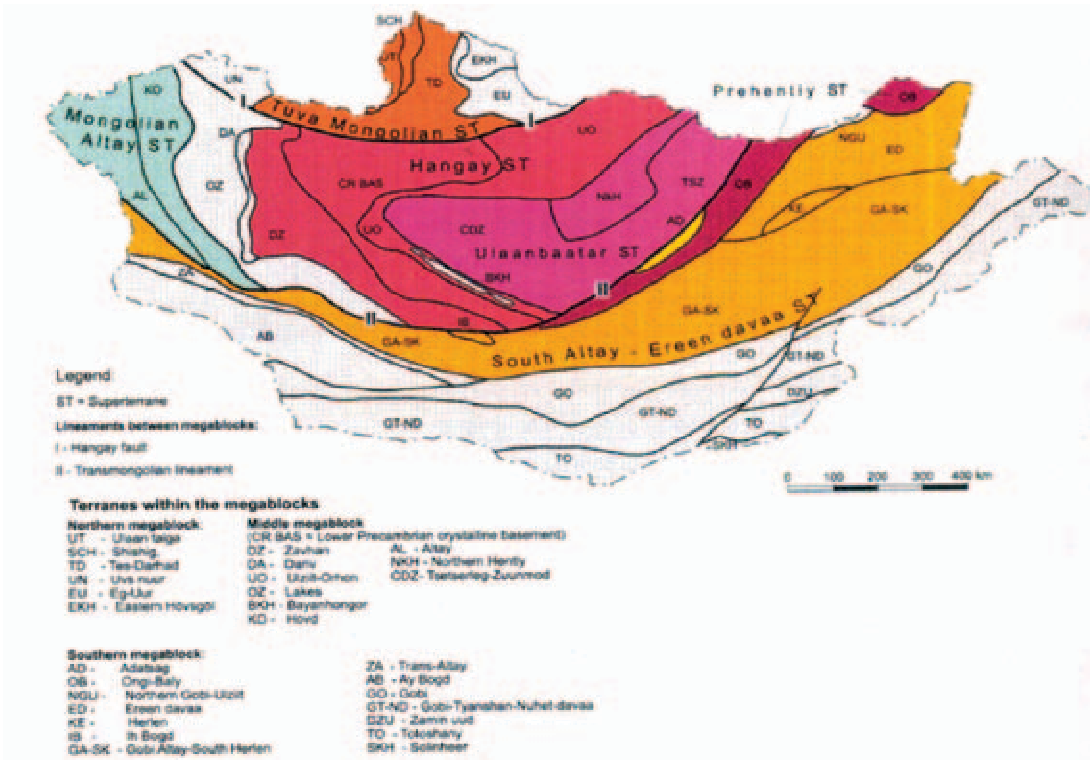
The total development is divided into two parts: from Precambrain up to the end of the Permian (i.e., up to the formation of the hard

Box 1. Planned depletion scenario of fossil groundwater

In the planned depletion scenario, the impact of the proposed exploitation of the aquifer reserves on traditional groundwater users needs to be assessed and some form of compensation provided for predicted or actual derogation. The fundamental concept should be to ensure that there are sufficient reserves of extractable groundwater of acceptable quality left in the aquifer system at the end of the proposed period of intensive exploitation to sustain the pre-existing activity (albeit at additional cost). Another way of achieving this would be to restrict the design drawdown of intensive exploitation to less than an average figure over the stated period.

Source: GWMATE/World Bank Briefing Note no. 11

Figure 9. Regional tectonic units of Mongolia (Tumurtogoo, 1996)



crust and the Mesozoic and Cenozoic periods). During the Mesozoic and Cenozoic, the recent territory of Mongolia was in a platform geodynamic situation where the formation of different overlapping structures was caused mainly by destruction of the previous continental crust. The formation of large basins mainly occurred not only in the southern megablocks, but also in parts of the central megablocks.

Aquifer Systems in the SGR

Aquifer productivity

The geological formations that are particularly interesting for groundwater occurrence are the Permian, Triassic, Jurassic, Cretaceous, Paleogene, Neogene, and Quaternary rocks and sediments. They form a complex set of local aquifers at different depth, extension, and lithology and can be divided into two types of aquifers: inter-granular (with primary porosity) and fissured (with mainly secondary porosity). Jadambaa and Buyanhishig (2007b) give a listing of the aquifers in the SGR in three classes of productivity:

- Locally highly productive aquifers,
- Low to locally moderately productive aquifers,
- Local limited groundwater resources or strata with no groundwater.

This description is included in Annex E and summarized in Table 18 indicating the number of formations based on age and litholoIgy:

Productive (high or moderate) aquifers in the SGR include the alluvial sand and gravel deposits in the wadis and bel areas of the mountains. These aquifers are usually *shallow* (less than 50 meters) and are the main source of drinking water and livestock water supply. At greater depth, the most productive aquifers are found in the *sandstone containing deposits*, of which the

Table 18. Number of formations for different productivity classes

	Locally high productive	Low /local moderate productive	Local limited resources or no groundwater
Inter granular rocks	2	7	1
Fissured rocks	—	1	2

Upper Cretaceous sandstone complex is the most productive.

A useful reference to understand the concept of aquifer system characterization is GWMATE (2006).

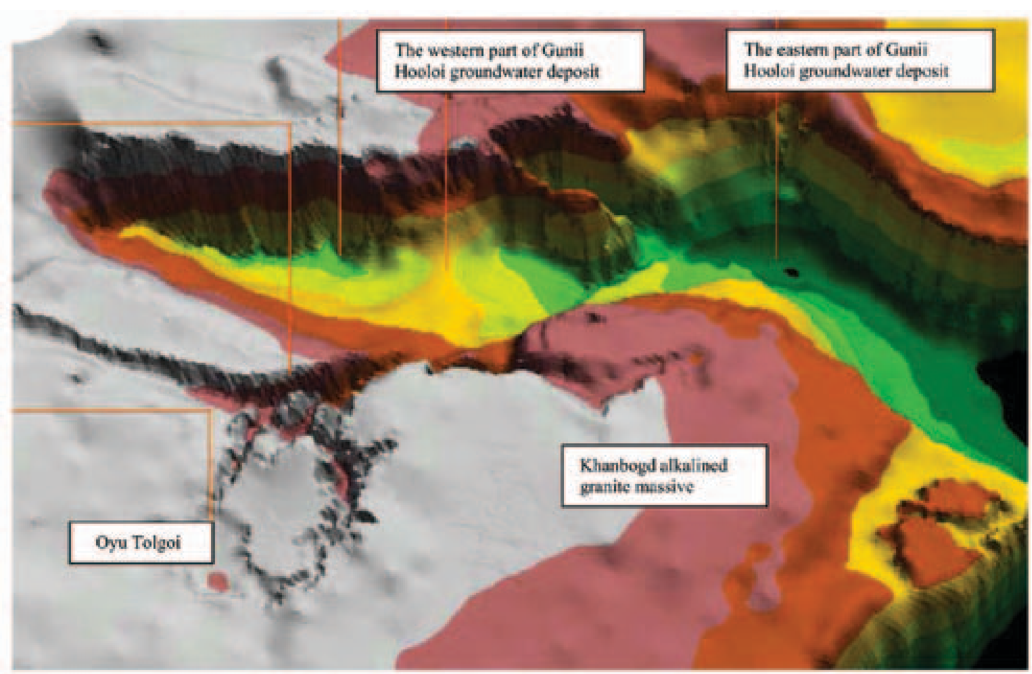
Aquifer Continuity

Aquifers in the SGR are not extensive, having the same geological structure and productivity over a large area. The more permeable and productive formations (aquifers) have generally a limited extension and are surrounded by rocks that have a very low permeability and are not considered as aquifers. Figure 10 illustrates this and that permeable rocks (aquifer) in the Gunii Hooloi area surrounded by less pervious basement rocks (Aquaterra, 2007).

Recharged aquifers and fossil aquifers

Recharge in the SGR comes from infiltration of rainwater that percolates in the upper shallow aquifers through which it is discharged to springs, feeds vegetation, wadis or temporary lakes, or is abstracted by shallow wells. A small portion percolates to the deeper aquifers, but its size is largely

Figure 10. The Gunii Holoi groundwater deposit (aquifer) and surrounding granite



unknown. The deep aquifers are the permeable rock sections from which groundwater can be abstracted (like the Gunii Holoi aquifer) and contain mainly fossil water. Pumping from these aquifers will cause lowering of the groundwater table in the layers above the aquifer (and its vicinity) and eventually a dewatering of the aquifer itself. The rate of abstraction from these aquifers is defined by the number of years of pumping and the acceptable lowering of the water table. This lowering may affect the wells in the upper aquifers and the environmental functions of the shallow groundwater (feeding vegetation, springs wetlands, etc.).

A groundwater resource assessment study is always needed to determine the aquifer characteristic and groundwater dynamics as basis for management decisions on the abstraction rate in relation to the water table lowering and number of years of pumping, and to define the environmental impacts of the abstraction. The study in the Gunii Holoi Basin is a good example of a technically sound approach to identify promising aquifers and to determine the impacts of groundwater abstraction as basis for detailed designs (Box 2).

Groundwater Recharge

The conceptual model in Figure 9 shows that a shallow aquifer is recharged by rainfall. Given the low annual rainfall (100–150 mm), the recharge is expected to be small but may still represent a substantial amount of renewable water given the large surface area of the SGR. Studies in the Gobi Desert in China under comparable climate conditions (Ma and others, 2007, and Gates, and others, 2008) show a recharge of 1–2 mm/year. A study in the Mandalgobi area (Kaihotsu, 2003) also concludes the presence of recharge, even at higher rates. A recharge of 1 mm/year is consistent with research in other arid and semi-arid desert

Box 2. The Gunii Holoi groundwater assessment study

The Gunii Holoi groundwater investigation and resource assessment study for the Oyu Tolgoi mine (Aquaterra, 2007) provides a good example for the approach in determining the impact of groundwater abstraction, and it provides the information for aiding decision making on the allowable abstraction.

The area of investigation (550 km^2) was identified through desk study and an initial exploration and test program. This study provided the basis for a feasibility study the covered the following:

- Surface geophysical surveying,
- Exploration well drilling to provide litho logical information,
- Drilling test production and observation wells for aquifer testing and long-term monitoring,
- Geophysical borehole logging to provide additional lithological data information,
- Pumping tests to determine aquifer characteristics,
- Down-the-hole flow logging to determine the main flow horizons,
- Groundwater sampling and analysis to determine the groundwater quality characteristics,
- A conceptual model and groundwater modeling to simulate abstraction scenarios.

The result of the model runs provided two abstraction scenarios:

- *Scenario 1*. Maximum acceptable drawdown till the top of the main aquifer for 40 years pumping, resulting in an abstraction of 1.325 l/sec;
- *Scenario 2*. Maximum acceptable drawdown corresponding with a 50 percent dewatering of the aquifer, resulting in an abstraction of 3.340 l/sec (40 years pumping).

Scenario 1 was selected for its consistency with Mongolian guidelines for fossil groundwater. The study also provided important information on the possible impacts of groundwater abstraction on the shallow groundwater (herder wells, vegetation, groundwater dependent ecosystems, and downstream users. It showed that this lowering hardly affects the shallow groundwater in herder wells in streambeds (recharged by infiltration of rainfall and run-off). Monitoring during operation of the well field is foreseen to verify this assumption based on field test and modeling results.

areas (e.g., Kalahari Desert) and with a composite figure of investigated recharge rates versus rainfall in different regions in the world (Figure 11).

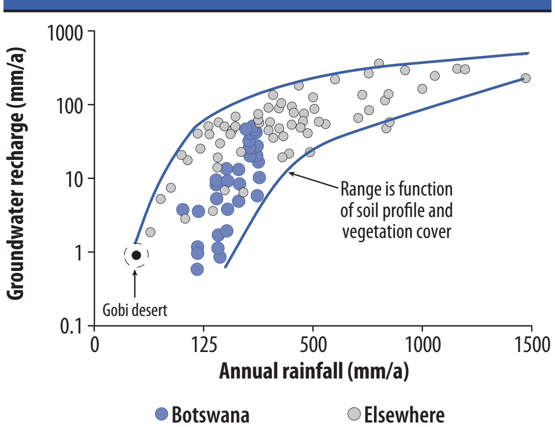
Impacts of Climate Change on Groundwater Recharge

Climate models for Asia from the International Panel on Climate Change (IPCC) (IPCC Fourth Assessment Report) indicate an annual temperature increase in Mongolia of 2.5–5°C occurring both in winter and summer months. Precipitation shows an increase in winter months with the annual precipitation decreasing slightly in the western desert to a slight increase across the steppe to the east (Angerer and others, 2008).

The water-related impacts of the climate change models include the prediction that the combination of precipitation decreases and temperature increases will likely reduce the run-off of rivers and cause a decline of lake water levels. With the absence of rivers, these impacts will occur largely outside the SGR.

In the SGR, the expected increase of evaporation of soil moisture (due to the temperature increase) is of more importance and may reduce the recharge to the groundwater in the upper aquifers. This may however be balanced by higher precipitation. Yet, the impacts of climate change may influence the recharge, and this should be included in further studies that will be needed to get a better understanding of the current recharge rates that are still largely unknown with estimates between 1–2 mm (see next chapter). A more effective use of the recharge from rainfall and run-off is an important issue as it concerns water that can be made more easily available than the deeper groundwater, which is often of lower quality.

Figure 11. Groundwater recharge versus annual rainfall



The shallow groundwater constitutes only a small portion of the total groundwater reserves in the Gobi Region. Most of the groundwater is in deeper aquifers and is mainly fossil. This water is not affected by current changes in climate variability since it was recharged under other climatic conditions and is now trapped in the deeper layers.

Investigations

There are earlier investigations of groundwater reserves and groundwater in Mongolia (see last chapter; Table 3) and in the Gobi Region. Jadambaa and Buyanhishig (2007a) refer to specific groundwater potential investigations in SGR:

- Jadambaa and Tserenjav (2003) estimated potential exploitable groundwater resources for pasture by Mongolian economic regions. This study estimated a potential of 82.5 m^3/second in the central region (including Selenge, Tuv, Darhan uul, Dundgovi, Dornogovi, Omnogovi aimags).
- A hydrogeological survey was done in Dornogovi and Omnogovi to determine potential exploitable groundwater sources. As a result, 16 separate, unconnected groundwater sources were identified in Dornogovi, and 25 separate, unconnected groundwater sources in Omnogovi, and the survey was also able to evaluate these exploitable groundwater resources.
- N. Jadambaa, Ch. Gombosuren, D.A. Jevagin explored Tsagaan Tsav groundwater source in 1967 and 1976. Ch. Gombosuren discovered the Zairmagtai groundwater source in 1978. G. Tserendondov investigated Nariin Zag groundwater source in 1987, Enkhtuya found

the water supply of Khanbogd soum in 1998, and G. Unudelger found the groundwater source in the center of Galbyn Gobi basin in 1994 (personal communication from Dr. Jadambaa, no references available)

Of particular importance are the many groundwater investigations carried out in the 1980s and 1990s by Mongolian and Russian experts. These were mainly groundwater investigations or water supply studies for population and industrial centers. About 200 groundwater sources were explored. The locations of the most important studies are given in Figure 12. Further details are given in Annex F.

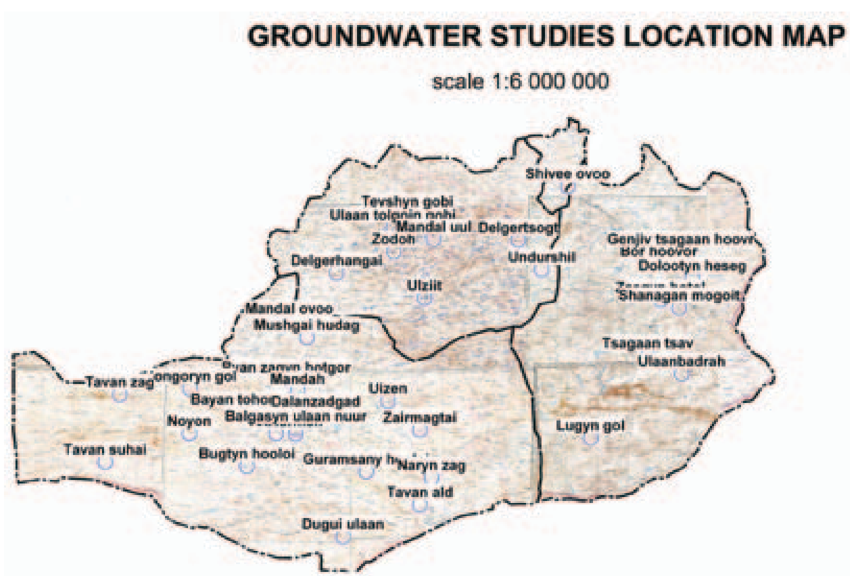
These investigations were for specific water supply purposes and included estimates of the groundwater reserve and groundwater potential using the Soviet-era-based Mongolian Regulation, *Instruction on classification of deposits by their exploitable reserved for technical and potable use*. The studies are classified into four steps ranging from prospecting exploration to detailed hydrogeological studies. Based on the results of these studies, there are four classes of groundwater potential:

- Class A – based on detailed hydrogeological studies,
- Class B – based on preliminary hydrogeological exploration studies,
- Class C1, C2 – estimates based on reconnaissance studies.

These groundwater potential estimates are in fact a planned depletion scenario (refer to Box 1) where the design drawdown of intensive exploitation is expressed as 40–60 percent depletion of the groundwater reserve in the aquifer over a fixed pumping period of 25–27 years. The studies covered local aquifers to a depth of 170–200 meters (due to limitations in the capacity of drilling rigs). Most of the reports are available from the Geological Information Center (GIC) and 40 of them were inspected during this assignment. The summary of the main data is given in Annex F.

Ivanhoe Mines Mongolia, Inc. has also conducted detailed geophysical and hydrogeological investigations in the Galbyn Gobi and Gunii Hooloi area for the water supply of the Oyu Tolgoi mine (Box 2). The groundwater reserves and groundwater potential were calculated on the basis of the groundwater model (Aquaterra, 2007) and

Figure 12. Location of main groundwater investigations in the SGR (Annex 6)



re-evaluated using the Class A, B, C1,2 approach (Turdendorj, 2008).

A recent groundwater investigation has been conducted in the Naimant area for the water supply of the Energy Resource Coal Mine development. The planned abstraction rate is 50 l/s.

Groundwater reserve and potential estimations

Groundwater reserve and potential are sometimes confusing terms. Groundwater *reserve* can be interpreted as the total amount of water stored in the SGR while *potential* refers to the amount of water that can be abstracted. Since most of the water is fossil, the abstraction potential is directly related to the accepted lowering of the groundwater table during a certain period of time.

Three different approaches are compared to make an estimate of the groundwater potential in the SGR:

1. Estimation of the total groundwater volume and the possible usable fraction;
2. Estimation made by Jadambaa and Buyanhishig (2007b);
3. Calculation based on results of investigation and recharge rates.

Total volume and usable fraction. The SGR underground (350,000 km^2) consists of a complex variety of different rocks. Below the groundwater table (50 meters below ground surface) all these rocks are saturated with groundwater. Assuming a porosity of 0.1, the volume of this water is 35,000 million m^3 per meter-thickness and even 3,500,000 million m^3 over a depth of 100 meters (from 50 to 150 meters below ground surface).

Lowering the water table over the entire area by 1 meter per year would produce 35 million m^3/year. This a theoretical approach because abstraction of groundwater is only possible from the rocks that have sufficient permeability (aquifers) causing a lowering of the groundwater table above the aquifer. The potential of such aquifers (abstraction rate) is directly related to the accepted lowering in a certain period of time. For the Gunii Holoi aquifer (550 km^2) this amount was calculated as 1,325 l/sec (42 million m^3/year) for a lowering of the water table of 100 meters over a 40 year-period.

The list of groundwater studies in Annex F shows that the aquifers in the SGR occupy at least 4,000 km^2. Assuming that 1–2 percent of the SGR area is underlain by aquifers (7,000 km^2), the figures of the Gunii Holoi study would indicate a total groundwater potential of 250–500 million m^3/year.

Estimates by Dr. Jadambaa. Dr N. Jadambaa (Jadambaa and Buyanhishig, 2007a) estimated the groundwater potential based on his experience in the SGR and presented them in a classification of the different aquifer productive types (Table 19). The total figure is about 500 million m^3/year or 1.36 million m^3/day. The assumptions and information on which this estimate is based could not be verified during this review, but in a personal communication, Dr. Jadambaa confirmed that this estimate is realistic according to his professional judgment.

Results of groundwater investigations and recharge rates. The figures in Table 20 have been verified with an approach to classify the aquifers based on depth and recharge and using the results of groundwater assessment studies and recharge estimations:

- *Shallow groundwater (<50m)* – mainly granular aquifers in river beds and depressions and recharged from infiltration by rainfall. These aquifers are the main source of water for rural purposes. A recharge of 1 mm/year represents 950,000 m^3/day storage over the total area (350,000 km^2). Assuming that 30 percent of this recharge is effective for use, it represents 300,000 m^3/day. It is still unclear how much of this water reaches the deeper aquifer and which part is abstracted by herder wells or discharged locally to springs, rivers, and local depression.

Table 19. Estimated groundwater potential by Jadambaa (2007)

Aquifer classification	Productivity (lit/ sec/ km²)	Estimated groundwater resources (Mm^3/year)		
		Dundgovi	Umnogobi	Dornogovi
High productive	>1	25	31	19
Moderate to locally high productive	0.1–1.0	77	138	71
Low to moderate productive	0.03–0.1	2	89	19
Low productive	0.003–0.03	3	3	4
Essentially y no groundwater	<0.003	0	0.0	0.0
Total		**107**	**261**	**113**

- *Deep groundwater (50–170 meter)* – These aquifers were studied in the last decades of the last century and a number of them are now exploited for urban and mining water supply, including the Tavan Tolgoi, Tsagaan Suvraga, and Shivee Ovoo mines. The maximum depth of 150–170 meters was mainly due to limitations in the capacity of drilling rigs. There is still a degree of uncertainty in the validity of these estimates, but the total amount can be considered the groundwater reserve. The groundwater potential is less, assuming a percentage (usable fraction) is actually available for exploitation.
- *Deeper groundwater (>200 meters)* – The Gunii Hooloi groundwater area for the Oyu Tolgoi mine is the first deeper aquifer (greater than 170 meter) to be investigated. The study concluded that 60,000 m^3/day can be pumped over a 40-year period, assuming that the groundwater table will be lowered no further than the top of the aquifer (meaning that the water will be mined from the layers overlying the aquifer from which the water is pumped). Future investigations may reveal the presence of other deeper aquifers in the SGR.

Table 20 gives the estimated groundwater potential assuming the following:

- Thirty percent of the recharge is reaching the groundwater and can be used.
- Fifty percent of the quantities (shown in Annex F) represent the groundwater potential in the aquifers less than 170–200 meters.
- The study in the Gunii Hooloi aquifer represents 100 percent of the groundwater potential reserves in the deeper aquifers below-200 meters (total 115,000 m^3/day).

Note: The estimates in Table 20 give a range of 200–500 million m^3/year. The lower figure can be considered a conservative estimate as it is based on results of studies and investigations and safe values of the usable fraction. It may be expected that further studies and investigations will reveal the presence of yet unknown deeper aquifers or that a better knowledge of the recharge will lead to an increase of the usable fraction of the shallow groundwater. Despite the uncertainties in the estimated groundwater reserves and potential, the likely presence of substantial amounts of groundwater in the SGR at different depths makes it worthwhile to take further steps in investigating the larger-scale exploitation of groundwater.

Groundwater Quality

Salinity is a main water quality concern in the SGR due to the high evaporation, low precipitation, and flat surface morphology. Salinity—or total dissolved solids (TDS) content—is a

Table 20. Estimated groundwater potential

Aquifer type	Parameter	Dimension	Dundgovi	Umnogobi	Dornogobi
Surface aquifer	Area	km	74,500	165,000	109,000
	Recharge	mm/year	1	1	1
	Usable fraction	%	30	30	30
	Potential	m^3/day	61,233	135,616	89,589
		Mm^3/year	22	50	33
Aquifer > 200 m	No. sites		10	25	16
	Est.reserve	m^3/day	17,000	120,000	220,000
		Mm^3/year	6	44	80
	Usable fraction	%	50	50	50
	Potential	m^3/day	8,500	60,000	110,000
Aquifer < 200 m	Gunii Hooloi	m^3/day		115,000	
		Mm^3/year		42	
Total		m^3/day	**69,733**	**310,616**	**199,589**
		Mm^3/year	**25**	**113**	**73**
		Liter/sec	**807**	**3,595**	**2,310**

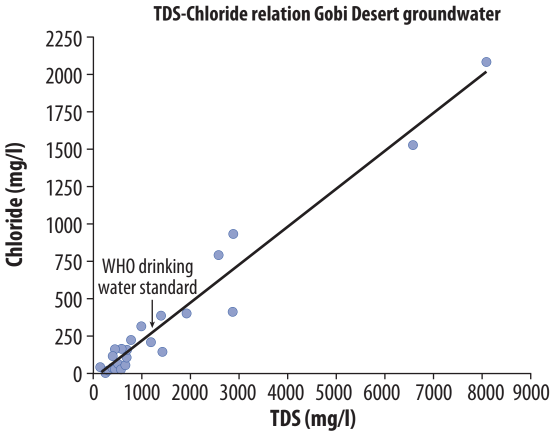
commonly used parameter to evaluate the potential use the water. Table 21 gives the main salinity classes that are generally distinguished.

Chloride is usually the main parameter that contributes to TDS. The relation between TDS and chloride depends also on the other anions in the water and can vary from place to place. From a number of available chemical groundwater analyses in the SGR, the TDS and chloride values are plotted in Figure 13. It shows that a chloride concentration of 250 mg/l (drinking water standard) represents TDS values of 1,200–1,400 mg/l (or parts per million), and that a chloride concentration of 1,000 mg/l represents TDS levels of around 4,000 mg/l and 1,500 mg/l chloride concentration represents TDS levels of 6,000 mg/l.

Table 21. Salinity classes of water

Salinity class	TDS range (in mg/l)	Chloride concentration (mg/l)
Fresh water	< 1,000	< 250–500
Brackish water	1,000–10,000	250–500 – 8,000/10,000
Saline water	10,000–100,000	10,000–40,000
Brine water	> 100,000	> 40,000

Figure 13. TDS-Chloride relation from chemical analyses of groundwater samples



JICA (2003) prepared a classification of 1,700 TDS values in the SGR (Table 22). It shows that around 50 percent of the wells are below a TDS value of 1,000–1,500 parts per million, and that 8 percent of the wells are above a TDS value of 6,000 mg/l (chloride, greater than 1,500 mg/l) and are unsuitable also for livestock water supply.

Water quality studies are also concerned about fluoride, arsenic, magnesium, and hardness. Arsenic and fluoride are toxic constituents and are dangerous to human health. Arsenic appears to be found in only a small number of wells (JICA, 2003) but that may be due to limited number of analyses on arsenic. High arsenic values are reported in the Inner Mongolia Region in northern China (IAH-NCC, 2007).

Fluoride poses a more widespread problem in large parts of Mongolia, including the SGR. High fluoride concentrations are found in many wells especially in the northeastern part of Omnogovi and also Dundgovi and Dornogovi. High concentration of hardness, magnesium, and evaporate residue are notably reported in Dornogovi (JICA, 2003) but also occur in the other aimags.

Both JICA (2003) and Jadambaa and Buyanhishig (2007a,b) present more detail on the spatial and vertical distribution of groundwater quality (mainly salinity) in the three SGR aimags. In general the groundwater quality in the shallow aquifers is better than in the deeper aquifers, which are more mineralized due to long residence time of the groundwater.

Table 22. TDS values in groundwater in de SGR (JICA, 2003)

TDS (mg/l)	< 1000	< 3000	<6000	<10000	< 15000	> 15000	Total
Dornogovi	272	166	28	6	2		474
Dundgovi	280	570	68	6			924
Omnogovi	186	102	12	3	2	1	306
Total	**738**	**838**	**108**	**15**	**4**	**1**	**1704**

4. Groundwater Development and Management

Groundwater Potential Versus Demands

The *groundwater potential* estimates give a range of 200–500 million m^3/year. This wide range results from uncertainty in available data and information. The figure of 200 million m^3/year (550,000 m^3/day) in Table 20 is a conservative estimate based on information from groundwater studies (Annex F, box 2) and a conservative estimate of the effective recharge (30 percent of 1 mm/year). The estimated current *water demand* is in the order of 80,000 m^3/day and will increase to 400,000–450,000 m^3/day in 2020.

These figures lead to the conclusion that the groundwater potential for the SGR as a whole is sufficient to cover the water demands in the next 10–12 years. Meeting water demands with groundwater resources requires a more detailed picture of the spatial (and vertical) distribution of the groundwater (quantity and quality), showing the distance between available water and points of use.

Water management is matching supply with demand, and it is hence equally important to make a more detailed assessment of the demand, both in terms of quality and quantity. This counts particularly for the mining development, which is the main water user. The water needed for mining is not only dependent on the extraction capacity, but also on the type of processing and level of treatment and re-use.

Regional Groundwater Assessment

To address these issues, an integrated hydrogeological assessment of the SGR will be needed using (and integrating) all existing information and should be complemented by additional surveys and investigations. This information should be matched with the spatial distribution of the water quantity and water quality demands and form the basis for a SGR groundwater development and management plan that will show the possible gaps between groundwater availability and water demands and how to overcome these.

Bringing available data and information and expertise together is a necessary first step in an integrated assessment of the groundwater occurrence and potential. The data and information available on the groundwater in the SGR is scattered among different agencies and institutions (GIC, Institute of Environment, MNET, private sector). A review of the available information and data, the storage of all data in a systematic (spatial) database, and the preparation of a spatial and lateral overview (maps) of the groundwater quantity and quality will form a basis to identify the main information gaps. This initial work should be followed by specific studies to provide information such as:

- Assessment of the effective recharge to the shallow aquifers, their flow, and the potential to increase their use through water conservation and groundwater storage systems (using experiences from India, Yemen, and East Africa).

- Detailed analysis of the studies conducted in 1970–1990. These studies contain a wealth of hard information (test drillings, geophysical surveys, aquifer tests, chemical analysis and local detailed hydrogeological maps.
- Assessment of the potential of deeper aquifers (greater than 200 meters) like the Gunii Holoi aquifer for the Oyu Tolgoi mine.
- Formulation of additional surveys and investigations to complement the overall understanding and potential of the groundwater system such as recharge studies using chloride tracers, a regional isotope study, or airborne geophysical surveys (time domain electro magnetics).
- Geographic Information System (GIS) and Remote Sensing based maps to visualize the groundwater characteristics and potential in a way that facilitates consultation with the other stakeholders.

This assessment study should go hand in hand with a more delayed mapping of the water demands also addressing in parallel the important issues related to the development and management of the groundwater:

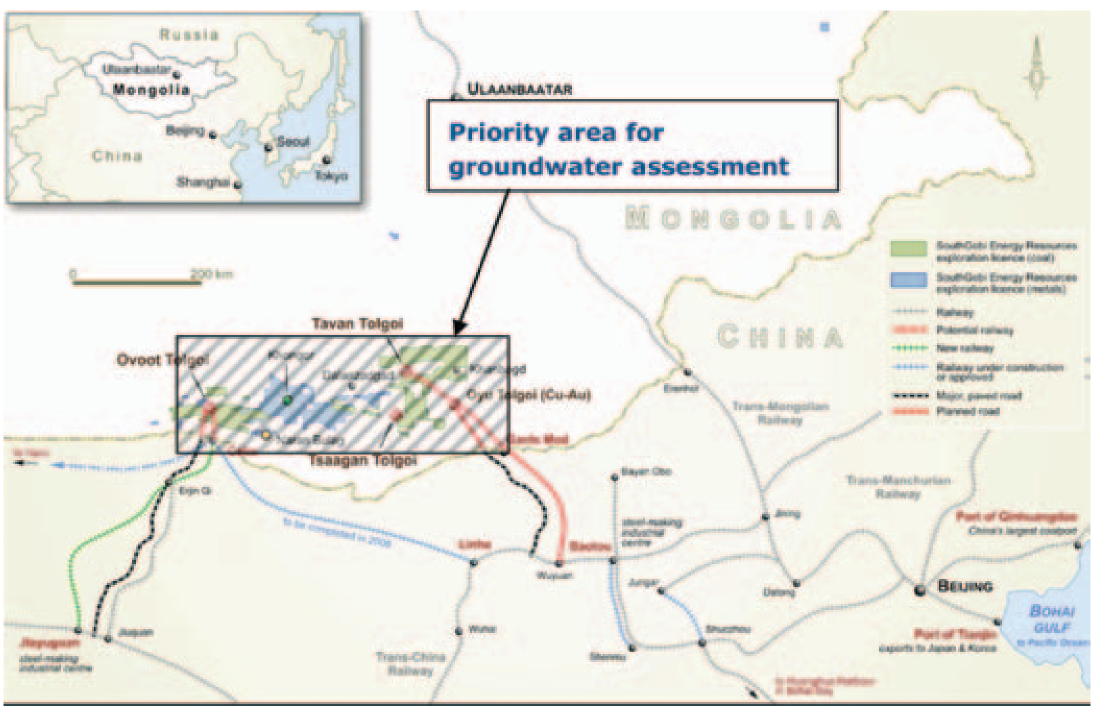
- Feasibility of alternative supplies, like surface water conveyances,
- Cost of groundwater development,
- Economic and environmental guidelines for the rate of lowering of fossil groundwater reserves,
- Institutional and regulatory requirements for groundwater development and management.

Given the concentration of mining developments the area around Dalanzadgad, it is recommended to focus the groundwater assessment initially on the greater Dalanzadgad area (Figure 14).

Institutional and Governance Challenges

The complex geology and often considerable depth of the aquifers hampers easy access to the

Figure 14. Priority area for groundwater assessment and planning



groundwater source. Groundwater development requires a good knowledge of the geology and the means to do the necessary investigations to confirm the presence of promising groundwater reserves. Before the 1990s many investigations were carried out by the Department of Geology and Mining, other government agencies, and universities, often by mixed teams of Russian and Mongolian scientists. This resource knowledge is still available through reports and through the Mongolian experts. However, the number of investigations has dropped in the last decades because of limitations in financial and personnel capacity. The most recent groundwater investigations in the Gobi Region for the mining industry have been financed by the private sector and carried out by joint teams of Mongolian and international consultants

The current routine is that assessment of groundwater in the Region is mainly a response to localized water demands (towns, soums, industries, tourism) or for local water points (livestock water supply). The groundwater sources, which are developed for these purposes, are generally from local aquifers that are not connected. The immediate challenge for the aimags and soums is to keep the wells and supply systems in running condition, to finance necessary repairs, and to attract funding for extension of the system (see report of field visit in Annex A). The water supply systems of some of the main towns receive support from the ADB-financed project on Basic Services in Provincial Towns. In the case of Dalanzadgad, the upgraded water supply (and sewerage) system is operated by a company in which the soum has a 51 percent share. If this model proves successful, it may also be introduced in other provincial towns.

The complexity and discontinuity of the groundwater system, as well as its scattered, mostly small-scale use in a vast area, and the lack of human resources on the national and aimag levels are some of the reasons why management and monitoring of the groundwater resource in the SGR are virtually absent. Without monitoring data and groundwater management structure, existing issues such as the insufficiencies in rural water supply provision and the operational problems in the town water supply systems, cannot be adequately addressed.

With the economic development and the associated increase in water demand in the SGR comes a growing awareness of environmental protection and emerging issues, such as climate change impact, groundwater pollution protection, and increased private sector involvement in conflicts of water supply provision and water allocation. And with this growing awareness comes the need for strong management and regulation of water resources in the SGR.

On the national level, the institutional and legal framework and tariff system for water resource management are in place but ineffective due to overlaps in mandates, inadequate policies, and lack of human and financial resources. The Strengthening Integrated Water Resources Management in Mongolia project (MNE, 2007) has made an inventory of the main constraints related to water management in Mongolia and has started a 4-year capacity-building project to strengthen the broader water resource sector in Mongolia (lead by the Water Authority) and will produce a National Integrated Water Resources Management Plan and Pilot River Basin plan for the Tuul River.

5. Long Distance Water Conveyance

There is no perennial surface water available in the SGR. Use of surface water from rivers and lakes would require long-distance conveyance of water from perennial rivers in the central part of the country. Two such projects are already proposed at a pre-feasibility level by the Mongolian National Water Programme Support Center (2007): the Herlen-Gobi Pipeline, and the Orhon-Gobi Pipeline.

The rationale behind the two projects is to secure long-term water availability in the SGR; in addition it focuses on securing available groundwater resources. This option assumes that the groundwater potential in the SGR has no further scope as a long-term source of water in view of the growing water demands under the expected economic development of the Region.

The Projects

The Herlen-Gobi Pipeline will convey 1,500 l/sec from the Herlen River through a 540 km-long pipeline to Shivee Ovoo, Sainshand, and Zamin-Udd with a side branch to Tsagaan Suvraga. The Orhon-Gobi Pipeline will pump 2,500 l/sec from the Orhon River through a 740 km-long pipeline to Tavan Tolgoi and Oyo Tolgoi with side branches to Mandalgobi and Dalanzadgad. The system includes a 20 MW hydropower plant (see layout in Figure 15)

The estimated water demand in the SGR in 2020 is 6,000 l/sec, of which 4,000 l/sec will be supplied by the Herlen-Gobi and Orhon-Gobi Pipelines and the remaining 2,000 l/sec by groundwater (Table 23). Table 23 shows that 50 percent of the water is for the mining and energy sectors and 30 percent for (irrigated) agriculture. Urban and rural water supply constitutes 7 percent of the demand. The environmental water demand (300 l/sec) is not further specified in the feasibility study. Part of this water will most likely be allocated to the Green Wall project, which is still in the pilot stage but there are doubts whether this is viable or desirable in the longer term.

Along the pipeline, there are many outlets proposed to provide water for rural and livestock water supply and for small-scale irrigation.

The larger portion of the water is for the major mining developments, and it is likely that the overall feasibility of the projects is largely dependent on the willingness of the mining companies to buy this water. Until now, the Oyu Tolgoi and Tavan Tolgoi mines focus fully on groundwater use.

The estimated total investment cost of the Herlen-Gobi Pipeline has been estimated at US$400 million (2005). Cost estimates of the Orhon-Gobi Pipeline are not available but will probably be higher because of the higher capacity and longer pipeline.

Figure 15. Layout of the Herlen-Gobi and Orhon-Gobi project

Feasibility Issues

Both pipeline projects are still at the pre-feasibility level. Only the project identification reports (Water Program Support Center, 2007) were available for this review. More detailed feasibility studies are in preparation, for which donor support is being sought. Further studies are needed to address the necessary issues for further decision making, including comparison with the groundwater option.

Both the groundwater and long-distance surface water conveyance options need further study and analysis to answer some critical question on the socio-economic, financial, and environmental feasibility. The main issues for the feasibility of the groundwater option are discussed in chapter 5.

For the long-distance water conveyance, the main issues include the sustainability of the source, the feasibility of using river water for agriculture far away from the river (where climate and soil conditions are less favorable), the land right/ownership, the cost and financial engineering of the project, and the commitment and role of both the mining companies as main clients, as well as other stakeholders in the project (government agencies, municipalities, agricultural companies).

The pre-feasibility reports do not specify how the mining companies will be involved in the conveyance projects or whether they are willing to make long-term financial commitments for the water delivery. For example, the Oyu Tolgoi mine is already investing in a groundwater supply system that will cover their water demands for the next 10 years and maybe beyond, depending on the rate of expansion of the mining operations and the updates of the groundwater potential once monitoring data are available from the first years of operation of the well field. Also, the Energy Resources Mine has almost completed the groundwater investigations in the Naimant area for the water supply of their coal mining operations in the Tavan Tolgoi area.

With these two groundwater supply systems in operation in the next few years, the cost, performance, and reliability of the groundwater supply option will be fairly well known to the of the main mining companies. Land and water rights for the Tavan Tolgoi well field and for the groundwater conveyance lines are still under discussion with the Water Authority and other government agencies

Table 23. Design water demands 2020 (l/sec)

No.	Water User	Estimated Demand liter/sec	Source: Surface	Source: Underground
		Energy and Mining Industry		
1	Shivee-Ovoo	616	467	149
2	Tsagaan Suvarga	604	300	304
3	Oyu Tolgoi	1060	360	700
4	Tavan Tolgoi	951	486	465
	Subtotal	**3231**	**1613**	**1618**
		Urban Water Supply		
5	Mandalgobi	50	50	0
6	Dalanzadgad	70	60	10
7	Choir	40	40	0
8	Sainshand	85	65	20
9	Zamiin-Udd	50	50	0
10	Soum Center and rural	104	52	52
	Subtotal	**399**	**317**	**82**
		Agriculture and Environment		
11	Livestock	200	100	100
12	Agriculture	1750	1750	0
13	Environment	300	100	200
	Subtotal	**2250**	**1950**	**300**
14	Other	120	120	0
	Total	**6000**	**4000**	**2000**

Source: Water Program Support Center (2007).

and will lay the foundation for the licensing system for future groundwater supply systems.

This experience will be the basis for mining companies—the main clients—to take a decision on their participation in a long-distance river water project. Further studies on the conveyance options should preferably be done in close consultation with the main mining companies. As the main (downstream) clients of the system, they will have an important say in the final feasibility of the conveyance options.

Irrigated agriculture, the other main client, will get its water from upstream distribution (near the intake) of the system and hence will have a much smaller impact on the feasibility of the long-distance conveyance.

6. Matching Demands with Available Resources

The key question is: *Is there sufficient water available to sustain the expected economic development in the South Gobi Region?* The analyses in this assessment conclude that the potential groundwater availability is sufficient to cover water demands for the near future. An additional question is: *Can groundwater also sustain the longer-term water needs?* This question depends on the outcome of a more in-depth regional groundwater assessment study and the speed of development of the water demands in the Region (both in space and time).

The SGR groundwater potential is only partly a renewable resource through recharge of rainwater in the upper aquifers. The main portion of the available groundwater is in the deeper aquifers—fossil groundwater—which is not recharged. Economic and environmental analyses of this resource and guidelines for its exploitation should be part of the regional groundwater study.

The only possible sustainable alternative source of supply is long-distance conveyance of water from rivers in the north (400–600 km away) such as the proposed Herlen-Gobi and Orhon-Gobi pipeline projects. It should be noted that long- distance conveyance of river water is in fact a conjunctive use option since it will not replace the current groundwater use. Further groundwater development is also needed to supply the areas outside the reach of the pipelines or as a backup for the surface water system.

In further analysis and decision making for the water supply to the SGR, the water demand projections are equally important. Current water demand projections, with their high degree of uncertainty, need more refinement. Since the water demand is dependent on economic and demographic development, it will be useful to develop water demand projections for different economic development scenarios.

Matching demands with available resources is a dynamic process in which the important decision for long-distance surface water conveyance can only be evaluated once the detailed groundwater assessment is completed and future water demands are known in more detail.

Long Distance Conveyance Versus Groundwater

Comparing groundwater development and long-distance surface water conveyance is not a straightforward exercise due to the following restrictions:

- Groundwater and surface water conveyance are typically different options in terms of design and operation, but also in terms of perception. Surface water is a centralized system with a concentrated flow of piped water (of a constant quality). The groundwater option is a decentralized approach with a large number of smaller supplies (well fields) providing water of different quality to nearby users. Groundwater is a diffused resource and would benefit the decision making process if groundwater was also presented as a *single* resource (like surface water).

- Groundwater is the sole source water for the SGR and will remain an important complementary source of water also in case of long-distance surface water conveyance.
- The decision making process has different dimensions and is not only based on technical, environmental, and financial considerations but also includes the political and social aspects.

Any comparison should be based on a good understanding of the options in terms of design, cost, operational efficiency, and other pertinent criteria. Given the above restrictions, a qualitative comparison of both options is presented in Table 24 showing the typical advantages and key issues of both options.

The need for further feasibility assessment of both options (chapters 5 and 6) is a prerequisite for decision making. However, the need for further groundwater development (and management) in the SGR is evident regardless of any future decision on the construction of a long-distance surface water conveyance system. In fact, a detailed groundwater assessment in the SGR may reveal which areas are difficult to supply with groundwater (quality or quantity wise) and as such provide an input for the feasibility of a conveyance system.

Cost of Groundwater Development and Long-distance Conveyance

Cost estimates of groundwater and surface water supply are difficult to make with the available data and information. An indication of surface water conveyance cost was obtained from the Water Center for the Herlen-Gobi Pipeline project. The cost for this project (1,500 l/sec) was estimated in 2005 at US$400 million and is assumed to be US$500 million at 2008 levels, with building materials and energy process having risen considerably in the past 5 years. The operation and maintenance cost are estimated at US$230 million per year (5 percent of the investment cost).

An attempt is made to compare these cost estimates with the investment in groundwater. Table 25 details a scenario under which there is a groundwater supply of 1,500 l/sec, supplying

Table 24. Comparison of groundwater and surface supply systems

Option	Selling points	Issues
Groundwater supply	• Estimated potential sufficient for the next 10–15 years + additional potential in deeper aquifers (not studied yet) • Available near the point of use • Lower investment cost • Phased implementation) • Security of supply (decentralized) • No transboundary issues	• Potential not fully known: continued investigations/mapping needed • Data and information scattered • Need for management, regulation and monitoring • Water quality often poor for domestic purposes: treatment needed • Mainly fossil water: mining • Energy supply may be costly at certain locations
Surface water conveyance	• One source (dam, reservoir) and intake • Secured quantity • Controlled supply along the pipeline • Constant water quality	• Resource sustainability (climate change, impacts, sedimentation) • High initial investment (no phased implementation) • Security of supply (back up storage) • User's commitment required (specially mining sector) • Transboundary issues • Feasibility of irrigation component (socially, economic)

Table 25. Cost estimate of groundwater supply

		Type of supply				
System items	**Parameter**	**Rural water**	**Town water**	**Irrigation**	**Mine**	**Total**
Demand						
Consumption	l/c/day	100	200			
	l/sec/ha			0.7		
Population		5,000	25,000			
Irrigated area	ha			70		
Demand per system	m^3/day	500	5000	4,234	36,720	
	l/sec	6	58	49	425	
No of systems		*8*	*2*	*10*	*2*	
Total demand	*l/sec*	*46*	*116*	*490*	*850*	***1,502***
Production wells						
Well capacity	l/sec	5	10	15	35	
Pumping hours	hrs/day	12	12	12	12	
No wells/system		2	10	7	25	
Daily production	m^3/day	432	4320	4536	37800	
Conveyance						
Distance	km	10	25	10	75	
Pipe diameter	inch	4	12	12	30	
Storage/Treatment						
Storage	hrs supply	4	6	2	6	
	m^3	83	1250	353	9180	
Treatment	Chlorination	Convential	Chlorination	Reversed		
Unit prices						
Well	US$	*200,000*	250,000	250,000	300,000	
Pipeline (+ laying)	US$/m	*200*	250	250	600	
Storage	US$/m^3	*1,000*	*1,000*	*1,000*	*1,000*	
Treatment	US$/unit	*50,000*	3,000,000	500,000	1,000,000	
Land acquisition						
Power supply	US$/unit	*200,000*	300,000	400,000	1,000,000	
Installation cost	Million US$	22	27	55	127	**231**
	% of investment	10	10	10	20	
Investigation cost	Million US$	2	3	6	25	
Total Cost	Million US$	24	29	61	153	**267**
Cost per l/sec	US$	519,552	252,806	123,532	179,802	
Cost per m^3/day	US$	6,013	2,926	1,430	2,081	

8 rural centers, 2 towns, 10 irrigation projects, and 2 mines. Unit costs are derived from Mongolia (2008 prices), supplemented with international unit costs and information from Ivanhoe Mining Mongolia, Inc., about the cost for investigations and development of the groundwater in the Gunii Holoi aquifer.

The investment costs include groundwater assessment investigations and the treatment to provide potable supply. The total investment costs are around US$250 million, which is about 50 percent of the cost for surface water.

Costs for groundwater assessment in the Gunii Holoi were about US$15–20 million and included the drilling of test production wells, which will be included in the final production well field. Groundwater feasibility studies are relatively expenses (10–15 percent of the investment cost) but are needed to develop the understanding of the aquifer system and the design of the well field, and to determine the long-term capacity.

The investment cost per cubic-meter installed capacity varies from US$1,400 to US$6,000. For the mine water supply, the investment cost per cubic-meter installed capacity is US$2,000. For only the production wells and pipelines, the cost is US$1,400, which is slightly higher than the actual cost provided by Ivanhoe Mining (US$1,250 per m^3) for the groundwater supply from the Gunii Holoi well field to the Oyu Tolgoi mine (a distance of 75 km). The operation and maintenance cost of (decentralized) groundwater supply will be somewhat higher than a piped surface water scheme.

Possible Scenarios

The present and future water demands are the main driver for water resource development and management. Given the uncertainties in demand projections and groundwater or surface supply options, the best way forward is to develop scenarios for different assumptions and update them on a regular basis.

Water demands

A more comprehensive overview and analysis of current and future water demands is needed as a basis for realistic water resources development scenarios and for decision making on investment planning. To answer the driving question—*is sufficient (ground) water available in the vicinity of the points of use?*—it important to distinguish among the various user groups:

- *Rural and livestock water supply.* This represents relatively small quantities that are spread over the entire SGR with quality standards for human and for livestock consumption.
- *Soums and aimag capitals*. Also relatively small quantities, but needed at specific locations and of potable quality.
- *Mining and industrial.* Large quantities of water within a radius of maximum 50–100 km at specific locations. A large proportion of this water has flexible water quality requirements (depending on use), but a small portion should reach drinking water standards.
- *Irrigated agriculture*. Large quantities of water at specific locations and with somewhat flexible water quality requirements.
- *Environmental water use*. Unknown quantities and quality, spread over the SGR but at specific locations.

Current and future water demand should be determined for specific uses and formulated both in terms of quantity, quality, and location while taking into account the following issues:

- *Regional economic development*. Development of the mining sector is crucial since it does not only determine mining water demand (in time) but also the water demand of related developments.
- *Water uses and required quality*. Large portion of future water demands (cooling water, dust suppression, washing water) has lower-quality requirements than, for example, drinking water.
- *Demand management.* To what extent can re-use and re-cycling further reduce the industrial and domestic water demands. *Is infiltration of treated wastewater an option?*

- *Agriculture. What are realistic scenarios for irrigated horticulture and agriculture and what are the related water quantity and quality demands?*

For the demand projections, it is recommended to develop different scenarios (slow, moderate, and fast development) for different planning time horizons (2020, 2030, and 2040). These scenarios should also take into the account the expected increases in water demand due to impacts of climate change. More frequent and prolonged droughts will increase the dependency of livestock, wildlife, and food production on point source water supply from wells (Angerer, 2008).

Groundwater

For the near future (2010–2020), groundwater will remain the only source of water in the SGR. Based on the groundwater potential estimates, it seems likely that groundwater can sustain the water demands during this period. But in order to set the background for the overall limits on regional development, a regional study of water resources should be conducted. This study should better understand the spatial and vertical distribution of the groundwater resources, its quality, and the environmentally sustainable limits on water extraction.

Based on a regional groundwater assessment study with a focus on the greater Dalanzadgad area (see last chapter), scenarios should be developed for area-wise availability of groundwater, its quality, and abstraction scenarios. These estimates should be given for 10, 20, and 30 years and be presented in confirmed quantities and estimated quantities that must be verified through detailed site investigation and monitoring. This will be a dynamic process to add to the overall understanding of the groundwater system provided that all new information is properly stored and integrated.

Surface water

The two proposed surface water conveyance projects should have further feasibility and economic analysis. Issues to be addressed are the economic feasibility of large-scale irrigation, social and economic feasibility of the rural water supply delivery points along the pipeline, environmental impacts in and around the source river, transboundary issues, and agreements with the main mining companies on the quantities and price of the delivered water. Here the quality of the water may be of more importance since most of the mine water is used for washing dust suppression, cooling water, and has low-quality requirements.

Institutional, Regulatory, and Capacity-building Aspects

Groundwater management structure in the SGR

An assessment of the groundwater in the SGR (with a focus on the greater Dalanzadgad area) is the first step toward a better utilization of the groundwater resources. Investing in correlating existing knowledge, defining important information gaps, and implementing targeted studies and investigations could support decision making on the future water infrastructure in the Region.

The sustainability of these investments will not only depend on results of the technical and hydrological work but also on the institutional embedding. All relevant agencies in groundwater assessment should work together and share their expertise and information. One entity should have the mandate and confidence of all main stakeholders as the decision making focal point for (ground) water information.

Potentially, a SGR Groundwater Management and Information Center (SGR-GMIC) could operate under the Water Authority but must be shared with the different ministries and other institutions in the country where groundwater knowledge and information is available. This SGR-GMIC could act as the focal point for groundwater management, monitoring, and regulation and could coordinate studies and investigations that will be needed to update and refine the groundwater potential and to develop guidelines for its sustainable allocation and use. This focal point would also ensure that groundwater is presented as a single resource and as such facilitate the process of decision making on future water supply investments.

Linking the regional and the national level

Groundwater management in the SGR should be part of the nationwide management and regulatory framework while addressing the specific features and management challenges of the Region.

The establishment of the new SGR-GMIC should be established in close consultation with all stakeholders on the national and regional levels. At the national level, the National Water Committee and the Water Authority of the MNE), other MNE agencies, Ministry of Food and Agriculture, and Ministry of Trade and Industry (Geology Division) are key players and should be involved from the onset. The Water Authority could provide useful support in establishing the SGR-GMIC in correlation with the objectives of the Strengthening Integrated Water Resources Management in Mongolia project.

The linkage with the national level and the Integrated Water Resources Management project is also important to assess if the existing legislation is covering the regulatory requirements that are needed to implement the groundwater management and protection strategies and plans. Legal amendments, new by-laws, and regulatory provisions are a national responsibility with the MNE as focal ministry.

Capacity building in groundwater resource assessment and management

In the inception phase of the Strengthening of Integrated Water Resources Management in Mongolia project (MNE, 2007), an important conclusion was that developing integrated water resources management should go hand in hand with capacity building and human resource development. The project has included universities and knowledge institutes as partners in the project design to increase the core expertise in water resources in the country.

The proposed establishment of the SGR-GMIC faces similar challenges. Groundwater assessment and management expertise must be strengthened by recruiting of national staff who are sufficiently skilled to implement the tasks of the SGR-GMIC. One of the constraints to training staff has been the lack of teaching materials in English & Mongolian and of teachers who are up to date on the existing knowledge, literature, & concepts. The Integrated Water Resources Management project should include a capacity building and training component in the implementation of the SGR groundwater assessment and in the establishment of the new SGR-GMIC.

Short-term Priorities (Phase 1)

Scenario development for matching water availability and water demand should begin addressing the short-term (2010–2020) water management priorities and include the following activities in phase 1:

- Establish the SGR-GMIC and collect all existing information on groundwater water resources mapping;
- Review the available information and data, store all data in a systematic (spatial) database, prepare a spatial and lateral overview of the groundwater quantity and quality (maps), and identify the main information gaps;
- Formulate the capacity building and training needs of the SGR-GMIC;
- Define short-term water demands (in terms of quality and quantity) and its spatial distribution based on confirmed economic development plans and mining development;
- Prepare a detailed groundwater assessment study in the Greater Dalanzadgad area that includes:
    - detailed study of the recharge form rainfall to the streambed aquifers and the potential to increase its use through water conservation and groundwater storage systems

  (using experiences from India, Yemen, and East Africa);
  - detailed analysis of the groundwater studies conducted in the last decades, including the recent studies for the mining industry;
  - formulation and implementation of additional surveys and investigations to complement the overall understanding and potential of the groundwater system such as recharge studies using chloride tracers, a regional isotope study, or air-borne geophysical surveys (time domain electro magnetics);
  - identification of suitable aquifers which have a promising potential and are relevant for further investigations;
  - coordination of detailed groundwater investigations in these aquifers in collaboration with (and co-financed by) the potential users in the mining sector;
- Prepare a plan for water supply provision to herders, rural settlements, and livestock, which are expected to be covered from the streambed and shallow groundwater and locally from deeper production wells. The large number of wells, which are presently abandoned, indicates that the main problem is not in the availability of groundwater but in institutional issues (ownership, operation and maintenance) and the first priority is to develop an institutional environment for sustainable use of herder wells.
- Prepare a groundwater management and monitoring plan for the Greater Dalanzadgad area, including guidelines for the abstraction of fossil groundwater based on an analysis of the environmental impacts of groundwater table lowering on the shallow groundwater.

Based on this information, an overall water resources development and management plan for the greater Dalanzadgad area can be set-up in consultation with the main stakeholders. The plan will have with a special focus on water provision for the coal mines and related developments and include cooperation between the concession holders in the management. This plan should also include the necessary legal, regulatory, and institutional aspects to effectively address demand management issues.

Priorities (Phase 2)

Upon completion of phase 1, the results can be evaluated and reviewed for up-scaling to the whole SGR (phase 2) and to contribute to the decision making process for investments in the conveyance of river water to the SGR.

This work will take 2–3 years, provided that the institutional setting and structure is in place and sufficient human and financial resources are available. A preliminary costing of this work is approximately US$2.5 million. This amount does not include detailed groundwater assessment studies for specific aquifers (like the Gunii Holoi aquifer). Terms of reference for these studies could be prepared, but actual implementation should be co-financed by the beneficiaries (for example, the coal mine concession holder who could potentially share the water from an identified aquifer).

The investment might be considered high but it is a good investment in view of the importance of water resources for the SGR economic development.

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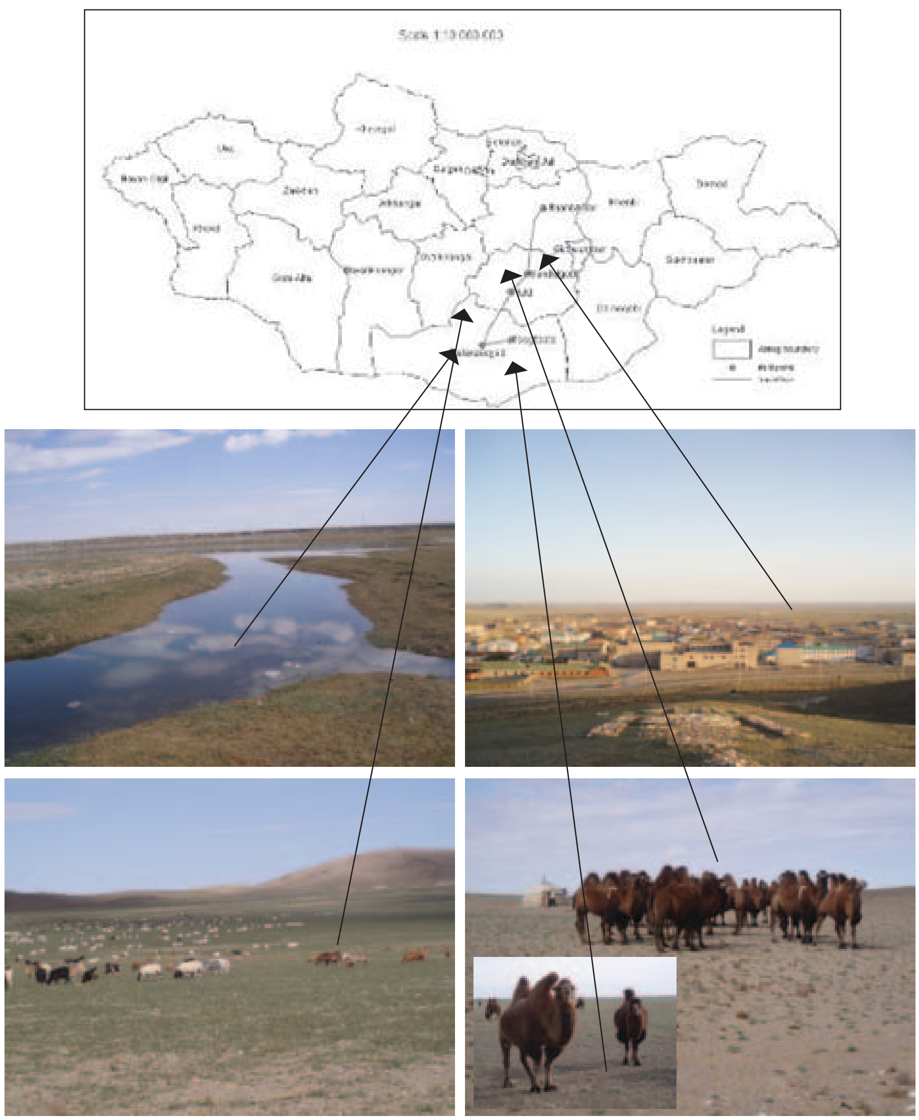
Annex A. Report of the Field Visit to Southern Mongolia

21–24 September, 2008

Participants: Albert Tuinhof, Enkhtsetseg Ayur, Buyankhising Nemer



Mandalgovi (Capital of Dundgovi aimag)

Mandalgovi

Meeting with the head of the administration department, Mr. Tseveenravdan, and his assistant, Mr. Jivaa and with the water supply operator,Mr. Gantulga.

Total population of Dundgovi 49,000, of which 13,000 are in Mandalgovi (plus Saintsagaan soum) and the remaining 36,000 in the other 14 soums.

Drinking water source is 30 kilometers north of Mandalgovi in a place called Olgoin Govi. Piped water supply system is through 3 operational wells at the well field (30 kilometers from the town) with a total production capacity of 90 m^3/hr (50, 20, 20, respectively) and 3 production wells in the town area with total capacity of 50 m^3/hr (20, 20, 10, respectively). Total installed capacity of 140 m^3/hr.

Total production is 1,000 m^3/day in winter and 750 m^3/day in summer. The water is pumped to a reservoir 3 kilometers outside the town and distributed under gravity. There is a chlorination unit at the reservoir that is not used because of complaints from the consumers about the taste and smell of the water. Salinity of the water is acceptable but hardness seems to be high.

A softening filter was installed some years ago (with Czech Republic support) but has been out of order for a long time. The water supply system is being upgraded under the ADB-financed Basic Urban Services in Provincial Towns Project.

In the town area, additional water is provided through a number of production wells from which the water is sold (kiosks):

- 8 kiosks operated by the water company. These kiosks have a small softening unit (USAID supported), but it appeared that most of these are not in use. Raw water sold for MNT 1 per liter and treated water for MNT5 per liter (cost price 9 MNT per liter). One kiosk was visited (**photos 1 and 2**, EC: 730 µS/cm, water sample taken). Water distribution is around 5 m^3/day.
- 3 kiosks (operated by the water company) are used for water distribution by tank car.
- 2 kiosks are privately operated one of which with a hand-pump. The other kiosk is said to have the best water quality (**photos 3 and 4**, EC: 835 µS/cm, water sold for 1MTN per lit).

Observations:

- The installed capacity is enough for the water demands
- Water quality is not optimal
- Treatment (chlorination, softening filters) are installed but not functioning
- The private water kiosk is said to have the best water quality and seems to have a high consumer demand. Yet the EC of this water is higher than that of the piped water

Soum Huldt (Dundgovi)

Conversation with Mr. Todgtbaatar (Soum Governor)

Soum center was founded in 1965 because of the availability of shallow groundwater at this location. Current population of the Soum is 2,500. Whole soum has 160 wells, of which 20 are deep wells. Number of operational wells is 60, of which 10 are deep wells.

The Soum center is served by 3 wells with hand-pumps, which were installed under the WASH 21 project. One of these wells was deepened and equipped with an electric pump. Another deep well was drilled with support of World Vision in 2007, but is currently out of order.

We visited one hand-pump well (30 meter deep, EC 1440, **photo 5**) and one water kiosk, which is located 500 meter from the Soum center and provides good quality water (EC: 840; sample taken). The water is pumped into a 1-cubic meter reservoir (**photos 6 and 7**) in order to reduce the switching on/off of the pump. The well is in high demand because of the good quality water. During the visit, we spoke to a herder who came from 40 kilometers away (by car) to load water in jerry cans and small tanks (**photo 6**)

Agriculture is not practiced, because of the poor soil and lack of water. One herder was farming on a small scale: Along the way from Holyt to Dalanzadgad, we visited a herder who was growing vegetables and trees (**photos 8 and 9**). He started with this a few years ago after a visit to the United States. The garden is not in full operation yet, and the vegetables are still for his use only.

Dalanzadgad

Meeting with the Soum Governor, Mr.Ulambayar

Dalanzadag, population 17,000, is the aimag capital but located in soum: Dalanzadgad. The Soum Governor, Mr.Ulambayar, briefed us on the general features of the Soum and on the water and sewerage facilities. He also addressed the importance of tree planting and the pilot projects that are undertaken.

The water supply and sewerage system were recently upgraded under the ADB-financed Basic Urban Services in Provincial Towns project. The soum has a 51 percent share in the company, Gunii Us, that operates the water supply (and sewerage) system. There are 4,400 households, of which 900 (department and private houses) are served by house connections and the rest by 30 kiosks.

Water is from 3 production wells (on average 70 meters deep, 3 kilometers outside the Soum) that produce good quality water (sample taken, EC 416; **photos 11 and 13**). The water is pumped to a 4,000 m^3 reservoir (2 days storage, **photo 12**) from which it is distributed under gravity to 900 houses and 30 kiosks. Production wells, reservoir, and kiosks are all in good order (**photo 12**).

Water tariff is MTN 1 per liter at the kiosk. Resident water tariffs are not precisely known, but the Soum Governor told us that he pays a flat rate of MTN 3,800 per month for the water supply to his apartment (2 persons).

Part of the drinking water supply is provided by private dug wells (**photo 15**)

There is 1 kilometer of sewerage line, which pumps the domestic wastewater (of the 900 households with a house connection.) to a wastewater treatment facility (under construction, **photo 16**), which are most likely oxidation ponds. The effluent will be used by a private company to grow fodder crops for the market.

Soum Tsogtsetsi (Aimag Omnogovi)

Meeting with the Soum Governor Mr Tsogtbayar.

Soum Tsogtsetsi (**photo 22**) has a population of 2,175, of which 750 are in the Soum center, excluding 1,200 seasonal mine workers (April-November). About 70 percent of the Soum area is situated in the mining-licensed area.

There are 150 herder wells in the Soum area (both hand-pump wells and motorized wells). A subsidy of MTN 80,000 is provided for 4–6 new wells per year.

Soum center has 3 wells, one of which is out of order. All wells are kiosks. Water price is MTN1 per liter for domestic use and MTN 2 per liter for commercial use. We visited one well (EC 1040, sample taken, **Photo 21**).

The Soum has a climate station (**photo 23**).

Energy Resources Groundwater investigations

Meeting with Mr. Baasandorj and Mrs Baigalmaa (Energy Resources), Paul Evans (Aquaterra) and David McPherson (AZTEC).

Energy Resources is carrying out groundwater investigations in Naimant area for the AT coal mine water supply. The study is carried out by Aquaterra, drilling work done by AIDD, and well testing by Aztek (Thailand). We visited the ger camp (**Photo18** where Aquaterra gave a presentation on the investigations), a drilling site (**photos 16 and 17**), and a site where test pumping was carried out (**photos 19 and 20**). The draft final report with the estimated groundwater potential will be ready in November 2008. The planned abstraction is 50 liters per second, of which a small portion will be needed for drinking water supply (AT personal and for the Soum Tsogtsetsi). EC of the water at the well testing site is 2,000 µS/cm. For drinking purpose, the water will need treatment (desalination). Energy Resources is interested to install a small desalination plant with solar energy.

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Mandalgobi


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Soum Huldt (Dundgovi)


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Dalanzadgad


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Groundwater Investigation for the AT mine


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Tsgotsetsi

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Annex B. Water Balance Parameters

Parameter	Unit	Dimension
Average annual precipitation		
Khangai, Khentii, Khuvsugul mountain ranges	300–350	mm
Mongol Altai and forest area	250–300	mm
Gobi Desert area	50–150	mm
Total surface water resources	500–599	km^3
Of which is fresh water resources; of which is in	410–509	km^3
Lake Khuvsugul	380	km^3
Other lakes	120	km^3
Rivers	28.5–40.1	km^3
Glaciers, glacier rivers	62.9	km^3
Total groundwater resources	5.6–12.9	km^3
Of which is available for utilization countrywide	0.6–10.8	km^3
Of which available for utilization in Ulaanbaatar (excluding private industries and ger-districts)	0.097	km^3
Of which exploited for: centralized system in UB	0.095	km3
Private industries in UB	0.019	km3
ger-districts in UB	0.009	km3
Transboundary river inflow	1.6	km^3
Annual water demand (2005/2006)		
Domestic and drinking water	0.071	km^3
Livestock	0.080	km^3
Crop irrigation	0.052	km^3

(*continued on next page*)

(*continued*)

Parameter	Unit	Dimension
Industrial, except mining	0.036	km^3
Mining	0.094	km^3
Hydropower	0.080	km^3
Energy production/power plants	0.028	km^3
Tourism	0.002	km^3
Green area	0.000	km^3
Water for nature	unknown	km^3
Total territory of Mongolia divided as follows:	1,564,110	km^2
Arctic basin (19.5% of total territory)	305,002	km^2
Pacific basin (11.5% of total territory	179,873	km^2
Central Asian internal basin (69% of total territory)	1,079,236	km^2
Area of water bodies (0.6% of total territory)	9,384	km^2
Of which are glaciers	659–703	km^2
Rivers and lakes	8,682–8,726	km^2
Number of water bodies (2003)		
Rivers	5,565	
Of which have dried up in past few years	683	
Springs	9,600	
Of which have dried up in past few years	1,484	
Lakes	4,184	
Of which have dried up in past few years	760	
Glaciers	240–262	

Note: Water balance parameters derived from earlier studies.
Source: "Overall Inventory and Assessment of the Water Sector in Mongolia", Summary report prepared for the Strengthening Integrated Water Resources Management in Mongolia Project (June, 2007).

Annex C. Government Agencies Involved in Water Management and Regulation

Government organizations	Responsibility
National Water Committee	Coordinating all ministries` policies on water issue to implement the "national water program"
1. Ministry of Nature and Environment	
1.1. Department of Environment and Natural Resources	Policy coordination on water resources management and protection in Mongolia and give direction to Water Authority
1.2. Water Authority	Make policy on water resources management and protection in Mongolia and implement that policy
1.2.1 Water Resources Assessment And River Basin Management Division	Give an assessment on the groundwater resources and estimate groundwater availability
1.2.2. Water Cadastre And Engineering Construction Division	Cadastre / survey and make a professional assessment on the designing and planning of the hydro construction
1.2.3. Water Economic Center	Study appropriate use of water resources and restoration, and set up ecological-economic assessment, estimate actual water demand of the water users, estimate groundwater resources, and inspect law implementation
1.3. Water Institute	Groundwater and surface water resources exploratory research, design, set up the equipment for drinking water softening in the country, and carry out activities to improve drinking water quality
1.3. Central Environmental Laboratory	Do chemical study on the water quality in Mongolia
1.4. Institute of Meteorology and Hydrology	Provide hydrological and metrological information and flooding disaster warning
1.4.1 Institute of Hydrology and Meteorology	Scientific research on hydrology and climate change
1.4.2. Section of Hydrology	Surface water monitoring (quality and quantity) and research
1.4.3. Section of Meteorology	Meteorological monitoring and research

(*continued on next page*)

(*continued*)

Government organizations	Responsibility
1.4.4. Forecast Research Laboratory	Forecast research on climate change and study on climate change impact on water and land resources
1.5. Environmental Protected Agencies in the 21 provinces & Ulaanbaatar	Policy coordination on water resources management and protection in a province, and inspect and monitor the implementation of the policy
2. Ministry of Food and Agriculture	
2.1. Division of Policy Coordination and Strategy	Policy coordination on agricultural water supply in the country
2.2. Pasture and Crop Irrigation Division	Herder, livestock, and irrigated crop area water supply (establishing and maintaining wells in the countryside, etc.)
2.3. Agricultural agencies in the 21 provinces	Policy coordination on agricultural water supply in provinces and inspect and monitor the implementation of the policy
3. Ministry of Trade and Industry	
3.1. Division of Geology Mining Heavy Industry Affairs	Policy coordination on hydrogeology research and mining and manufactories industries' water supply
3.2. Mineral and Nature Oil Authority	Implementing the policy on hydrogeology research and mining and manufactories industries' water supply
3.3. Geological Division	Hydrogeology research
4. Ministry of Construction and Urbanization	
4.1. Policy coordination of public enterprises construction and urbanization	Policy coordination on drinking and domestic water supply in Mongolia and flood protection management
4.2. National center of construction, urbanization, and public enterprises	Hydro construction, mapping, drinking water supply of urban area, waste water treatment plant and flood protection
5. Ministry of Health	
5.1. Health Policy and Planning Division	Policy coordination of public health issues
5.2. Institute of Public Health	Drinking water health and sanitation
6. Ministry of Fuel and Energy	
6.1. Fuel and Energy Strategy and Policy Planning Division	Policy coordination on energy source, renewable energy
6.1.1. Renewable energy	Policy coordination on energy source, renewable energy
6.2. Energy Research and Development Center	Exploratory research of larger hydro power stations, planning, and designing
6.3. National Center for Renewable Energy	Scientific research on hydro power energy and sources
7. Ministry of Culture and Education	
7.1. Professional Education Office	Policy coordination on the preparation of professionals in the water sector

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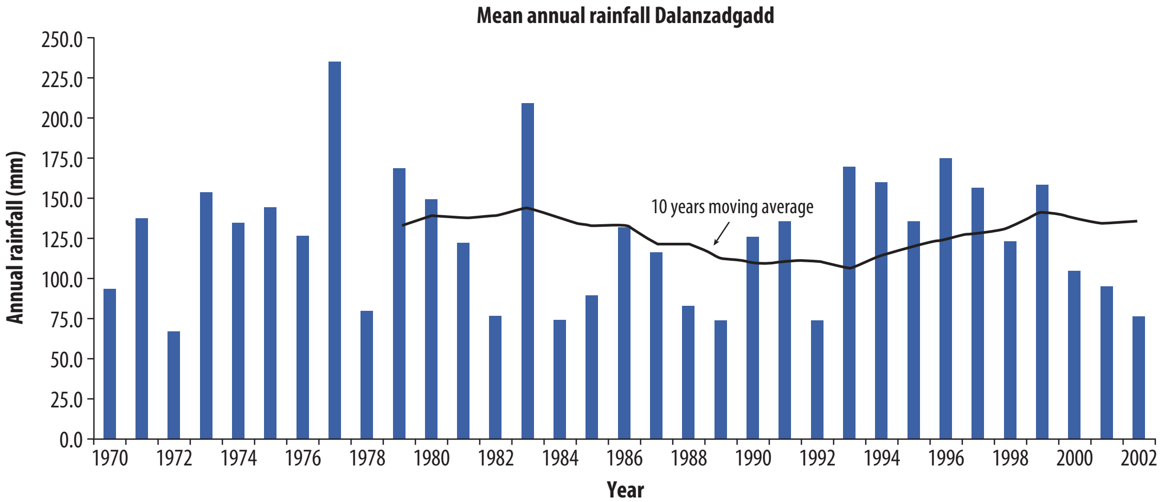
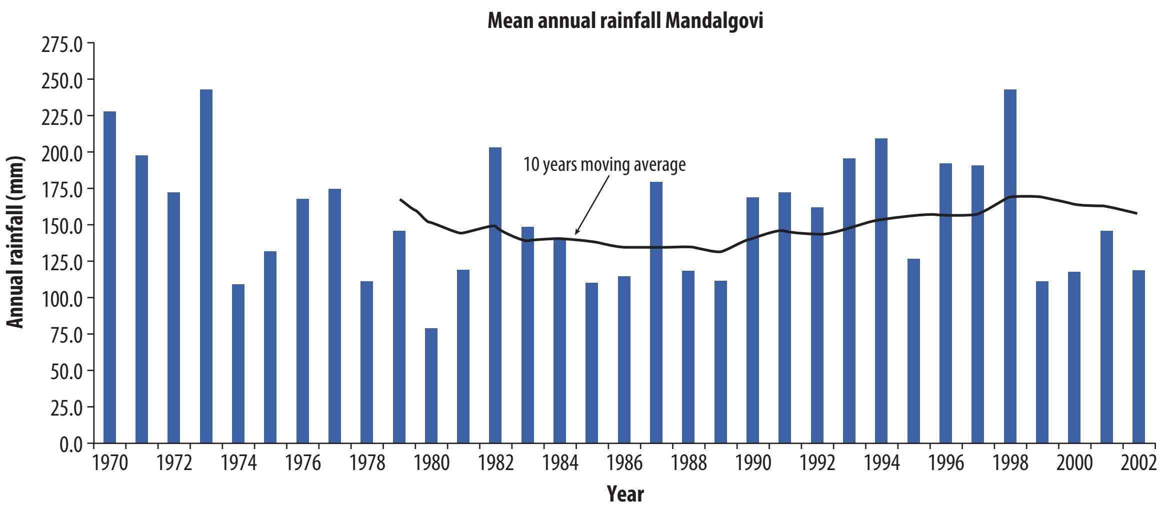
Government organizations	Responsibility
7.2. Universities	Implementation of preparing professionals
7.3. Science and Technological Office	Policy coordination on the scientific research and studies in the water sector
7.4. Academy of Science	Basic scientific research and studies on water and water resources
7.5. Institute of Geo-ecology	Water resources, water use research (designing, water research, chemical study on the water quality)
7.6. Institute of Geography	Surface water research (basic study)
7.7. Institute of Geology and Mineral	Hydrogeology research
8. Ministry of Defense	
8.1. Rear of general staff and armed forces	Military and defense water supply
9. Ministry of Foreign Affairs	
9.1. Division of Neighborhood Countries	Transboundary water issues
10. Ministry of Road transportation and tourism	
10.1. Transport Division	Policy coordination on road transportation
10.2. Road Transport and Water-Way Transport Department	Sea and water-way transport possibility research
11. City Governor Office	
11.1. Water Supply and Sewage Authority	Water supply and sewage network of Ulaanbaatar city
12. State Specialized Inspector Agency	
12.1. State Inspection Office of Environmental and Mining	Inspect on implementation of laws on water resources use and protection
12.2. State Inspection Office in the provinces, provincial laboratories	Inspect on implementation of laws on water resources use and protection and chemical study on water quality
13. Power plants	Produce energy and provide country with electricity and heat
13.1. Industry and Technical Divisions	In charge of water supply of the power plants
Private organizations	***Responsibility***
14. Mining industries, manufactories	Water users
15. Private consultants and contractors	Carries out water exploratory surveys, research and designing of the hydro construction etc.
16. NGOs and others	Various

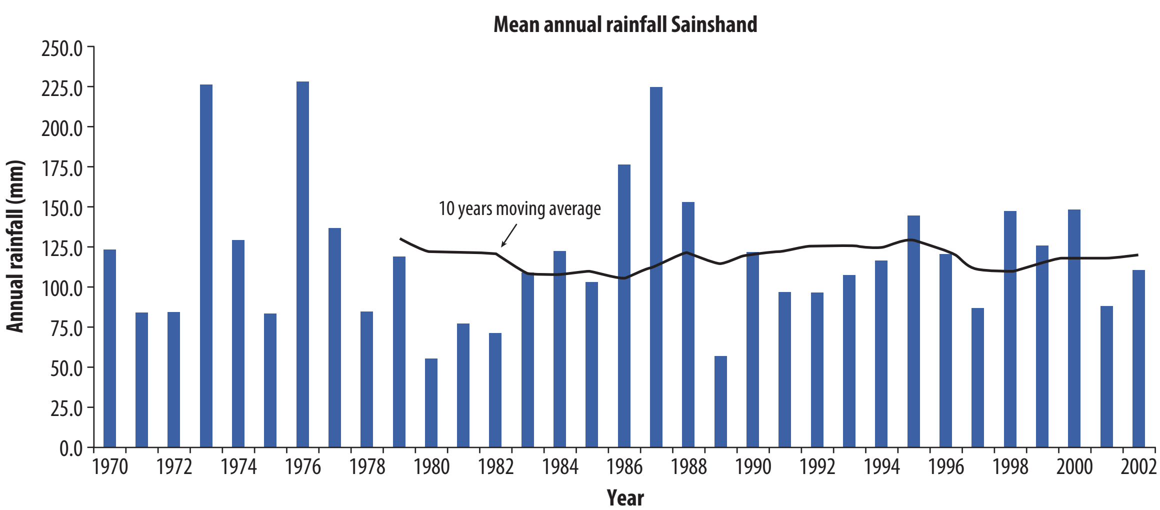
Source: "Overall inventory and assessment of the water sector in Mongolia", Summary report prepared for the Strengthening Integrated Water Resources Management in Mongolia Project (June, 2007).

Annex D. Rainfall Data Dalanzadgad, Mandalgobi and Sainshand 1970–2002

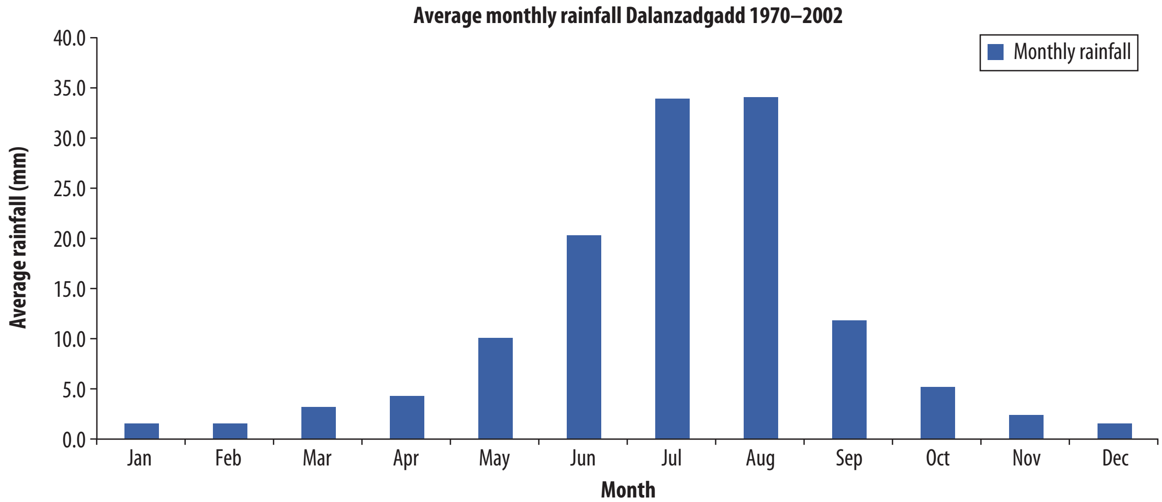
Annual rainfall Dalanzadgad, Mandalgovi and Sainshand

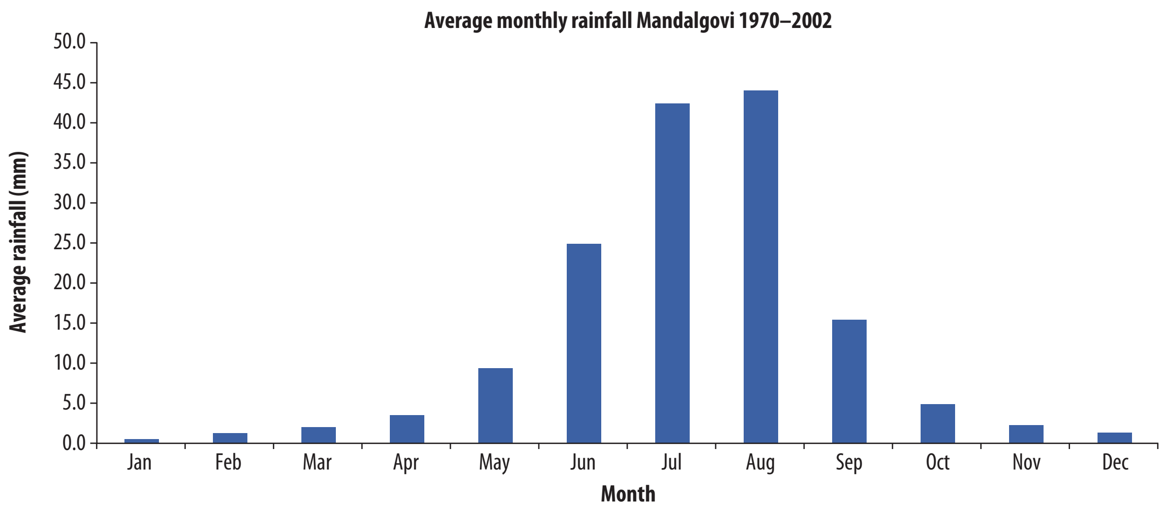


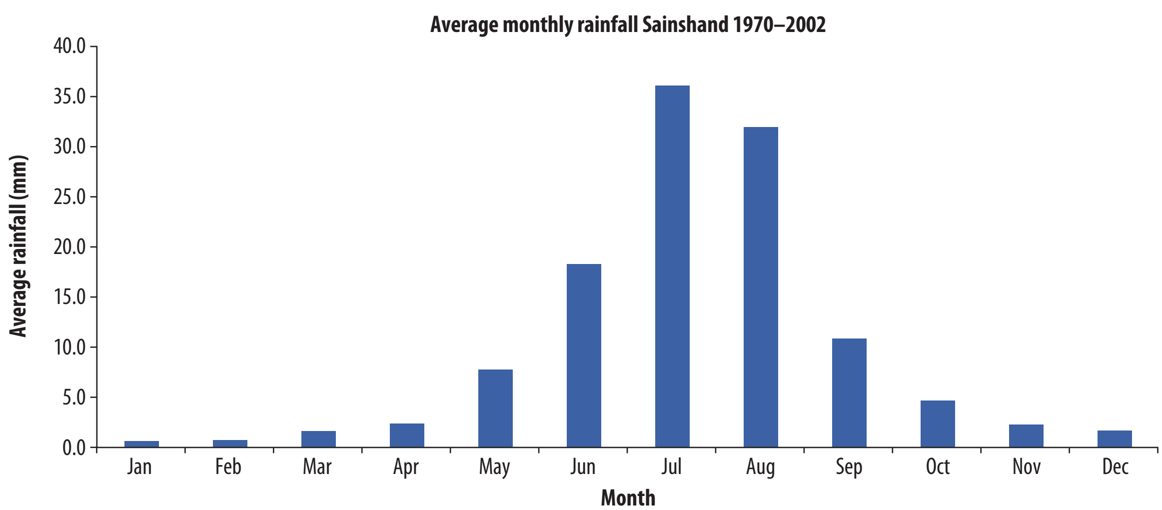




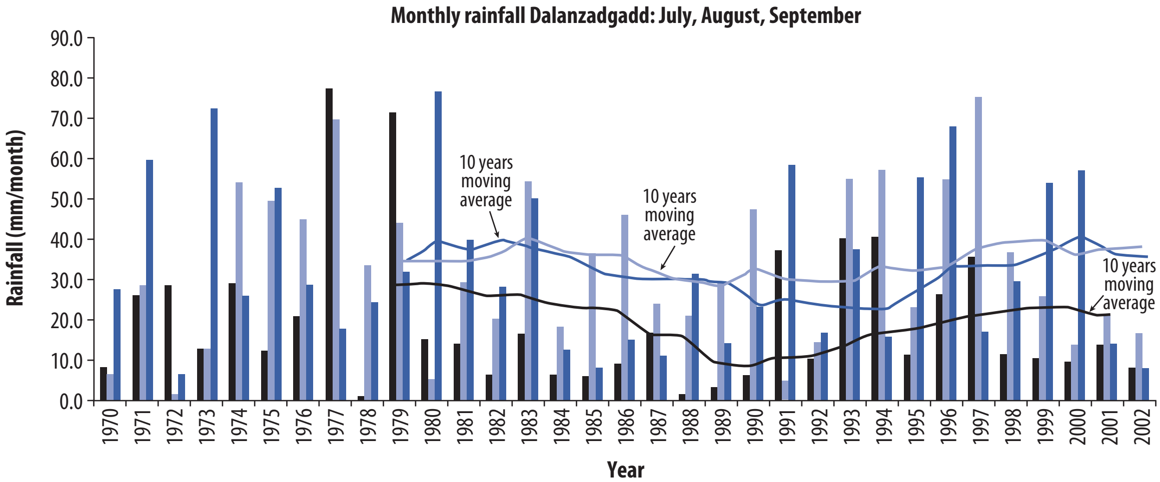
Average monthly rainfall 1970–2002 Dalanzadgad, Mandalgovi and Sainshand

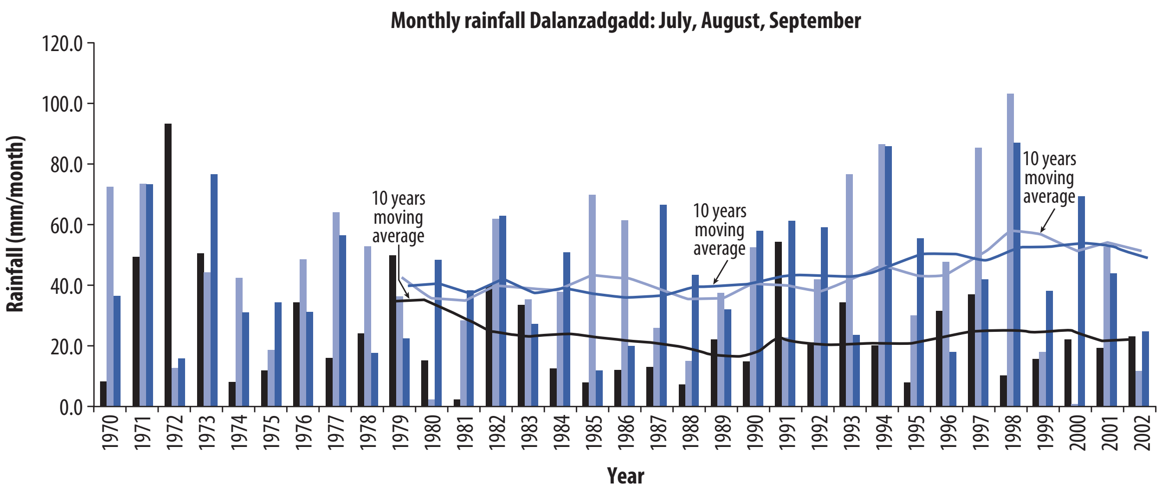


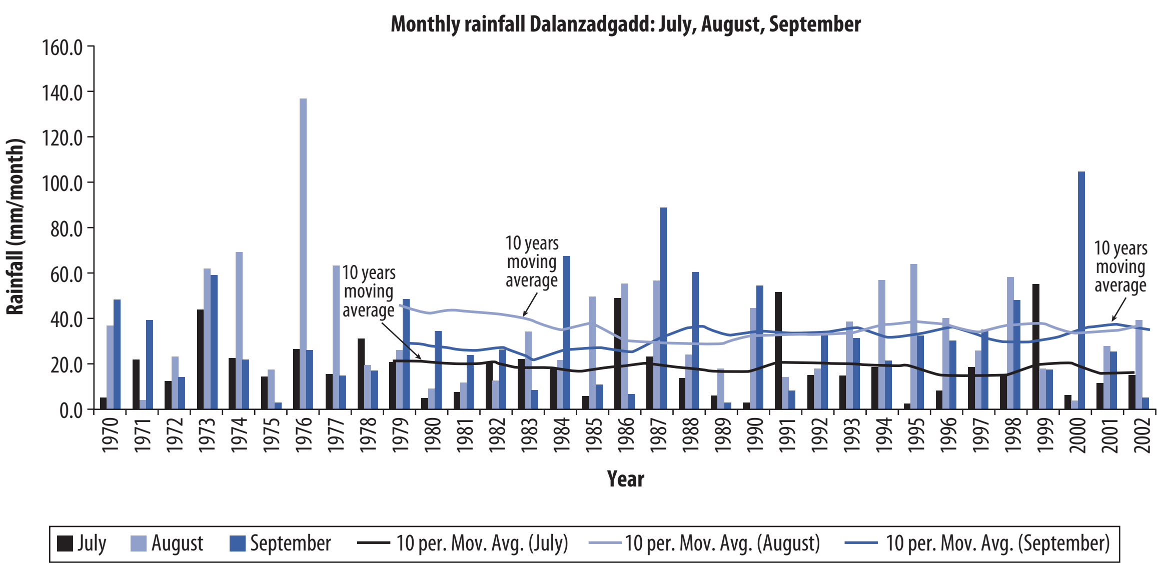




Monthly rainfall July. August, September / Dalanzadgad, Mandalgovi and Sainshand







Annex E. Aquifer Classification in the SGR (Jadambaa, 2007)

Main aquifers in the Southern Gobi Region

Distribution of water resources in a geological system are controlled lithology (mineral composition, grain size, grain packing of the sediments or rocks); stratigraphy (geometrical and age relations between geological formations of sedimentary origin); and structure of geological formations (structural features, such as cleavage, fractures, folds, and faults).

1. Intergranular aquifers

Lithologically and stratigraphically, there are two different types of deposits within this group of aquifers: local, highly productive aquifers; and low-to-local moderate productive aquifer.

1.1. Local, highly productive aquifers

Local, highly productive aquifers include Undifferentiated Quaternary (qh+q) and from Upper Cretaceous (c_2) geological formations.

Undifferentiated Quaternary (qh+q) alluvial, proluvial sand, gravel with loam, clay, sandy loam are distributed in Balgasiin Ulaan nuur area (Umnugovi aimag) where wells had different yields, including maximum yield of 60 liters per second, depth of this well (156 meters), thickness of aquifer (36.3 meters).

Upper Cretaceous (c_2) red or different colored sandstone, conglomerate, gravelate with gravel, landwaste with interlayer and lens of clay and loam are distributed in Gunii Hooloi area (Umnugovi aimag), where hydrogeological investigations were carried out by Australian Aquaterra Limited Company, and also in Tsagaan tsav, Zuunbayan, Bor Huuvur areas, where hydrogeological condition was studied by Mongolian and Russian hydrogeologists before 1990. Local, highly productive, Upper Cretaceous (c_2) aquifer is used for water supply of towns of Sainshand and Mandalgobi.

1.2. Low-to-local-moderate productive aquifers

Low-to-local-moderate productive aquifers comprise 7 different ages of aquifers. These aquifers with low-to-moderate productivity are distributed in *bel* area of mountains and dry valleys in desert areas. Most of the test boreholes in these sediments were drilled in dry valleys. The wells had yields up to 0.1 liters per second at drawdown up to 5.0 meters. The discharge of springs was mainly between 0.01–5 liters per second. The content of total dissolved solids (TDS) in the groundwater was mainly 0.6–1.5 grams per liter.

Proluvial aquifer is used for water supply of some party of Dalanzadgad and series of villages and some pastureland.

Upper Cretaceous (c_2) red or various colored, low-to-local-moderate productive conglomerate, sandstone, claystone, siltstone are distributed in Galbyn govi area and investigated by Aquaterra Limited Company.

Neogene red-colored sand, conglomerate, sandstone with clay, loam as well as Upper Cretaceous sands, sandstones, conglomerates and gravels are widespread. The sediments in particular are extremely important for water supplies in the steppe and desert zones of southern Mongolia. The lithological properties of the aquifers vary considerably (laterally as well as vertically). Groundwater is mainly pumped from wells at depth up to 100 meters. Wells mostly have yields between 0.5 and 2.0 liters per second.

Jurassic (Triassic), Permian sandstones, siltstones, and conglomerates with horizontal or slightly inclined strata mainly have yields between 0.1 and 1.0 liters per second. The concentration of TDS is usually more than 1 gram per liter. Near the border of Mongolia and China, south of the village of Gurvantes, Jurassic, and Permian deposits occupy a relatively large area where a group of springs was found. The discharge of spring was 2.5 liters per second. Borehole 15 in the same area encountered a fault zone and had a yield of 2.2 liters per second, the drawdown was 1.6 meters.

1.3. Local limited groundwater resources or strata with no groundwater

Intergranular rocks with local, limited groundwater resources or no groundwater are represented by all genetic and stratigraphic units [1]. There are alluvial sediments of this type in the dry valleys of Umnugobi and Dornogovi aimags and in the courses of ephemeral rivers in the southern Gobi of Mongolia. The intergranular aquifer with limited groundwater resources are used for animal husbandry and herdsman water supply. Their productivity is extremely low

2. Fissured aquifer, including karst

2.1. Low-to-local-moderate productive aquifers

Karst aquifers, composed from Paleozoic limestone, dolomite, and other carbonate rocks, are distributed in local small areas separately.

2.2. Local limited groundwater resources or strata with no groundwater

Fissured zones in undifferentiated intrusives with local and limited groundwater resources are distributed underlying Quaternary thin-cover intergranular aquifers. These intergranular and fissured aquifers are used together for pasture water supply.

Fissured zones in undifferentiated extrusives, metamorphosed sedimentary and metamorphic rocks of different ages with limited groundwater resources or with essentially no groundwater are widespread throughout the Southern Gobi region, including Umnugobi and Dornogovi aimags. Dry intrusive, volcanic and metamorphic rocks of different ages, as well as Carboniferous and pre-Carboniferous sediments are widespread in the Gobi. The fact that these rocks essentially contain no groundwater is in most cases perceptible at least in one of the following circumstances: lack of springs, high surface runoff due to its orographic position of the outcrop, and low infiltration capacity of the rock due the lithological properties. The areas with essentially no groundwater to very low resources had 25.4 percent of Dundgovi, 24.6 percent of Umnugovi, 30.3 percent of Dornogovi and Govisumber aimags.

Annex F. Groundwater Studies in the SGR

Groundwater Potential Studies: Dundgobi

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area km²	Average tichness m	Volume stored 10^6 m³	Proposed abstraction m³/day	Proposed abstraction Type	Purpose of study	Year
1	Undurshil	108°14'48" 45°14'15"	4534	Fractured	Y		40		346	B	Soum ws	1991
2	Ulziit	106°14'????????????" 44°45′????????????"	4371	Cretaceous Sand and gravel	Y						Soum ws	1990
3	Shine usnii honhor	106°14'–106°17' 44°55'–44°57'30"		Cretaceous fractured tuff		3	40	7	259	B	Soum ws	
4	Zodohyn heseg	105°45'02" 45°30'					20	9	518	B	Soum ws	
5	Ulaan tolgoin gobi	105°43' 45°46'10"	4455			3.75	40		2,549	C2	City ws	1991
6	Mandal uul	106°25' 45°37'30"							432	B		
7	Delgerkhangai	104°46' 45°13'35"	4476	Cons. sediments Fractured granite	Y				259 130	C1 C2	Soum ws	1991
8	Olgoin gobi	105°48'–106°1'55" 45°56'33"–45°51'10"	4294			24	30		1,382 864 432	A B C1		
9	Delgertsogt	105°50'–106°361' 45°55′–46°20'	4456	Fractured Aquifer					518	B	Soum ws	
10	Rashaant	106°00'–106°30' 45°40'–46°00'	3686			27.25	55.6	30.3	5,393	A	Aimag center	1984

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Groundwater Potential Studies: Dundgobi *(continued)*

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area	Average tichness	Volume stored	Proposed abstraction		Purpose of study	Year
						km^2	m	10^6 m^3	m^3/day	Type		
11	Moritiyn	108°02'48" 45°43'30"							3,440			
12	Dersiyn us	104°37'00" 45°07'00"							388			
								Total	**16,910**			

Groundwater Potential Studies: Umnogobi

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area km²	Average tichness m	Volume stored 10^6 m^3	Proposed abstraction m^3/day	Proposed abstraction Type	Purpose of study	Year
1	Mushgai hudag	103°34'–104°40' 44°15'–44°50'	4385	Cretaceous con- glomerate Fractured	Y	103	28		6,444	C2		1990
2	Dugui Ulaan	104°52'–104°55'39" 42°08'47"–47°08'00"	1982	Limestone Unconfined		2.83	69	3.89	1,227	B	Mining	1973
3	Guramsany hooli		4458	Fractured Conglomerate			25		605 216	C1 B	Soum ws	1991
4	Bayan ovoo	105°40'–106°12' 42°50'–43°35'	2929	Niogene Unconsolidated			30	85	2,529	C1	Pasture ws	1979
5	Bugtyn hooloi Heseg Hurmen uulyn omno Zuramtai uulyn hooloi Gun zagyn hooloi Tavan suhai Hurmen soum	102°30'–104°19' 42°40'–43°20' 103°01 30"' 42°54	4366	Upper cretaceous sand sandstone sandy clay consoli- dated gravel gravel	Y Y	157.7 68 35 112 59 35.8	47.3 53.3 39.6 36.4 60 62		1,173 2,592 5,339 2,220 1,630 710 1,814 5,833	B+ C1 C1 C2 C2 C2 C2 C1 B + C1	Pasture wa- ter supply Soum ws	1990
6	Noyon		5271	Volcanic rocks			27		206	C1	Soum ws	1999
7	Gurvan tes	101°02'00"– 101°03'00" 43°12'50"–43°13'30"	5187	Alluvial fan		3	31	92	500 58	C1 C2	Soum ws	1998

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Groundwater Potential Studies: Umnogobi *(continued)*

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area km²	Average tichness m	Volume stored 10^6 m³	Proposed abstraction m³/day	Proposed abstraction Type	Purpose of study	Year
8	Bayantuhum Baishint Tesgene Dalain bulag	102°35'–104°10' 43°10'–43°50' 103°47' 43°18	4478	Unconsolidated Quarternary Sand and gravel	Y	93 84 42 29	50 38 35	235 225 100	2,592 9,054 2,436 5,296 2,160 2,549 1,331	B C1 B C1 B C1 B1	Pasture ws Soum ws	1991
9	Dalanzadgad		3583	Quarternary Gravely Sand		24	30	17	2,592 1,469	A B	City ws	1983
10	Mandah		3836	Quarternary Alluvial		80	23	65	1,823 777 941	A B C1	TT mine	1985
11	Tavan zag Hongoriyn	100°30–101'20' 43°44'–43°5'1 102°21'30' 43°49'	4198	Quarternary Quarternary	Y Y	35 **7625**	57 **59**	74 **89670**	1,728 691 1,728 2,246	C1 C2 B C1	Agriculture	1988
12	Tavan ald	106°07'00' 42°26'00	4197	Quarternary	Y				2,246 4,493	B C1	TT mine	1988
13	Zairmagtai	105°00–106'30' 43°30'–42°05'	4107	Quarternary Gravel with sand and clay		45	27	84	1,322 661 559	B C1 C2	TT mine	1987
14	Uizen Duh Tolgoi Huren tolgoi	105°36'30' 43°41'30	4448	Granite Fractured			14 13 25		143 143 26 174	C1 C2 C1 C2	Soum ws	1990

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Groundwater Potential Studies: Umnogobi *(continued)*

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area	Average tichness	Volume stored	Proposed abstraction		Purpose of study	Year
						km^2	m	10^6 m^3	m^3/day	Type		
15	Baynzagiyn hotgor	103°56'00' 43°57'00	3870	Quarternary Gravel and sand		40	36	41	2,696	A+B	TT mine	1986
16	Balgasiyn ulaan nuur				Y				6,652 6,380	B C1	Mine water supply	
17	Nariyn zag	106°18'00' 42°45'25	4249	Sandstone		95	16	148	6,500	C2		1988
18	Mandal Ovoo		3697	Upper cretaceous Sandstone		280	35	294	8,812	C2	TT mine	1984
19	Bulgan								2,592			
20	Gsahuun hudag	105°36'00' 43°56'00							1,300			
							Total		**117,208**			

Groundwater Potential Studies: Dornogobi

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area	Average tichness	Volume stored	Proposed abstraction		Purpose of study	Year
						km²	m	10^6 m³	m³/day	Type		
1	Ulaanbadrah	110°27'10" 43°52'20'	4759		Y		19.5		86	C1+C2	Soum ws	1994
2	Doloodyn gobi	110°45'–113°00' 45°00'–46°20'	4728	Sand and gravel		256	28.7	22.04	22,982	C1+C2	Request by Aimag government	1992
3	Lugyn gol (Bayan mod)	108°00'–109°00' 42°50'–43°15'	4394	Volcanic	Y	4.6	30		864	B+C1	Mine ws	1990
4	Bor hoovor	110°00'–110°31' 45°20'46"–45°00'90"	4296	Gravel and sand		1070	38.0 50.0	60.99 1070	27,925 36,979	B+C1 C2	Soum ws	1989
5	Shivee ovoo Hoit Choi Jargalant	108°44'15" 45°55'35'	4306	Sand gravel, sandstone, fractured brown coal		368.5	40.9		432 6,460 7,516 4,320 6,480 8,208	A B C1+C2	City ws	1992
7	Zeegyn hutul	110°00'–110°31' 45°40'–46°00'	3811	Ancient lake deposit		25	40	90	4,968	A	City ws	1986
8	Tsagaan tsav		1787						69,120		Agriculture	
9	Shanagan mogoit		3873	Ancient lake deposit					864	A	Mine	
10	Salaa								897 176	C2		

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Groundwater Potential Studies: Dornogobi *(continued)*

No.	Name	Coordinates	GIC index number	Aquifer type	Chem. Analysis	Area	Average tichness	Volume stored	Proposed abstraction		Purpose of study	Year
						km²	m	10^6 m³	m³/day	Type		
11	Ulaanshand								7,257			
12	Bor undur								14,900			
								Total	**220,435**			