2.5 Present Condition of Water Supply Sector

2.5.1 Profile of Water Supply Sector

2.5.1.1 Institutional Framework of Water Supply Sector

The organizations that are concerned with water supply sector are Liberian Water and Sanitation Corporation (LWSC) and Liberian Hydrological Services (LHS) of Ministry of Land, Mines and Energy (MLME).

In order to supply safe water to the whole of Liberia, LWSC was established in 1973 in accordance with the act of the government. LWSC manages water supply and works especially for the center of Greater Monrovia and main towns of each county under the supervision of MLME. LWSC has the following vision and mission.

(Vision)

- Supply safe water and serve good hygiene at affordable cost to all nationals.

(Mission)

- Reduce the burden of water and other related diseases in Liberia
- Provide sustainable, effective and efficient services.
- Is accountable and responsible for the beneficiaries who receive water supply and sanitation service.
- Has responsibility for cost recovery on water supply and sanitation sector.

In 2009, LWSC had 140 staffs and the breakdown is shown in Table 2.5-1. At the same time, LWSC reformed its organization and established individual maintenance section in the technical service division (see Figure 2.5-1).

Table 2.5-1 Staff of LWSC

Category	Numbers of staff	%
TOP MANAGEMENT	3	2
PROFESSIONAL	41	29
SUPERVISORY	10	7
SKILLED	39	28
SEMI-SKILLED	25	18
UNSKILLED	22	16
Total	140	100

Source: LWSC Annual Report 2008 (Draft)

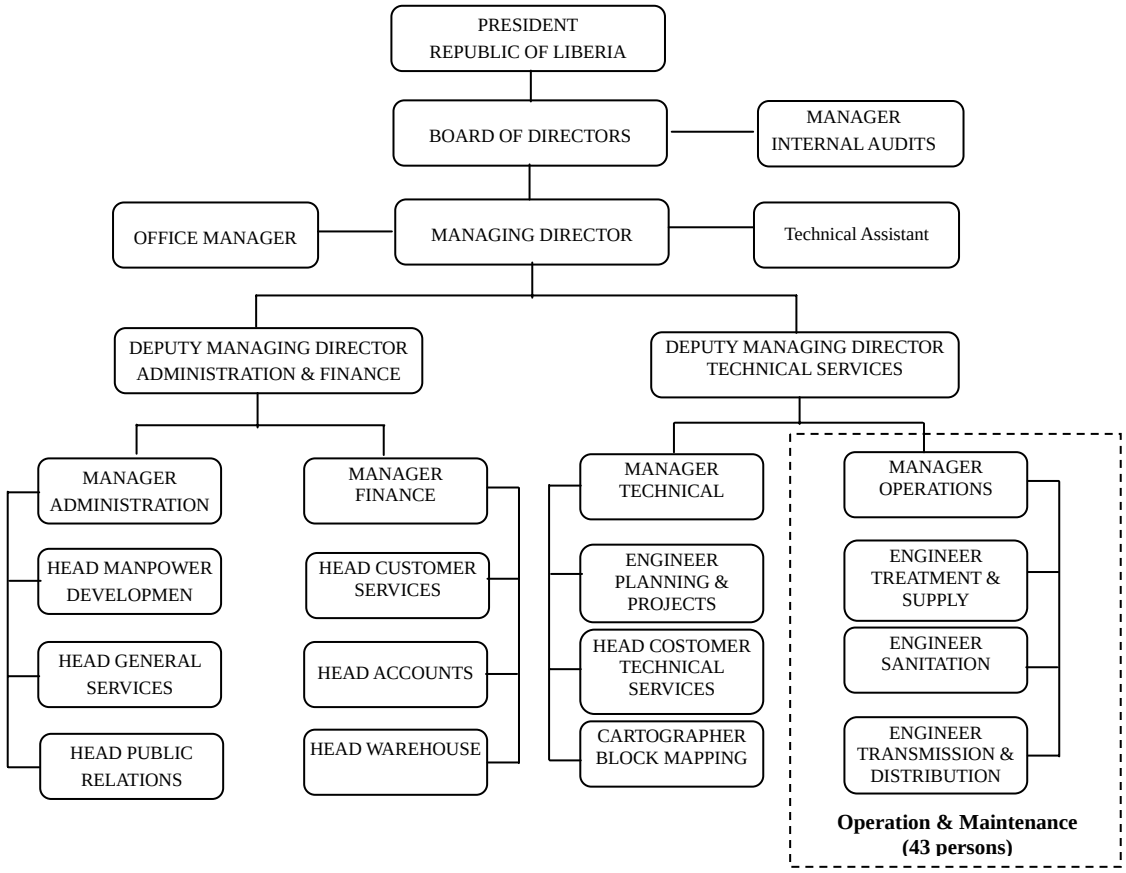

Figure 2.5-1 Organization Chart of LWSC

On the other hand, LHS is engaged in the overall groundwater development, its technical support using basic hydrological data and responsible for designing water sources such as deep, shallow, and dug wells. Regarding land acquisition for securing land for any water supply facilities, MLME and LHS are the responsible organizations..

2.5.1.2 Existing Policy and Strategy

The National Poverty Reduction Strategy Program was finalized in April 2008. This contains not only an overall vision of the Liberian government as the main national strategy but also implementation plans from 2008 to 2011 (four years), which focus on the sustainable national growth and national development. In addition, the National Poverty Reduction Strategy Program is a process to the long term development plan of the Socio-Economic Transformation Strategy - SETS.

In terms of water supply sector, the water access rate[1] of 37% in 1990 was reduced to that of 17% in 2003. After the civil war, the water access rate reached 25% in 2004 as the rehabilitation project has been carried out. From this viewpoint, the National Poverty Reduction Strategy Program focuses on the following goals.

- Improvement of Water Access Rate from 25% to 50% by 2011
- Operation and Maintenance Sustainability on 90% of water supply facilities

The specified countermeasures for water and sewerage sectors to achieve the goals are as follows:

- **Improvement of Water Access Rate from 25% to 50% by 2011**
  - Renovation of LWSC branch offices in 7 rural towns
  - Rehabilitation of 90% of stand posts including those of rural communities

[1] Water Access Rate is defined as ration that dwellers access any types of water supply facilities such as urban water supply facilities, satellite water supply facilities, shallow wells with hand pump and dug wells, etc.

- Construction of satellite water supply system with water source of groundwater (Monrovia)
- Construction of 700 boreholes with hand pumps (rural)
- Construction of 800 hand dug wells with hand pumps (rural)
- Construction of 100 spring protection facilities (hilly rural town)
- Construction of 2,000 bacteriological filters (rural)
- Establishment of water quality laboratory, recruitment of water quality analyst and procurement of the water analysis equipments (Overall Liberia)

➢ **Operation and Maintenance Sustainability on 90% of Water Supply Facilities**

- Establishment of warehouse at 200 sites for storing hand pump spare parts, and procurement of standard hand pump spare parts.
- Quality control of construction material and water supply and sewerage facilities, and establishment of theft control system.

In order to sustain safe drinking water supply and hygiene environment to satisfy the lives of communities, LWSC has goals and action plans for the 3rd short term from 2008 to 2010 based on the National Poverty Reduction Strategy Program and Millennium Development Goal as follows:

(Goals)

- Reduction of "Unaccounted for" Water (or Non Revenue Water)
- Capacity improvement of LWSC staff
- Service improvement for users
- A secure water supply service
- Rationalization of salary system
- Increase of LWSC annual revenue
- Increase of the rate of water tariff collection
- A secure operating profit
- Improvement of water supply service in suburb of urban area and squatter area
- Enhancement of purification process control and water quality monitoring
- Capacity recovery of drainage system
- Improvement of water and sewerage services in Monrovia city and main urban areas
- Improvement of water supply service coverage

(Action Plans)

The followings are action plans to achieve the above targets.

- Urgent rehabilitation of rising mains and distribution pipelines as well as purification plants
- Replacement of distribution network
- Evaluation of groundwater potential
- Rehabilitation of sewer intermediate pump station
- Procurement of vacuum trucks
- Capacity building

2.5.1.3 Financial Structure and Budgeting of LWSC

LWSC manages rehabilitation of water supply with national subsidy and donor's fund with the exception of disturbance period of 2004 and 2005. In terms of operation and maintenance cost, LWSC has basically made earnest efforts to cover those cost with water revenue, but it is envisaged that the rehabilitation of water supply facilities needs much expenses because troubles such as damages of the deteriorated pipelines occur frequently. Table 2.5-2 shows profit and loss statement (2004-2007) of LWSC. According to the Table, financial status in 2004 and 2005 shows a deficit of USD0.1-0.3mln. However, water revenue, which was downturn in 2004 and 2005, has changed to increase since 2006 and the financial status of the management was in surplus. This is because not only water revenue increased sharply but also subsidy of the government and donor's fund of about USD 0.2mln were given.

For the future, in order to go to surplus financial status following water sale increase, improvement of

the revenue water rate is one of the main issues for LWSC. Therefore, efforts of the LWSC are required to improve management furthermore.

Table 2.5-2 Profit and Loss Statement of LWSC

(Unit: USD)

Items \ Year		2004	2005	2006	2007
Revenue	Water Sales	501,667	470,000	590,000	1,028,672
	Material sales and Sewerage	78,333	50,000	95,000	210,152
	Subsidy and other Grants	0	0	186,667	293,400
	Total	**580,000**	**520,000**	**871,667**	**1,532,224**
Expenses	Personnel	160,000	181,667	168,833	321,689
	Electric and Fuel	82,167	58,500	261,667	391,069
	Chemicals and Other Materials	260,167	186,667	123,333	196,667
	Contract out Service	81,667	31,667	45,000	51,667
	Others	100,000	200,000	116,667	127,322
	Company Overhead	20,000	6,667	18,333	204,441
	Total	**704,001**	**665,168**	**733,833**	**1,292,855**
Net Income		**▲ 124,001**	**▲ 145,168**	**137,834**	**239,369**

Source: LWSC

2.5.1.4 Existing Project in Water Supply and Sewer Sector

The largest project is Monrovia Water and Sanitation Rehabilitation Program which focuses on Greater Monrovia. Currently, international donors such as the World Bank and EC have been assisting the Program. The summary of project is categorized into the following five sections.

(1) Rehabilitation of Water Supply Facility

The existing water supply facilities were damaged and the associated equipments were stolen by thieves, and the facilities have become inoperative. From the aspect of the background, this is a rehabilitation project of the White Plain purification plant constructed in 1966 and 1982, and the rising and distribution facilities laid from 1950 to 1970 for recovering the function of the existing water supply facilities. However, components of the rehabilitation program are the only replacement of mechanical equipments of the purification plant and partial rehabilitation of the critical parts on the existing pipelines.

(2) Rehabilitation of Sewerage System and Improvement of On-site Sanitation Facilities

Sewerage treatment plant with sludge lagoon constructed in 1979 is located in the wetland which is a southern part of Greater Monrovia. Not only wastewater of households which connect to sewer system, but also night soil drawn by vacuum trucks from other households that cannot use sewer system, has been discharged into the sewerage treatment plant. However, the sewerage treatment plant has been suspended for long periods and the wastewater and night soil have flown down into the stabilization pond without any treatment. The channel for discharging night soil is a small hand trench which is dug in cultivating land. The content of rehabilitation work, in order to facilitate disposal of night soil discharged from vacuum trucks, is the restoration of the inlet stabilization pond of 26,000m^2.

In addition, the rehabilitation programs are composed of the construction of 11 public toilets, rehabilitation of 30 existing public toilets, procurements of maintenance equipments such as vacuum trucks and jet cleaning vehicles.

(3) Capacity Building for LWSC

The Capacity building program focuses on LWSC, which has issues on management system of water works. The program includes establishment of users' inventory and procurement of communication equipment and maintenance vehicles.

(4) Assistance on Program Management

This is a technical assistance for detailed design and construction supervision including on-the-job training (OJT) for carrying out the projects mentioned in the above (1) to (3).

(5) Assistance on Sector Reform

This is a study to deal with the projects strategically on formulation of policy and strategy, establishment of legislation, capacity building and formulation of investment program as one of the sector reforms.

Table 2.5-3 shows the total implementation cost of Monrovia Water and Sanitation Rehabilitation Program (2007-2011) and the cost submitted by the donors. LWSC has furthermore been expecting the donors' assistances, because about 65% (USD44.6 mln) is short against the total implementation budget as shown in Table 2.5-3.

Table 2.5-3 Total Implementation Cost of Monrovia Water and Sanitation Rehabilitation Program and Budget Committed by Donors

(Unit : mln USD)

Contents	Total Cost	Donors	Balance
1) Rehabilitation of Water Supply Facilities	38.5	27.7	10.8
2) Rehabilitation of Sewerage System and Improvement of On-site Sanitation Facilities	15.0	2.9	12.1
3) Capacity Building for LWSC	5.0	1.2	3.8
4) Assistance on Program Management	7.0	4.1	2.9
5) Assistance on Sector Reform	2.0	1.0	1.0
Total	67.5	36.9	30.6

Source: WB

Table 2.5-4 shows a program demarcation of rehabilitation works which are being assisted by the donors. Moreover, Figure 2.5-2 shows the targeted location and the current progress of the rehabilitation work.

Table 2.5-4 Program Demarcation of Rehabilitation Work by Donors on Water and Sewerage Sectors

Donors	Water Supply Sector	Sewerage Sector (including On-site Sanitation)	Remarks (Other Areas other than Greater Monrovia)
WB	• Rehabilitation for White Plain Purification Plant, Booster Pump Station, Rising Main and Distribution Pipelines and Service Reservoirs	• Rehabilitation for 20-30 Public Toilets and Procurement of one Jet Cleaning Equipment	
	USD5.1mln（2008-2010）	**USD2.3mln(2008-2010）**	
	• Capacity Development and Program Management		
	USD1.8mln（2008-2010）		
	• Study on Sector Reform (Formulation of Policy, Strategy and Investment Program, Establishment of legislation)		
	USD0.3mln（2008-2010）		
EC	• Rehabilitation for Intake Pump, White Plain Purification Plant, Booster Pump Station, Rising Main and Distribution Pipelines and Service Reservoirs	—	
	USD5.9mln（2008-2010）		
	• Program Management		
	USD1.0mln（2008-2010）		

Donors	Water Supply Sector	Sewerage Sector (including On-site Sanitation)	Remarks (Other Areas other than Greater Monrovia)
	• Study on Sector Reform (Formulation of Policy, Strategy and Investment Program, Establishment of legislation) **USD0.7mln（2008-2010）**		
DFID / AfDB	• Rehabilitation for Booster Pump Station and Distribution Pipeline, and Procurement of Generators **USD16.7mln（2008-2010）**	• Restoration on Stabilization Pond, Construction of 11 Public Toilets and Procurement of One Vacuum Truck **USD0.6mln（2008-2010）**	• Assistance on Water and Sewerage Sector through NGO **USD6.9mln（2007-2010）**
	• Capacity Development and Program Management **USD2.3mln（2008-2010）**		
USAID （Including US Army）	－	－	
UNICEF	－	－	• Health Guidance, Hygiene Protection Guidance, Assistance on water treatment of individual households **USD2mln／Year**
Population Service International (NGO)	－	－	• Grant Delivery of low concentration Chlorine (Liquid Type) to 3 Zones (Grand Bassa, Grand Gedeh, Bomi)

Source: Donors such as WB, EC, DIFID, AfDB, etc

Figure 2.5-2 Targeted Location of Rehabilitation Works and Current Progress

2.5.2 Present Condition of Water Supply System

2.5.2.1 Present Condition of Water Supply Facilities

(1) Water Supply Services

(a) Water Consumption

Water production has been increasing steadily in the past five years. Revenue water is about 0.29Billion Gal in 2008 which is about 19% of the water production (1.56Billion Gal). The water consumption per capita per day is about 2 Gal, which is obtained by dividing the revenue water with the service population of 370,000. According to the report of "Water Demand and Market Study in Monrovia, Liberia" funded by the EC, the required water consumption per capita per day in Monrovia is assumed to be 13 Gal. The actual ratio of water consumption comes to about 16% (2 Gal per capita per day) of the required water consumption in Monrovia. This is because residential water such as washing, shower, etc. other than drinking water is taken from shallow wells, which were drilled for emergency purpose under the funds of international organization or NGOs. However, theses wells depend on groundwater of shallow aquifer, which is easily affected by external contaminated sources. Therefore, LWSC needs establishment of the water supply system focusing on the whole of Greater Monrovia.

(b) Present Conditions of Water Supply Service

LWSC has been conducting operation and maintenance of the urban water supply system with the water source of the Saint Paul River and two small scale water supply systems with water source of groundwater, and provides water with population of 370,000 through those of water supply systems. The purified water is pumped up from the White Plain purification plant to the center of Monrovia. As the rising pump operates for 12 hours a day, the water supply hours are maximized at 12 hours a day as well. However, the water supply hours are further shorter than 12 hours because rising main pipelines are also used as distribution pipelines. Sometimes, water does not reach to the service areas located downstream.

In addition, dwellers who do not receive sufficient water from Kiosk connected with the water supply system, hotels and other bulk consumers depend on water transported by water trucks and carts. Especially, most of the hotels and bulk consumers purchase water transported by water trucks several times a day.

Change of water service coverage ratio in the past five years is shown in Table 2.5-5. The water service coverage ratio between 2004 and 2007 is calculated using service population which was provided by LWSC. Moreover, since water service coverage ratio in 2008 was not available, it was assumed based on the historical revenue water in 2008 and the estimated future service coverage ratio as shown in Table 2.5-6. Figure 2.5-3 shows water service coverage ratio in 2008 and the fact that the service area where the water service coverage ratio is at least 50% concentrate at Bushrod Island which is an active commercial area and Mamba Point where many international organizations are located.

Table 2.5-5 Trends of Water Service Coverage Ratio in Greater Monrovia

Items	2004	2005	2006	2007	2008
Administrative Population (mln)	0.90	0.93	0.95	0.98	1.00
Service Population (mln)	0.10	0.10	0.35	0.35	0.37
Service Coverage Ratio	11.1%	10.8%	36.8%	35.7%	37.0%

Source: Population Census in 2008, Water Demand and Market Study in Monrovia, Liberia, and LWSC

Table 2.5-6 Water Service Coverage Ratio in 2008 (Estimated)

No.	Zone name	Pop. in 2004	Pop. in 2008	House Connections			Kiosks			Total		
				%	Service Pop.	Water Consumption (Gal/d)	%	Service Pop.	Water Consumption (Gal/d)	%	Service Pop.	Water Consumption (Gal/d)
1	New Kru Town	93,357	73,379	4	2,935	38,155	39	28,618	22,894	43	31,553	61,049
2	Logan Town	86,535	58,168	7	4,072	52,936	49	28,502	22,802	56	32,574	75,738
3	Clara Town	85,203	55,462	11	6,101	79,313	49	27,176	21,741	60	33,277	101,054
4	West Point	78,456	29,516	7	2,066	26,858	56	16,529	13,223	63	18,595	40,081
5	Central Monrovia A	62,422	42,139	25	10,535	136,955	42	17,698	14,158	67	28,233	151,113
6	Central Monrovia B	105,133	40,688	25	10,172	132,236	42	17,089	13,671	67	27,261	145,907
7	Sinkor	44,016	43,780	11	4,816	62,608	25	10,945	8,756	36	15,761	71,364
8	Lakpazee	35,813	42,045	7	2,943	38,259	21	8,829	7,063	28	11,772	45,322
9	Old Road	40,784	48,274	7	3,379	43,927	21	10,138	8,110	28	13,517	52,037
10	Congo Town	17,674	25,217	7	1,765	22,945	25	6,304	5,043	32	8,069	27,988
11	Paynesville	136,355	350,998	4	14,040	182,520	25	87,750	70,200	29	101,790	252,720
12	Gardnersville	57,922	80,397	4	3,216	41,808	21	16,883	13,506	25	20,099	55,314
13	New Georgia	41,296	54,188	4	2,168	28,184	21	11,379	9,103	25	13,547	37,287
14	Barnersville	30,390	35,224	4	1,409	18,317	21	7,397	5,918	25	8,806	24,235
15	Johnsonville	2,885	4,514	4	181	2,353	21	948	758	25	1,129	3,111
16	Caldwell	19,519	26,586	4	1,063	13,819	21	5,583	4,466	25	6,646	18,285
	Total	**937,760**	**1,010,575**		**70,861**	**921,193**		**301,768**	**241,412**		**372,629**	**1,162,605**

Source: Population Census in 2008 and Water Demand and Market Study in Monrovia, Liberia
Note: Current Service coverage was re-considered based on the above study report

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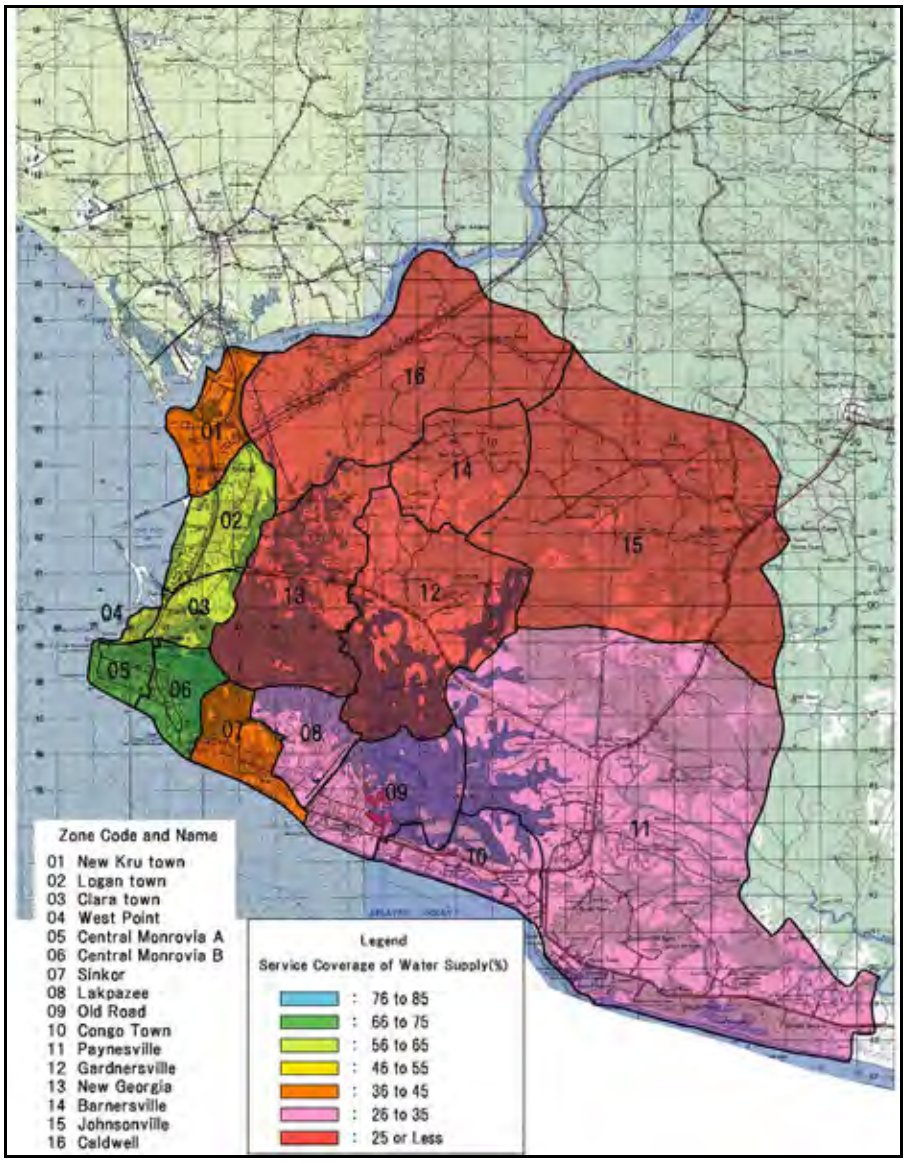


Figure 2.5-3 Outlines of Water Service Coverage Ratio in Greater Monrovia in 2008

(2) Present Condition of Water Supply Facilities

Raw water pumped up from the Saint Paul River (Minimized flow: 1,140MGD) is treated in the White Plain Purification Plant (plant capacity: 16MGD), in which the intake point is located nearby. Purified water of about 4.3MGD (2008) is supplied to Greater Monrovia passing through the rising main pipelines systematized into two booster pump stations. Two rising main pipelines of cast iron (dia. of 12 and 16 inches) and three concrete pipes (dia. of 12, 24 and 36 inches) were laid from 1950s to 1970s.

Figure 2.5-4 Water Distributed from Rising Main

Two existing service reservoirs (Ducor Reservoir: 0.6MG and Mamba Reservoir: 1.0MG) were constructed for supplying water to the high elevated area in 1952 and 1960 respectively. However, purified water has not reached to those service reservoirs due to the lack of capacity of the White Plain Purification Plant and rising pump, and the fault of booster pumps, and the service reservoirs have not worked. Therefore, the purified water flown in the rising main pipes is directly distributed to the recipient dwellers using individual house connections, kiosks and water trucks (see Figure 2.5-4).

Figure 2.5-7 shows current status of the existing water supply facilities.

(3) Water Sources

LWSC's water sources in Greater Monrovia are composed of i) Saint Paul River (see Figure 2.5-5), ii) Paynesville Groundwater, iii) Airfield Groundwater (see Figure 2.5-6). In terms of ii), there are two wells (Well Depth: 30-50m) with water yield of about 0.02MGD and 0.05MGD respectively. However, groundwater of only 0.05MGD was pumped up due to a fault of the submersible pump of the other wells in January 2009. The main users of groundwater pumping up from these wells are the Coca Cola factory as a major consumer and common dwellers using groundwater transported by carts and water tracks. Regarding iii), one well (well depth: about 10m) with water yield of 0.03MGD is located in the environs of the Airfield. Groundwater pumped up from the well is used for dwellers through kiosks and water tracks. Small size pumps are used for pumping up water to water trucks.

Figure 2.5-5 Saint Paul River as Water Source for Urban Water Supply

Figure 2.5-6 Groundwater Well at Airfield

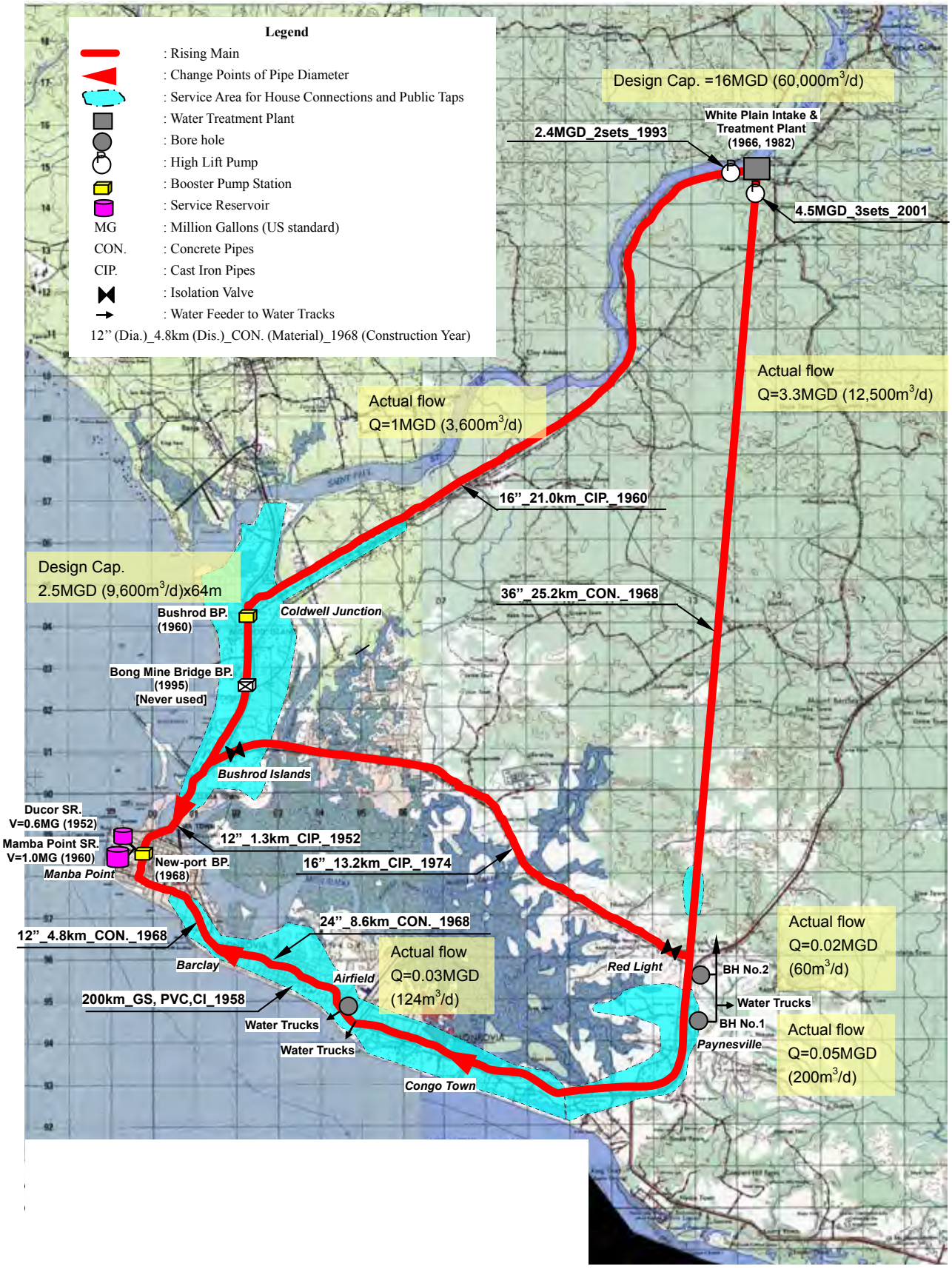


Figure 2.5-7 Outlines of the Overall Existing Water Supply System

(4) Outline of White Plains Water Treatment Plant (WTP)

White Plains Water Treatment Plant (White Plains WTP), which is located at the northeast of about 20km away from central area in Greater Monrovia, is now supplying water to Monrovia city. This water treatment plant was originally constructed in two phases in 1960 and 1979. Design capacity of this plant is around 16MGD (the maximum hydraulic capacity is around 24MGD).

There are two (2) intake points in the northern parts of Greater Monrovia. One is located along the Saint Paul River next to White Plains WTP. Another is located at the dam, around 5 km upstream in the Saint Paul River from White Plains WTP which was originally utilized for hydraulic electrical power generation.

The treatment process of White Plains WTP is shown in Figure 2.5-8.

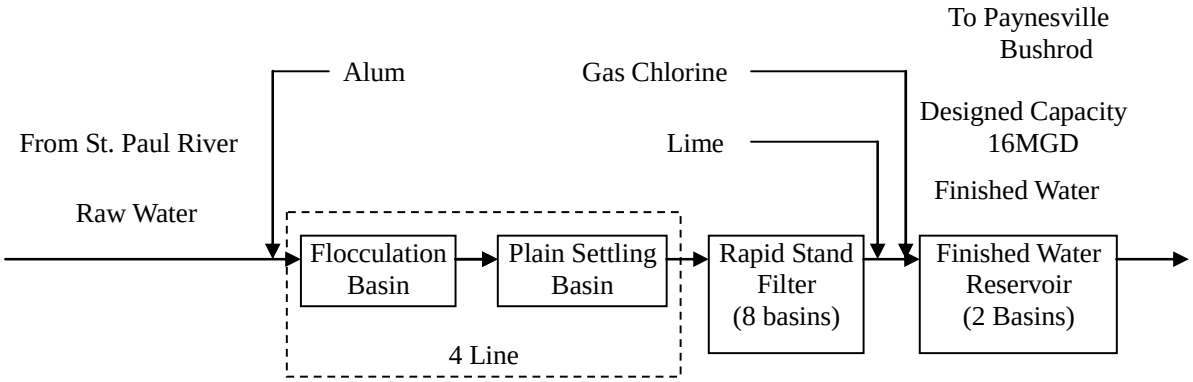


Figure 2.5-8 Flow Sheet of White Plains Water Treatment Plant (Condition in 1980)

The WTP consists of 4 coagulant sedimentation basins and 8 rapid sand filter basins. The volume of finished water basin is around 2.5mln Gal, equivalent to approximate 3.8 hours of hydraulic retention time.

Treated water is supplied to the central area, the Paynesville and Bushrod area through two (2) rising mains.

(a) Present Condition of White Plain WTP

White Plains WTP was damaged by the civil conflict for 15 years and has currently been operated with the condition with lower capacity than the original design capacity in 1980s.

The survey result by the Study Team on the present conditions of the White Plains WTP is shown below:

- Present treated water production rate is around 4.2MGD, because of the failure of mechanical and electrical facilities.
- Raw water is taken only from the intake point next to WTP in the Saint Paul River. Another intake, which was originally a dam for hydraulic electrical power generation, is difficult to be used because of low flow rate around the intake in the Saint Paul River.
- Line 3 and line 4 in WTP are impossible to be operated because of the failure of mechanical facilities such as the flocculator, drain pumps for settlement basin and so on.
- Line 1 and line 2 are operated by trial and error of operators in spite of the failure of flocculator and so on.
- It is impossible for 5 out of the total 8 basins for the sand filter to operate because there is no sand in the filtration basin.
- Solid alum is used for coagulant. Solid alum is dissolved by means of an automatic solution

device and the solution is put into the inlet of flocculation basin.

- Lime is used for alkali agent. Lime is dissolved by the automatic solution and the solution is put into inlet of treated water reservoir.
- Gas chlorine is used for chlorine regent for disinfection. Calcium hypo-chloride is also used in case of non-gas chlorine.
- Diesel generator is used for supplying electrical power to intake pumps and the other facilities because electrical power from outside is not supplied to WTP.
- The number of operators including water quality control at the time of our survey is 5 staff members.
- It was confirmed that there is sufficient area in the White Plains WTP for additional WTP equivalent to the capacity of the existing WTP.

(b) Present Condition of Water Quality Control

Water quality control in LWSC is conducted at White Plains WTP. Most of their work is water quality control only for WTP. Water quality control at the point of distribution and at the water tap is not actually conducted.

The survey results of the Study Team for the present conditions of water quality control are explained as follows:

- pH and turbidity for raw water and treated water by sedimentation are analyzed once a day. pH, color, turbidity and residual chlorine for finished water are analyzed more than 10 times a day and every one hour. Daily records data for more than 5 years are stored in WTP. (The Study Team received all the daily data in 2008.)
- The Study Team requested the staff to analyze the parameters of daily water quality at the time of our survey to check whether appropriate method is applied or not. It was confirmed that the analysis for pH, color, turbidity and residual chlorine adopted phenol-red method, colorimetric method, transparency and DPD method respectively. Each analysis was appropriately conducted although simple methods are applied.
- Electrical conductivity and E-Coli were analyzed until 2007 and the data was recorded. At present these items are not analyzed because of the failure of apparatus.
- Other analysis apparatus of the laboratory include Jar tester.
- For reference, water quality data of the White Plains WTP in 2008 regarding raw water, settled water (water after settling basin) and finished water (water after sand filter) submitted by water laboratory of LWSC are shown in the Table 2.5-7., Table 2.5-8 and Table 2.5-9 below.

Table 2.5-7 Monthly Water Quality Data in White Plains WTP in 2008 (Raw Water)

Month	pH (-)				Turbidity (°)			
	Ave.	Max.	Min.	Number	Ave.	Max.	Min.	Number
Jan	7.1	7.5	7.0	45	9	11	0	45
Feb	7.1	7.4	7.0	46	9	50	0	45
Mar	7.1	7.4	7.0	39	10	100	0	39
Apr	7.1	7.4	7.0	40	8	20	0	40
May	7.0	7.2	7.0	40	12	30	5	40
Jun	7.0	7.2	7.0	36	18	30	10	36
Jul	7.0	7.2	7.0	45	26	50	18	45
Aug	7.0	7.1	6.9	29	28	40	10	29
Sep	7.0	7.2	6.7	30	29	40	20	30
Oct	7.0	7.2	7.0	33	25	40	10	33
Nov	7.1	7.4	7.0	35	18	22	10	35
Dec	7.0	7.2	7.0	52	11	21	0	52
Yearly	7.0	7.5	6.7	470	16	100	0	469

Table 2.5-8 Monthly Water Quality Data in White Plains WTP in 2008 (Settled Water)

Month	pH (-)				Turbidity (°)			
	Ave.	Max.	Min.	Number	Ave.	Max.	Min.	Number
Jan	6.8	7.0	6.8	45	0	0	0	45
Feb	6.8	7.1	6.8	46	0	0	0	45
Mar	6.8	7.0	6.8	39	0	0	0	39
Apr	6.8	7.1	6.8	40	0	0	0	40
May	6.8	6.8	6.8	40	1	10	0	40
Jun	6.8	6.8	6.8	36	3	10	0	36
Jul	6.8	6.8	6.8	45	2	10	0	45
Aug	6.8	6.8	6.8	29	2	5	0	29
Sep	6.8	7.1	6.8	30	5	10	0	30
Oct	6.8	6.9	6.8	33	1	10	0	33
Nov	6.8	6.8	6.8	35	0	0	0	35
Dec	6.8	7.1	6.8	52	0	0	0	52
Yearly	6.8	7.1	6.8	470	1	10	0	469

Table 2.5-9 Monthly Water Quality Data in White Plains WTP in 2008 (Finished Water)

Month	pH (-)				Turbidity (°)				Color (°)			
	Ave.	Max.	Min.	Number	Ave.	Max.	Min.	Number	Ave.	Max.	Min.	Number
Jan	7.1	7.5	6.8	349	0	0	0	349	4	4	4	349
Feb	7.1	7.5	6.8	373	0	0	0	373	4	4	4	373
Mar	7.0	7.5	6.8	376	0	0	0	376	4	4	4	376
Apr	7.0	7.5	6.8	359	0	0	0	359	4	4	4	359
May	7.0	7.5	6.8	365	0	0	0	365	4	4	4	365
Jun	6.9	7.5	6.8	348	0	0	0	348	4	4	4	348
Jul	7.0	7.5	6.8	380	0	0	0	380	4	4	4	380
Aug	7.0	7.5	6.8	259	0	0	0	259	4	4	4	259
Sep	6.9	7.3	6.8	366	0	0	0	376	4	4	4	376
Oct	6.9	7.5	6.8	365	0	0	0	369	4	4	4	369
Nov	7.0	7.5	6.8	356	0	0	0	358	4	4	4	358
Dec	7.1	7.5	6.8	413	0	0	0	413	4	4	4	413
Yearly	7.0	7.5	6.8	4309	0	0	0	4325	4	4	4	4325

(5) Current Status of Rising Main and Distribution Pipelines

Purified water is conveyed to the center of Monrovia through two rising main pipelines. Table 2.5-10 shows specification of rising main and distribution pipeline materials. Some of the purified water is distributed through two rising main pipelines and the remained water is conveyed to the New Port booster pump station.

On the other hand, distribution pipelines should be used to supply water stored in service reservoirs, but distribution pipelines have not been used, because water has not been stored in two service reservoirs due to faults on the booster pumps, etc. Even if water is distributed from the service reservoirs, much leakage may occur on the distribution pipelines because of serious deterioration and damages of the pipelines due to suspension of water supply system for a long period during the civil war (see Figure 2.5-9).

Figure 2.5-9 Damaged PVC Pipelines (Right)

Table 2.5-10 Information on Rising Main and Distribution Pipelines

Pipelines	Routes	Diameter (inches)	Material	Pipeline Length (km)	Construction Year
Rising Main	Purification Plant-Congo Town	36	Concrete	25.2	1968
	Congo Town-Barclay	24	PVC	8.6	1968
	Barclay-Mamba Point	12	Concrete	4.8	1968
	Purification Plant-Bushrod Islands	16	Cast Iron	21.0	1960
	Bushrod Islands-Mamba Point	12	Cast Iron	1.3	1952
	Bushrod Islands-Red Light	16	Cast Iron	13.2	1974
Sub-Total				74.1	
Distribution	Network		PVC、GS、Cast Iron	200.0	1958
Total				274.1	

Source: LWSC

2.5.2.2 Current Situation of Water Supply Services

(1) Overview of Water Supply and Sewerage Services by LWSC

Summary of water supply and sewerage services by LWSC in the past five years is shown in Table 2.5-11. They are characterized by the facts that the cost of water supply (per Gal) exceeds the unit price of water supply (per Gal). In addition, water production has significantly increased since 2007 due to the replacement of the mechanical equipment such as intake pumps, and water of about 1.5Billion Gal has been produced in 2008, but the revenue water has been limited to only 0.3Billion Gal (about 19%). This is because at least 80% of the water production is wasted due to various causes such as leakage, the gapped water between actual water consumption and the apparent water consumption for frat rate tariff due to the water meter deficiency, etc. Figure 2.5-10 shows the historical trend of production water and billed water.

Table 2.5-11 Summary of Water Supply and Sewerage Services by LWSC

Items \ Year	2004	2005	2006	2007	2008
Administrative Population (Million)	0.90	0.93	0.95	0.98	1.00
Service Population (mln)	0.10	0.10	0.35	0.35	0.37
Coverage rate	11.1%	10.8%	36.8%	35.7%	37.0%
Water Production (mln Gal)	238	264	647	925	1,551
Billed Water (mln Gal)	221	188	196	243	289
Rate of Billed Water	92.9%	71.2%	30.3%	26.3%	18.6%
Production Cost (mln USD)	0.7	0.8	0.7	1.3	-
Production Cost (USD) per 100 Gal	**0.3**	**0.4**	**0.4**	**0.5**	-
Revenue (mln USD)	0.5	0.5	0.6	1.0	-
Revenue (USD) per 100 Gal	**0.2**	**0.3**	**0.3**	**0.4**	-

Source: LWSC

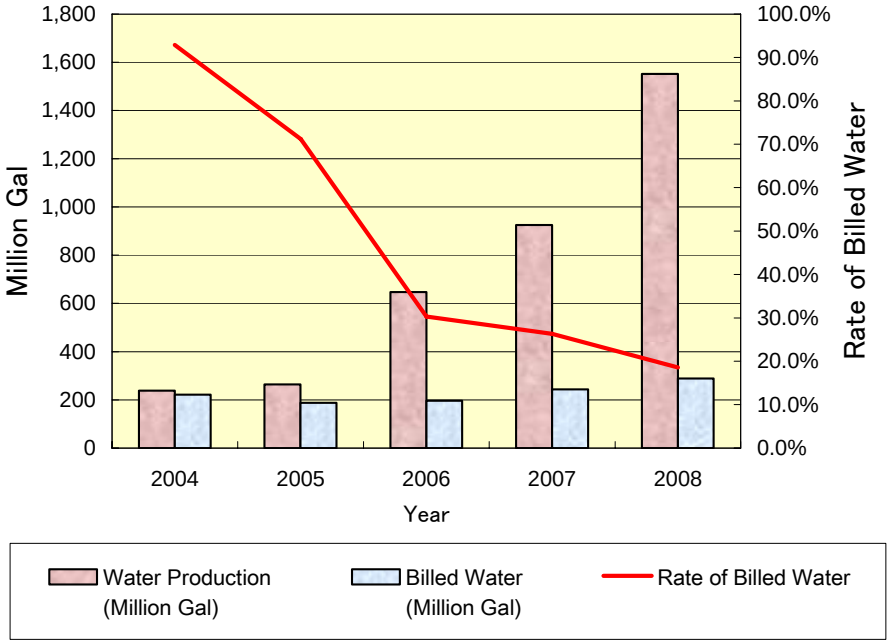


Figure 2.5-10 Water Production and Billed Water

(2) Operation and Maintenance

The Operation Department of the LWSC is in charge of operation and maintenance (O&M) as shown in Figure 2.5-1. The Operation Department is responsible not only for O&M of water supply and sewerage facilities in Greater Monrovia but also the technical services and the support for financial management of the water supply system of the satellite cities and villages. The Department consists of water treatment, transmit, distribution and sewerage sections with 43 staff members.

Main task of each section is as follows:

- Water treatment section: Operation and maintenance for the whole White Plain purification plant
- Transmission and distribution section: Rehabilitation of leakage points on rising main and distribution pipelines
- Sewerage section: Rehabilitation and new construction of manholes, and collection of night soil from public and private toilets.

(3) Maintenance Equipment

LWSC has 11 vehicles for daily operation and maintenance of water supply facilities, two vacuum trucks and one jet cleaning for sewerage facilities.

(4) Non-Revenue Water

Since the existing water supply facilities of Monrovia have been rehabilitated with the assistance of the donors such as World Bank and EC, leakage rate may be reduced. Rehabilitation has been carried out without any leakage survey and the pipelines have been replaced at the sites where critical problems are visibly found. Therefore, effects on the reduction of leakage rate by the rehabilitation projects are uncertain for the future.

(5) Water Tariff System

Current water tariff system of LWSC is divided into the following four categories mainly by types of water supply and water usage.

- Residential Group
- Business User Group
- Large Consumer Group
- Water Truck User Group

(a) Residential Group

Residential group is defined as common households, and is categorized into three users such as Category A (users with house connection), Category B (Kiosk users) and users living in high elevated area such as Mamba Point and UN Drive.

(b) Business User Group

Business user group is defined as commercial and industrial activities, and governmental office. Furthermore, water tariff of this group is divided into two types of users by area of high elevation and others.

(c) Large Consumer Group

This group is defined as those consume large amount of water both official and private.

(d) Water Truck User Group

Water tariff of this group is divided into two categories. The respective water tariff focuses on the center of Greater Monrovia and its suburban areas such as Paynesville and Gardnersville.

Current water tariff system of LWSC is divided into two (2) categories. Table 2.5-10 shows the metered tariff system. According to Table 2.5-10, the water tariff related to water trucks is 10 times higher than that for residential house connection and kiosk. In case that the household size is five (5) and water consumption rate is 60LCD, the water charge (USD0.16 per 100gal) for one household is estimated as about 4% of the household income. Therefore, it is considered that the water tariff of house connection should be acceptable even for low income households with USD150 monthly.

Table 2.5-12 Water Tariff System

USD/100Gal

Family	Category	Up to 2,250gal	Over 2,250gal	Container (5gal)
	Category A	0.16	0.42	-
	Category B	-	-	1.67
	Enclave	0.42	0.67	-
Average		**0.29**	**0.55**	**1.67**
Business	Category	Up to 500,000gal	Over 500,000gal	
	Business	0.80	0.75	
	Enclave	1.20	1.00	
Average		**1.00**	**0.88**	
Bulk Carry	Category	Up to 1,000gal	Over 1,000gal	
	Bulk Carry	0.75	0.70	
Average		**0.75**	**0.70**	
Water Truck	Category	Lot of 500gal	Lot of 1,000gal	
	Around Monrovia	2.40	2.50	
	Outside Monrovia	3.00	3.00	
Average		**2.70**	**2.75**	

Source: LWSC

On the other hand, in terms of flat rate tariff system, which is applied for households without water meter including not-functional, LRD1,091.40 for household size of five (5) to seven (7), which is equivalent to 6,000gal per month and LRD1,650.00 for that of eight (8) to nine (9), which is equivalent to 9,000gal per month is charged to users who have no water meters. These water tariff rates are converted to USD0.26 per 100gal that is a bit higher than the metered rate.

The number of registers is about 3,988 in 2008, and out of that, the residential and business registers including other purposes are 3,035 and 953 respectively. Water of the other users who do not register to LWSC is supplied by water tracks, carts and kiosk.

Water revenue which is the main income source of LWSC was about USD 1mln in 2007 (see Table 2.5-11). The water tariff collection ratio was 50-75% of the water bill before 2006. However, it exceeded the bill in 2007. This is because the payment by governmental office that had the biggest arrear was settled down that year. Commercial service (Customer service) section is in charge of collection of water tariff and collect water tariff from the tariff collectors of kiosks twice (Wednesday and Friday) a week, and receives water tariff from users of house connections monthly.

Table 2.5-13 Status of Water Tariff Collection

Year	Bill for Water Supply				Collected Water Tariff			
	Domestic (Households)	Non Domestic (Commerce & Institution)	Bulk Water	Total	Domestic (Households)	Non Domestic (Commerce & Institution)	Bulk Water	Total
2007	266,667	713,333	50,000	1,030,000	190,000	913,333	50,000	1,153,333
					71.2%	**128.0%**	**100.0%**	**112.0%**
2006	76,667	643,333	46,667	766,667	66,667	466,667	45,000	578,333
					87.0%	**72.5%**	**96.4%**	**75.4%**
2005	50,000	633,333	50,000	733,333	28,333	383,333	51,667	463,333
					56.7%	**60.5%**	**103.3%**	**63.2%**
2004	50,000	766,667	66,667	883,333	38,333	400,000	66,667	505,000
					76.7%	**52.2%**	**100.0%**	**57.2%**

Source: LWSC

LWSC also takes the following actions as a penalty for arrears:

- House connections (domestic and commercial): Unless users pay LWSC water tariff in grace period of 48hours after warning from LWSC, house connections are disconnected by LWSC. USD10 and USD5

are charged for commercial and domestic users respectively to re-connect the lines by LWSC.

- House connections (Institution such as governmental, international office): Unless users pay LWSC water tariff, appropriately, LWSC gives users a warning letter. However, most of the users settle down after receiving the warning letter.
- Kiosks: Unless water committees pay LWSC water tariff in grace period of three months after warning from LWSC, house connections are disconnected by LWSC. LWSC has not taken an action to disconnect the lines so far.

(6) Wastewater (Night Soil) Disposal Tariff

The existing sewerage system in Monrovia has been inoperative. However, LWSC charges beneficiaries sewerage tariff for disposing sewage and night soil. Sewerage tariff system is shown in Table 2.5-14. House connection users of water supply have an advantage in the sewerage tariff system. They are charged only 40% of the water tariff. On the other hand, house connection users for sewerage are charged USD10-15 monthly. This accounts for 6 to 10% of USD150 as monthly income of low income households. It is envisaged that this charge is not acceptable for the low income households.

Table 2.5-14 Sewerage Tariff

(Unit: USD)

Users	Category	Tariff
Customers having water supply and sewerage connections		40% of Water tariff
Customers having only sewerage connections	Two to three-bed room in a house	10 per month
	4-bed room in a house	15 per month
	Two-apartment building	50 per month
	Hotels	250 per month
	Other commercial centers	75 per month
Customers that rely on vacuum truck	Around Monrovia	100 per trip
	Bushrod Island	125 per trip
	Gardnerville/Paynesville	150 per trip
	Outside of Monrovia	Negotiable

Source: LWSC

2.5.3 Results of Hydrogeological Investigation

2.5.3.1 Watershed and Groundwater Basin

The watershed division of the study area is shown in Figure 2.1-11 in Section 2.1.2. Ordinarily a watershed corresponds with a groundwater basin. In the study area a groundwater basin without shallow portion is different from a watershed because of low and gentle undulation of the surface. Furthermore aquifer structure is supposed to spread widely through several watersheds. The groundwater basin of the study area is divided as follows:

1) Mesurado river north basin (Gb-1),
2) Monrovia south basin (Gb-2),
3) Du river Basin (Gb-3),
4) St. Paul river Basin (Gb-4), and
5) Bushrod Island Basin (Gb-5).

The groundwater basin division of the study area is shown in Figure 2.5-11.

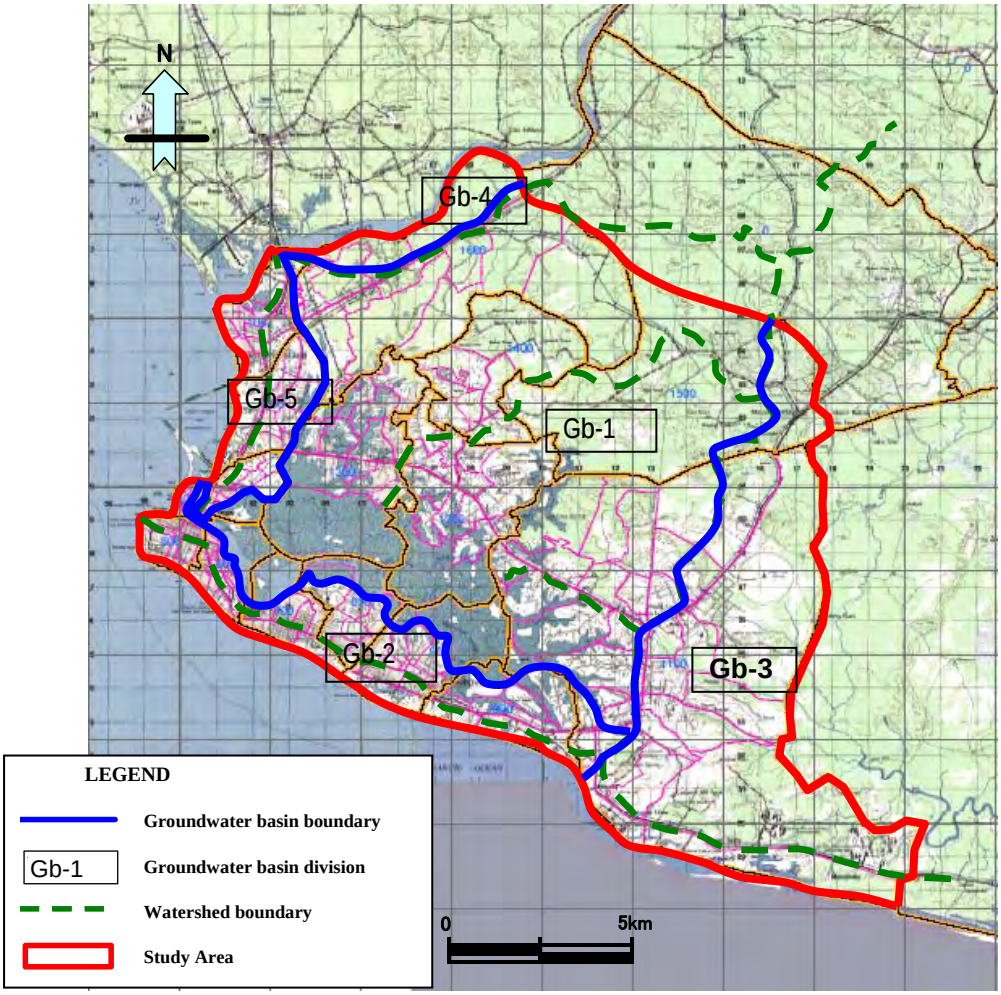


Figure 2.5-11 Groundwater Basin Division of the Study Area

2.5.3.2 Hydrological Condition

Hydrological data is very important to make analysis of groundwater condition, especially groundwater balance. In the study area the hydrological data is inadequate because of long-term missing observation during the civil war and the lack of observation system up to present. The report is obliged to use deficient data which is obtained from LHS.

(1) Rainfall

Monthly mean rainfall of every rainfall station surrounding Monrovia is shown in Figure 2.5-13.

Annual mean rainfall of every rainfall station is as follows;

(a) Monrovia area

1) Monrovia MPW (1944-1973): 4641mm
2) Sprigs Payne (1969-1981): 4199mm
3) ELWA (1971-1983): 4804mm

(b) Central to east area

1) Firestone Harble (1936-1989): 3096mm
2) Robertsfield Monrovia international airport (1949-1989): 3568mm
3) Agriculture Company (2000-2006): 3409mm

(c) Northern area

1) Bong mines (1961-1983): 2742mm
2) Salala Rubber Company (1961-1983): 2339mm

If it is disregarded that the mean annual rainfall of every station is mutually different observation period, the Isohyetal line is assumed as shown in Figure 2.5-12. In the study area, southern area is more than 4000mm zone; northern area is 3000mm-4000mm zone.

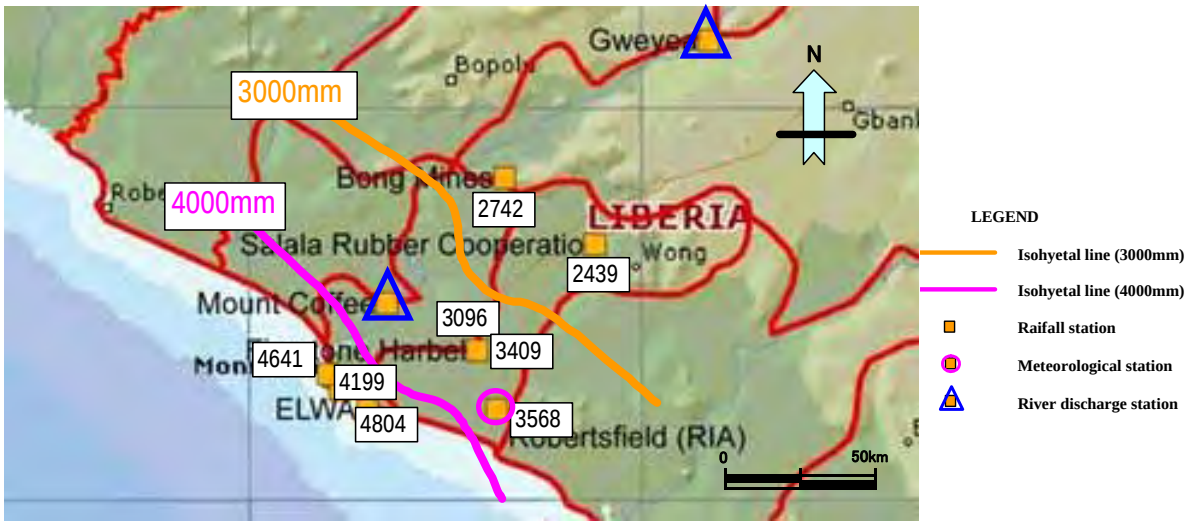


Figure 2.5-12 Isohyetal Line of Surrounding the Study Area

(2) River Discharge and Water Level

The river discharge and water level data of St. Paul river can collect following data from LHS.

(a) Discharge

1) Mount Coffee (April 1958 – Match 1961)
2) Gweyea (1971)

(b) Water Level

1) Gweyea (1961-1971)

The monthly mean discharge and water level is shown in Figure 2.5-14. The monthly mean discharge shows maximum 805m^3/sec in October at Gweyea and 1,045m^3/sec in September at Mount Coffee, minimum 42m^3/sec in April at Gweyea and 92m^3/sec in February at Mount Coffee. The mean annual discharge is 233m^3/sec at Gweyea and 531m^3/sec at Mount Coffee.

The daily discharge shows maximum 1920m^3/sec at Gweyea and 2334m^3/sec at Mount Coffee, and minimum 37m^3/sec at Gweyea and 57m^3/sec at Mount Coffee.

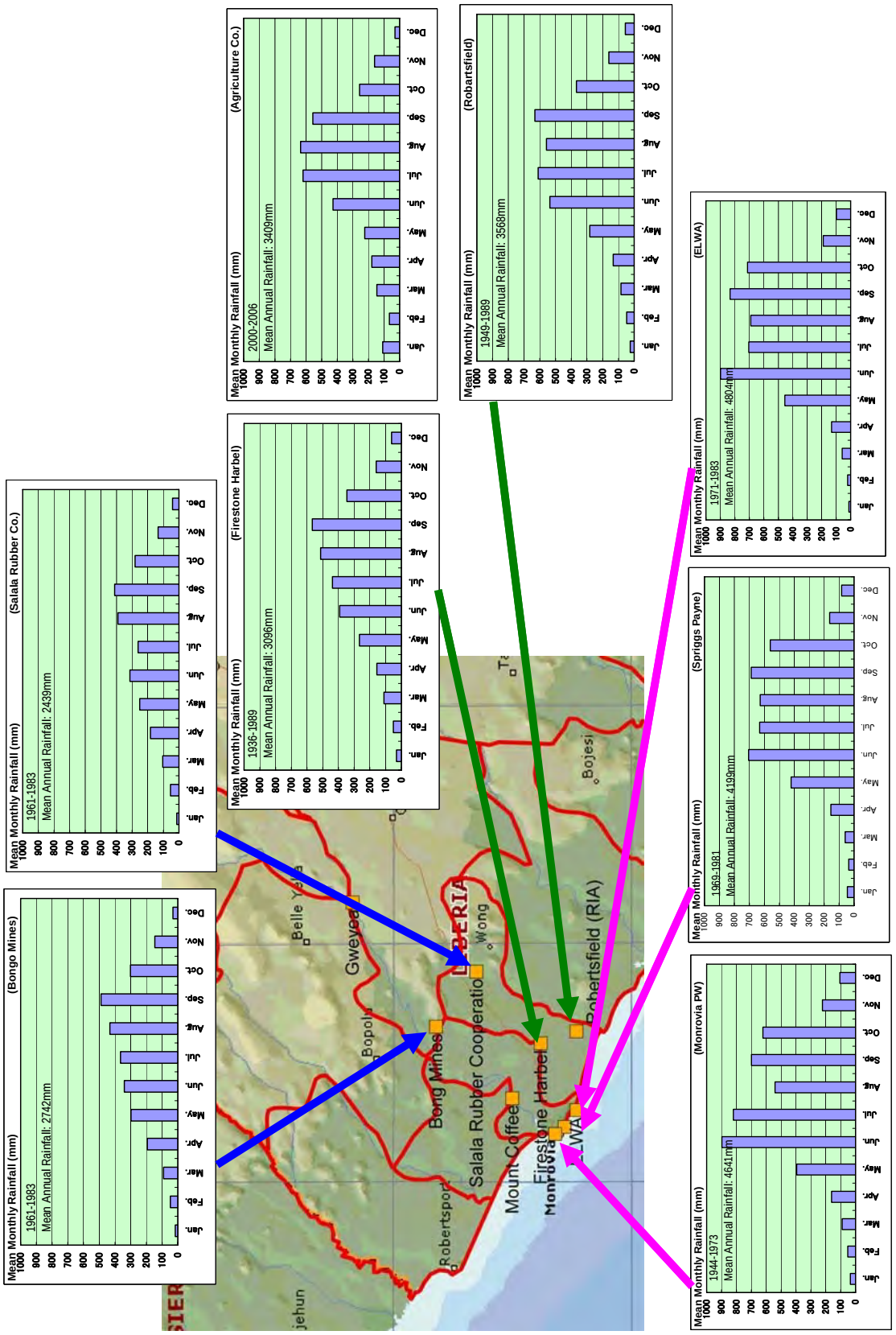


Figure 2.5-13 Monthly Mean Rainfall of Every Rainfall Station of Surrounding the Study Area

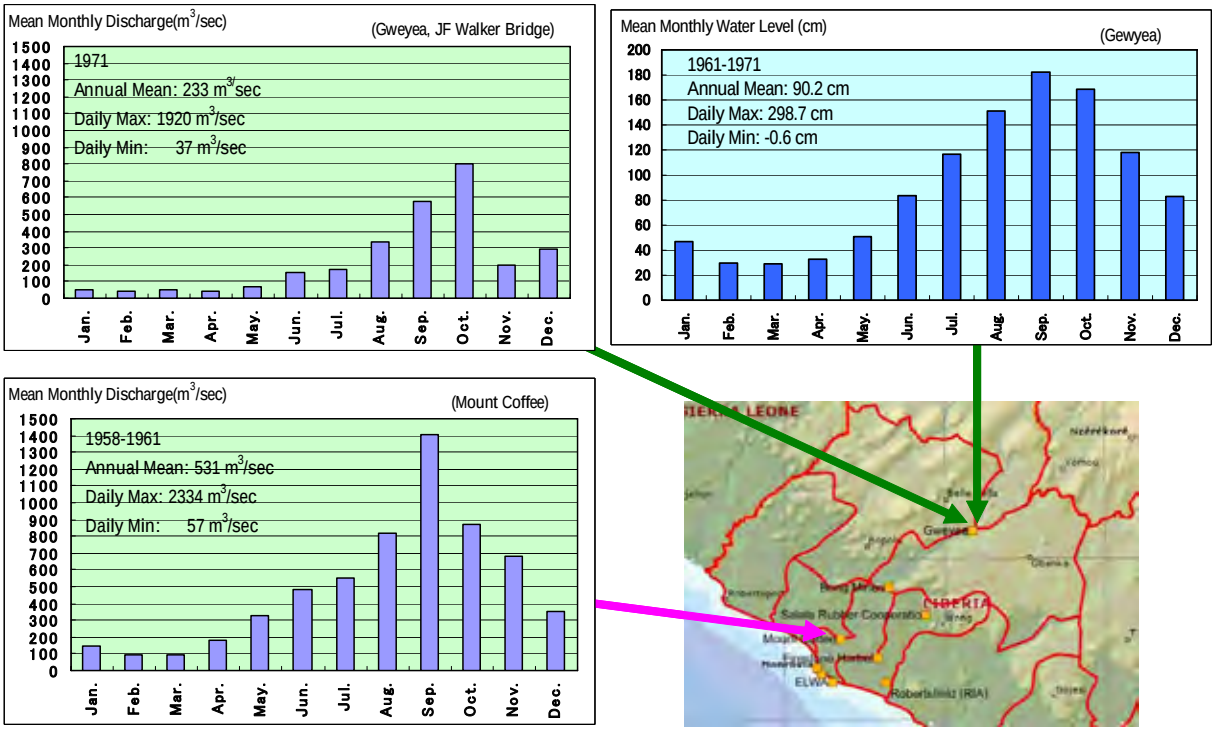


Figure 2.5-14 Monthly Mean Discharge and Water Level of St. Paul River

The monthly mean water level shows maximum 182.2cm in September and minimum 29.1cm in March at Gweyea. The mean annual water level is 90.2cm at Gweyea. The daily water level shows maximum 298.7cm and minimum -0.6cm at Gweyea. The water level record of Mount Coffee does not remain.

The discharge and water level of Mesurado river are not measured until now.

2.5.3.3 Possibility of Aquifer in Each Formation and Aquifer Structure

(1) Possibility of Aquifer in each formation

The possibility of aquifer assumed from the feature of formation is shown in Table 2.5-15. The feature of each formation as an aquifer is as follows:

(a) Shallow Aquifer

Quaternary beach and Fluvial deposit has possibility of aquifer for shallow well at sand and gravel portion. Quaternary deposit (Qb2 and Qf) is distributed widely and thinly at lowland on base rock. Quaternary deposit (Qb1) is distributed along the present coast.

Tertiary Edina sandstone has possibility of aquifer for shallow well. Edina sandstone is distributed thinly at upstream of Mesurado river.

(b) Deep Aquifer

Cretaceous Farmington river formation has possibility of aquifer for deep well at sandstone portion. But the formation is not indicated in the study area on the geological map. It is supposed to underline under Quaternary deposit at east side.

Devonian Paynesville sandstone has possibility of good aquifer for deep well. Paynesville formation is not simple and monotonous stratum. It sometimes intercalates mudstone, siltstone, shale and alternation. Although it is said that formation thickness exceeds 1000m, for its development, investigation is required.

(c) Dike and Intrusive Rock

Jurassic Diabase generally has no possibility of aquifer because of hard rock. However, cracky portion or fissure portion at nearby boundary has possibility of groundwater presence. It is supposed to be rather difficult to encounter the cracky or fissure portion.

(d) Base Rock

Base rock of Precambrian generally is non aquifer. However, highly weathered portion or fissure portion nearby fault has possibility of groundwater presence. But, weathered portion of melanocratic gneiss easily becomes clay or silt condition due to mafic rich mineral composition. It is supposed to be rather difficult to encounter the deep weathered portion or fissure portion.

Table 2.5-15 Possibility of Aquifer in Each Formation

Symbol	Formation	Feature as Aquifer	Possibility of Aquifer
Qb/Qf	Beach and Fluvial Deposit	Quaternary deposit is supposed to be thinly deposited on the lowlands of the stable basin. Sand strata have possibility of an aquifer for shallow well.	Possible for shallow well
Te	Edina Sandstone	Tertiary sandstone has possibility of an aquifer. However, according to literature, this formation is as thin as several meters.	Possible for shallow well
Kf	Farmington River Formation	Sandstone formation has possibility of an aquifer. However, the distribution of this formation is not well known in the study area.	Unknown in the study area
Jd	Diabase	Generally dike and intrusive rock has not possibility of an aquifer, However, Crackly zone or boundary portion with fissure sometimes storage groundwater.	Unsuitable for well
Dp	Paynesville Sandstone	Sandstone formation has high possibility of an aquifer. Sometimes mudstone and shale layer are intercalated.	Possible for deep well
gnl	Leucocratic Gneiss	Generally this formation is non aquifer because of hard rock of a part of Precambrian craton. Highly weathered or fissure zone has possibility of ground water presence	Unsuitable for well
gnm	Melanocratic Gneiss	Generally this formation is non aquifer because of hard rock of a part of Precambrian craton. Fissure zone nearby fault has possibility of ground water presence	Unsuitable for well

(2) Structure of Aquifer

The main aquifer is the Paynesville sandstone. The distribution of Paynesville sandstone on geological cross section is shown in Figure 2.5-15. The Paynesville sandstone shows the trend to decline and become thick towards the south and the east. The Paynesville sandstone receives the intrusion of Jurassic diabase in many parts. The inside structure of the Paynesville sandstone, especially distribution of intercalated mudstone, siltstone and shale will become clear by progress of this investigation.

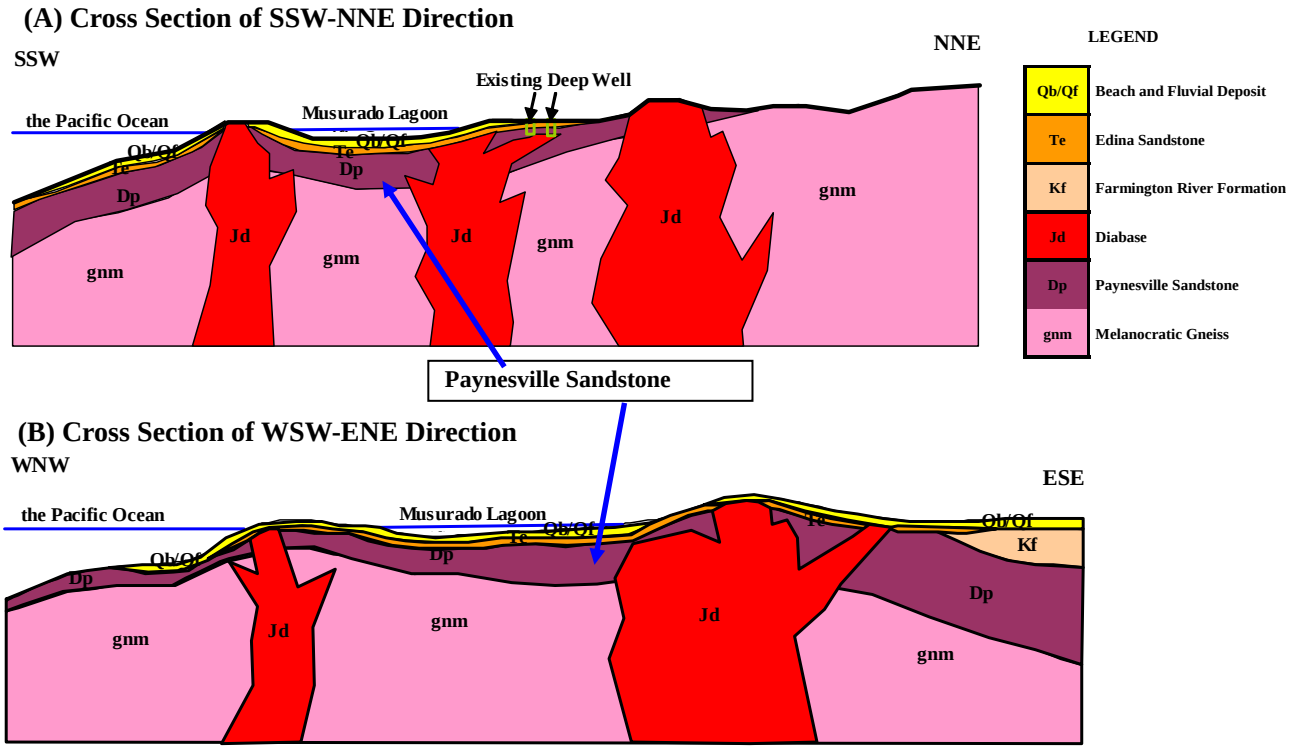


Figure 2.5-15 Schematic Geological Cross Section and Structure of Paynesville Sandstone

(3) Situation of Existing Production Well

The information from two existing deep wells can be gathered. The lithological log of LWSC's production wells is shown in Figure 2.5-16.

(a) Well No.1

At well No.1 it is possible to have Quaternary or Tertiary Edina formation up to 23m including gravel layer, Devonian Paynesville sandstone up to 23.5m, and Jurassic diabase dike under 23,5m. Total depth is 32m. The 6" screen is installed in 5m section of clayey sand and conglomerate layer, 5m section of sandy gravel layer and 2m section of clay with sand layer. The submergible pump is set in a depth of 23.8m. Water level is 3.0m in Dec.1992 and 2.8m in Oct. 1996. The yield is 200m^3/day.

(b) Well No.2

At well No.2 it is possible to have Devonian Paynesville sandstone up to 42m, and Jurassic diabase dike under 42m. Total depth is 48m. The 6" screen is installed in 23.5m section of sand and upper part of sandstone, and 5m section of lower part of sandstone. The submergible pump is set in a depth of 31.0m. Water level is 2.6m in Jul. 1996 and 4.9m in Apr. 1996. The yield is 60m^3/day.

(4) Estimation of Hydraulic Parameter

Since the pumping test data does not remain, the following assumptions are set, and the hydraulic parameters are calculated to grasp a rough hydraulic situation.

(a) Well No.1

Yield: 417lit/min as 8hours pump work for 200m^3/day, Drawdown: 5m to 10m, Aquifer thickness: 25m from lithological condition, Well diameter 6", Unconfined aquifer condition, Full penetrating well, and Coefficient of storage: 5 x 10^{-2} as sand and gravel of unconfined aquifer are assumed.

The results of calculation by Jacob's non equilibrium equation with unconfined aquifer corrections are as follows:

1) Transmissibility of Quaternary deposit or Edina formation; 40-106 m^3/day/m
2) Permeability of Quaternary deposit or Edina formation; 1.8 x 10^{-5} – 4.9 x 10^{-5} m/sec

According to 1 hour yield test of existing data, Yield 7.58 lit/sec, Drawdown: 5.38m after 1 hour pumping, and other condition: same as mentioned above.

The results of calculation by Jacob's non equilibrium equation are as follows;

1) Transmissibility of Quaternary deposit or Edina formation; 87 m^3/day/m
2) Permeability of Quaternary deposit or Edina formation; 5.6 x 10^{-5} m/sec

(b) Well No.2

Yield: 125lit/min as 8hours pump work for 60m^3/day, Drawdown: 5m to 10m, Aquifer thickness: 28.5m as affective screen section, Well diameter 6", Confined aquifer condition, Full penetrating well, and Coefficient of storage: 1.0 x 10^{-3} as dense sand of confined aquifer are assumed.

The results of calculation by Jacob's non equilibrium equation are as follows;

1) Transmissibility of Paynesville sandstone; 21-45 m^3/day/m
2) Permeability of Paynesville sandstone; 8.6 x 10^{-6} – 1.8 x 10^{-5} m/sec

Table 2.5-16 Estimated Hydraulic Parameter of Existing Production Wells

Item		Well No.1	Well No.2
Transmissibility	m^3/sec/m	4.6 x 10^{-4} – 1.2 x 10^{-3}	2.5 x 10^{-4} – 5.2 x 10^{-4}
	m^3/day/m	40 – 106	21 – 45
Storability		5 x 10^{-2}	1 x 10^{-3}
Permeability Coefficient (m/sec)		2.5 x 10^{-5} – 6.8 x 10^{-5}	8.6 x 10^{-6} – 1.8 x 10^{-5}

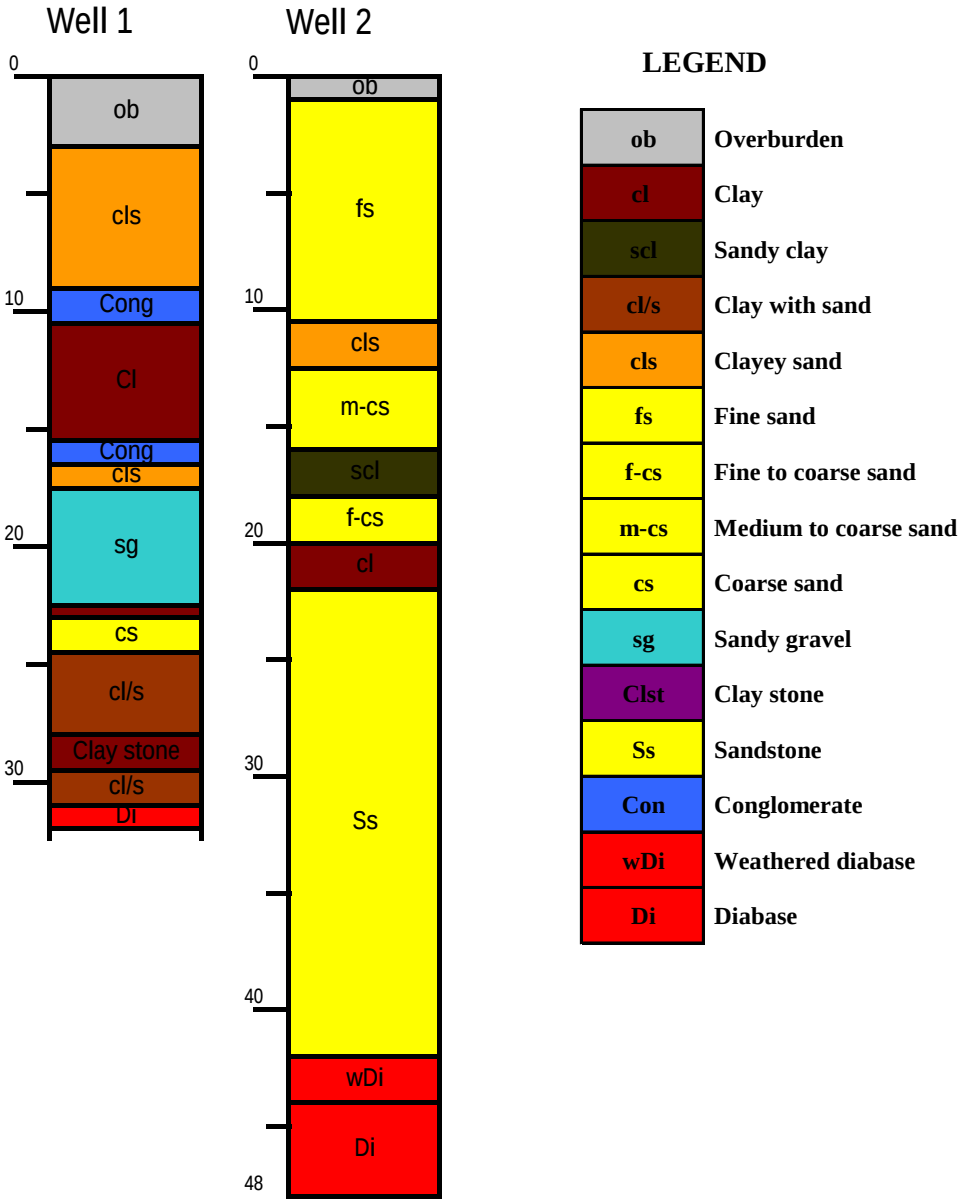


Figure 2.5-16 Lithological Log of LWSC's Production Wells

2.5.3.4 Well Inventory Investigation

(1) Well Inventory Survey

The well inventory survey was carried out from 9th Jan. 2009 to 3rd Feb. 2009 by 3 survey teams including a hydrogeologist of the JICA Study Team to confirm groundwater use condition. 3 to 12 wells per each community, total 826 wells were surveyed. It covers almost all communities in the study area. Although at the beginning the survey aimed at 5 wells and more per each community. According to the old community boundary, rearrangement by new community boundary set by LISGIS was performed after the survey.

The well inventory record is arranged as the one of data base in the GIS system. The table of well inventory including main items for aggregation is also arranged as the data base in the GIS system. The location of well inventory is shown in Figure 2.5-17. An well inventory record is shown in Figure 2.5-18 as an example.

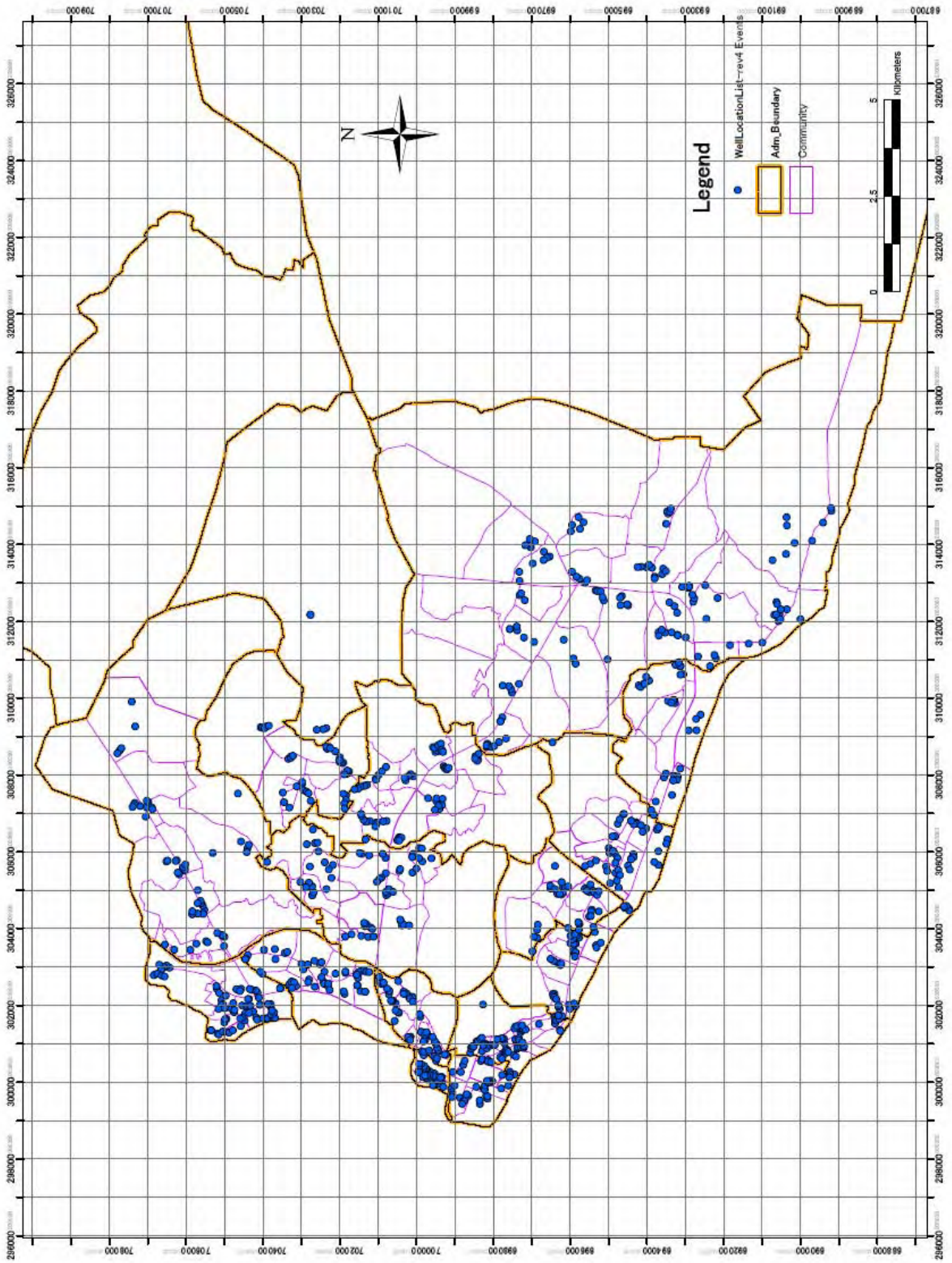


Figure 2.5-17 Location of Inventory Well

WELL INVENTORY					101-2
Registered Well Numbe or Well Name			NPHC - 012		
Construction Year	**1990**	**Provider**	Koiboi Nuatah		
Location	**Community Name**	Bong Mine Bridge			
	Coordinates(GPS:UTM	Easting	0302447	Northing	0703544
Depth of Well	3.55 m	**Structure of Well**	**Hand Pump/Hand Drawing**		
Casing Depth	Culverts (0.9m)	**Screen Depth**	**N/A**		
Ground Elevation	**EL. -1 m(GPS)**	**Ground Water Level**	**GL- 1.60 m**		
Ground Water Elevation	**EL. 3.4 m**	**Survey date**	**9th / Jan. / 2009**		

Photo of Well

Water Usage	**Drinking Water** **Washing etc.** **Others (Gardening, Car wash)**
Situation of daily use of the Well	**Pumping Hour: 24** **Estimete yield Volume** **300 Gallon/day**
Number of person who use the Well usually	**15**
Others	

Water Quality

Water Temparature	**28.9°C**
pH	**7.03**
EC	**45.70**
DO	
Turbidity	
TDS	
Colour	
Salt	

Note	**Pump removed - open well/water log**

Figure 2.5-18 Well Inventory Record (An Example of Well Inventory Record Form)

(2) Feature of Well Condition of Every Zone

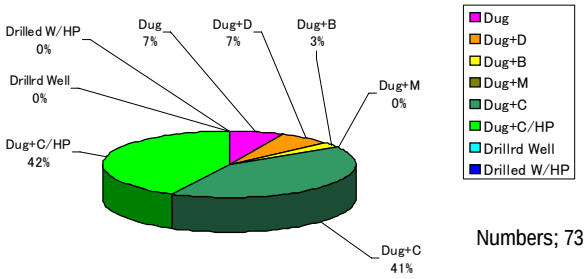
The feature of well condition of every zone is as follows;

(a) New Kru Town

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 14%. It indicates that rather many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 44%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 42%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.0 to 7.5m (Average 3.7m). Water level is 0.9 to 4.6 m (Average 2.2m).

< Well equipment >

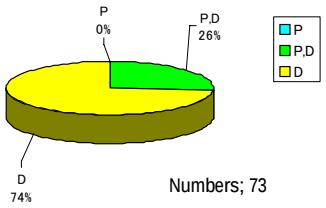


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	19.0	Max.	7.5	Max.	4.6	Max.	16.2
Min.	2.0	Min.	1.0	Min.	0.9	Min.	0.8
Average	9.0	Average	3.9	Average	2.2	Average	6.9
Median	9.0	Median	3.7	Median	2.1	Median	6.9
Mode	12.0	Mode	4.3	Mode	1.9	Mode	2.1
Total N	71	Total N	59	Total N	42	Total N	42

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 26%. It means that wells which can not be used as portable water are rather many. According to the conducted interviews, water users per well range between 11 and 1000 persons (Average of about 238 persons). Per capita water use volume is 10 to 60 gallons/day (Average 36.3 gallons/day).

< Purpose of groundwater use >

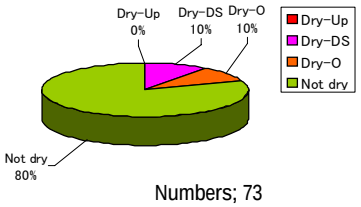


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	1000	Max.	60.0	(X1,000 Gal/day)	
Min.	11	Min.	10.0		
Average	238	Average	35.3	Average	2,593
Median	200	Median	40.0		
Mode	300	Mode	50.0		
Total N	73	Total N	73		

3) Dry-up condition, other condition as resident consciousness and water quality

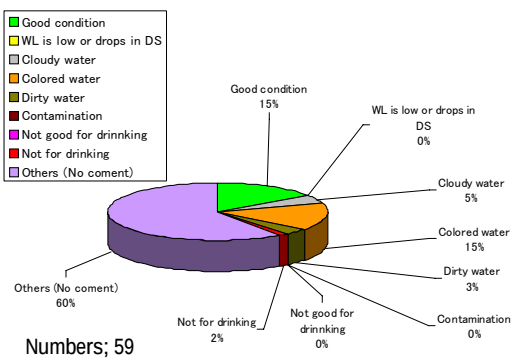
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 20%. It shows rather severe conditions. Other negative conditions like resident consciousness such as cloudy water, colored water, dirty water and not-for-drinking water is 25%. The pH is low in some wells (pH<0.6).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.8	Max.	7.9	Max.	68.6
Min.	27.8	Min.	4.7	Min.	8.0
Average	29.0	Average	6.4	Average	33.1
Median	29.0	Median	6.6	Median	30.9
Mode	29.2	Mode	5.7	Mode	34.4
Total N	72	Total N	72	Total N	72

< Other conditions as resident consciousness >

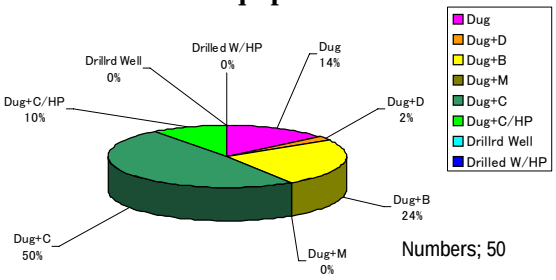


(b) Logan Town

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and Dug wells with drum as mouth protection (Dug+D) are 16%. It indicates that rather many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 74%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 10%. It shows that the maintenance of well equipment is not so progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.2 to 6.1m (Average 2.9m). Water level is 0.9 to 3.3 (Average 1.7).

< Well equipment >

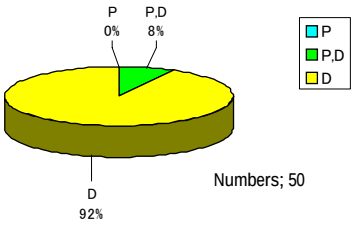


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	14.0	Max.	6.1	Max.	3.3	Max.	12.8
Min.	1.0	Min.	1.2	Min.	0.9	Min.	0.8
Average	7.4	Average	2.9	Average	1.7	Average	5.7
Median	7.5	Median	2.7	Median	1.7	Median	5.4
Mode	9.0	Mode	1.8	Mode	1.0	Mode	3.0
Total N	50	Total N	47	Total N	43	Total N	43

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 8% only. It means that wells which can not be used as portable water are many. According to the conducted interviews, water users per well range between 30 and 700 persons (Average of about 398 persons). Per capita water use volume is 20 to 50 gallons/day (Average 39.3 gallons/day).

< Purpose of groundwater use >

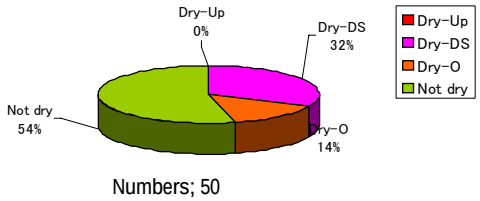


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	700	Max.	50.0		
Min.	30	Min.	20.0		
Average	259	Average	39.8	Average	2,315
Median	200	Median	40.0		
Mode	200	Mode	40.0		
Total N	50	Total N	50		

3) Dry-up condition, other condition as resident consciousness and water quality

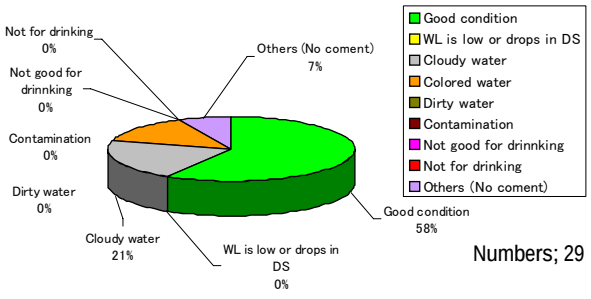
Dry-up in dry season (Dry-DS) and dry-up by excessive drawing are 46%. It shows severe condition. Other negative conditions as resident consciousness such as cloudy water and colored water are 35%. The pH is low in some wells (pH<6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.6	Max.	7.2	Max.	86.9
Min.	27.6	Min.	4.4	Min.	10.0
Average	28.5	Average	6.5	Average	36.1
Median	28.5	Median	6.6	Median	31.9
Mode	28.1	Mode	6.9	Mode	70.5
Total N	50	Total N	50	Total N	50

< Other conditions as resident consciousness >

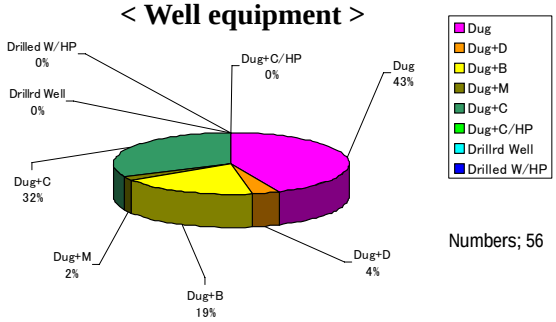


(c) Clara Town

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 52%. It indicates that many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B), dug wells with masonry protection (Dug+M) and dug wells with concrete protection (Dug+C) are 46%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 0%. It shows that the maintenance of well equipment is not progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 0.8 to 3.6m (Average 1.6m). Water level is 0.2 to 2.1 m (Average 1.1m).

< Well equipment >

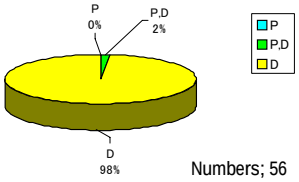


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	13.0	Max.	3.6	Max.	2.1	Max.	11.4
Min.	1.0	Min.	0.8	Min.	0.2	Min.	0.2
Average	5.7	Average	1.6	Average	1.1	Average	4.6
Median	6.0	Median	1.5	Median	1.1	Median	4.6
Mode	7.0	Mode	1.9	Mode	1.3	Mode	4.7
Total N	56	Total N	55	Total N	54	Total N	54

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is only 2%. It means that wells which can be used as portable water are very rare. According to the conducted interviews, water users per well range between 30 and 600 persons (Average of about 210 persons). Per capita water use volume is 10 to 50 gallons/day (Average 27.6 gallons/day).

< Purpose of groundwater use >

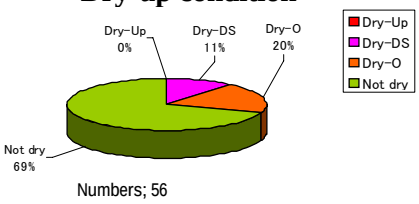


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	600	Max.	50.0		
Min.	30	Min.	10.0		
Average	210	Average	27.6	Average	1,530
Median	200	Median	30.0		
Mode	200	Mode	20.0		
Total N	56	Total N	56		

3) Dry-up condition, other conditions as resident consciousness and water quality

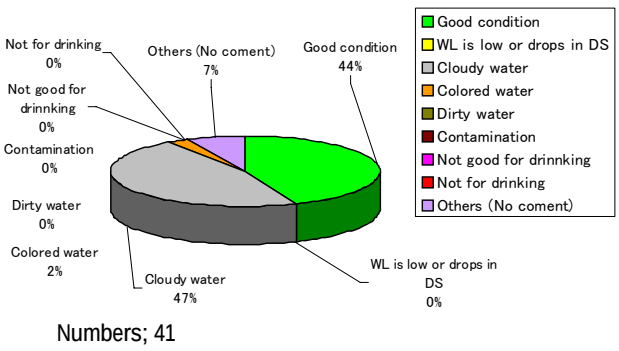
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 31%. It shows severe condition. Other negative conditions as resident consciousness such as cloudy water, colored water, dirty water and not-for-drinking water is 49%. The pH is high in some wells (ph>9.0). The electric conductivity is high in some wells (EC>100mS/m).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	51.9	Max.	10.0	Max.	167.1
Min.	25.2	Min.	6.0	Min.	0.3
Average	28.9	Average	7.2	Average	76.8
Median	27.9	Median	7.3	Median	80.3
Mode	27.8	Mode	6.4	Mode	121.2
Total N	54	Total N	54	Total N	54

< Other conditions as resident consciousness >

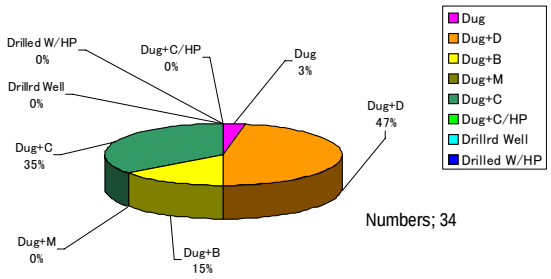


(d) West Point

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 45%. It indicates that many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 50%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 0%. It shows that the maintenance of well equipment is not progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.2 to 6.2m (Average 2.7m). Water level is 0.9 to 3.5 m (Average 2.1m).

< Well equipment >

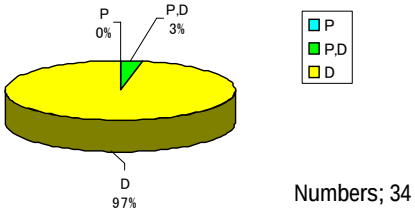


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	8.0	Max.	6.2	Max.	3.5	Max.	7.2
Min.	3.0	Min.	1.2	Min.	0.9	Min.	0.8
Average	5.7	Average	2.7	Average	2.1	Average	3.7
Median	6.0	Median	2.8	Median	1.9	Median	3.5
Mode	7.0	Mode	1.8	Mode	1.2	Mode	3.8
Total N	34	Total N	34	Total N	34	Total	34

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 3%. It means that wells which can be used as portable water are very rare. According to the conducted interviews, water users per well range between 75 and 600 persons (Average of about 254 persons). Per capita water use volume is 20 to 50 gallons/day (Average 31.5 gallons/day).

< Purpose of groundwater use >

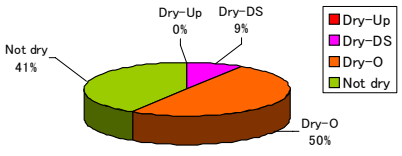


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	600	Max.	50.0	(X1,000 Gal/day)	
Min.	75	Min.	20.0		
Average	254	Average	31.5	Average	929
Median	200	Median	30.0		
Mode	200	Mode	30.0		
Total	34	Total	34		

3) Dry-up condition, other condition as resident consciousness and water quality

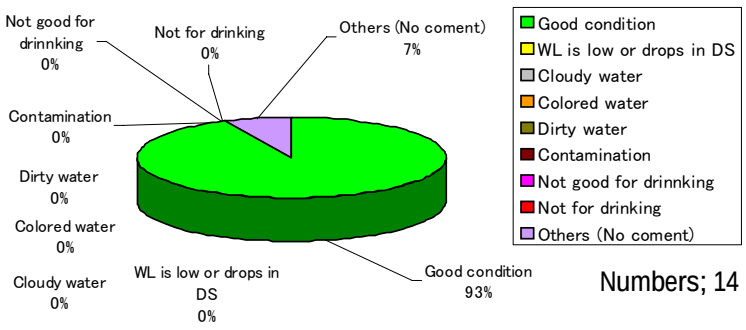
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 59%. It shows very severe condition. Other negative conditions as resident consciousness are nothing. Residents feel water yield and quality is in rather good condition. But, the pH is high in some wells (ph>9.0) and electric conductivity is high in some wells (EC>100mS/m).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.6	Max.	12.0	Max.	114.8
Min.	26.4	Min.	7.2	Min.	39.4
Average	28.2	Average	8.1	Average	80.2
Median	28.3	Median	7.9	Median	77.1
Mode	28.3	Mode	7.9	Mode	-
Total	33	Total	33	Total	32

< Other conditions as resident consciousness >

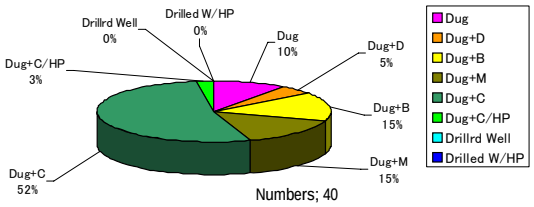


(e) Central Monrovia A

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 15%. It indicates that rather many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B), dug wells with masonry protection (Dug+M) and dug wells with concrete protection (Dug+C) are 82%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 3%. It shows that the maintenance of well equipment is not so progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.2 to 8.7m (Average 4.6m). Water level is 0.8 to 8.5 m (Average 4.0m).

< Well equipment >

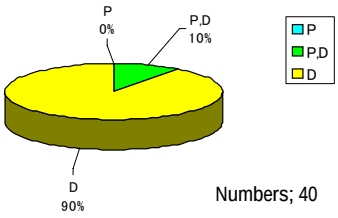


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	53.0	Max.	8.7	Max.	8.5	Max.	44.6
Min.	4.0	Min.	1.2	Min.	0.8	Min.	0.3
Average	14.9	Average	4.6	Average	4.0	Average	10.7
Median	10.0	Median	4.2	Median	3.7	Median	7.6
Mode	10.0	Mode	2.8	Mode	2.5	Mode	3.3
Total N	40	Total N	40	Total N	38	Total N	38

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 10%. It means that wells which can not be used as portable water are rather many. According to the conducted interviews, water users per well range between 25 and 1000 persons (Average of about 233 persons). Per capita water use volume is 3 to 50 gallons/day (Average 27.8 gallons/day).

< Purpose of groundwater use >

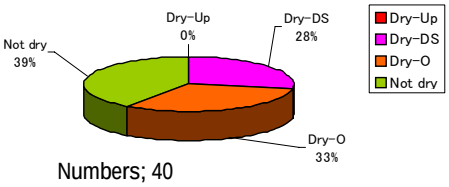


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	1000	Max.	50.0	(X1,000 Gal/day)	
Min.	25	Min.	2.7		
Average	233	Average	27.8	Average	1,173
Median	200	Median	30.0		
Mode	200	Mode	30.0		
Total N	40	Total N	38		

3) Dry-up condition, other condition as resident consciousness and water quality

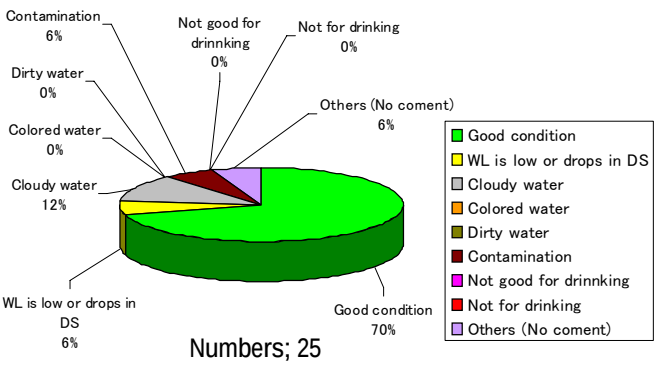
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 61%. It shows an extreme severe condition. Other negative conditions as resident consciousness such as water level is low, cloudy water, colored water, contamination is 24%. The pH is high in some wells (pH>9.0), and pH is low in some wells (pH<6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.7	Max.	10.1	Max.	89.9
Min.	20.6	Min.	5.1	Min.	13.1
Average	28.2	Average	8.2	Average	53.1
Median	28.5	Median	8.0	Median	52.2
Mode	28.9	Mode	7.8	Mode	56.8
Total N	40	Total N	40	Total N	40

< Other conditions as resident consciousness >

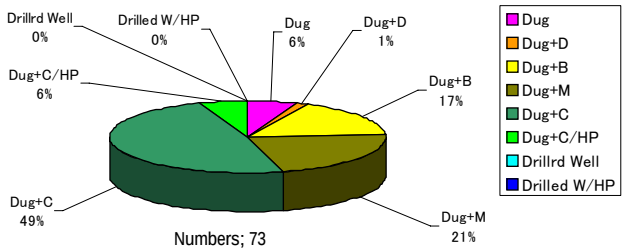


(f) Central Monrovia B

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 7%. It indicates that rather few wells of inferior circumstance still remain. Dug wells with block protection (Dug+B), dug wells with masonry protection (Dug+M) and dug wells with concrete protection (Dug+C) are 71%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 8%. It shows that the maintenance of well equipment is little progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.5 to 10.2m (Average 4.4m). Water level is 0.2 to 8.7 m (Average 3.1m).

< Well equipment >

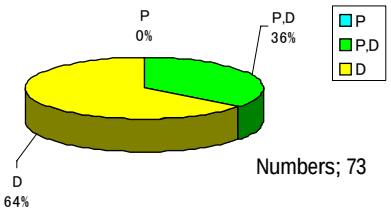


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	41.0	Max.	10.2	Max.	8.7	Max.	35.6
Min.	2.0	Min.	1.5	Min.	0.2	Min.	-0.2
Average	14.0	Average	4.4	Average	3.1	Average	10.3
Median	11.0	Median	4.1	Median	2.5	Median	8.6
Mode	9.0	Mode	3.9	Mode	2.2	Mode	8.8
Total N	73	Total N	72	Total N	64	Total N	64

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 36%. It means that wells which can not be used as portable water are rather many. According to the conducted interviews, water users per well range between 4 and 1500 persons (Average of about 229 persons). Per capita water use volume is 4 to 100 gallons/day (Average 30.2 gallons/day).

< Purpose of groundwater use >

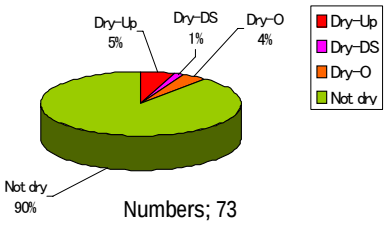


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	1500	Max.	100.0		
Min.	4	Min.	4.0		
Average	229	Average	30.2	Average	1,230
Median	100	Median	30.0		
Mode	100	Mode	10.0		
Total N	73	Total N	71		

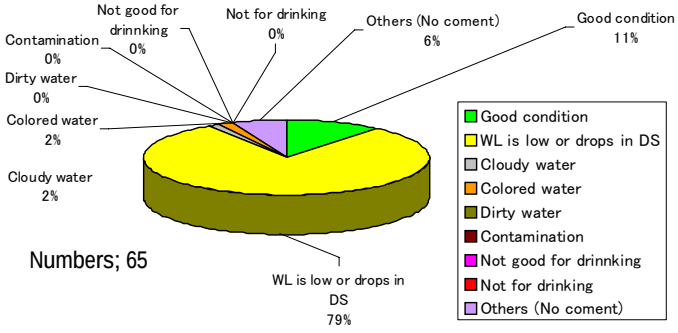
3) Dry-up condition, other condition as resident consciousness and water quality

Dry-up usually (Dry-up), Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 10%. It shows a rather little condition. Other negative conditions as resident consciousness such as cloudy water and colored water are 4%. The pH is high in some wells (pH>9.0), and electric conductivity is high in some wells (EC>100mS/m).

< Dry-up condition >



< Other conditions as resident consciousness >



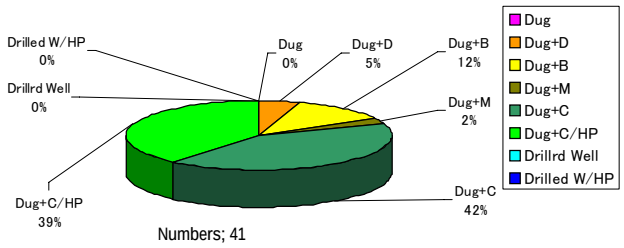
Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.4	Max.	10.2	Max.	130.2
Min.	25.1	Min.	6.0	Min.	14.9
Average	27.6	Average	7.5	Average	49.5
Median	27.6	Median	7.5	Median	44.3
Mode	27.8	Mode	7.5	Mode	26.7
Total N	71	Total N	71	Total N	71

(g) Sinkor

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 5%. It indicates that few wells of inferior circumstance still remain. Dug wells with block protection (Dug+B), dug with masonry protection (Dug+M) and dug wells with concrete protection (Dug+C) are 62%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 39%. It shows that the maintenance of well equipment is progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.7 to 11.0m (Average 4.6m). Water level is 0.9 to 6.9 m (Average 2.6m).

< Well equipment >

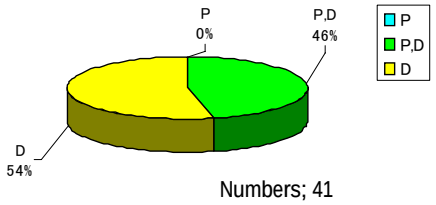


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	29.0	Max.	11.0	Max.	6.9	Max.	22.0
Min.	2.0	Min.	1.7	Min.	0.9	Min.	0.2
Average	11.9	Average	4.6	Average	2.6	Average	8.5
Median	10.0	Median	4.8	Median	1.9	Median	7.1
Mode	9.0	Mode	1.8	Mode	0.9	Mode	-
Total N	41	Total N	39	Total N	24	Total N	24

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 46%. It means that wells which can be used as portable water are rather many. According to the conducted interviews, water users per well range between 25 and 500 persons (Average of about 130 persons). Per capita water use volume is 10 to 100 gallons/day (Average 42.3 gallons/day).

< Purpose of groundwater use >

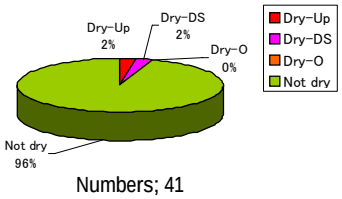


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	500	Max.	100.0	(X1,000 Gal/day)	
Min.	25	Min.	10.0		
Average	130	Average	42.3	Average	1,850
Median	100	Median	50.0		
Mode	100	Mode	50.0		
Total N	41	Total N	40		

3) Dry-up condition, other condition as resident consciousness and water quality

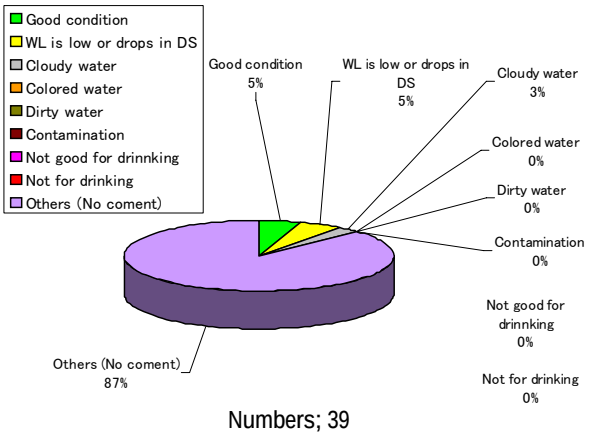
Dry-up usually (Dry-up) and Dry-up in dry season (Dry-DS) are 4%. It shows that dry-up condition is rare. Other negative conditions as resident consciousness such as low water level and cloudy water are 6%. The pH and electric conductivity indicate good condition

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.3	Max.	7.2	Max.	66.8
Min.	27.2	Min.	5.4	Min.	11.0
Average	28.9	Average	6.5	Average	27.2
Median	28.8	Median	6.5	Median	26.8
Mode	28.8	Mode	6.6	Mode	33.4
Total N	40	Total N	40	Total N	40

< Other conditions as resident consciousness >

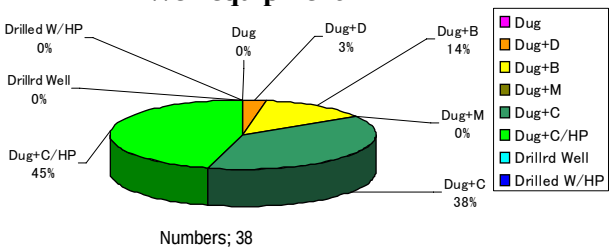


(h) Lakpazee

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 3%. It indicates that very few wells of inferior circumstance remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 52%. Dug wells with concrete cover and hand pump (Dug+C/HP) is 45%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.0 to 10.7m (Average 4.7m). Water level is 0.6 to 5.3m (Average 2.2m).

< Well equipment >



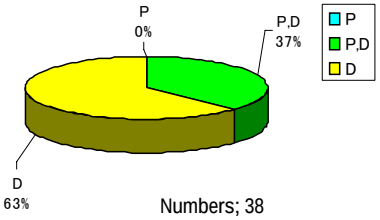
Numbers; 38

Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	24.0	Max.	10.7	Max.	5.3	Max.	20.4
Min.	2.0	Min.	1.0	Min.	0.6	Min.	0.5
Average	9.9	Average	4.7	Average	2.2	Average	6.5
Median	9.0	Median	4.3	Median	2.0	Median	6.4
Mode	4.0	Mode	1.4	Mode	0.9	Mode	-
Total N	38	Total N	33	Total N	22	Total N	22

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 37%. It means that wells which can be used as portable water are rather many. According to the conducted interviews, water users per well range between 8 and 1000 persons (Average of about 148 persons). Per capita water use volume is 15 to 50 gallons/day (Average 38.2 gallons/day).

< Purpose of groundwater use >



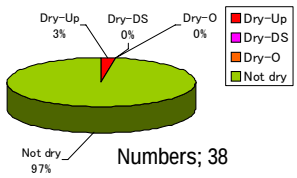
Numbers; 38

Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	1000	Max.	50.0		
Min.	8	Min.	15.0		
Average	148	Average	38.2	Average	1,608
Median	100	Median	40.0		
Mode	100	Mode	50.0		
Total N	38	Total N	37		

3) Dry-up condition, other condition as resident consciousness and water quality

Dry-up usually (Dry-up) is 3%. It shows that dry-up condition is rare. Other negative conditions as resident consciousness such as cloudy water is 3%, but, pH is high in some wells (pH>9.0), pH is low in some wells (pH<6.0) and electric conductivity is high in some wells (EC>100).

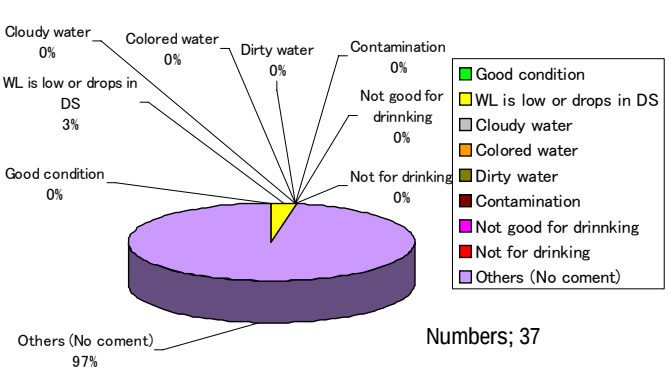
< Dry-up condition >



Numbers; 38

Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.6	Max.	11.1	Max.	129.5
Min.	27.9	Min.	5.5	Min.	5.3
Average	29.1	Average	7.0	Average	27.2
Median	29.0	Median	6.6	Median	25.1
Mode	28.9	Mode	6.5	Mode	-
Total N	36	Total N	36	Total	36

< Other conditions as resident consciousness >



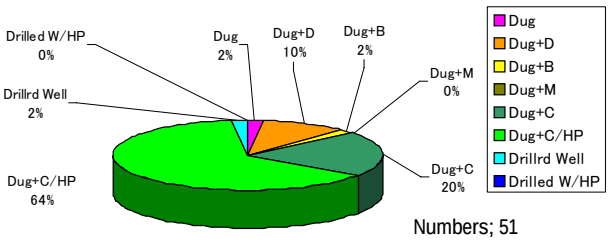
Numbers; 37

(i) Old Road

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 12%. It indicates that rather many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 22%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 64%. Drilled wells without hand pump are 2%. It shows that the maintenance of well equipment is progressing, but it is not enough. Dug well diameter is 0.9 to 1.2 m. Drilled well casing diameter is 10cm. Total depth is 1.3 to 10.4m (Average 5.6m). Water level is 1.0 to 5.6 m (Average 3.0m).

< Well equipment >

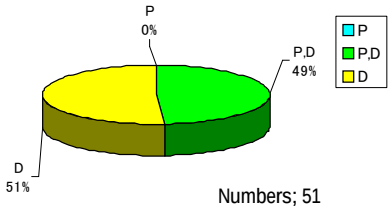


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	51.0	Max.	10.4	Max.	5.6	Max.	45.8
Min.	2.0	Min.	1.3	Min.	1.0	Min.	0.1
Average	11.5	Average	5.6	Average	3.0	Average	8.3
Median	10.0	Median	5.8	Median	2.8	Median	7.7
Mode	10.0	Mode	5.0	Mode	4.9	Mode	-
Total N	51	Total N	39	Total N	18	Total N	18

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 49%. It means that wells which can be used as portable water are rather many. According to the conducted interviews, water users per well range between 6 and 500 persons (Average of about 205 persons). Per capita water use volume is 3 to 75 gallons/day (Average 22.3 gallons/day).

< Purpose of groundwater use >

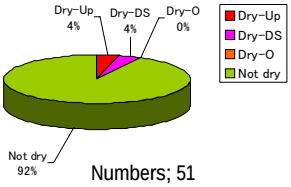


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	500	Max.	75.0		
Min.	6	Min.	3.0		
Average	205	Average	22.3	Average	1,078
Median	200	Median	15.0		
Mode	200	Mode	5.0		
Total N	47	Total N	47		

3) Dry-up condition, other conditions as resident consciousness and water quality

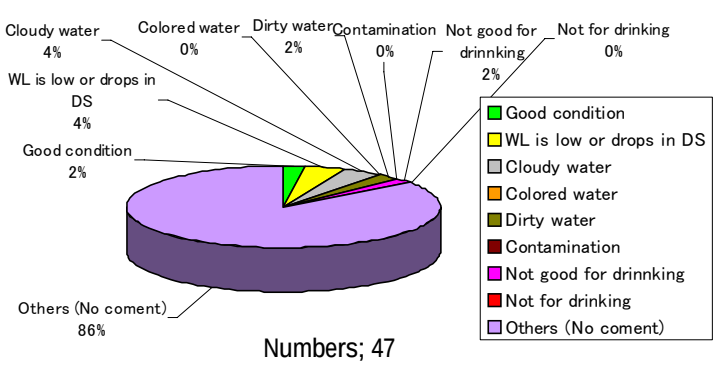
Dry-up usually (Dry-up), Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 8%. It shows dry-up condition is rather few. Other negative conditions as resident consciousness such as low water level, cloudy water, dirty water and not-for-good-drinking water are 12%. The pH and electric conductivity indicate good condition.

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.3	Max.	7.0	Max.	62.8
Min.	27.8	Min.	5.2	Min.	5.4
Average	29.2	Average	6.4	Average	22.9
Median	29.2	Median	6.4	Median	20.7
Mode	29.3	Mode	6.2	Mode	30.7
Total N	46	Total N	47	Total N	47

< Other conditions as resident consciousness >

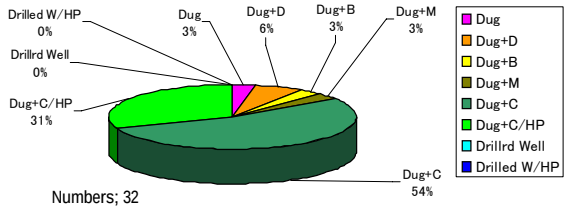


(j) Congo Town

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 9%. It indicates that rather few wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 60%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 31%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.7 to 13.0m (Average 5.3m). Water level is 1.3 to 9.6 m (Average 5.7m).

< Well equipment >

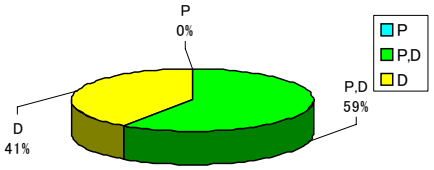


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	25.0	Max.	13.0	Max.	9.6	Max.	20.5
Min.	4.0	Min.	1.7	Min.	1.3	Min.	0.5
Average	9.7	Average	5.3	Average	3.9	Average	5.7
Median	8.5	Median	5.0	Median	3.6	Median	4.8
Mode	7.0	Mode	4.0	Mode	3.6	Mode	4.4
Total N	32	Total N	26	Total N	24	Total N	24

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 59%. It means that wells which can be used as portable water are many. According to the conducted interviews, water users per well range between 15 and 500 persons (Average of about 154 persons). Per capita water use volume is 10 to 50 gallons/day (Average 32.9 gallons/day).

< Purpose of groundwater use >

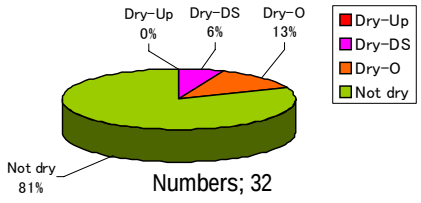


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	500	Max.	50.0		
Min.	15	Min.	10.0		
Average	154	Average	32.9	Average	830
Median	125	Median	30.0		
Mode	300	Mode	50.0		
Total N	32	Total N	32		

3) Dry-up condition, other conditions as resident consciousness and water quality

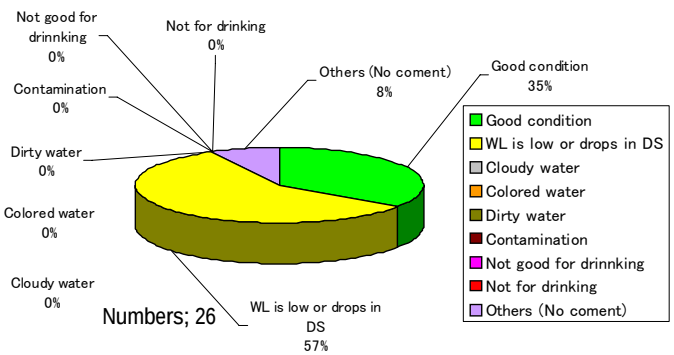
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 21%. It shows rather severe condition. Other negative conditions as resident consciousness such as low water level and water level decline in dry season or by excessive withdrawal are 57%. The pH is high in some wells (pH>0.9), and pH is low in some wells (pH<0.6).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.2	Max.	12.0	Max.	28.4
Min.	27.4	Min.	5.4	Min.	3.4
Average	28.7	Average	7.5	Average	13.0
Median	28.7	Median	7.1	Median	12.5
Mode	28.6	Mode	12.0	Mode	16.1
Total N	32	Total N	32	Total N	32

< Other conditions as resident consciousness >

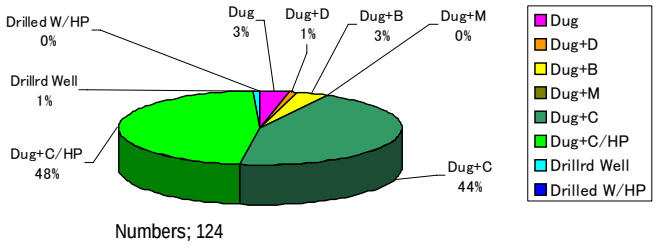


(k) Paynesville

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 4%. It indicates that few wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 47%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 48%. Drilled wells without hand pump are 1%. It shows that the maintenance of well equipment is progressing. Dug well diameter is 0.9 to 1.2 m. Drilled well casing diameter is 10cm. Total depth is 1.0 to 122.0m (Average 8.4m). Water level is 0.9 to 10.1 m (Average 4.3m).

< Well equipment >

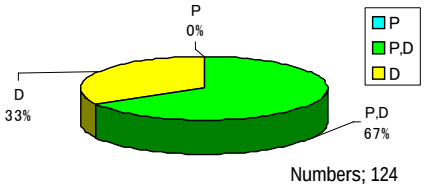


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	40.0	Max.	122.0	Max.	10.1	Max.	37.5
Min.	1.0	Min.	1.0	Min.	0.9	Min.	2.1
Average	15.0	Average	8.4	Average	4.3	Average	10.8
Median	15.0	Median	6.0	Median	4.4	Median	10.4
Mode	12.0	Mode	5.3	Mode	5.5	Mode	9.6
Total N	121	Total N	59	Total N	42	Total N	42

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 33%. It means that wells which can be used as portable water are many. According to the conducted interviews, water users per well range between 3 and 1000 persons (Average of about 253 persons). Per capita water use volume is 0.5 to 50 gallons/day (Average 9.5 gallons/day). Water use volume is smaller than other zones.

< Purpose of groundwater use >

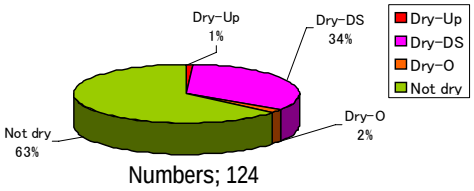


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	1000	Max.	50.0		
Min.	3	Min.	0.5		
Average	253	Average	9.5	Average	3,327
Median	200	Median	5.5		
Mode	200	Mode	5.0		
Total N	124	Total N	122		

3) Dry-up condition, other conditions as resident consciousness and water quality

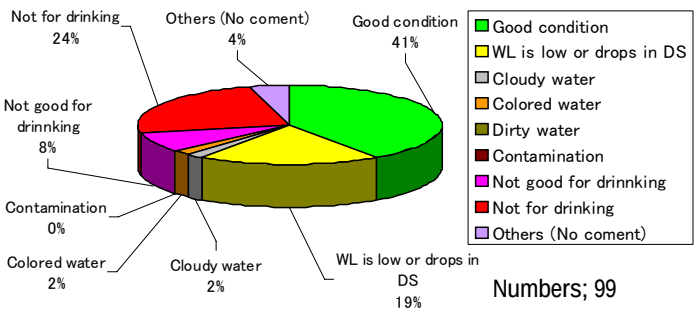
Dry-up usually (Dry-up), Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 33%. It shows rather severe condition. Other negative conditions as resident consciousness such as low water level, cloudy water, colored water, not-good-for-drinking water and not-for-drinking water are 55%. The pH is low in some wells (pH<6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.6	Max.	8.1	Max.	63.2
Min.	20.3	Min.	4.3	Min.	0.1
Average	28.5	Average	5.8	Average	16.3
Median	28.6	Median	5.8	Median	13.0
Mode	29.0	Mode	6.0	Mode	7.0
Total N	122	Total N	122	Total N	122

< Other conditions as resident consciousness >

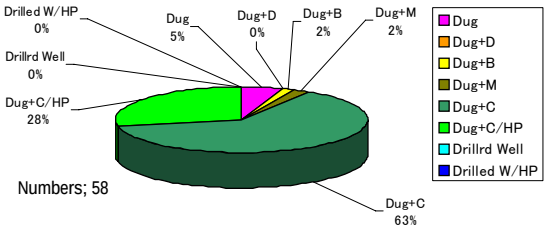


(l) Gardnersville

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 5%. It indicates that rather few wells of inferior circumstance still remain. Dug wells with block protection (Dug+B), Dug wells with masonry protection (Dug+M) and dug wells with concrete protection (Dug+C) are 67%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 28%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.8 to 10.1m (Average 4.2m). Water level is 1.1 to 7.1 m (Average 2.8m).

< Well equipment >

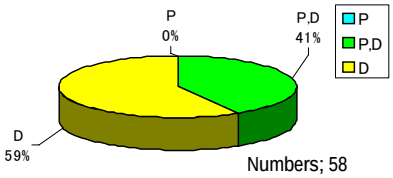


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	15.0	Max.	10.1	Max.	7.1	Max.	13.2
Min.	2.0	Min.	1.8	Min.	1.1	Min.	0.2
Average	7.6	Average	4.2	Average	2.8	Average	5.0
Median	7.0	Median	3.9	Median	2.5	Median	4.0
Mode	7.0	Mode	4.8	Mode	2.0	Mode	0.5
Total N	54	Total N	51	Total N	48	Total N	44

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 41%. It means that wells which can be used as portable water are many. According to the conducted interviews, water users per well range between 5 and 600 persons (Average of about 189 persons). Per capita water use volume is 1.5 to 50 gallons/day (Average 19.4 gallons/day).

< Purpose of groundwater use >

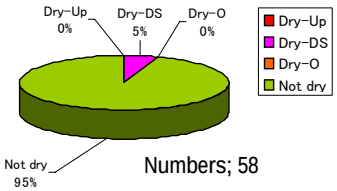


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	600	Max.	50.0		
Min.	5	Min.	1.5		
Average	189	Average	19.4	Average	1,556
Median	200	Median	10.0		
Mode	200	Mode	10.0		
Total N	58	Total N	58		

3) Dry-up condition, other conditions as resident consciousness and water quality

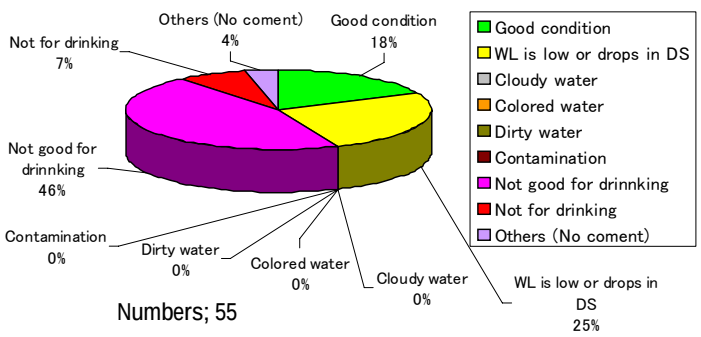
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 5%. It shows that the dry-up condition is little. Other negative conditions as resident consciousness such as low water level, not-good-for-drinking water and not-for-drinking water are 78%. The pH is low in some wells (pH<6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.7	Max.	7.7	Max.	83.8
Min.	26.6	Min.	4.8	Min.	4.5
Average	28.0	Average	6.0	Average	21.1
Median	28.0	Median	6.0	Median	16.8
Mode	27.8	Mode	6.0	Mode	15.1
Total N	58	Total N	58	Total N	56

< Other conditions as resident consciousness >

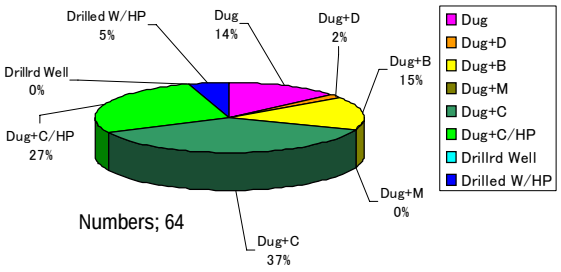


(m) New Georgia

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dugs well with drum as mouth protection (Dug+D) are 16%. It indicates that rather many wells of inferior circumstance still remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 42%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 27%. Drilled wells with hand pump are 5%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Drilled well casing diameter is 10cm. Total depth is 1.3 to 14.1m (Average 3.7m). Water level is 0.7 to 5.4m (Average 2.4m).

< Well equipment >

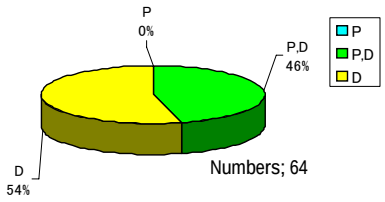


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	22.0	Max.	14.1	Max.	5.4	Max.	20.6
Min.	3.0	Min.	1.3	Min.	0.7	Min.	1.1
Average	8.4	Average	4.2	Average	2.4	Average	5.8
Median	7.5	Median	3.7	Median	2.1	Median	5.1
Mode	7.0	Mode	4.3	Mode	2.1	Mode	3.0
Total N	64	Total N	49	Total N	38	Total N	38

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 46%. It means that wells which can be used as portable water are rather many. According to the conducted interviews, water users per well range between 30 and 600 persons (Average of about 200 persons). Per capita water use volume is 3 to 50 gallons/day (Average 29.5 gallons/day).

< Purpose of groundwater use >

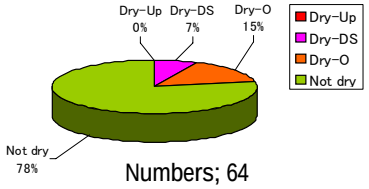


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	500	Max.	50.0	(X1,000 Gal/day)	
Min.	30	Min.	3.0		
Average	200	Average	29.5	Average	1,599
Median	200	Median	30.0		
Mode	200	Mode	30.0		
Total N	63	Total N	63		

3) Dry-up condition, other conditions as resident consciousness and water quality

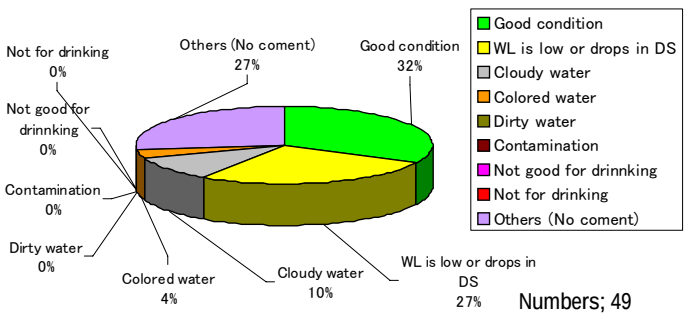
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 26%. It shows that the rather severe condition. Other negative conditions as resident consciousness such as low water level, cloudy water, and colored water are 41%. The pH is low in some wells (pH<6.0), pH is high in some wells (pH>9.0), and electric conductivity is high in some wells (EC>100).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	51.9	Max.	12.0	Max.	154.0
Min.	26.1	Min.	5.2	Min.	2.6
Average	28.5	Average	7.0	Average	21.2
Median	28.2	Median	6.9	Median	14.6
Mode	28.6	Mode	6.4	Mode	4.9
Total N	63	Total N	63	Total N	63

< Other conditions as resident consciousness >

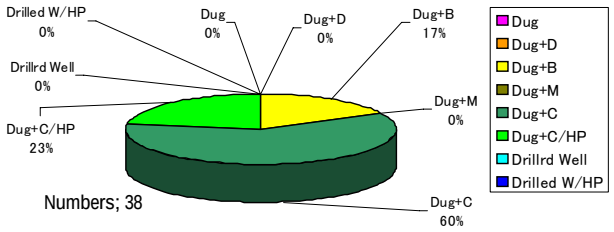


(n) Barnesville

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are nothing. It indicates that well of inferior circumstance does not remain. Dug wells with block protection (Dug+B) and dug wells with concrete protection (Dug+C) are 77%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 28%. It shows that the maintenance of well equipment is rather progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 2.6 to 17.0m (Average 4.3m). Water level is 1.9 to 5.4 m (Average 3.0m).

< Well equipment >

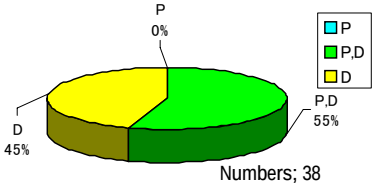


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	19.0	Max.	17.0	Max.	5.4	Max.	16.1
Min.	3.0	Min.	2.6	Min.	1.9	Min.	0.3
Average	8.8	Average	5.0	Average	3.0	Average	5.4
Median	8.0	Median	4.3	Median	2.6	Median	5.0
Mode	10.0	Mode	3.9	Mode	2.3	Mode	-
Total N	37	Total N	33	Total N	27	Total N	27

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 53%. It means that wells which can be used as portable water are many. According to the conducted interviews, water users per well range between 10 and 1000 persons (Average 238 persons). Per capita water use volume is 4 to 50 gallons/day (Average 25.4 gallons/day).

< Purpose of groundwater use >

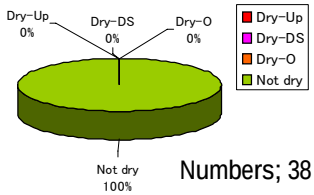


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone)	
Max.	1000	Max.	50.0	(X1,000 Gal/day)	
Min.	10	Min.	4.0		
Average	196	Average	25.4	Average	895
Median	73	Median	30.0		
Mode	30	Mode	30.0		
Total N	38	Total N	38		

3) Dry-up condition, other conditions as resident consciousness and water quality

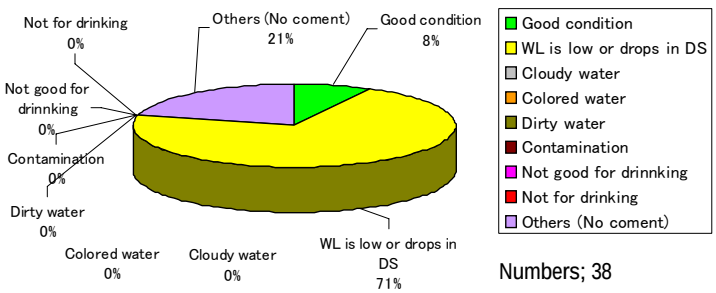
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are nothing. It shows that the dry-up condition is nothing. Other negative conditions as resident consciousness such as low water level, water level decline by excessive withdrawal are 71%. The pH is low in some wells (pH<6.0), and pH is high in some wells (pH>9.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.8	Max.	9.9	Max.	38.8
Min.	25.7	Min.	2.0	Min.	1.5
Average	28.1	Average	8.2	Average	10.9
Median	28.1	Median	9.0	Median	9.2
Mode	27.6	Mode	9.0	Mode	-
Total N	38	Total N	38	Total N	38

< Other conditions as resident consciousness >

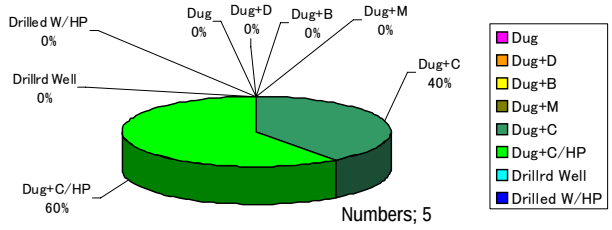


(o) Johnsonville

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are nothing. It indicates that wells of inferior circumstance do not remain. Dug wells with concrete protection (Dug+C) are 40%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 60%. It shows that the maintenance of well equipment is progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 3.9 to 9.2m (Average 6.2m). Water level is 2.0 m (Average 2.0m).

< Well equipment >

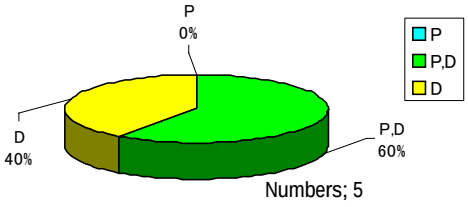


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	22.0	Max.	9.2	Max.	2.0	Max.	5.0
Min.	5.0	Min.	3.9	Min.	2.0	Min.	5.0
Average	13.4	Average	6.2	Average	2.0	Average	5.0
Median	11.0	Median	4.6	Median	2.0	Median	5.0
Mode	22.0	Mode	9.2	Mode	-	Mode	-
Total N	5	Total N	5	Total N	1	Total N	1

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 60%. It means that wells which can be used as portable water are many. According to the conducted interviews, water users per well range between 60 and 1000 persons (Average of about 302 persons). Per capita water use volume is 10 to 50 gallons/day (Average 38.0 gallons/day).

< Purpose of groundwater use >

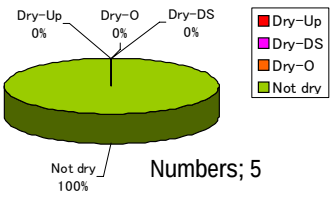


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	1000	Max.	50.0		
Min.	60	Min.	10.0		
Average	302	Average	38.0	Average	172
Median	150	Median	50.0		
Mode	150	Mode	50.0		
Total N	5	Total N	5		

3) Dry-up condition, other conditions as resident consciousness and water quality

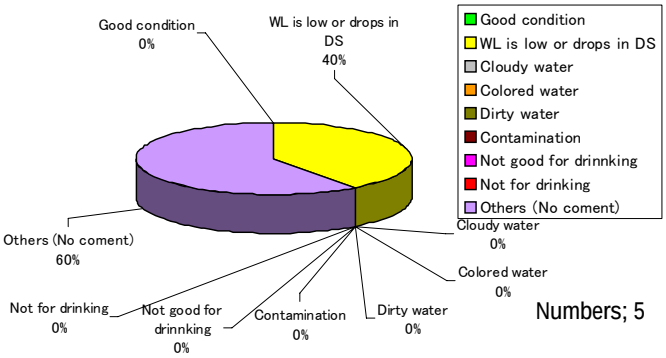
Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are nothing. It shows that the dry-up condition is nothing. Other negative conditions as resident consciousness such as low water level or water level decline by excessive drawing are 40%. The pH is low in some wells (pH<6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	29.6	Max.	7.7	Max.	16.0
Min.	27.8	Min.	5.9	Min.	13.0
Average	28.5	Average	6.8	Average	14.3
Median	28.3	Median	6.5	Median	13.4
Mode	27.8	Mode	7.7	Mode	16.0
Total N	5	Total N	5	Total N	5

< Other conditions as resident consciousness >

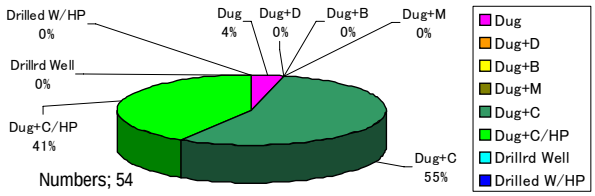


(p) Caldwell

1) Well equipment, dimension and water level

Dug wells without cover (Dug) and dug wells with drum as mouth protection (Dug+D) are 4%. It indicates that few wells of inferior circumstance still remain. Dug wells with concrete protection (Dug+C) are 55%. Dug wells with concrete cover and hand pump (Dug+C/HP) are 41%. It shows that the maintenance of well equipment is progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 2.1 to 11.6m (Average 4.5m). Water level is 1.4 to 5.2m (Average 2.8m).

< Well equipment >

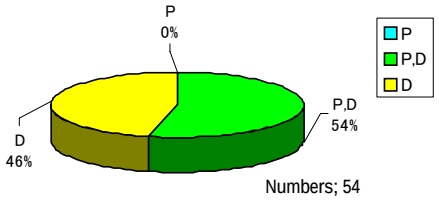


Well Dimension and Water Level							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	23.0	Max.	11.6	Max.	5.2	Max.	19.1
Min.	2.0	Min.	2.1	Min.	1.4	Min.	0.4
Average	8.8	Average	4.5	Average	2.8	Average	6.1
Median	7.5	Median	4.4	Median	2.8	Median	4.5
Mode	9.0	Mode	5.0	Mode	2.9	Mode	0.5
Total N	54	Total N	50	Total N	35	Total N	34

2) Purpose of groundwater use and volume

Portable and domestic use (P,D) is 54%. It means that wells which can not be used as portable water are rather many. According to the conducted interviews, water users per well range between 6 and 800 persons (Average of about 147 persons). Per capita water use volume is 4 to 50 gallons/day (Average 34.3 gallons/day).

< Purpose of groundwater use >

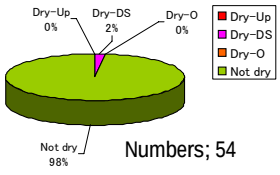


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	800	Max.	50.0		
Min.	6	Min.	4.0		
Average	147	Average	34.3	Average	912
Median	60	Median	40.0		
Mode	20	Mode	50.0		
Total N	54	Total N	53		

3) Dry-up condition, other condition as resident consciousness and water quality

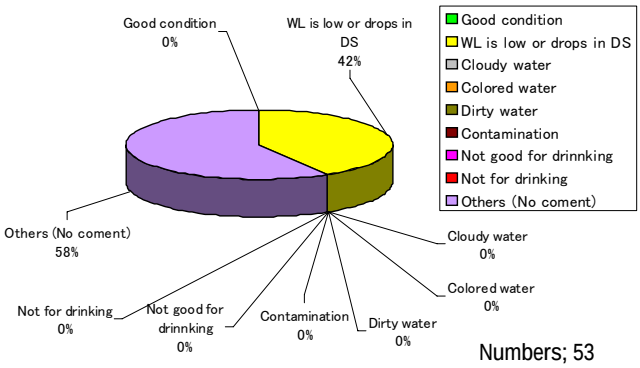
Dry-up usually (Dry-up), Dry-up in dry season (Dry-DS) and Dry-up by excessive drawing (Dry-O) are 2%. It shows that the dry-up condition is rare. Other negative conditions as low water level or water level decline by excessive withdrawal are 42%. The pH is high in some wells (pH>9.0), and pH is low in some wells (pH>6.0).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.3	Max.	12.0	Max.	31.6
Min.	25.2	Min.	5.4	Min.	1.6
Average	28.0	Average	7.7	Average	10.3
Median	27.9	Median	7.1	Median	8.3
Mode	27.7	Mode	12.0	Mode	6.5
Total N	53	Total N	53	Total N	53

< Other conditions as resident consciousness >



(3) Evaluation of Well Condition of Every Zone

To evaluate well condition of every zone, criteria for each item such as a) well equipment, b) use for portable water, c) dry-up condition, d) water quality problem and e) resident consciousness for well condition is set as shown in Table 2.5-17. Relative evaluation of well condition is performed by the total sum of a score for every item based on the criteria of Table 2.5-18.

The result of relative evaluation for the well condition of every zone is shown in Table 2.5-19. The communities, which have problem for dry-up condition at more than 3 wells or water quality problem such as high pH, low pH and high electric conductivity (EC) at more than 2 wells respectively, are shown in Table 2.5-20. The summary of evaluation is as follows:

i) Logan Town, Clara Town, West point and Central Monrovia A are Ranked **D** for well condition. Well equipment is inadequate in quality, especially inferior in Clara town and West point. Use for drinking water is rare. Water quality including resident consciousness is rather in bad condition. It indicates difficult circumstances of well condition.

ii) New Kru Town, Paynesville, Gardnersville and New Georgia are Ranked **C** for well condition. Well equipment and use for drinking water are relatively good without New Kru Town. There are dry up conditions and water quality problem including resident consciousness.

iii) Central Monrovia B, Sinkor, Lakpazee, Old Road, Congo Town, Barnesville and Caldwell are Ranked **B** for well condition. Conditions for well equipment, use for drinking water and dry-up are relatively good. There is water quality problem including resident consciousness in some places.

iv) Johnsonville is Ranked **A** for well condition. Each item shows rather good or good without water quality in some wells. But number of samples is rare as a zone because of no community division.

Since the survey data is gathered at well places, the total number of wells in the zone and the shortage of wells per population in the zone is not investigated. Northern area, especially hill areas, dug wells are rather few because the water level is deep and dug well digging is difficult due to shallow and hard base rock. At those areas residents is obliged to use nearby stream water. Those difficult circumstances and conditions are investigated in the resident consciousness survey for water supply.

Table 2.5-17 Criteria for Each Item Evaluation

Well Equipment

Level	Criteria	Description
1	Dug, Dug+D>=40%	Inferior condition
2	10%=<Dug, Dug+D<40%	Rather inferior condition
3	Dug, Dug+D<10%	Medium condition
4	20%=<HP Well<50%	Rather good condition
5	HP Well>=50%	Good condition

Use for Portable Water

Level	Criteria	Description
1	PW=<10%	Bad quality
2	10%<PW=<20%	Rather bad quality
3	20%<PW=<30%	Medium quality
4	30%<PW=<50%	Rather good quality
5	PW>50%	Good quality

Dry-up Condition

Level	Criteria	Description
1	Dry-up => 40%	Severe condition
2	20% =< Dry-up < 40%	Rather severe condition
3	5% =< Dry-up < 20%	Medium condition
4	WL down => 20%	Rather good condition
5	WL down < 20%	Good condition

Water Quality Problem

Level	Criteria	Description
1	3 Problems	Bad quality
2	2 Problems	Rather bad quality
3	1 Problem	Slightly bad quality
4	-	
5	Nothing	Good quality

Problem; Low pH (<6.0), High pH (>9.0). High EC (>100mS/m)

Resident Consciousness for Well

Level	Criteria	Description
1	Problems >= 40%	Bad condition
2	20% =< Problems <40%	Rather bad condition
3	10% =< Problems < 20%	Medium condition
4	Problems < 10%	Rather good condition
5	Good condition =>50%	Good condition

Problem; Not for drinking, Not good for drinking, Contamination, Colored water, Cloudy water

Table 2.5-18 Criteria for Well Condition of Every Zone

Rank	Criteria	Description
A	Total points > 20	Relatively good condition
B	15 < TP =< 20	Rather good condition, but it has problems such as water level down by excessive withdrawal and partly rather bad water quality portion.
C	10 < TP =< 15	Bad condition with not enough well equipments, rather little of portable water use, and problems such as partly dry-up and bad water quality
D	TP =<10	Severe condition with low quality of well equipments, difficulty of portable water use, and problems such as dry-up and bad water quality

Table 2.5-19 Evaluation of Well Condition of Every Zone

No.	Zone	Well equipment	Use for portable water	Dry-up condition	Water quality	Resident consciousness	Total	Rank
1	New Kru Town	2	2	2	3	2	11	C
2	Logan Town	2	1	1	3	2	9	D
3	Clara Town	1	1	2	1	1	6	D
4	West Point	1	1	1	2	5	10	D
5	Central Monrovia A	2	1	1	2	3	9	D
6	Central Monrovia B	3	4	3	2	4	16	B
7	Sinkor	4	4	4	3	4	19	B
8	Lakpazee	4	4	5	1	4	18	B
9	Old Road	5	4	3	3	4	19	B
10	Congo Town	4	5	3	2	4	18	B
11	Paynesville	4	5	2	3	1	15	C
12	Gardnesville	4	4	3	3	1	15	C
13	New Georgia	4	4	2	1	3	14	C
14	Barnesville	4	5	4	2	4	19	B
15	Johnsonville	5	5	4	3	4	21	A
16	Caldwell	4	5	4	2	4	19	B

Table 2.5-20 Problems per Community on Well Condition for Dry-up or Water Quality

No.	Zone	Problem community
1	New Kru Town	Crab Hole(Dry-up, Low pH), Point Four (Dry-up), Tweh Farm(Low pH)
2	Logan Town	King Peter Town, Stockton Creek, Zond Town (Dry-up)
3	Clara Town	Cow Factory (Dry-up), Giblata, River View (High EC)
4	West Point	Central West Point (High EC), Fish Town, Power Plant, West Point (Dry-up), Groundcess Yard (High pH)
5	Central Monrovia A	Central Monrovia A, Lyuch/Center Street, Rock Crucher, Snapper Hill, Sports Commission (Dry-up),
11	Paynesville	Bassa Town, Pipe Line A, Pollice Academy (Low pH)
13	New Georgia	Chocolate City B, New Georgia Estate (Dry-up)
16	Caldwell	Caldwell Market, DixvilleA, Dixville Water Side (High pH)

Remarks; (Dry-up); Dry-up condition such as dry-up in dry season, dry-up by excessive withdrawal
(High pH); pH<6.0, (Low pH); pH>9.0, High EC; Electric conductivity >100 mS/m

2.5.3.5 Geophysical Sounding

(1) Outline of Geophysical Sounding

(a) Objectives and Method

The vertical electric sounding (VES) is carried out to grasp a widely hydro-geological condition in the study area and to select exploratory well sites. The Schlumberger method is applied as vertical electric

sounding in consideration of the method generally performed in Liberia and the method of enforcing a number of people. The field work of vertical electric sounding is carried out by Bezaleel + Turnkey Contractors Inc. Liberia from 29th Jan. 2009 to 10th Feb. 2009.

(b) Location and Quantity

The location map of the electrical sounding is shown in Figure 2.5-19. The quantity of the sounding is shown in Table 2.5-21. The vertical electric sounding is carried out at selected 10 places, 3 points per each place, total 30 points. The current electrode spacing (AB) is set from 2m to maximum 900m, and the potential electrode spacing (MN) is set from 0.66m to 15m at each measuring point. Point No.1 and point No.2 are at the same points, but measurement lines intersect at right angles, and point No.3 has a distant of 100m from point No.1 and No.2 at each VES place.

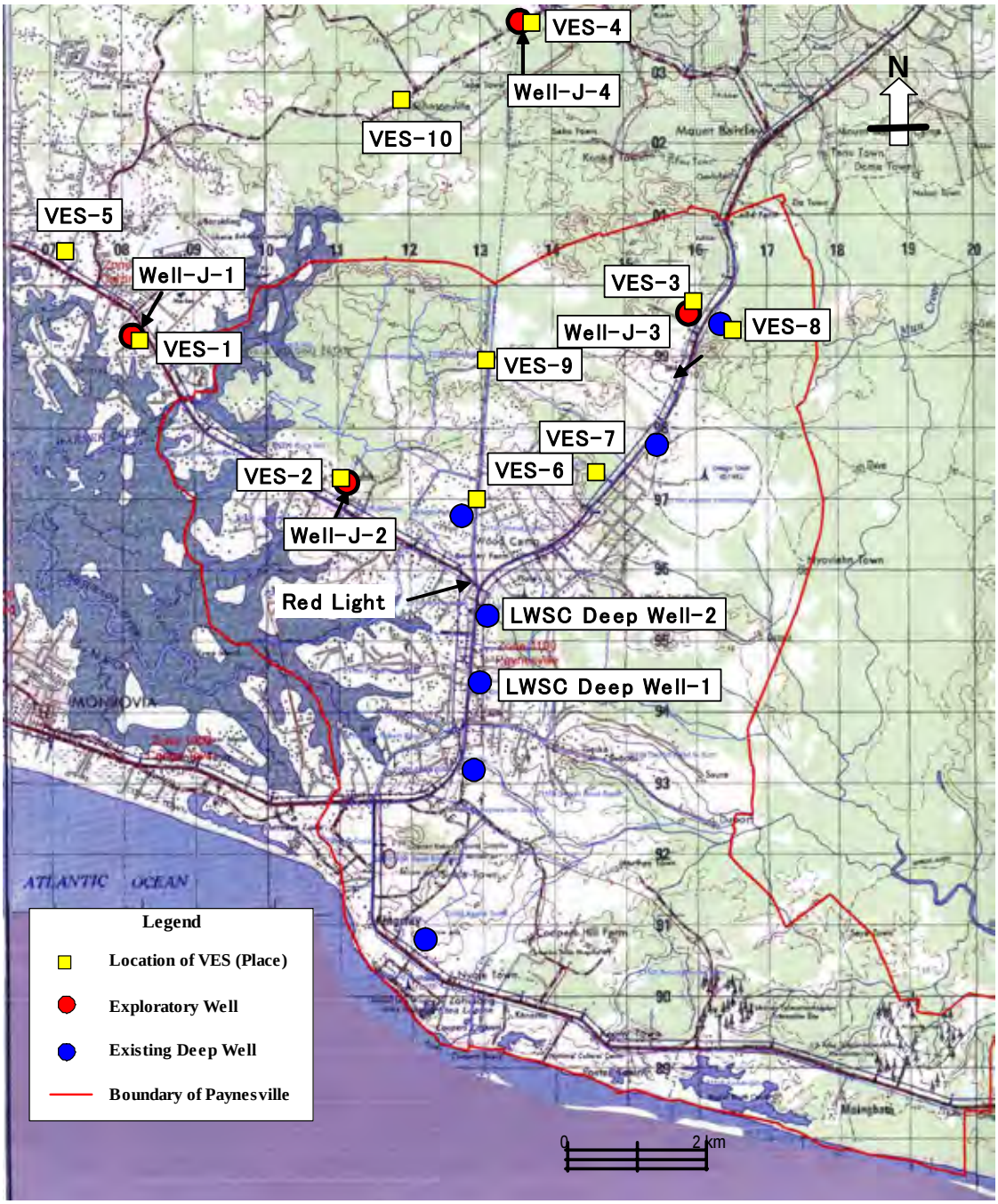


Figure 2.5-19 Location of Electric Sounding

Table 2.5-21 Location and Quantity of Vertical Electric Sounding

No.	Latitude	Longitude	Measurement (Point)	AB (Max. m)	MN (Max. m)	Remarks
VES-1	6 ° 19'25.2"N	10 ° 44'02.0"W	3	900	15	Well J-1
VES-2	6 ° 18'12.2"N	10 ° 42'31.1"W	3	900	15	Well J-2
VES-3	6 ° 19'30.9"N	10 ° 39'45.5"W	3	900	15	Well J-3
VES-4	6 ° 21'49.4"N	10 ° 41'08.4"W	3	900	15	Well J-4
VES-5	6 ° 21'01.9"N	10 ° 44'28.2"W	3	900	15	
VES-6	6 ° 18'04.1"N	10 ° 41'25.7"W	3	900	15	
VES-7	6 ° 18'09.3"N	10 ° 40'35.0"W	3	900	15	
VES-8	6 ° 19'31.2"N	10 ° 39'34.4"W	3	900	15	
VES-9	6 ° 19'39.1"N	10 ° 41'19.2"W	3	900	15	
VES-10	6 ° 21'13.1"N	10 ° 42'02.5"W	3	900	15	
Total			30 Points			

(2) Results of Electric Sounding and Analysis

The appearance resistivity – depth curve and analysis result of each point is shown in Figure 2.5-20.

The columnar indication of the vertical electric sounding results is shown in Figure 2.5-21.

The relation of resistivity and stratum or rock is shown in Table 2.5-22. The resistivity related stratum, rock, aquifer and aquiclude are interpreted as follows:

1) The resistivity of rain shows 1,000-1,500 ohm-m. Generally, the resistivity of groundwater in shallow aquifer shows 50-100 ohm-m, and the resistivity of groundwater in deep aquifer shows 20-50 Ohm-m
2) Rocks which have less than 100 ohm-m of resistivity have possibility of aquiclude.
3) Rocks which have more than 1,000 ohm-m of resistivity have possibility of igneous rock, metamorphic rock or dry condition among aquifer's rock.
4) Rocks which have more than 1,000 ohm-m of resistivity undergroundwater have possibility of rock belonging to aquiclude except for a kind of gravel layer such as fun gravel.
5) Aquifer saturated groundwater shows 100-1,000 ohm-m except for a kind of gravel layer such as fun gravel.

(Source; Shimura (1984) Method of Electric Sounding, Shoukodo Publish Japan)

Furthermore, there is following information;

a) In case of increase of moistured contents at fault or weathered portion, resistivity remarkably decreases. In case of increase of graphite or iron ore content, resistivity clearly decreases.
b) Crackly portion or weathered portion of hard rock shows 100-1,000 ohm-m, and hard weathering clay zone shows less than 100 ohm-m.
c) In case of Tertiary soft rock, conglomerate shows more than 100 ohm-m, sand stone shows 80-100 Ohm-m, and alternation portion of sand stone and mud stone shows 20-80 ohm-m.

The interpretation of resistivity classification is presumed as shown in Table 2.5-23. The summary of interpretation is as follows:

1) The Resistivity < 100 ohm-m zone shows a possibility of silt, clay, mudstone and shale (Aquiclude). 50 =< Resistivity <100 ohm-m zone may show a part of sandstone, alternation of sandstone (Possibility of Aquifer) and mudstone. Sometimes groundwater in fissure zone may show very low resistivity (Possibility of Aquifer).

2) The 100 =< Resistivity <400 ohm-m zone shows a possibility of sand and sandstone (Aquifer).
3) The 400 =< Resistivity < 1,000 ohm-m zone shows a possibility of weathered or crackly portion of hard rock and a part of sandstone (Aquifer to Aquiclude).
4) The 1,000 =< Resistivity < 5,000 ohm-m zone shows a possibility of hard rock (Non-Aquifer).
5) The Resistivity >= 5,000 ohm-m zone shows very hard portion of base rock (Non-Aquifer).

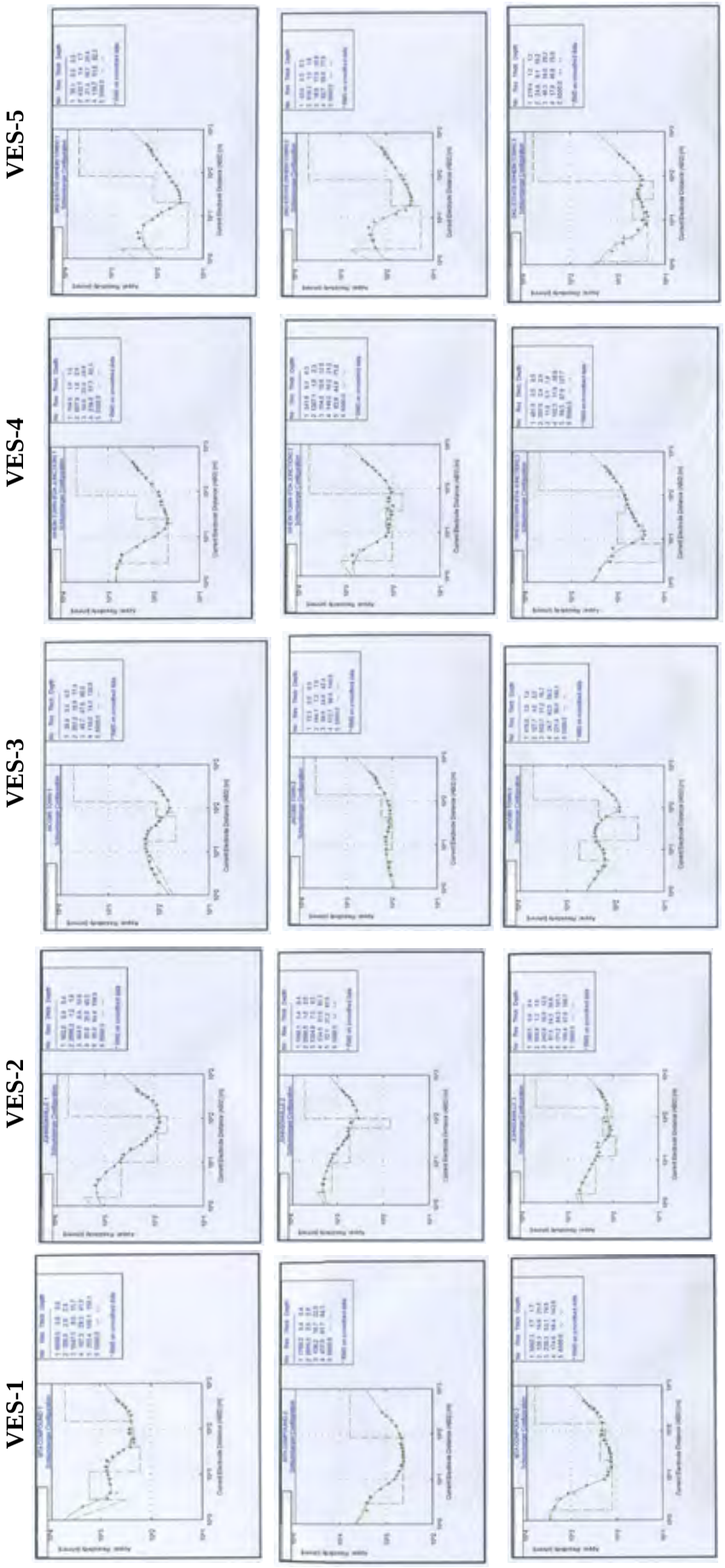


Figure 2.5-20 Appearance Resistivity – Depth Curve and Interpretation Result (1)

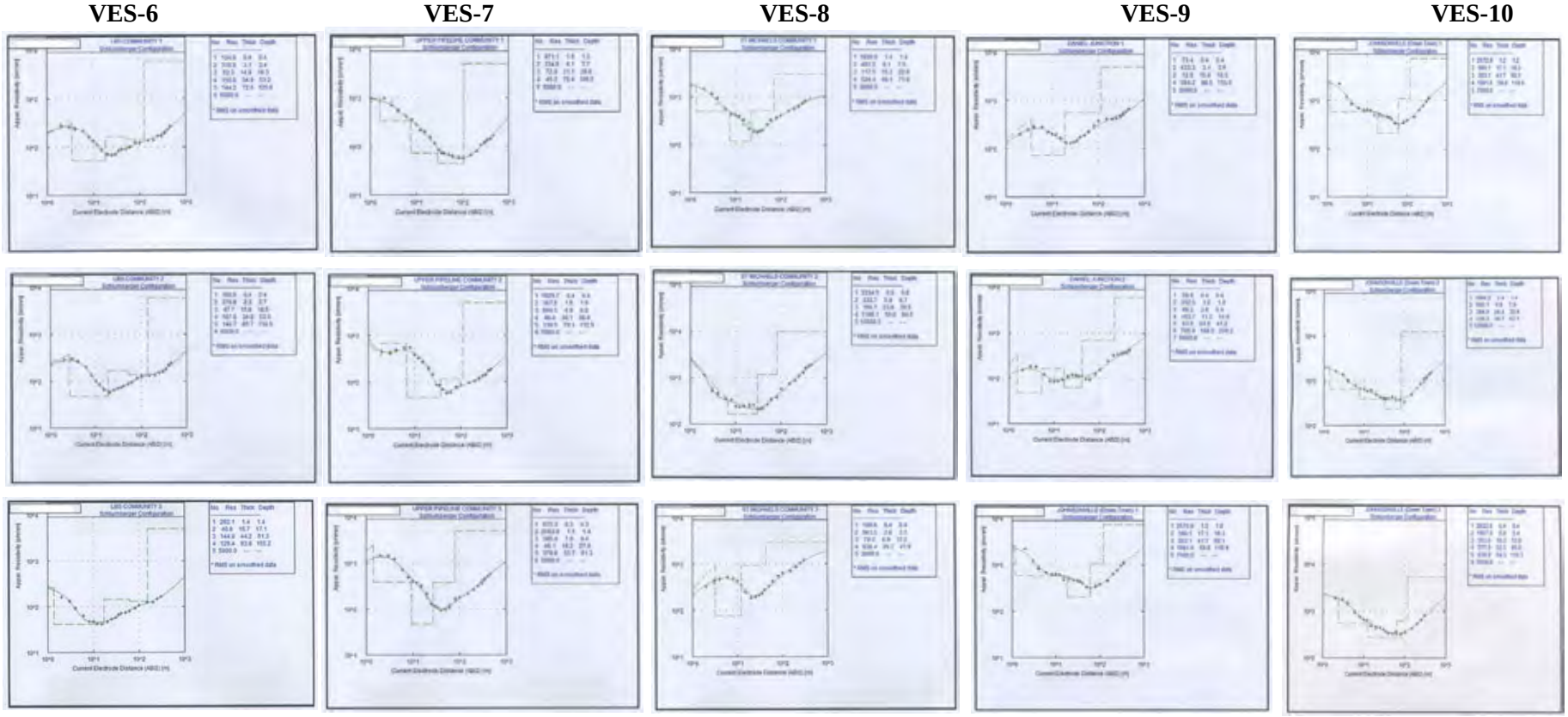


Figure 2.5-20 Appearance Resistivity – Depth Curve and Interpretation Result (2)

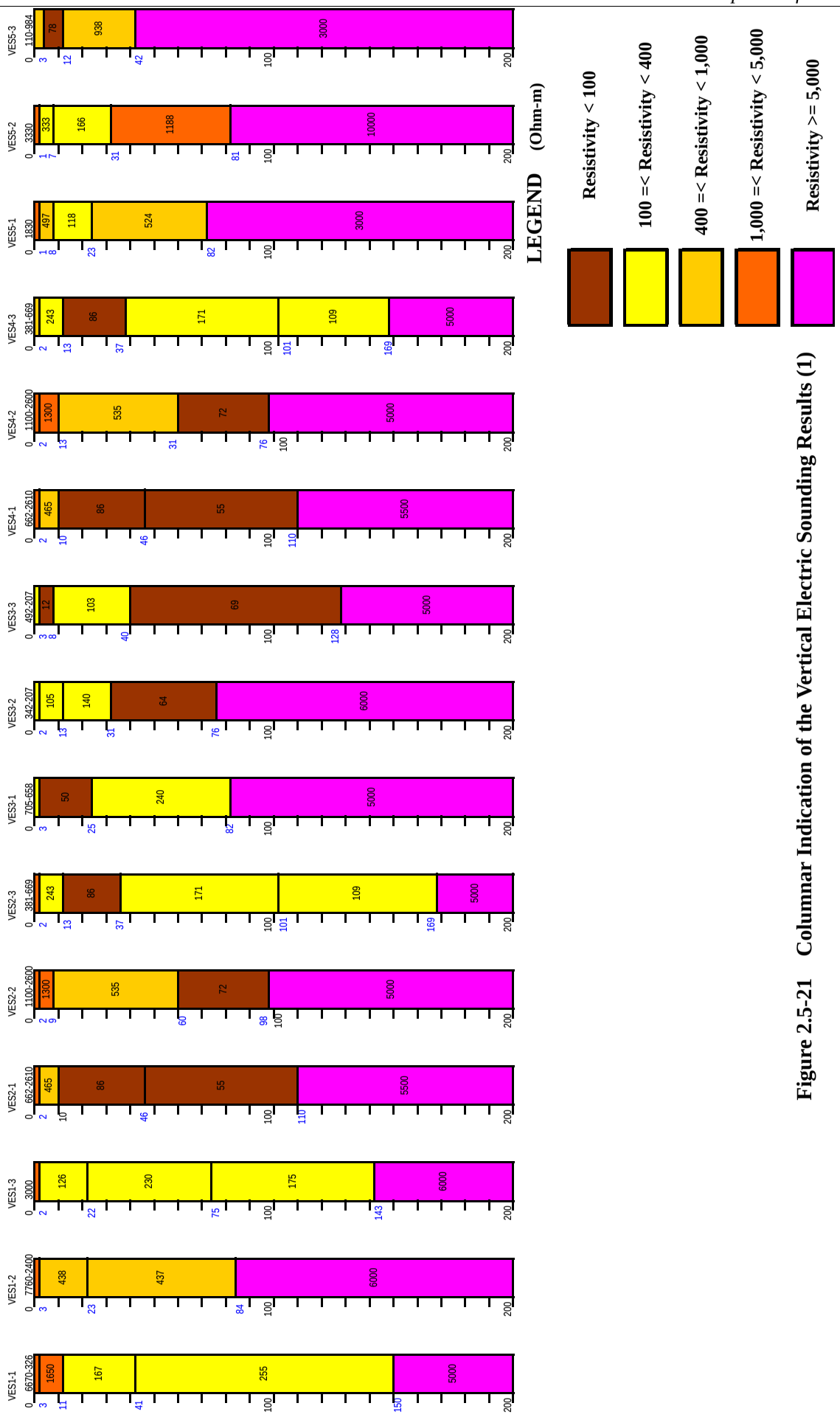


Figure 2.5-21 Columnar Indication of the Vertical Electric Sounding Results (1)

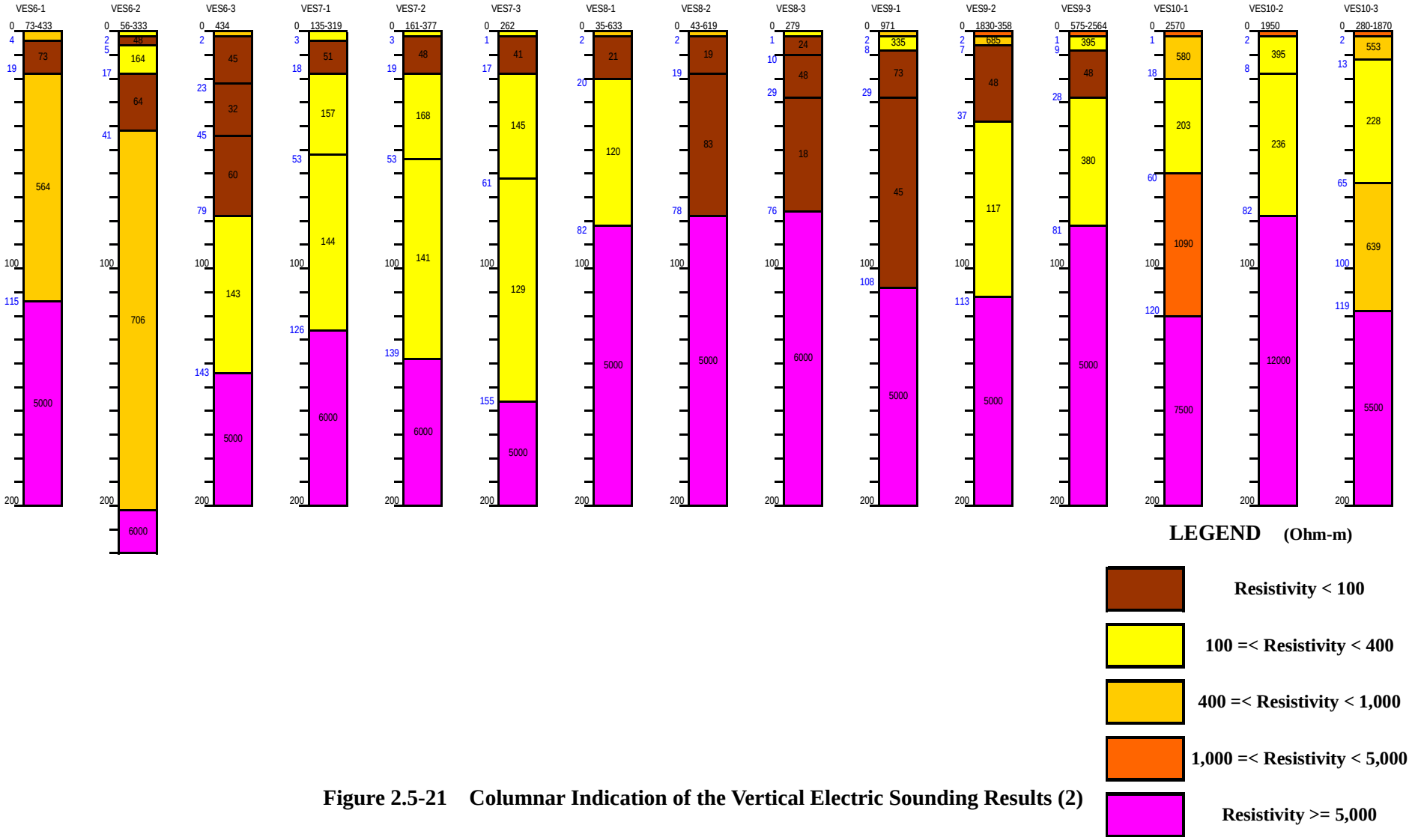


Figure 2.5-21 Columnar Indication of the Vertical Electric Sounding Results (2)

The yellow zone (100 =< Resistivity <400 ohm-m), deep yellow zone (400 =< Resistivity < 1,000 ohm-m) and a part of brown zone (Resistivity < 100 ohm-m) have possibility of Aquifer. In any case, the electrical sounding is only the information of current electrical easiness in the ground. The confirmation by exploratory well drilling is necessary.

Table 2.5-22 Resistivity of Stratum or Rock

	Stratum/ Rock	Resistivity (Ohm-m)	
		Dry	Wet
Aquifer	Gravel	1,000-15,000	200-10,000
	Gravel with sand	1,000-7,000	200-5,000
	Sand	300-7,000	100-700
	Conglomerate	300-1,800	100-500
	Sand stone	200-2,500	100-500
Aquiclude	Silt		<100
	Clay		<100
	Marl		<100
	Sale		<100
	Tuff breccia	100-1,000	
Non-Aquifer	Granite	1,000-10,000	
	Andesite	200-10,000	
	Basalt	20,000	
	Crystaline shist	200-20,000	
	Gneiss	200-20,000	
	Limestone	60-500,000	

Source; Shimura (1984) Method of Electric Sounding, Shoukodo Publish Japan

Table 2.5-23 Interpretation of Resistivity Classification

Classification	Resistivity Range	Description
	Resistivity < 100	Slit, clay, mudstone, shale, alternation, a part of sandstone, groundwater of fissure zone
	100 =< Resistivity < 400	Sand, sandstone, tuff breccia
	400 =< Resistivity < 1,000	Weathered or crackly portion of hard rock, a part of sandstone
	1,000 =< Resistivity < 5,000	Hard rock, a kind of gravel and congromerate
	Resistivity >= 5,000	Base rock

(3) Hydrogeological Structure Assumed from Electric Sounding

The 3 dimensional indications of results of vertical electric sounding are shown in Figure 2.5-22 and Figure 2.5-23. The hydrogeological condition of every VES surveyed place is assumed as shown in Table 2.5-24. The hydrogeological structure assumed from vertical electrical sounding is summarized as follows:

1) There is a possibility of rather widely spread sandstone aquifer in the survey area. But, the sandstone aquifer portion is supposed to have often mudstone or fine material layer portions or alternated portions or hard rock weathered portions. It means that the sandstone aquifer has no monotonous and stable condition but rather complicated condition. VES-1, VES-6, VES-7 and VES-10 (shallow portion) are assumed to have possibility of good aquifer condition.

2) The sandstone aquifer has no clear aquiclude at the upper portion. It means an imperfect confined aquifer.

3) The sandstone aquifer increases thickness towards the east, south east and south direction (VES-1, VES-6 and VES-7).

4) The depth of hard portion of base rock in the survey area is 42 to 200m according to VES results. VES-5 and VES8 show relatively shallow condition.

Table 2.5-24 Assumed Hydrogeological Condition of Every VES Survey Place

No.	Assumed Condition	Base Rock Depth (Average, m)
VES1	Possibility of sandstone or weathered rock portion	99
VES2	Possibility of mudstone or alteration, partly weathered rock portion	103
VES3	Possibility of mudstone or alteration	95
VES4	Possibility of mudstone or alteration, partly weathered rock portion	118
VES5	Possibility of thin sandstone, weathered rock or hard rock portion	68
VES6	Possibility of weathered rock, mudstone and sandstone	153
VES7	Possibility of sandstone, confined aquifer condition by covering mudstone	140
VES8	Possibility of mudstone, sandstone and alteration	79
VES9	Possibility of mudstone, sandstone and alteration	100
VES10	Possibility of sandstone and hard rock or weathered rock at lower part	107

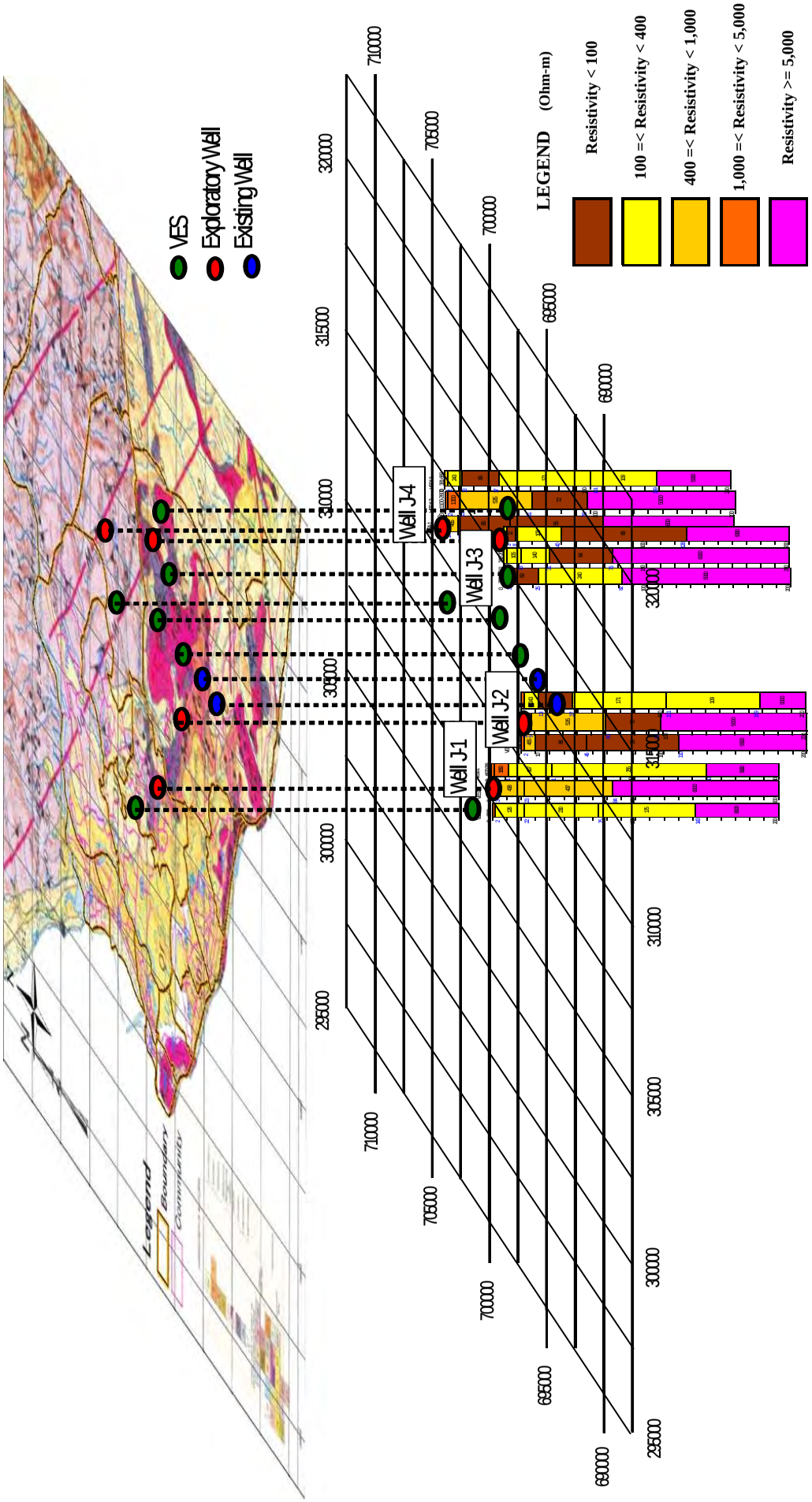


Figure 2.5-22 3 D Indications of Results of Vertical Electric Sounding (Exploratory Well Portion)

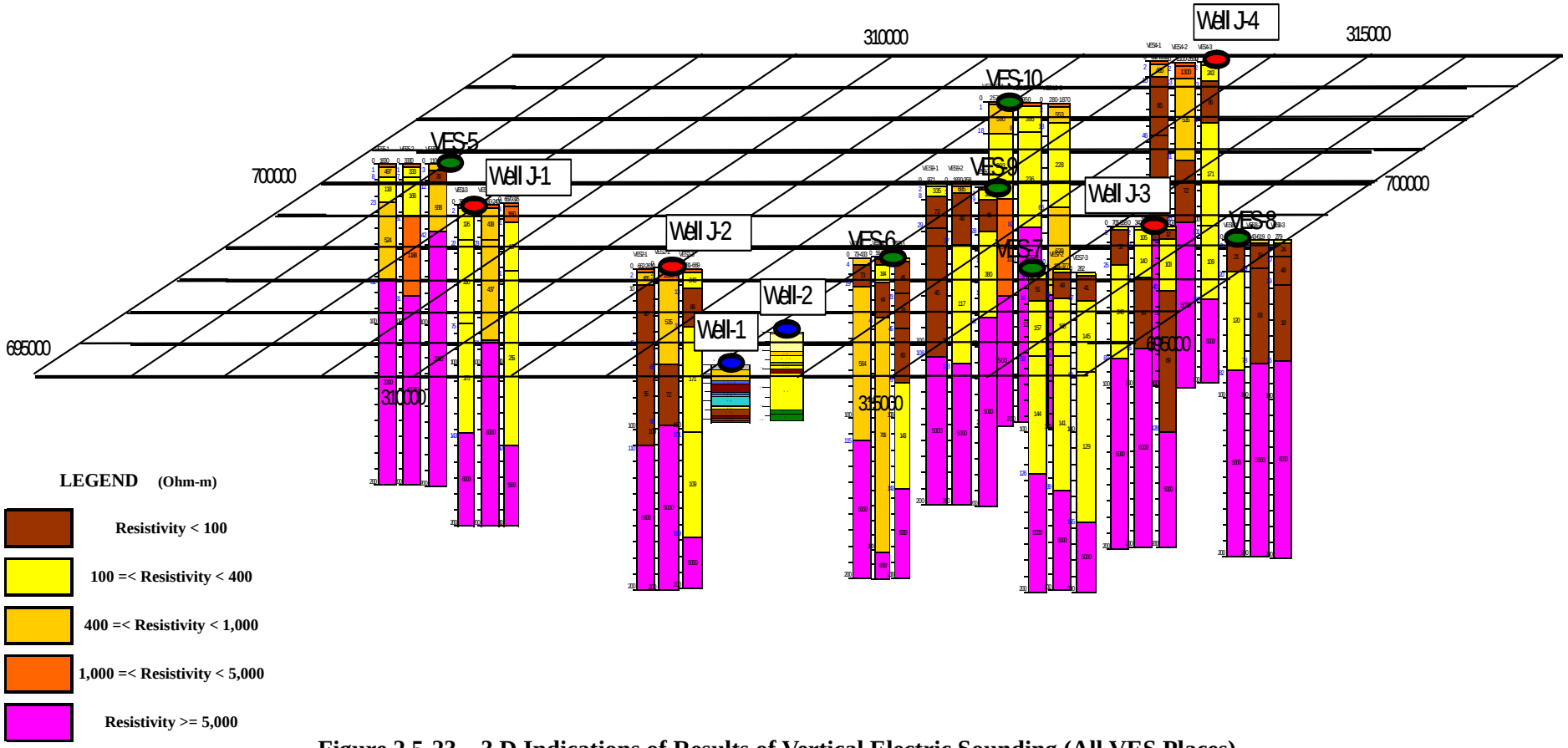


Figure 2.5-23 3 D Indications of Results of Vertical Electric Sounding (All VES Places)

2.5.4 Result of Water Quality Analysis

2.5.4.1 Purpose of the Water Quality Survey

JICA Study Team conducted the water quality survey regarding river, groundwater, public water tap, sewage and exploratory well drilling work in Monrovia city and the surrounding area to examine items as described below:

- Appropriateness for water source, whether the water quality of river water and groundwater meet the level as water source for drinking water in Monrovia and the surrounding areas
- Current polluted level in the river water and groundwater in Monrovia and the surrounding areas
- Current situation regarding water quality management by LWSC in Monrovia and the surrounding areas
- Current water quality in the sewage drained to public water bodies in Monrovia and the surrounding areas

2.5.4.2 Methods of Water Quality Survey

The location where water quality survey was conducted is shown in Figure 2.5-24. And the sampling points for each item are shown in Table 2.5-25.

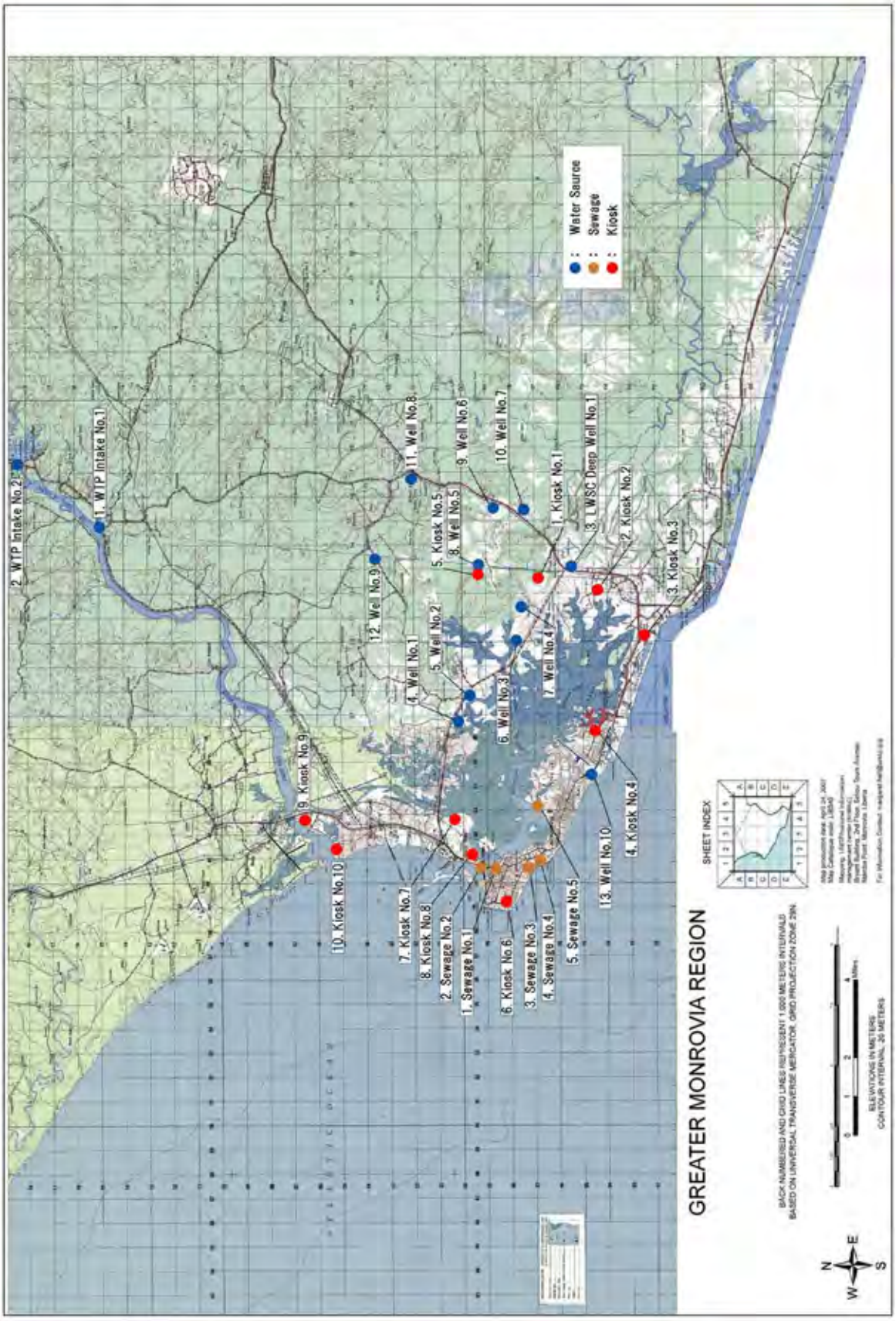


Figure 2.5-24 Location of the Water Quality Survey

Table 2.5-25 Sampling Points for Each Item

Item	Sampling Points
River	Total 2 points, existing intake and old intake used in the past for White Plain water treatment plant
Groundwater	Total 11 points, 9 points for wells operated by each community and 2 points for wells operated by LWSC
Public Water Tap	Total 10 points, public water taps supplied from White Plain water treatment plant operated by LWSC.
Sewage	Total 5 points, sewage discharged and the surrounding point in the river.
Exploratory Well	Total 4 points, in which JICA team planed to construct boreholes to supply water in each community.

As water analysis methods, simple method conducted by JICA Study Team and official method conducted by the local water analysis company were adopted. Detailed methods for each water quality items will be reported in Appendix 9.

2.5.4.3 Results of Water Quality Survey and Discussion

Summary for results of water quality survey on river, groundwater, public water tap, sewage and exploratory well is described below. Details of their results are reported in Appendix 10.

(1) Survey for Water Quality at River

Water analysis results regarding river are shown in Table 2.5-26.

Table 2.5-26 Results of Water Quality Survey at River

Location	Existing WTP Intake					Old Intake					WHO Guideline Value
Analysis Method ※1	Simple	Official	Simple	Official	Official	Simple	Official	Simple	Official	Official	
Sampling Date	14 Jan.	22 Jan.	22 Jan.	16 Jul.	28 Aug.	14 Jan.	22 Jan.	22 Jan.	16 Jul.	28 Aug.	
pH (-)	7.5	6.32	6.0	5.86	-	7.8	6.17	6.5	5.86	-	-
T (°C)	28.5	25.9	-	26.6	-	29.8	26.8	-	27.1	-	-
Turbidity (NTU)	3.10	2.3	1.83	3.8	14.8	4.50	15.2	11.5	18.8	18.1	5※2
Color (°)	5	-	4	136	-	10	-	20 ≤	164	-	15※2
EC (mS/m)	2.7	2.71	4.0	1.8	1.4	3.1	2.87	3.6	2.0	1.0	-
Alkalinity -OH^-(mg/l as $CaCO_3$)	-	0	-	0	-	-	0	-	0	-	-
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	-	0	-	0	-	-	0	-	0	-	-
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	-	23.2	-	18.2	-	-	25.2	-	14.2	-	-
Calcium (mg/L)	-	1.2	-	2.4	-	-	≤ 0.4	-	4.0	-	-
Magnesium (mg/L)	-	1.7	-	1.7	-	-	2.1	-	1.5	-	-
Total Hardness (mg-$CaCO_3$/l)	-	10	-	13	-	-	≤ 7	-	16	-	-
LI (-)	-	-3.5	-	-3.7	-	-	-	-	-3.6	-	-
Potassium (mg/L)	-	1.1	-	1.1	-	-	0.8	-	1.5	-	-
Sodium (mg/L)	-	4	-	4.5	-	-	5	-	4.0	-	-
Chlorides (mg/L)	-	5.0	-	3.6	-	-	5.2	-	4.2	-	-
SO_4^{2-} (mg/L)	-	≤ 7	-	≤ 7	-	-	≤ 7	-	≤ 7	-	250
TDS (mg/L)	-	13.6	-	9.1	-	-	14.2	-	10.0	-	1000
NH_4 -N (mg/L)	0.1	≤ 0.09	0.2	≤ 0.09	-	0.1	≤ 0.09	0.3	≤ 0.09	-	-
NO_3 -N (mg/L)	≤ 0.2	1.9	≤ 0.2	0.5	-	≤ 0.2	1.6	≤ 0.2	≤ 0.5	-	11
NO_2 -N (mg/L)	-	0.002	-	0.002	-	-	≤ 0.001	-	≤ 0.001	-	0.9
PO_4^{3}-P (mg/L)	≤ 0.05	-	≤ 0.05	-	-	≤ 0.05	-	≤ 0.05	-	-	-
COD (mg/L)	6	-	5	-	-	5	-	5	-	-	-
SiO_2 (mg/L)	20 ≤	9.85※4	20	4.1※4	-	20 ≤	21※4	20	4.44※4	-	-
Fe (mg/L)	≤ 0.05	0.52	≤ 0.05	0.79	-	≤ 0.05	4.3	0.1	1.45	-	0.3
Mn (mg/L)	≤ 0.5	0.0046	≤ 0.5	0.0206	-	≤ 0.5	0.0031	≤ 0.5	0.0318	-	0.5
Arsenic (mg/L)	-	≤ 0.001	-	≤ 0.001	-	-	≤ 0.001	-	≤ 0.001	-	0.01
Selenium (mg/L)	-	≤ 0.001	-	≤ 0.001	-	≤ 0.001	≤ 0.001	-	≤ 0.001	-	0.01
Copper (mg/L)	-	0.0023	-	0.0037	-	-	0.003	-	0.0034	-	2
Cadmimum (mg/L)	-	0.00036	-	0.00039	-	-	0.00048	-	-	≤ 0.0005	0.003
Chromium (mg/L)	-	≤ 0.001	-	≤ 0.001	-	-	≤ 0.001	-	≤ 0.001	-	0.05
Cyanide (mg/L)	-	≤ 0.02	-	≤ 0.02	-	-	≤ 0.02	-	≤ 0.02	-	0.07
Lead (mg/L)	-	0.0034	-	-	≤ 0.001	-	0.0028	-	0.00161	-	0.01
Mercury (mg/L)	-	≤ 0.0005	-	-	≤ 0.0001	-	≤ 0.0005	-	≤ 0.0005	-	0.001
Boron (mg/L)	-	≤ 0.05	-	≤ 0.05	-	-	≤ 0.05	-	≤ 0.05	-	0.5
Barium (mg/L)	-	0.007	-	0.033	-	-	0.04	-	0.040	-	0.7
Molybdenum (mg/L)	-	≤ 0.005	-	≤ 0.005	-	-	≤ 0.005	-	≤ 0.005	-	0.07
Nickel (mg/L)	-	≤ 0.0025	-	≤ 0.0043	-	-	≤ 0.0025	-	0.0014	-	0.02
Flurorine (mg/L)	-	0.49	-	≤ 0.2	-	-	≤ 0.2	-	≤ 0.2	-	1.5
Total Coliforms (CFU/100ml)※3	1400	-	600	4500	-	5800	-	2000	2300	-	0※2
E.Coli. (CFU/100ml)※3	500	-	600	1700	-	1900	-	1800	40	-	0※2
HClO (mg/L)	≤ 0.1	-	≤ 0.1	-	-	≤ 0.1	-	≤ 0.1	-	-	-
Fhenolic compounds (mg/L)	≤ 0.2	-	≤ 0.2	-	-	≤ 0.2	-	≤ 0.2	-	-	-

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.

※2 This value means value on water tap.

※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml" is used in simple method.

※4 Value stand for Si conc.(mg/L)

These data explain the following:

- Regarding the existing intake, the concentration of nitrogen such as ammonium and nitrate shows very low compared with WHO guideline value. And E.Coli. concentration, which represents index as pollution by fecal matter, is also low and the concentration is equivalent to Group A based on Japanese environmental standards.
- Regarding existing intake, because Langelier's index, which shows index as corrosiveness on facilities, is lower than 0(-), water quality control and plan for water facility shall be taken measures for these matters.
- Regarding old intake used before, according to field survey, our Study Team confirmed that water flow rate is so low that this water can't apply to water source for drinking water. In addition, according to water quality survey, concentration of color, coliform bacteria and E.coli.are high so that this water also can not be applied for drinking water as water source.

- On existing WTP intake and old intake there were no items beyond WHO guideline value but bacteria. So water on existing intake point in St.Paul river be able to apply for water source of drinking water by treating with sedimentation and sand filtration using coagulant and adding chlorine to raw water appropriately.

(2) Survey for Water Quality at Well

Water analysis results regarding well are shown in Table 2.5-27, Table 2.5-28, Table 2.5-29 and Table 2.5-30 respectively

Table 2.5-27 Results of Water Quality Survey at Wells (No.1)

WELL No.	NO.1			NO.2			NO.3			WHO Guideline Value
Location	Sister Agnes Clinic			Sister Barbara-Ann Health Center			James Davis Block Factory			
Aprox. Well Depth	15m			4m			5m			
Analysis Method ※1	Simple	Official	Simple	Simple	Official	Simple	Simple	Official	Simple	
Sampling Date	26 Jan.	29 Jan.	29 Jan.	26 Jan.	29 Jan.	29 Jan.	26 Jan.	29 Jan.	29 Jan.	
pH (-)	6.4	5.79	6.4	6.2	5.86	6.2	6.4	6.18	6.6	–
T (°C)	26.5	28.0	–	27.2	28.5	–	27.0	28.5	–	–
Turbidity (NTU)	≤ 0.01	–	0.05	0.09	–	1.14	3.03	–	1.60	5※2
Color (°)	≤ 2	–	≤ 2	≤ 2	–	≤ 2	2	–	≤ 2	15※2
EC (mS/m)	20.0	13.70	20.0	29.0	19.60	29.0	97.0	96.00	106.0	–
Alkalinity -OH^-(mg/l as $CaCO_3$)	–	0	–	–	0	–	–	0	–	–
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	–	0	–	–	0	–	–	0	–	–
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	–	37	–	–	64	–	–	92	–	–
Calcium (mg/L)	–	18	–	–	24	–	–	51	–	–
Magnesium (mg/L)	–	3	–	–	9	–	–	15	–	–
Total Hardness (mg-$CaCO_3$/l)	–	58	–	–	97	–	–	190	–	–
LI (-)	–	-2.6	–	–	-2.2	–	–	-1.4	–	–
Potassium (mg/L)	–	1.1	–	–	4.5	–	–	8.1	–	–
Sodium (mg/L)	–	4	–	–	27	–	–	88	–	–
Chlorides (mg/L)	–	17	–	–	46	–	–	329	–	–
SO_4^{2-} (mg/L)	–	30	–	–	32	–	–	64	–	250
TDS (mg/L)	–	68	–	–	98	–	–	481	–	1000
NH_4 -N (mg/L)	≤ 0.1	≤ 0.09	0.1	0.1	≤ 0.09	0.1	0.1	≤ 0.09	0.1	–
NO_3 -N (mg/L)	2	5	3	0.3	7	0.3	1	3.3	3	11
NO_2 -N (mg/L)	–	0.006	–	–	0.002	–		0.008	–	0.9
PO_4^3-P (mg/L)	–	–	0.05	–	–	0.05	–		0.05	–
COD (mg/L)	–	–	3	–	–	6	–		4	–
SiO_2 (mg/L)	–	1.60	3	–	9.50	10	–	7.54	10	–
Fe (mg/L)	–	≤ 0.25	≤ 0.05	–	≤ 0.25	≤ 0.05	–	≤ 0.25	≤ 0.05	0.3
Mn (mg/L)	–	0.001	≤ 0.5	–	0.020	≤ 0.5	–	0.0198	≤ 0.5	0.5
Arsenic (mg/L)	–	≤ 0.001	–	–	≤ 0.001	–	–	≤ 0.001	–	0.01
Selenium (mg/L)	–	0.001	–	–	≤ 0.001	–	–	0.001	–	0.01
Copper (mg/L)	–	0.009	–	–	0.007	–	–	0.002	–	2
Cadmimum (mg/L)	–	0.0008	–	–	0.0001	–	–	0.0001	–	0.003
Chromium (mg/L)	–	≤ 0.001	–	–	≤ 0.001	–	–	≤ 0.001	–	0.05
Cyanide (mg/L)	–	≤ 0.02	–	–	≤ 0.02	–	–	≤ 0.02	–	0.07
Lead (mg/L)	–	0.0109	–	–	0.0031	–	–	0.0034	–	0.01
Mercury (mg/L)	–	≤ 0.0005	–	–	≤ 0.0005	–	–	≤ 0.0005	–	0.001
Boron (mg/L)	–	≤ 0.05	–	–	≤ 0.05	–	–	0.08	–	0.5
Barium (mg/L)	–	0.007	–	–	0.022	–	–	0.024	–	0.7
Molybdenum (mg/L)	–	≤ 0.005	–	–	≤ 0.005	–	–	≤ 0.005	–	0.07
Nickel (mg/L)	–	≤ 0.0025	–	–	≤ 0.0025	–	–	≤ 0.0025	–	0.02
Flurorine (mg/L)	–	≤ 0.2	–	–	≤ 0.2	–	–	≤ 0.2	–	1.5
Residensial Chrorine-Total (mg/L)	–	≤ 0.01	–	–	≤ 0.01	–	–	≤ 0.01	–	–
Total Coliforms (CFU/100ml)※3	700	–	1000	400	–	500	700	–	500	0※2
E.Coli. (CFU/100ml)※3	0	–	300	100	–	100	200	–	0	0※2
HClO (mg/L)	–	–	≤ 0.1	–	–	≤ 0.1	–	–	≤ 0.1	–
Fhenolic compounds (mg/L)	–	–	≤ 0.2	–	–	≤ 0.2	–	–	≤ 0.2	–

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.

※2 This value means value on water tap.

※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.

Table 2.5-28 Results of Water Quality Survey at Wells (No. 2)

WELL No.	NO.4			NO.5			NO.6		WHO Guideline Value
Location	Mud Town			Pipeline Community			Wein Town School		
Aprox. Well Depth	7m			14m			5m		
Analysis Method ※1	Simple	Official	Simple	Simple	Official	Simple	Official	Simple	
Sampling Date	26 Jan.	29 Jan.	29 Jan.	26 Jan.	29 Jan.	29 Jan.	22 Jan.	22 Jan.	
pH (-)	5.5	5.07	5.8	6.0	5.59	6.0	5.75	6.2	–
T (°C)	27.0	28.0	–	26.5	28.2	–	29.3	–	–
Turbidity (NTU)	0.31	–	0.70	11.5	–	2.12	–	6.88	5※2
Color (°)	≤ 2	–	≤ 2	≤ 2	–	≤ 2	–	2	15※2
EC (mS/m)	8.1	4.29	7.4	11.1	6.43	10.1	12.49	16.5	–
Alkalinity -OH^-(mg/l as $CaCO_3$)	–	0	–	–	0	–	0	–	–
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	–	0	–	–	0	–	0	–	–
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	–	18	–	–	25	–	83	–	–
Calcium (mg/L)	–	6	–	–	8	–	31	–	–
Magnesium (mg/L)	–	1	–	–	1	–	4	–	–
Total Hardness (mg-$CaCO_3$/l)	–	18	–	–	25	–	96	–	–
LI (-)	–	-4.1	–	–	-3.3	–	-2.1	–	–
Potassium (mg/L)	–	1.1	–	–	1.2	–	2.1	–	–
Sodium (mg/L)	–	7	–	–	10	–	4	–	–
Chlorides (mg/L)	–	9	–	–	14	–	13	–	–
SO_4^{2-} (mg/L)	–	≤ 7	–	–	≤ 7	–	≤ 7	–	250
TDS (mg/L)	–	21	–	–	32	–	63	–	1000
NH_4 -N (mg/L)	≤ 0.1	≤ 0.09	0.1	≤ 0.1	≤ 0.09	0.1	≤ 0.09	0.3	–
NO_3 -N (mg/L)	0.3	2	0.3	0.5	2.9	1.5	1.2	≤ 0.05	11
NO_2 -N (mg/L)	–	0.005	–	–	0.009	–	0.002	–	0.9
PO_4^3-P (mg/L)	–	–	0.05	–	–	0.05	–	≤ 0.05	–
COD (mg/L)	–	–	2	–	–	3	–	4	–
SiO_2 (mg/L)	–	4.93	5	–	9.85	15	11.35	20	–
Fe (mg/L)	–	≤ 0.25	≤ 0.05	–	≤ 0.25	≤ 0.05	0.63	≤ 0.05	0.3
Mn (mg/L)	–	0.0041	≤ 0.5	–	0.0072	≤ 0.5	0.0030	≤ 0.5	0.5
Arsenic (mg/L)	–	≤ 0.001	–	–	≤ 0.001	–	≤ 0.001	–	0.01
Selenium (mg/L)	–	≤ 0.001	–	–	≤ 0.001	–	≤ 0.001	–	0.01
Copper (mg/L)	–	0.007	–	–	0.002	–	0.008	–	2
Cadmimum (mg/L)	–	0.0005	–	–	0.0004	–	0.0009	–	0.003
Chromium (mg/L)	–	≤ 0.001	–	–	≤ 0.001	–	≤ 0.001	–	0.05
Cyanide (mg/L)	–	≤ 0.02	–	–	≤ 0.02	–	≤ 0.02	–	0.07
Lead (mg/L)	–	0.0043	–	–	0.0040	–	0.0098	–	0.01
Mercury (mg/L)	–	≤ 0.0005	–	–	≤ 0.0005	–	≤ 0.0005	–	0.001
Boron (mg/L)	–	≤ 0.05	–	–	≤ 0.05	–	≤ 0.05	–	0.5
Barium (mg/L)	–	0.016	–	–	0.046	–	0.010	–	0.7
Molybdenum (mg/L)	–	≤ 0.005	–	–	≤ 0.005	–	≤ 0.005	–	0.07
Nickel (mg/L)	–	≤ 0.0025	–	–	≤ 0.0025	–	≤ 0.0025	–	0.02
Flurorine (mg/L)	–	≤ 0.2	–	–	≤ 0.2	–	≤ 0.2	–	1.5
Residensial Chrorine-Total (mg/L)	–	≤ 0.01	–	–	≤ 0.01	–	≤ 0.01	–	–
Total Coliforms (CFU/100ml)※3	100	–	0	0	–	0	–	0	0※2
E.Coli. (CFU/100ml)※3	0	–	0	0	–	0	–	0	0※2
HClO (mg/L)	–	–	≤ 0.1	–	–	≤ 0.1	–	≤ 0.1	–
Fhenolic compounds (mg/L)	–	–	≤ 0.2	–	–	≤ 0.2	–	≤ 0.2	–

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.

※2 This value means value on water tap.

※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml" is used in simple method.

Table 2.5-29 Results of Water Quality Survey at Wells (No. 3)

WELL No.	NO.7		NO.8		NO.9			WHO Guideline Value
Location	Omega up hill cmn.		Mount Barclay		Jhonsonville			
Aprox. Well Depth	40 m		15m		15m			
Analysis Method ※1	Official	Simple	Official	Simple	Simple	Official	Simple	
Sampling Date	22 Jan.	22 Jan.	22 Jan.	22 Jan.	26 Jan.	29 Jan.	29 Jan.	
pH (-)	5.65	6.2	4.65	5.5	6.9	5.36	6.2	–
T (°C)	28.9	–	28.6	–	27.5	27.4	–	–
Turbidity (NTU)	–	≤ 0.01	–	0.03	3.51	–	3.22	5※2
Color (°)	–	≤ 2	–	≤ 2	≤ 2	–	≤ 2	15※2
EC (mS/m)	10.18	15.1	6.45	15.4	2.6	2.04	3.6	–
Alkalinity -OH^-(mg/l as $CaCO_3$)	0	–	0	–	–	0	–	–
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	0	–	0	–	–	0	–	–
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	91	–	8	–	–	13.8	–	–
Calcium (mg/L)	22	–	2	–	–	≤ 0.4	–	–
Magnesium (mg/L)	2.9	–	2.7	–	–	≤ 0.24	–	–
Total Hardness (mg-$CaCO_3$/l)	67	–	16	–	–	≤ 1	–	–
LI (-)	-2.3	–	-5.4	–	–	-	–	–
Potassium (mg/L)	2.6	–	1.3	–	–	0.5	–	–
Sodium (mg/L)	7	–	7	–	–	2	–	–
Chlorides (mg/L)	5.6	–	10.5	–	–	5.3	–	–
SO_4^{2-} (mg/L)	≤ 7	–	≤ 7	–	–	≤ 7	–	250
TDS (mg/L)	50.8	–	32.5	–	–	10.1	–	1000
NH_4 -N (mg/L)	≤ 0.09	0.2	≤ 0.09	0.2	1	1.75	1	–
NO_3 -N (mg/L)	1.5	≤ 0.2	5.6	5	≤ 0.1	1.1	≤ 0.2	11
NO_2 -N (mg/L)	0.003	–	0.004	–	–	0.003	–	0.9
PO_4^3-P (mg/L)		0.1		0.05	–		0.2	–
COD (mg/L)		1		1	–		5	–
SiO_2 (mg/L)	20 ≤	20 ≤	8.14	10	–	4.54	5	–
Fe (mg/L)	≤ 0.05	≤ 0.05	≤ 0.25	≤ 0.05	–	0.31	≤ 0.05	0.3
Mn (mg/L)	≤ 0.5	≤ 0.5	0.0129	≤ 0.5	–	0.0137	≤ 0.5	0.5
Arsenic (mg/L)	≤ 0.001	–	≤ 0.001	–	–	≤ 0.001	–	0.01
Selenium (mg/L)	≤ 0.001	–	≤ 0.001	–	–	≤ 0.001	–	0.01
Copper (mg/L)	0.0038	–	0.0381	–	–	0.0032	–	2
Cadmimum (mg/L)	0.00055	–	0.00049	–	–	0.00031	–	0.003
Chromium (mg/L)	≤ 0.001	–	≤ 0.001	–	–	≤ 0.001	–	0.05
Cyanide (mg/L)	≤ 0.02	–	≤ 0.02	–	–	≤ 0.02	–	0.07
Lead (mg/L)	0.0045	–	0.0035	–	–	0.0027	–	0.01
Mercury (mg/L)	≤ 0.0005	–	≤ 0.0005	–	–	≤ 0.0005	–	0.001
Boron (mg/L)	≤ 0.05	–	≤ 0.05	–	–	≤ 0.05	–	0.5
Barium (mg/L)	0.040	–	0.030	–	–	0.012	–	0.7
Molybdenum (mg/L)	≤ 0.005	–	≤ 0.005	–	–	≤ 0.005	–	0.07
Nickel (mg/L)	≤ 0.0025	–	≤ 0.0025	–	–	≤ 0.0025	–	0.02
Flurorine (mg/L)	0.6	–	≤ 0.2	–	–	≤ 0.2	–	1.5
Residensial Chrorine-Total (mg/L)	≤ 0.01	–	≤ 0.01	–	–	0.07	–	–
Total Coliforms (CFU/100ml)※3	–	0	–	0	0	–	0	0※2
E.Coli. (CFU/100ml)※3	–	0	–	0	0	–	0	0※2
HClO (mg/L)	–	≤ 0.1	–	≤ 0.1	–	–	≤ 0.1	–
Fhenolic compounds (mg/L)	–	≤ 0.2	–	≤ 0.2	–	–	≤ 0.2	–

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.

※2 This value means value on water tap.

※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.

Table 2.5-30 Results of Water Quality Survey at Wells (No. 4)

WELL No.	NO.10			LWSC NO.1					WHO Guideline Value
Location	Airfield			Red Light					
Aprox. Well Depth	15m			45m					
Analysis Method ※1	Simple	Official	Simple	Simple	Simple	Official	Simple	Official	
Sampling Date	26 Jan.	29 Jan.	29 Jan.	13 Dec.	14 Jan.	22 Jan.	22 Jan.	16 Jul.	
pH (-)	6.7	5.27	5.5	5.1	5.2	4.39	5.3	4.55	–
T (°C)	27.0	29.6	–	28.2	27.3	28.4	–	28.9	–
Turbidity (NTU)	1.98	–	0.35	-	≤ 0.01	–	≤ 0.01	0.56	5※2
Color (°)	≤ 2	–	≤ 2	≤ 2	≤ 2	–	≤ 2	8	15※2
EC (mS/m)	18.9	12.55	18.5	12.2	9.1	6.40	9.3	10.39	–
Alkalinity -OH^-(mg/l as $CaCO_3$)	–	0	–	–	–	0	–	0	–
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	–	0	–	–	–	0	–	0	–
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	–	18.4	–	–	–	7.2	–	6.4	–
Calcium (mg/L)	–	12.8	–	–	–	4	–	13.2	–
Magnesium (mg/L)	–	2.2	–	–	–	1.5	–	4.1	–
Total Hardness (mg-$CaCO_3$/l)	–	41	–	–	–	16	–	50	–
LI (-)	–	-3.6	–	–	–	-5.4	–	-4.8	–
Potassium (mg/L)	–	6	–	–	–	2	–	3.5	–
Sodium (mg/L)	–	22.5	–	–	–	5	–	16.5	–
Chlorides (mg/L)	–	19.2	–	–	–	10.6	–	17.2	–
SO_4^{2-} (mg/L)	–	17	–	–	–	9	–	11	250
TDS (mg/L)	–	62.8	–	–	–	32	–	51.9	1000
NH_4 -N (mg/L)	0.1	≤ 0.09	0.1	≤ 0.1	≤ 0.1	≤ 0.09	0.2	≤ 0.09	–
NO_3 -N (mg/L)	4	7.9	5	2	4	4.9	5	8.4	11
NO_2 -N (mg/L)	–	0.008	–	–	–	0.003	–	0.005	0.9
PO_4^{3-}P (mg/L)	–	–	0.05	≤ 0.05	≤ 0.05	–	≤ 0.05	–	–
COD (mg/L)	–	–	2	–	≤ 2	–	1	–	–
SiO_2 (mg/L)	–	6.29	10	–	4	2.36	4	0.8	–
Fe (mg/L)	–	≤ 0.25	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.25	≤ 0.05	≤ 0.25	0.3
Mn (mg/L)	–	0.0136	≤ 0.5	≤ 0.5	≤ 0.5	0.0025	≤ 0.5	0.0058	0.5
Arsenic (mg/L)	–	≤ 0.001	–	–	–	≤ 0.001	–	≤ 0.001	0.01
Selenium (mg/L)	–	0.0014	–	–	–	≤ 0.001	–	≤ 0.001	0.01
Copper (mg/L)	–	0.0011	–	–	–	0.0381	–	0.0373	2
Cadmimum (mg/L)	–	0.00039	–	–	–	0.00024	–	0.00072	0.003
Chromium (mg/L)	–	≤ 0.001	–	–	–	≤ 0.001	–	≤ 0.001	0.05
Cyanide (mg/L)	–	≤ 0.02	–	–	–	≤ 0.02	–	≤ 0.02	0.07
Lead (mg/L)	–	0.0065	–	–	–	0.0027	–	0.0034	0.01
Mercury (mg/L)	–	≤ 0.0005	–	–	–	≤ 0.0005	–	≤ 0.0005	0.001
Boron (mg/L)	–	≤ 0.05	–	–	–	≤ 0.05	–	≤ 0.05	0.5
Barium (mg/L)	–	0.081	–	–	–	0.010	–	0.012	0.7
Molybdenum (mg/L)	–	≤ 0.005	–	–	–	≤ 0.005	–	≤ 0.005	0.07
Nickel (mg/L)	–	≤ 0.0025	–	–	–	≤ 0.0025	–	≤ 0.001	0.02
Flurorine (mg/L)	–	≤ 0.2	–	–	–	≤ 0.2	–	≤ 0.2	1.5
Total Coliforms (CFU/100ml)※3	0	–	0	–	0	–	0	0	0※2
E.Coli. (CFU/100ml)※3	0	–	0	–	0	–	0	20	0※2
HClO (mg/L)	–	–	–	–	≤ 0.1	–	≤ 0.1	–	–
Fhenolic compounds (mg/L)	–	–	–	–	≤ 0.2	–	≤ 0.2	–	–

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.

※2 This value means value on water tap.

※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.

These data explain the followings:

- Regarding lead, the concentration for well No.1 is more than WHO guideline value and the concentration for the other wells is relatively high. It is assumed that the concentration of groundwater in Monrovia and the surrounding area is relatively high.
- Regarding toxic substances except for lead, the concentration for all the wells is less than

WHO guideline value. Therefore, it is supposed that the risk of pollution by these substances is very low in Monrovia and the surrounding areas.

- Langelier's index, which represents index as corrosiveness of facilities, is lower than 0(-) for all the wells. Therefore, it is supposed that the corrosiveness in the groundwater in Monrovia and the surrounding areas is high. In the facility planning, some countermeasures to improve Langelier's index such as addition of lime shall be taken.
- For the wells which are deeper than 40m such as No.7 well and LWSC No.1, E.Coli which shows index as pollution by fecal matters, was not detected. Whereas, for the wells which are shallower than 15m, E.Coli was detected. It is supposed that the groundwater is polluted by fecal matters.
- The concentration of nitrate-nitrogen is more than 5mg/L in some areas. It is supposed that one of the reasons for the pollution is the lack of sanitary facilities.

(3) Survey for Water Quality at Water Tap

The results of water quality at water tap are shown in Table 2.5-31. For reference, the results of treated water from White Plain water treatment plant conducted by the Study Team are also shown in the following Table 2.5-31.

Table 2.5-31 Results of Water Quality Survey at Water Tap

Tap No.	NO.1		NO.2		NO.3		NO.4		NO.5		WHO Guideline Value
Location	PIPELINE LOAD		POLICE ACADEMY		CONGO TOWN		OLD STR.		24TH STR.		
Analysis Method ※1	Simple	Official	Simple	Official	Simple	Official	Simple	Official	Simple	Official	
Sampling Date	28 Jan.	5 Mar.	28 Jan.	5 Mar.	28 Jan.	5 Mar.	28 Jan.	5 Mar.	28 Jan.	12 Feb.	
pH (-)	7.9	6.73	7.5	6.33	7.5	6.38	7.3	6.65	7.7	6.37	–
T (°C)	27.8	31.0	28.0	32.6	26.8	31.4	27.9	32.2	27.3	31.7	–
Turbidity (NTU)	0.44	1.09	1.93	0.87	0.76	2.12	≤ 0.01	0.95	0.83	–	5
Color (°)	≤ 2	–	≤ 2	–	≤ 2	–	≤ 2	–	≤ 2	–	15
EC (mS/m)	4.9	–	5.1	–	5.1	–	5.8	–	5.5	46.2	–
Residensial Chrorine-Total (mg/L)	0.05	0.04	0.05	≤ 0.01	0.05	≤ 0.01	0.05	≤ 0.01	0.05	≤ 0.01	–
Residensial Chrorine-Free (mg/L)	0	–	0	–	0	–	0	–	0	–	–
Total Coliforms (CFU/100ml)※2	0	0	0	0	0	0	0	0	0	–	0
E.Coli. (CFU/100ml)※2	0	440	0	0	0	20	0	0	0	–	0

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.
※2 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.

Tap No.	NO.6		NO.7		NO.8		NO.9		NO.10		WHITE PLAIN TREATED WATER	WHO Guideline Value
Location	MAMBAPOINT		S.K.DO COMMUN.		CLARA TOWN		ST.PAUL BRIDGE		NEW KRU TOWN			
Analysis Method ※1	Simple	Official	Simple	Official	Simple	Official	Simple	Official	Simple	Official	Simple	
Sampling Date	28 Jan.	12 Feb.	28 Jan.	12 Feb.	28 Jan.	12 Feb.	28 Jan.	12 Feb.	28 Jan.	12 Feb.	14 Jan.	
pH (-)	7.7	6.69	7.5	6.29	7.5	6.71	7.5	6.69	7.5	6.65	7.3	–
T (°C)	28.9	31.6	28.3	30.4	28.9	32.3	30.5	33.4	29.5	31.2	28.5	–
Turbidity (NTU)	0.83	–	0.65	–	≤ 0.01	–	0.20	–	≤ 0.01	–	0.43	5
Color (°)	≤ 2	–	≤ 2	–	≤ 2	–	≤ 2	–	≤ 2	–	3	15
EC (mS/m)	5.6	4.7	5.4	4.7	4.7	4.7	5.2	4.6	5.4	4.2	5.3	–
Residensial Chrorine-Total (mg/L)	0.05	–	0.05	0.29	0.05	≤ 0.1	0.05	0.04	0.05	0.02	1.5	–
Residensial Chrorine-Free (mg/L)	0	–	0	–	0	–	0	–	0	–	–	–
Total Coliforms (CFU/100ml)※2	0	–	0	–	0	–	0	–	0	–	–	0
E.Coli. (CFU/100ml)※2	0	–	0	–	0	–	0	–	0	–	–	0

※1 Simple means simple analyssis method on site. Offical means offical analysis method conducted by authorized analysis company.
※2 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.

These data explain the followings:

- Turbidity and color for water from all the public water taps supplied from White Plain water treatment plant are less than WHO guideline value. E.coli for water from all the public water taps was also not detected. The conductivity for all the public water taps is almost the same value. Therefore, it can be assumed that water supply and distribution system are not contaminated at present and water quality control has been conducted by LWSC at the minimum required level.

- However, residual chlorine for water from public water taps was almost not detected. It is supposed that it is because chlorine reacted with ammonia and organic compounds in water supply and distribution system. Therefore, the risk of contamination in water supply and distribution system is high and the management of chlorine dosage based on appropriate chlorine demand is required.

(4) Survey for Water Quality at Sewage

The results of water quality for sewage are shown in Table 2.5-32.

No.1, No.3 and No.5 shows the sewage taken at sewer pipe and No.2 and No.4 shows the river water taken at the point 10m away from No.1 and No.4, respectively.

Table 2.5-32 Results of Water Quality Survey for Sewage

Tap No.	NO.1	NO.2	NO.3	NO.4	NO.5
Location	MESURADO DRAIN	MESURADO RIVER	BTC DRAIN	BTC SEWER CHANNEL	FIAMAH INTAKE
Sampling Date	12 Feb.	12 Feb.	12 Feb.	12 Feb.	12 Feb.
pH (-)	6.89	7.52	6.87	6.89	6.49
T (°C)	31.0	30.0	31.4	31.7	30.4
EC (mS/m)	450	4,830	675	376	261
BOD (mg/L)	510	-	340	360	30
COD_{Cr} (mg/L)	130	550	940	990	121
SS (mg/L)	620	85	220	270	13
T-N (mg/L)	190	12	130	130	35
T-P (mg/L)	31	0.1	22	22	5.3
Total Coliforms (CFU/ml)	1000 ≤	184	1000 ≤	1000 ≤	1000 ≤
E.Coli. (CFU/ml)	1000 ≤	500 ≤	1000 ≤	1000 ≤	1000 ≤

These data explain the following:

- It can be assumed that sewage in Monrovia and the surrounding areas which is not appropriately treated cause pollution in public water bodies by organic compounds such as BOD, COD, nitrogen and phosphate.

(5) Survey for Water Quality at Exploratory Well

As mentioned in “2.5.6 Result of Exploratory Well Drilling Work”, the study team constructed four boreholes, J-1, J-2, J-3 and J-4 to supply water in each community and we conducted water quality survey to meet the level as water source for drinking water.

The results of water quality for exploratory well are shown in Table 2.5-33.

Table 2.5-33 Results of Water Quality Survey for Exploratory Well

Well No.	J-1		J-2			J-3			J-4	WHO Standard
Sampling Date	13-Apr-09	16-May-09	5-May-09	16-May-09	24-Jun-09	14-May-09	16-May-09	24-Jun-09	14-Apr-09	
Aprox. Well Depth	73m		60m			63m			70m	
Analysis Method ※1	Official	Official※2	Official	Official※2	Official※2	Official	Official※2	Official※2	Official	
pH (-)	6.87	9.06	5.73	7.21	7.14	5.99	6.65	5.98	7.00	
T (°C)	28.6	30.9	30.1	29.8	29.3	31.1	29.5	29.2	27.4	
Turbidity (NTU)	0.61	12.4	2.35	11	15	38	22.4	70.4	4.2	5
Color (°)	<1	-	18	-	-	156	-	-	30	15
EC (mS/m)	33.8	-	67.2	104	57.6	14.8	22.5	26.4	19.8	
Alkalinity -OH^-(mg/l as $CaCO_3$)	0	-	0	-	-	0	-	-	0	
Alkalinity -CO_3^{2-}(mg/l as $CaCO_3$)	0	-	0	-	-	0	-	-	0	
Alkalinity -HCO^{3-}(mg/l as $CaCO_3$)	212	-	54	-	-	126	-	-	178	
Calcium (mg/L)	35.0	-	36.8	-	-	23.1	-	-	31.7	
Magnesium (mg/L)	10.0	-	16.5	-	-	5.6	-	-	10.0	
Total Hardness (mg-$CaCO_3$/l)	128	-	160	-	-	103	-	-	120	
LI (-)	-0.5	-	-2.2	-	-	-1.8	-	-	-0.5	
Potassium (mg/L)	5.8	-	6.55	-	-	1.6	-	-	2.1	
Sodium (mg/L)	32.5	-	93.9	-	-	6.8	-	-	20.0	
Chlorides (mg/L)	9.4	-	231	-	-	5.7	-	-	5.2	
SO_4^{2-} (mg/L)	<7	-	26	-	-	7	-	-	8	250
TDS (mg/L)	171	-	337	-	-	73.8	-	-	98.8	1000
NH_4 -N (mg/L)	<0.09	-	<0.09	-	-	<0.09	-	-	<0.09	
NO_3 -N (mg/L)	0.9	-	1.1	-	-	0.3	-	-	1.0	11
NO_2 -N (mg/L)	0.002	-	0.003	-	-	<0.001	-	-	0.006	0.9
SiO_2 (mg/L)	8.1	-	6.9	-	-	9.1	-	-	15.1	
Fe (mg/L)	<0.25	-	<0.25	-	-	4.3	-	<0.01	<0.25	0.3
Mn (mg/L)	0.390	-	0.435	-	-	0.277	-	-	0.271	0.5
Arsenic (mg/L)	<0.001	-	<0.001	-	-	<0.001	-	-	<0.001	0.01
Selenium (mg/L)	<0.001	-	<0.001	-	-	<0.001	-	-	<0.001	0.01
Copper (mg/L)	0.0098	-	0.0026	-	-	0.0039	-	-	0.007	2
Cadmimum (mg/L)	0.00092	-	0.00076	-	-	0.00088	-	-	0.00066	0.003
Chromium (mg/L)	<0.001	-	<0.001	-	-	<0.001	-	-	<0.001	0.05
Cyanide (mg/L)	<0.02	-	<0.02	-	-	<0.02	-	-	<0.02	0.07
Lead (mg/L)	0.0144	<0.001※4	0.00124	-	-	0.0034	-	-	0.0117	0.01
Mercury (mg/L)	<0.0005	-	0.005	<0.00005※4	<0.00005※4	0.004	<0.00005※4	<0.00005※4	<0.0005	0.001
Boron (mg/L)	<0.1	-	<0.05	-	-	<0.05	-	-	<0.1	0.5
Barium (mg/L)	0.25	-	0.14	-	-	0.10	-	-	0.055	0.7
Molybdenum (mg/L)	<0.005	-	<0.005	-	-	<0.005	-	-	<0.005	0.07
Nickel (mg/L)	<0.0025	-	0.0095	-	-	0.0036	-	-	<0.0025	0.02
Flurorine (mg/L)	<0.2	-	0.39	-	-	0.60	-	-	0.2	1.5
Total Coliforms (CFU/100ml)※3	500	0	200	-	30000※5	600	-	100※5	1000	
E.Coli. (CFU/100ml)※3	0	0	-	-	0※5	-	-	0※5	0	

※1 Offical means offical analysis method conducted by authorized analysis company.
※2 Thiese samples were anlyzed at offical water quality lab. in Japan
※3 As unit for total coliform and E.coli, "CFU/100ml"is used only in offical method. Whereas "units/100ml"is used in simple method.
※4 These values stand for the values of water filterated using filter with pore size of 1um.
※5 These analysis was conducted with simplified paper.

Turbidity in the water from J-1, J-2, J-3 and J-4 is high, compared with WHO guideline value. It is because washing of borehole is insufficient. It is supposed that turbidity for water from these boreholes from which sufficient water volume is taken is low because the turbidity will be filtrated whether the water quality of these boreholes meets the level as water source for drinking water.

The results of water quality for these boreholes are shown in Table 2.5-33.

- Because lead was detected above WHO guideline value, 0.01mg/L in the water from J-1and J-4, the study team conducted water analysis of lead again for crosscheck by sending the sample of J-1 to official water quality lab. in Japan. As the results of crosscheck, the concentration of lead in the water from J-1 found to be below WHO guideline value.
- Because Mercury was detected above WHO guideline value, 0.001mg/L in the water from J-2 and J-3, the study team conducted water analysis of lead two more times for crosscheck by sending the samples of J-1 and J-2 to official water quality lab. in Japan. As the results of crosscheck, the concentration of mercury in the water from J-2 and J-3 found to be below WHO guideline value.
- Regarding bacterial analysis, E.Coli., which stands for indicator of fecal pollution, was not detected on all the boreholes, but total coliform was detected on all the boreholes. It is supposed that the reason why total coliform was detected is through insufficient washing in the all boreholes. We will analyze bacterial items on these boreholes periodically to judge

whether the water quality of these borehole meet the level as water source for drinking water.

- On J-1, J-2 and J-3 there was no item beyond WHO guideline value but bacteria. So the study team concluded that the water on these wells is able to apply for water source of drinking water.

2.5.4.4 Summary of Water Quality Survey

Results of Water Quality Survey are summarized as follows:

- Regarding existing intake, the concentration of nitrogen such as ammonium and nitrate is very low compared with WHO guideline value. E.Coli. concentration, which represents index as pollution by fecal matters, is also low. The concentration is equivalent to Group A by Japanese environmental standards.
- Regarding old intake used in the past, according to the field survey, it was confirmed that the water flow rate is so low that the old intake cannot be used as the water source for drinking water. In addition, according to the water quality survey, concentration of color, coliform bacteria and E.Coli.are so high that this water also cannot be applied for water source as drinking water.
- On existing WTP intake and old intake there was no item beyond WHO guideline value but bacteria. So water on existing intake point in St.Paul river is able to apply for water source of drinking water by treating with sedimentation and sand filtration using coagulant and adding chlorine to raw water appropriately.
- Regarding lead, the concentration for the well No.1 is more than WHO guideline value and the concentration for the other wells is relatively high. It can be assumed that the concentration of groundwater in Monrovia and the surrounding areas is relatively high.
- Regarding toxic substances except for lead, the concentration for all the wells is less than WHO guideline value. Therefore, it is assumed that the risk of pollution by these substances is very low in Monrovia and the surrounding areas.
- Turbidity and color for all the public water taps supplied from White Plain water treatment plant are less than WHO guideline value. E.coli for all the public water taps is also not detected. And the conductivity for all the public water taps is almost the same value. Therefore, it is supposed that water supply and distribution system are not contaminated at present and water quality control has been conducted by LWSC at the minimum required level.
- It can be assumed that the sewage in Monrovia and the surrounding areas which is not appropriately treated causes pollution in public water bodies by organic compounds such as BOD and COD, nitrogen and phosphate.
- On J-1, J-2 and J-3 there was no item beyond WHO guideline value but bacteria. So the study team concluded that water on these wells is able to apply for water source of drinking water.

2.5.5 Results of Public Awareness Survey

2.5.5.1 Objectives of the Survey

The objectives of the Survey is to check the conditions of water and sanitation of citizens, their attitudes and satisfactory level towards water and sanitation, and their willingness to pay for improved services related to water and sanitation in Greater Monrovia. Specifically, the survey sought to achieve the following objectives:

- To assess the current conditions of water and sanitation in Greater Monrovia;
- To determine the attitudes and behavior of the people towards water and sanitation in local communities;

- To determine public management structures in place to ensure their effectiveness and efficiency;
- To determine the willingness of the people to pay for the improved water and sanitation services; and
- To determine the level of ability (affordability) of the people to pay for the improved water and sanitation services.

2.5.5.2 Scope of the Survey

(1) Survey Area

Survey area including Johnsonville and Paynesville, which is the target area of the proposed Master Plan Study, consists of 16 zones and 163 communities (this is the former number of communities before the boundary was verified in the Study). For the propose of developing the Master Plan, the 163 communities in Greater Monrovia are divided into 128 Urban Communities and 33 Rural Communities as shown in Figure 2.5-25. In addition, the distribution of number of communities by zones is shown in Table 2.5.34. 436 households were interviewed in the survey and the associated dwellers were 3,420 persons.

(2) Key and Specific Issues Covered by the Survey

- Accessibility of water to the community dwellers and its proximities;
- Sources of water for community dwellers;
- Current status of water consumption of community dwellers;
- Willingness of community dwellers to participate in the management of LWSC facilities in their communities;
- Level of satisfaction and dissatisfaction of community members with water and sewerage services in their communities; and
- Ability and willingness of community members to pay for water and sanitation services.

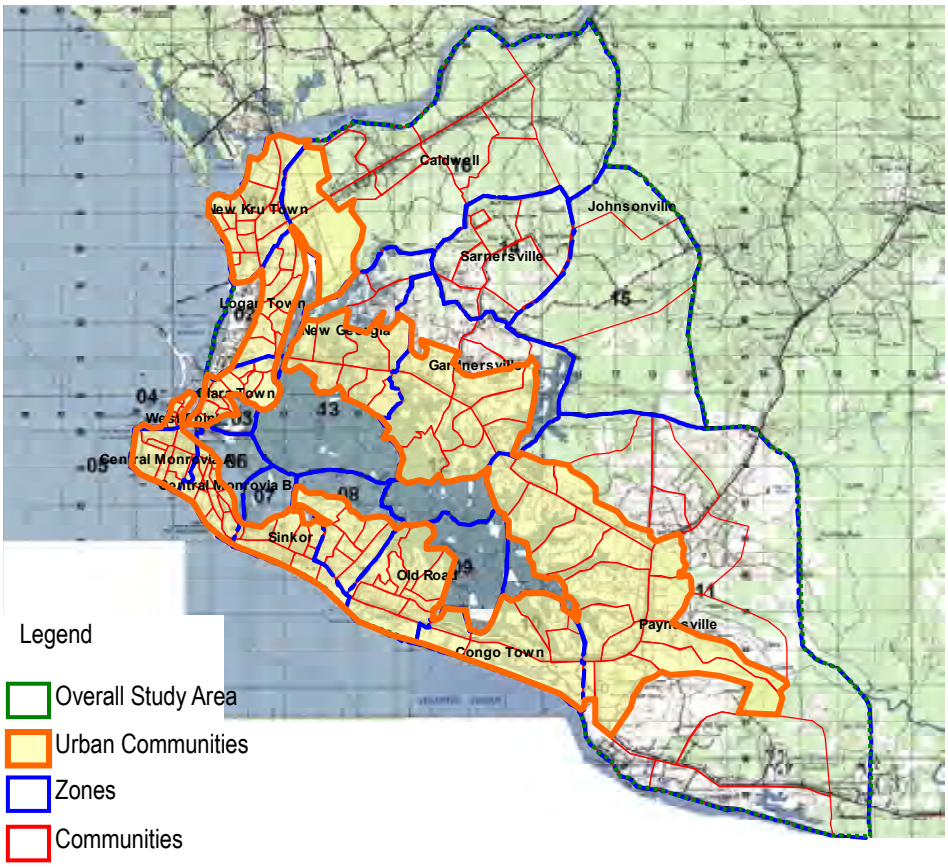


Figure 2.5-25 Survey Area

Table 2.5-34 Number of Communities and Interviews by Zones

Zone Code	General Name	No. of Communities	No. of Interviews	Percent
100	New Kru Town	14	42	9.63
200	Logan Town	10	30	6.88
300	Clara Town	12	37	8.49
400	West Point	6	18	4.13
500	Monrovia A	7	24	5.50
600	Monrovia B	13	44	10.09
700	Sinkor- 1	8	25	5.73
800	Sinkor-2	6	18	4.13
900	Old Road	10	31	7.11
1000	Congo Town	7	21	4.82
1100	Paynesville	29	66	15.14
1200	Gardnerville	12	28	6.42
1300	Bardnersville	6	35	8.03
1400	New Georgia	11	8	1.83
1500	Johnsonville	2	2	0.46
1600	Caldwell	10	7	1.61
Total No. of Items		**163**	**436**	**100**

Source: Public Awareness Survey Report

2.5.5.3 Survey Methodology

This survey contained two stages in its sampling design. Communities were considered as the primary sampling units (PSUs). The zones have different sizes in terms of number of communities. The communities are also subdivided into enumeration areas (EAs). For the purpose of this survey, communities were directly used as primary sampling units, instead of EAs, since it was easier and much more convenient to clearly identify the communities involved. A complete enumeration was carried out at the community level. Three (3) households are sampled in each urban community and one (1) in each rural community.

2.5.5.4 Survey Findings

(1) Household Income

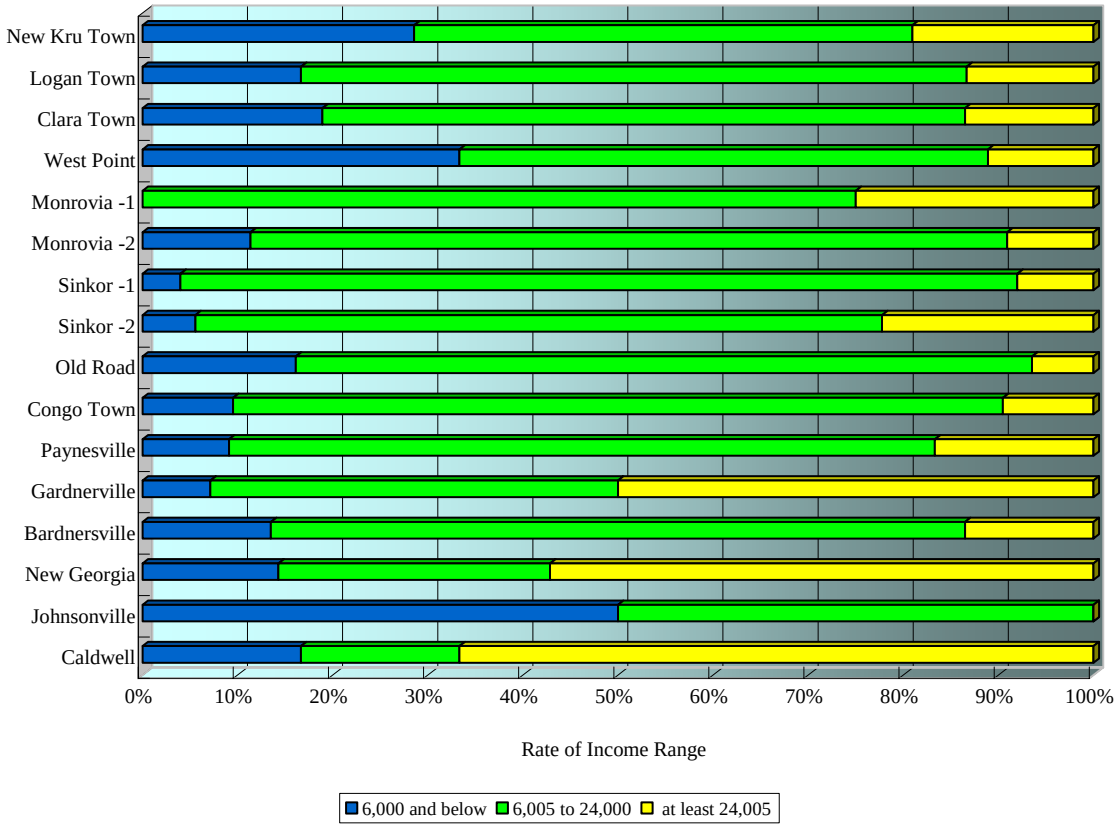
The total of 3,420 enumerated people in the sample contain 1,832 out of which labor force is 54 % (at least age 18). Of 1,832, it was reported that 584 (32%) were engaged in income earning activities at the time of the survey. On the average (arithmetic means), the income earner was one (1) person in each household.

Table 2.5-35 shows household income by zones. About 83% of households monthly earnings is from LRD6,000 to LRD24,000 (or less than USD400). While the rest (about 17%) monthly earnings is over LRD24,000 and over half of the latter (about 57%) earn up to LRD30,000 (USD500). Greater proportions of households in the areas with high rate of at least LRD24,000 are New Georgia with 63%, Gardnerville with 50% and Caldwell with 44% (see Figure 2.5-26).

Table 2.5-35 Number and Rate of Households by Amounts of Income

Zone Code	Neighbor-hood	Household Income Categories																					
		6,000 and below		6,005 to 12,000		12,005 to 18,000		18,005 to 24,000		24,005 to 30,000		30,005 to 36,000		36,005 to 42,000		42,005 to 48,000		48,005 to 54,000		54,005 to 60,000		Above 72,000	
100	New Kru Town	12	28.6%	7	16.7%	5	11.9%	10	23.8%	4	9.5%	0	0.0%	2	4.8%	0	0.0%	1	0.0%	1	2.4%	1	2.4%
200	Logan Town	5	16.7%	5	16.7%	12	40.0%	4	13.3%	2	6.7%	1	3.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	3.3%
300	Clara Town	7	18.9%	15	40.5%	8	21.6%	2	5.4%	4	10.8%	0	0.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	2.7%
400	West Point	6	33.3%	6	33.3%	3	16.7%	1	5.6%	1	5.6%	1	5.6%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
500	Monrovia-1	0	0.0%	8	33.3%	3	12.5%	7	29.2%	4	16.7%	0	0.0%	0	0.0%	1	4.2%	1	4.2%	0	0.0%	0	0.0%
600	Monrovia-2	5	11.4%	17	38.6%	16	36.4%	2	4.5%	2	4.5%	1	2.3%	1	2.3%	0	0.0%	0	0.0%	1	4.2%	0	0.0%
700	Sinkor-1	1	4.0%	13	52.0%	5	20.0%	4	16.0%	0	0.0%	2	8.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
800	Sinkor-2	1	5.6%	4	22.2%	6	33.3%	3	16.7%	4	22.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
900	Old Road	5	16.1%	13	41.9%	9	29.0%	2	6.5%	1	3.2%	0	0.0%	1	3.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1000	Congo Town	2	9.5%	9	42.9%	4	19.0%	4	19.0%	0	0.0%	2	9.5%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1100	Paynesville	6	9.1%	16	24.2%	23	34.8%	10	15.2%	9	13.6%	1	1.5%	1	1.5%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1200	Cardnerville	2	7.1%	1	3.6%	6	21.4%	5	17.9%	7	25.0%	2	7.1%	0	0.0%	1	3.6%	1	3.6%	2	7.1%	0	3.6%
1300	Bardnersville	5	13.5%	17	45.9%	8	21.6%	2	5.4%	4	10.8%	0	0.0%	0	0.0%	1	2.7%	0	0.0%	0	0.0%	0	0.0%
1400	New Georgia	1	14.3%	1	14.3%	0	0.0%	1	14.3%	1	14.3%	1	14.3%	0	0.0%	0	0.0%	0	0.0%	1	14.3%	1	14.3%
1500	Johnsonville	1	50.0%	0	0.0%	1	50.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1600	Caldwell	2	16.7%	0	0.0%	2	16.7%	0	0.0%	0	0.0%	2	16.7%	0	0.0%	0	0.0%	0	0.0%	1	8.3%	5	41.7%
Total		61	14	132	30.3	111	25.5	57	13.1	43	9.9	13	3	5	1.1	3	0.7%	2	0.5%	4	0.9	10	2.3

Source: Public Awareness Survey Report

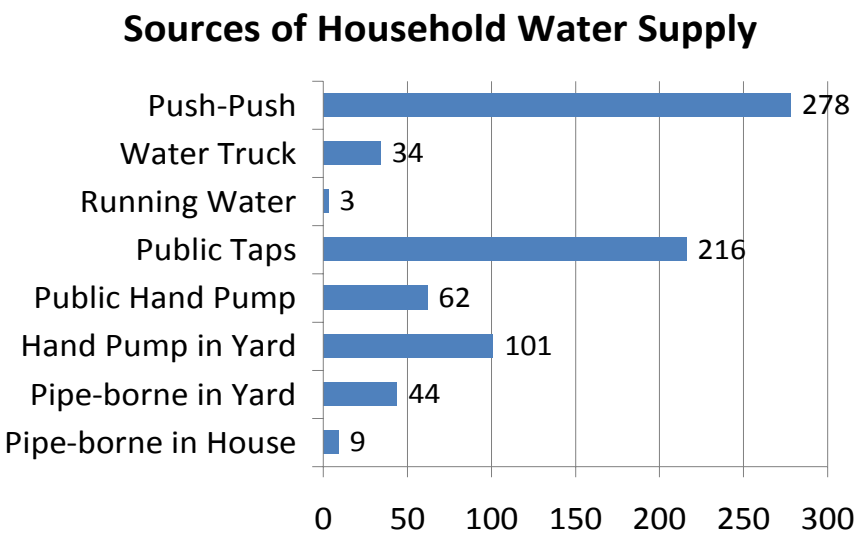


Source: Public Awareness Survey Report

Figure 2.5-26 Rate of Income Range by Zone

(2) Sources of Household Water Supply

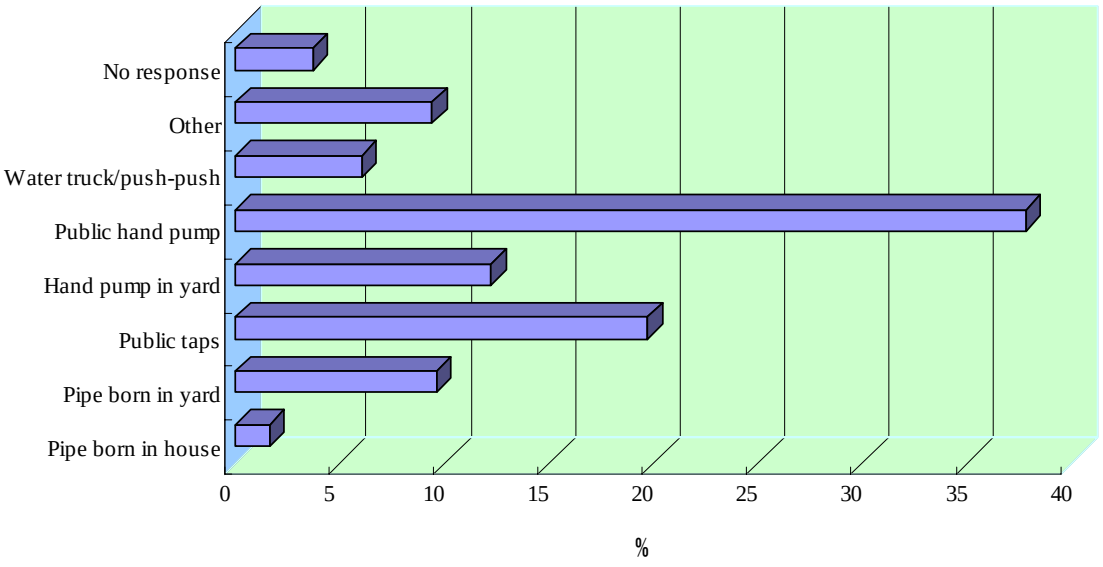
Main water sources for residential purpose are categorized into only two. One is LWSC's facilities and another is private source. On contrary, types of water supply are very various as shown in Figure 2.5-27. According to the Figure 2.5-27, 'Push-Push' (namely, carts) is the most major tool of water supply. Its water source is either LWSC facilities or private water source. Next major tool is public taps (Kiosk), and the water source of which is LWSC facilities.



Note: This is the results of multiple responses.
Source: Public Awareness Survey Report

Figure 2.5-27 Types of Sources for Household Water Supply

On the other hand, main water sources for drinking water are as shown in Figure 2.5-28. Public hand pump and public taps make up over 50% of all the tools of water supply. The percentage of water supply by means of 'Push-Push' is relatively low. It is supposed that this is because the source of water transported by 'Push-Push' is uncertain and the provision of water is not reliable for dwellers to drink such water.



Source: Public Awareness Survey Report

Figure 2.5-28 Water Sources of Drinking Water

(3) Water Supply Hours

According to Table 2.5-36, water is available for at least 6 hours daily to about 46 % of households, which rely on the pipe-borne water. On the other hand, water is available only for every other day to about 26%. Water supply hours vary largely by zones.

Table 2.5-36 Water Supply Hours

Zone Code	Neighbor-hood	>6hr		6hr		4-6hr		1-3hr		Every Other Day		Once		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
100	New Kru Town	1	5.3	6	31.6	3	15.8	0	0.0	8	42.1	1	5.3	19	100
200	Logan Town	3	13.6	6	27.3	0	0.0	1	4.5	12	54.5	0	0.0	22	100
300	Clara Town	0	0.0	7	31.8	6	27.3	0	0.0	11	40.9	0	0.0	24	100
400	West Point	0	0.0	1	14.3	2	28.6	0	0.0	4	57.2	0	0.0	7	100
500	Monrovia-1	1	14.3	1	14.3	3	42.9	0	0.0	1	14.3	1	14.3	7	100
600	Monrovia-2	3	15.0	4	20.0	1	5.0	11	55.5	1	5.0	0	0.0	20	100
700	Sinkor-1	2	25.0	3	37.5	0	0.0	3	37.5	0	0.0	0	0.0	8	100
800	Sinkor-2	3	42.9	3	42.9	0	0.0	1	14.3	0	0.0	0	0.0	7	100
900	Old Road	3	50.0	2	33.3	0	0.0	1	16.7	0	0.0	0	0.0	6	100
1000	Congo Town	1	25.0	2	50.0	0	0.0	1	25.0	0	0.0	0	0.0	4	100
1100	Paynesville	3	33.3	4	44.4	0	0.0	2	22.2	0	0.0	0	0.0	9	100
1200	Cardnerville	0	0.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	1	100
1300	Bardnersville	2	66.7	0	0.0	0	0.0	1	33.3	0	0.0	0	0.0	3	100
1400	New Georgia	1	16.7	3	50.0	1	16.7	1	16.7	0	0.0	0	0.0	6	100
1500	Johnsonville	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	100
1600	Caldwell	0	0.0	3	42.9	2	28.6	2	28.6	0	0.0	0	0.0	7	100
Total		**25**	**16.3**	**46**	**29.6**	**18**	**11.1**	**24**	**15.6**	**37**	**25.9**	**2**	**1.5**	**152**	**100**

Source: Public Awareness Survey Report

(4) Time Spent for Fetching Water

Table 2.5-37 shows the time spent to fetch water by zone. People that take 5 to 10 minutes at a time to fetch water once from their residential water points, make up 47% of all households. For the remaining 53%, it takes from 10 to over 30 minutes to fetch water once at any time during the day. The worst experiences are felt by 13% of households, who take 30 minutes at a time to fetch their residential water. In certain zone, the time spent to fetch water varies in the wide range of 5-30 minutes with the exception of Monrovia Two, Sinkor Two and Johnsonville.

Table 2.5-37 Time Spent to Fetch Water by Zone

Zone Code	Neighborhood	Description of Frequency	Length of Time					Total
			5 - 10 min.	10 - 20 min.	20 - 30 min.	> 30 min.	No response	
100	New Kru Town	Count	11	6	9	13	3	42
		Percemt	26.2%	14.3%	21.4%	31.0%	7.1%	100.0%
200	Logan Town	Count	13	9	3	4	0	29
		Percemt	44.8%	31.0%	10.3%	13.8%	0.0%	100.0%
300	Clara Town	Count	17	3	8	7	1	36
		Percemt	47.2%	8.3%	22.2%	19.4%	2.8%	100.0%
400	West Point	Count	6	2	0	10	0	18
		Percemt	33.3%	11.1%	0.0%	55.6%	0.0%	100.0%
500	Monrovia-1	Count	7	5	5	4	0	21
		Percemt	33.3%	23.8%	23.8%	19.0%	0.0%	100.0%
600	Monrovia-2	Count	23	11	2	0	4	40
		Percemt	57.5%	27.5%	5.0%	0.0%	10.0%	100.0%
700	Snkor-1	Count	16	2	2	1	3	24
		Percemt	66.7%	8.3%	8.3%	4.2%	12.5%	100.0%
800	Snkor-2	Count	11	4	0	0	1	16
		Percemt	68.8%	25.0%	0.0%	0.0%	6.3%	100.0%
900	Old Road	Count	19	4	2	2	3	30
		Percemt	63.3%	13.3%	6.7%	6.7%	10.0%	100.0%
1000	Congo Town	Count	12	2	0	1	1	16
		Percemt	75.0%	12.5%	0.0%	6.3%	6.3%	100.0%
1100	Paynesville	Count	28	14	11	7	2	62
		Percemt	45.2%	22.6%	17.7%	11.3%	3.2%	100.0%
1200	Gardnerville	Count	10	5	9	2	0	26
		Percemt	38.5%	19.2%	34.6%	7.7%	0.0%	100.0%
1300	Bardnesville	Count	21	9	3	1	0	34
		Percemt	61.8%	26.5%	8.8%	2.9%	0.0%	100.0%
1400	New Georgia	Count	2	4	2	3	0	11
		Percemt	18.2%	36.4%	18.2%	27.3%	0.0%	100.0%
1500	Johnsonville	Count	2	1	1	0	1	5
		Percemt	40.0%	20.0%	20.0%	0.0%	20.0%	100.0%
1600	Caldwell	Count	1	5	2	2	0	10
		Percemt	10.0%	50.0%	20.0%	20.0%	0.0%	100.0%
Total		Count	199	86	59	57	19	420
		Percemt	47.4%	20.5%	14.0%	13.6%	4.5%	100.0%

Source: Public Awareness Survey Report

(5) Water Consumption

As the following table shows, about 60% of households consumed between 15 and 30 gallons of water a day per household, while 27% consumed between 35 and 50 gallons a day. Adding to this is another 4%, who consumed at least 55 gallons a day. Only around 10% consumed less than 10 gallons a day. Daily water consumption of the range between 15 and 30 gallons is the highest in all the zones.

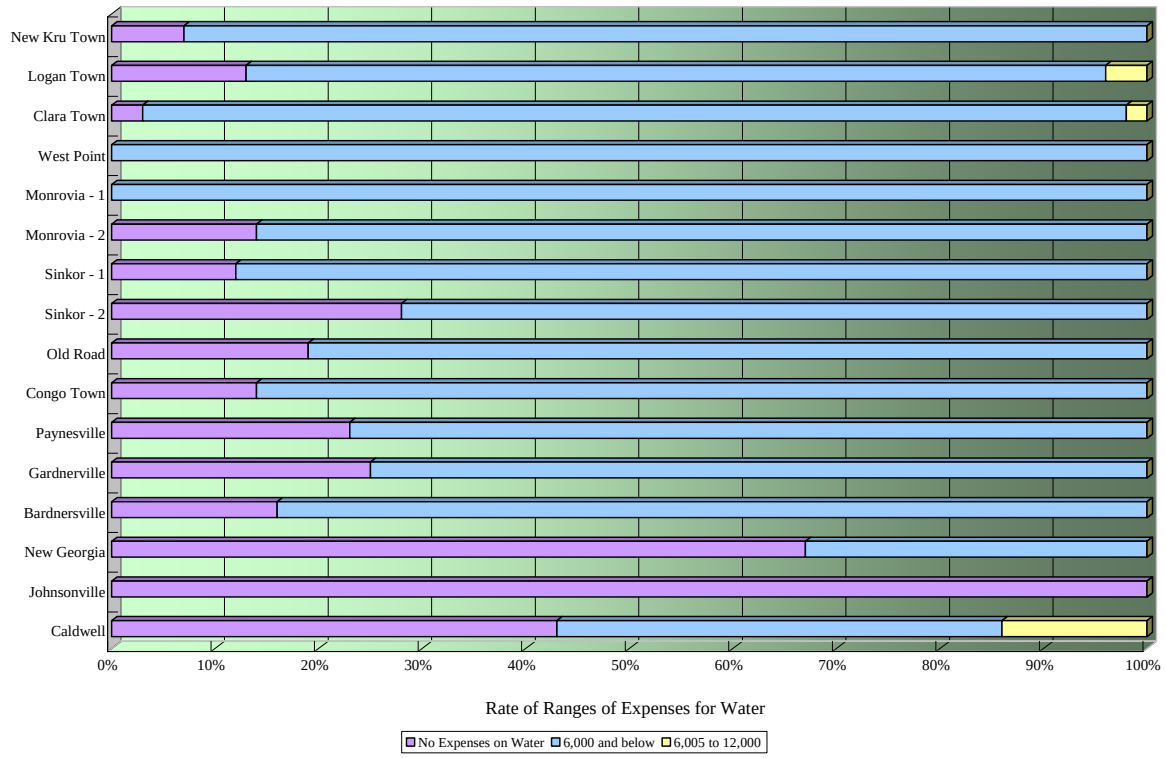
Table 2.5-38 Water Consumption by Zone

Zone Code	Neighborhood	Description of Frequency	Quantity of Water in Gallons							**Total**
			<15	15-20	25-30	35-40	45-50	55-60	65+	
100	New Kru Town	Count	4	10	10	7	8	1	2	**42**
		Percent	9.5%	23.8%	23.8%	16.7%	19.0%	2.4%	4.8%	**100.0%**
200	Logan Town	Count	3	9	7	6	3	1	1	**30**
		Percent	10.0%	30.0%	23.3%	20.0%	10.0%	3.3%	3.3%	**100.0%**
300	Clara Town	Count	5	8	7	10	6	1	0	**37**
		Percent	13.5%	21.6%	18.9%	27.0%	16.2%	2.7%	0.0%	**100.0%**
400	West Point	Count	0	5	5	5	3	0	0	**18**
		Percent	0.0%	27.8%	27.8%	27.8%	16.7%	0.0%	0.0%	**100.0%**
500	Centra Monrovia A	Count	1	5	8	4	4	1	1	**24**
		Percent	4.2%	20.8%	33.3%	16.7%	16.7%	4.2%	4.2%	**100.0%**
600	Centra Monrovia B	Count	8	17	15	3	1	0	0	**44**
		Percent	18.2%	38.6%	34.1%	6.8%	2.3%	0.0%	0.0%	**100.0%**
700	Sinkor 1	Count	4	10	8	0	2	1	0	**25**
		Percent	16.0%	40.0%	32.0%	0.0%	8.0%	4.0%	0.0%	**100.0%**
800	Sinkor 2	Count	1	12	3	2	0	0	0	**18**
		Percent	5.6%	66.7%	16.7%	11.1%	0.0%	0.0%	0.0%	**100.0%**
900	Old Road	Count	6	13	7	1	2	1	1	**31**
		Percent	19.4%	41.9%	22.6%	3.2%	6.5%	3.2%	3.2%	**100.0%**
1000	Congo Town	Count	1	8	6	2	3	0	1	**21**
		Percent	4.8%	38.1%	28.6%	9.5%	14.3%	0.0%	4.8%	**100.0%**
1100	Paynesville	Count	7	23	20	14	2	0	0	**66**
		Percent	10.6%	34.8%	30.3%	21.2%	3.0%	0.0%	0.0%	**100.0%**
1200	Gardnerville	Count	0	8	10	8	2	0	0	**28**
		Percent	0.0%	28.6%	35.7%	28.6%	7.1%	0.0%	0.0%	**100.0%**
1300	New Georgia	Count	2	8	12	8	3	2	2	**37**
		Percent	5.4%	21.6%	32.4%	21.6%	8.1%	5.4%	5.4%	**100.0%**
1400	Bardnersville	Count	0	1	1	3	1	0	0	**6**
		Percent	0.0%	16.7%	16.7%	50.0%	16.7%	0.0%	0.0%	**100.0%**
1500	Johnsonville	Count		1	1					**2**
		Percent		50.0%	50.0%					**100.0%**
1600	Caldwell	Count	1	2	0	1	2	1	0	**7**
		Percent	14.3%	28.6%	0.0%	14.3%	28.6%	14.3%	0.0%	**100.0%**
Total		**Count**	**43**	**140**	**120**	**74**	**42**	**9**	**8**	**436**
		Percent	**9.9%**	**32.1%**	**27.5%**	**17.0%**	**9.6%**	**2.1%**	**1.8%**	**100.0%**

Source: Public Awareness Survey Report

(6) Expenditure for Water

Households in most of the zones spend LRD6,000 or less for water as shown in Figure 2.5-29. While about 20% of the surveyed households dose not spend money for water at all. This is because most of their water is supplied from their own water sources or other public water sources such as shallow wells with hand pump, which was funded by NGO, etc.



Source: Public Awareness Survey Report

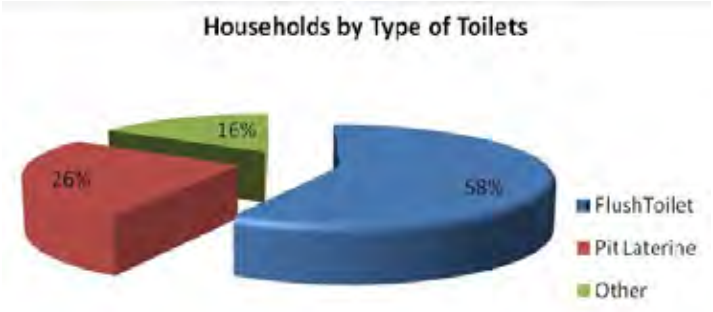
Figure 2.5-29 Rate of Range of Expenses for Water

(7) Willingness to Pay for Water Supply

The households covered by the survey generally agreed to pay more than the amount that they are currently paying for water. If the piped water became available to them, only around 7% and 3%, respectively, would be willing to pay above LRD850 (about USD15) monthly for it in the house and in the yard. While, the rest of between 80% and 88% were willing to pay only a maximum of LRD550 (about USD10) for piped water in their houses and yards.

(8) Types of Toilets

Nearly half (58%) of the households covered by the survey have used flush toilets as shown in Figure 2.5-30. The rest have used other means, the most common being pit latrine, which was made popular since the war, after the breakdown of the modern sewerage system in Monrovia and other cities in Liberia.



Source: Public Awareness Survey Report

Figure 2.5-30 Types of Household Toilets

(9) Types of Sanitation System

Table 2.5-39 shows the types of sanitation facilities of the households, which were covered by the public awareness survey.

According to the results of public awareness survey, the most common type of sanitation facilities used among households is the septic tank. However, only around 11% of the surveyed households are connected to the sewerage system, which indicates the severe limitation of the current sewerage system. In addition to septic tanks and the sewerage system, pit latrines are in use by about 20% of the households, while a staggering 21% does not have sanitation facilities. This means that mostly to a large extent, safe wastewater disposal is a critical challenge.

Table 2.5-39 Types of Sanitation Facilities

Zone Code	Zone	Unit	Sewer connection	Septic tank	Pit latrine	No sanitation facilities	No response	Total
100	New Kru Town	Count	2	13	15	15	0	45
		Percent	4.4%	28.9%	33.3%	33.3%	0.0%	100.0%
200	Logan Town	Count	0	14	11	2	0	27
		Percent	0.0%	51.9%	40.7%	7.4%	0.0%	100.0%
300	Clara Town	Count	3	11	13	10	0	37
		Percent	8.1%	29.7%	35.1%	27.0%	0.0%	100.0%
400	West Point	Count	0	1	7	10	0	18
		Percent	0.0%	5.6%	38.9%	55.6%	0.0%	100.0%
500	Centra Monrovia A	Count	13	10	0	1	0	24
		Percent	54.2%	41.7%	0.0%	4.2%	0.0%	100.0%
600	Centra Monrovia B	Count	8	24	4	7	1	44
		Percent	18.2%	54.5%	9.1%	15.9%	2.3%	100.0%
700	Sinkor 1	Count	5	10	1	9	0	25
		Percent	20.0%	40.0%	4.0%	36.0%	0.0%	100.0%
800	Sinkor 2	Count	1	12	1	4	0	18
		Percent	5.6%	66.7%	5.6%	22.2%	0.0%	100.0%
900	Old Road	Count	5	15	3	8	0	31
		Percent	16.1%	48.4%	9.7%	25.8%	0.0%	100.0%
1000	Congo Town	Count	1	7	1	12	0	21
		Percent	4.8%	33.3%	4.8%	57.1%	0.0%	100.0%
1100	Paynesville	Count	5	39	14	7	1	66
		Percent	7.6%	59.1%	21.2%	10.6%	1.5%	100.0%
1200	Gardnerville	Count	0	25	3	0	0	28
		Percent	0.0%	89.3%	10.7%	0.0%	0.0%	100.0%
1300	New Georgia	Count	5	16	11	5	0	37
		Percent	13.5%	43.2%	29.7%	13.5%	0.0%	100.0%
1400	Bardnersville	Count	0	6	0	0	0	6
		Percent	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
1500	Johnsonville	Count	0	1	0	1	0	2
		Percent	0.0%	50.0%	0.0%	50.0%	0.0%	100.0%
1600	Caldwell	Count	0	4	1	2	0	7
		Percent	0.0%	57.1%	14.3%	28.6%	0.0%	100.0%
Total		Count	48	208	85	93	2	436
		Percent	11.0%	47.7%	19.5%	21.3%	0.5%	100.0%

Source: Public Awareness Survey Report

(10) Expenditure for Wastewater Disposal

Not over 86% of the surveyed households pay expenses for wastewater disposal. Only the rest 14% pays it, but it is very low expenditure which is between LRD100 (USD1.6) and LRD250 (USD4) monthly.

LWSC has a sewerage tariff system but since the existing sewerage facilities have not been functional, it is envisaged that the LWSC has not concentrated to bill users for wastewater.

(11) Willingness to Pay for Wastewater Disposal

According to the results based on the multiple answers in the survey, around 75% of the surveyed households would be willing to pay for septic tank and its maintenance services, if provided. But there is a limit to how much they are willing to pay for it; close to two-thirds are willing to pay only up to LRD250, which is about USD4/month.

In the case of pit latrines and maintenance services, only close to 33% would be willing to pay for it. This low willingness rate may be due to the fact that only 22% do use pit latrines; and because of the low income experiences of most pit latrine users. Of the households of 33% who would be willing to pay for the pit latrine and its maintenance, around 55% are willing to pay only up to LRD100 monthly for such services. Around 35% are willing to pay up to LRD250.

(12) Conclusion on Survey Findings

The unemployment rate is quite high, which is about 30% of the labor force in Greater Monrovia. In addition, it should be noted that household incomes are at low level as the incomes in majority range from USD100 to 400 monthly. In case of such incomes if the common rate of about 4% of incomes that is based on one of the indexes given by the World Bank for developing countries is applied to assume the ability to pay safe water expenses, USD4 to 16 monthly shall be given for paying the water expenses. It was found that the willingness to pay (USD10) observed in the survey is within this range (USD4 to 16). Even if the dwellers have the willingness to access to safe water and sanitation facilities, it is envisaged that their abilities and willingness to pay are very limited for safe water and wastewater disposal. From these consequences, in order to plan the future new and/or rehabilitation programme of water and sanitation facilities, the cost recovery of operation and maintenance shall be examined carefully.

2.5.6 Results of Exploratory Well Drilling

The exploratory well drilling work, namely the drilling work of 4 wells (Well No.J-1, J-2, J-3 and J-4) including following works, is carried out to obtain the aquifer structure and aquifer properties including hydraulic parameter in detail at each well site.

The exploratory well drilling work includes 14-1/2 inches and 11-1/4 inches-well drilling work, geophysical logging work, 6 inches screen and casing installation work, gravel packing and grouting work, pumping test work and well head installation work.

2.5.6.1 Exploratory Well Drilling Work

(1) Location and Quantity of Drilling Well

The Location of exploratory wells is shown in Figure 2.5-31. The Quantity of drilling work is shown in Table 2.5-40.

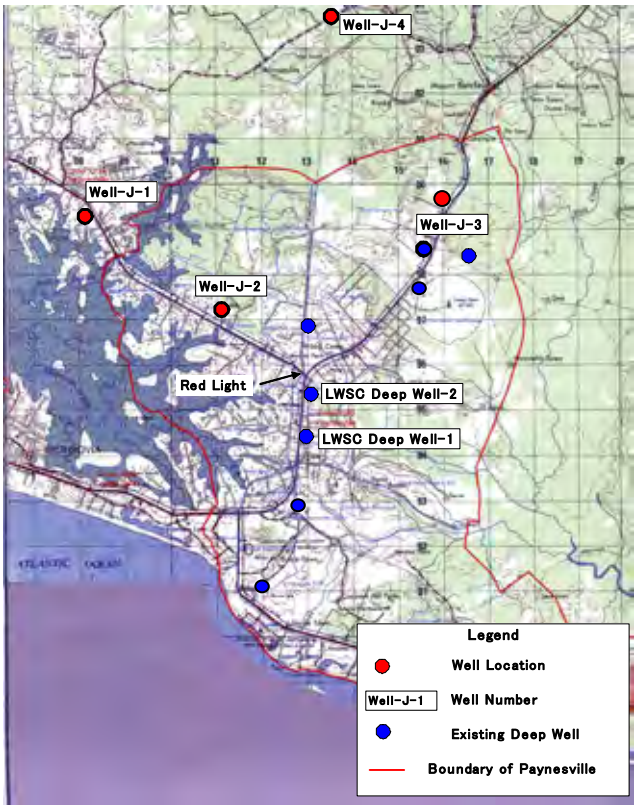


Figure 2.5-31 Location of Exploratory Well

Table 2.5-40 Location and Quantity of Exploratory Well Drilling Work

Item		J-1	J-2	J-3	J-4	Total
Coordinates by UTM (m)	Easting	308194	310989	316088	313557	
	Northing	699299	697063	699445	703713	
	Elevation	6	6	10	20	
Total depth (m)		73.0	60.0	63.0	70.0	266.0
Drilling diameter (cm)		11.25	11.25	11.25	11.25	
Casing diameter (cm)		6.0	6.0	6.0	6.0	
Casing length (m)		21.0	18.0	23.5	36.0	98.5
Screen length (m)		46.5	32.5	37.0	49.5	165.5
Gravel packing (m)		64.0	39.0	44.0	50.0	197.0
Grouting length (m)		6.0	6.0	6.0	6.0	24.0

(2) Lithology and Electric Resistivity of Drilling Well

The lithological log and electric resistivity log of Well No.J-1 to Well No.J-4 is shown in Figure 2.5-32

(a) Well No.J-1

The lithology of Well No.J-1 consists of overburden up to the depth of 1m, weathered sandstone and sandstone at the depth of 1m to 27m, alternation of mudstone and sandstone at the depth of 27m to 61m, and Shale at the depth of 61m to 73m. The shale portion has rather crackly portion by dike of diabase.

The electric resistivity log shows that the resistivity range of 100-200 ohm-m of upper portion is sandstone, and the resistivity range 50-150 ohm-m of lower potion is alternation zone of mudstone (shale) and sandstone, and the resistivity range around 200 ohm-m is supposed to be hard portion of mudstone or shale with intrusive affection of diabase according to lithological information.

The sandstone of upper portion, alternation part of lower portion and fissure zone of mudstone or shale affected by diabase intrusion at deeper potion is expected as groundwater presence layers. This well is expected to have rather high water producing capacity.

(b) Well No.J-2

The lithology of Well No.J-2 consists of overburden up to the depth of 1m, weathered medium sandstone at the depth of 1m to 4m, intercalated alternation of sandstone and mudstone at the depth of 4m to 14m, fine sandstone at the depth of 14m to 25m, mudstone (shale) at the depth of 25m to 45m with diabase dike mixed portion at lower part and diabase intrusion portion at the depth of 45m to 60m. The upper part of diabase intrusion portion has rather crackly portion.

The electric resistivity log shows that the resistivity range 80-180 ohm-m at the depth of 12m to 24m is sandstone, and the unchanged and almost stable resistivity zone with 100-200 ohm-m range under 24m is supposed to be stacking condition of the logging probe by swelling of clay zone of upper part of mudstone (shale) layer. This well is expected to have rather low water producing capacity.

(c) Well No.J-3

The lithology of Well No.J-3 consists of overburden up to the depth of 1m, fine sandstone with thin intercalated alternation layer of mudstone and sandstone at the depth of 1m to 8m, rather thick mudstone predominant zone with alternation layers of mudstone and sandstone at the depth of 8m to 44m, and mudstone (shale) at the depth of 44m to 63m. The lowest mudstone (shale) layer has diabase dyke intrusion part at the lower portion.

The electric resistivity log shows that the resistivity range 0-50 ohm-m of whole portion is mudstone (shale) and the resistivity range 50-100 ohm-m of 3 layers is alternation zone of mudstone (shale) and sandstone. The sandstone of upper portion is expected as groundwater presence layer, and the alternation layers of middle portion are also expected as a little bit ground water presence layers. This well is expected to have rather low water producing capacity.

(d) Well No.J-4

The lithology of Well No.J-4 consists of overburden up to 2m, very high weathered portion of base rock like silt at the depth of 2m to 13m, high weathered portion of base rock like coarse sand at the depth of 13m to14m, weathered melanocaratic gneiss at the depth of 14m to 21m, and melanocratic gneiss at the depth of 21m to 70m.

The electrical resistivity log shows 50 or less ohm-m which is very low resistivity. The whole section is presumed to be slightly weathered hard rock and fresh hard rock portion of melanocratic gneiss from lithology. Relatively high resistivity portion and low resistivity portion may have possibility of little groundwater presence of crackly or small fissure zone according to driller's field record of water tap feeling. This well is expected to have rather little water producing capacity.

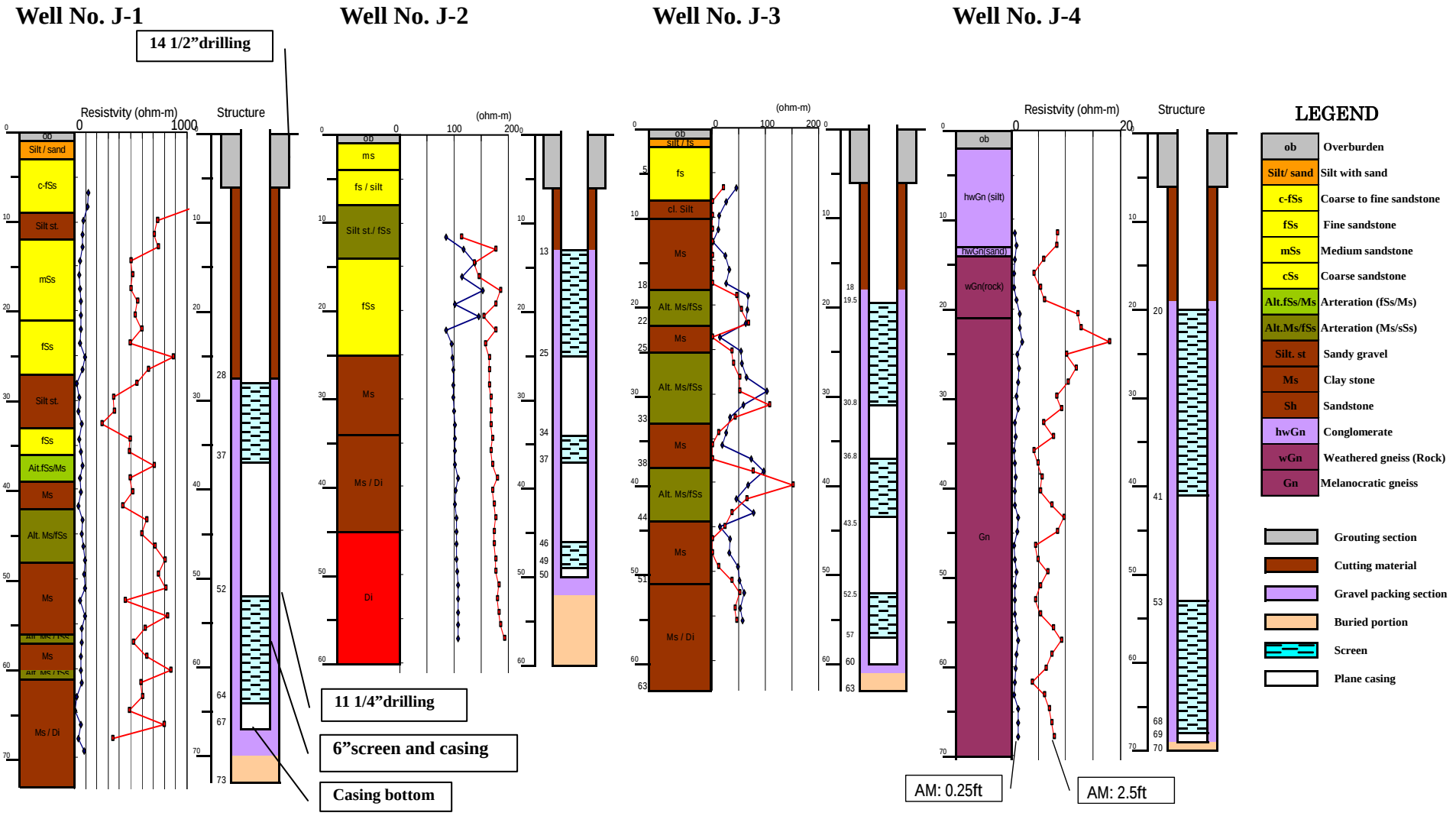


Figure-2.5-32 Lithological Log, Electric Resistivity Log and Well Structure of Well No.J-1 and Well No.J-4

(3) Screen and Casing Installation, Gravel Packing and Grouting

The well structure of Well No.J-1 and Well No.J-4 is shown in Figure 2.5-32. The condition of screen set is as follows;

(a) Well J-1

The screen is installed at the depth of 28-37m for alternation zone of sandstone and mudstone (Resistivity range 50-150 ohm-m), and at the depth of 52-64m for crackly or fissure zone of mudstone or shale with affection of intrusive diorite (Resistivity range 50-150 ohm-m). The gravel packing is carried out at the depth of 28m-70m section, and the grouting is conducted at the section of ground level to the depth of 6m. The depth of 70m-73m section is filled with digging materials, and the depth of 6m-38m section between the casing and the drilling hole is filled up with the cutting materials.

(b) Well J-2

The screen is installed at the depth of 13-25m for sandstone layer (Resistivity range 80-180 ohm-m), and at the depth of 34-37m and 45-49m for crackly or fissure zone of mudstone or shale with affection of intrusive diorite. The gravel packing is carried out at the depth of 13m-52m section, and the grouting is conducted at the section of ground level to the depth of 6m. The depth of 52m-60m section is filled with digging materials, and the depth of 6m-13m section between the casing and the drilling hole is filled up with the cutting materials.

(c) Well J-3

The screen is installed at the depth of 19.5-30.8m and 36.8-43.5m for alternation zone of mudstone and sandstone (Resistivity range 50-100 ohm-m), and at the depth of 52.5-57.0m for crackly or fissure zone of mudstone or shale with affection of intrusive diorite (Resistivity range 50-60 ohm-m). The gravel packing is carried out at the depth of 18m-61m section, and the grouting is conducted at the section of ground level to the depth of 6m. The depth of 61m-63m section is filled with digging materials, and the depth of 6m-18m section between the casing and the drilling hole is filled up with the cutting materials.

(4) Well J-4

The screen is installed at the depth of 21-42m for slightly weathered or crackly melanocratic gneiss (Resistivity range 5-50 ohm-m), and at the depth of 54-69m for partly crackly or fissure zone of melanocratic gneiss (Resistivity range 5-10 ohm-m). Since rather little water producing is expected, the section of screen is set rather long. The gravel packing is carried out at the depth of 19m-69m section, and the grouting is conducted at the section of ground level to the depth of 6m. The depth of 69m-70m section is filled with digging materials, and the depth of 6m-19m section between the casing and the drilling hole is filled up with the cutting materials.

2.5.6.2 Pumping Test

The pumping test (Pre-pumping test, Multi-stage pumping test, 72 hours constant discharge pumping test, and Recovery test) is carried out after well development at each exploratory well.

(1) Multi-stage Pumping Test

The drawdown(s)–time(t) graph and the drawdown(s)–yield(Q) graph of the multi-stage pumping test are shown in Figure 2.5-33. The maximum yield and the optimum yield of each exploratory well estimated from the results of the multi-stage pumping test are shown in Table 2.5-41.

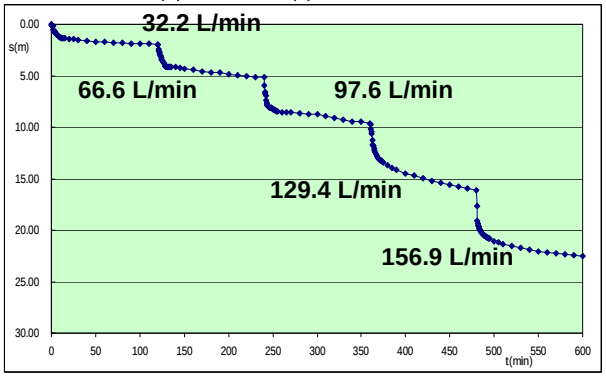
The optimum yields are 96 L/min (1.6 L/sec) in J-1, 19L/min (0.32 L/sec) in J-2, 29L/min (0.48 L/sec) in J-3 and 6L/min (0.10 L/sec) in J-4.

Table 2.5-41 Maximum and Optimum Yield of Exploratory Wells

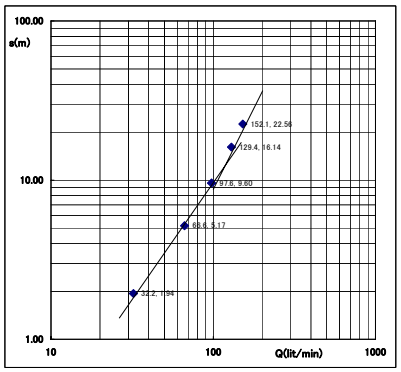
Well No.	Maximum Yield	Optimum Yield
J-1	120 L/min	96 L/min
J-2	< 41 L/min	19 L/min
J-3	< 36 L/min	29 L/min
J-4	< 8 L/min	6 L/min

Well No. J-1

Drawdown (s) – Time (t)

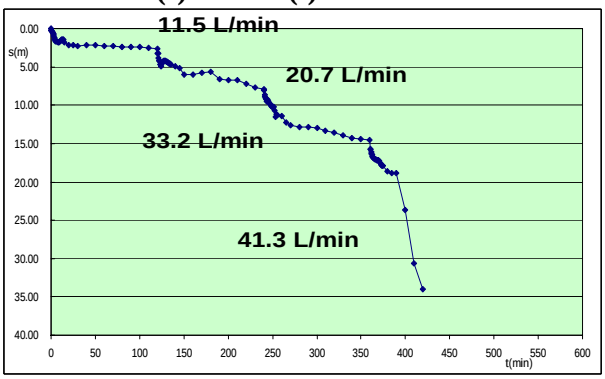


Drawdown (Log s) – Yield (Log Q)

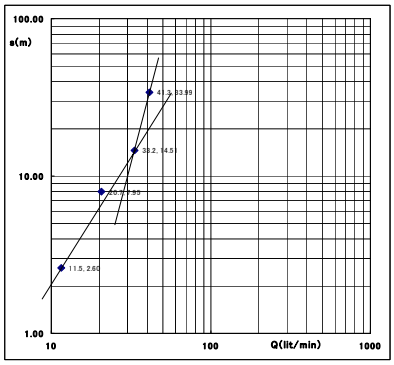


Well No. J-2

Drawdown (s) – Time (t)

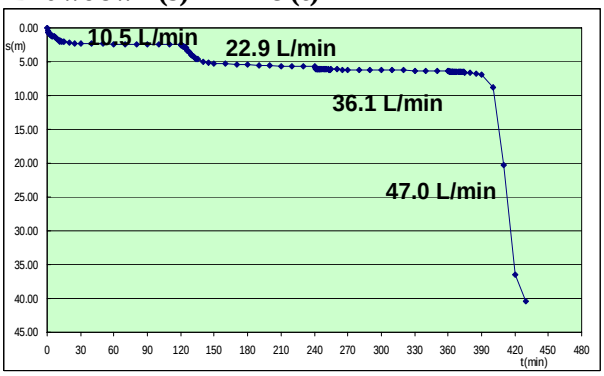


Drawdown (Log s) – Yield (Log Q)

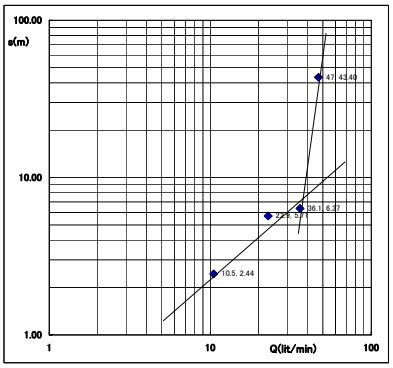


Well No. J-3

Drawdown (s) – Time (t)

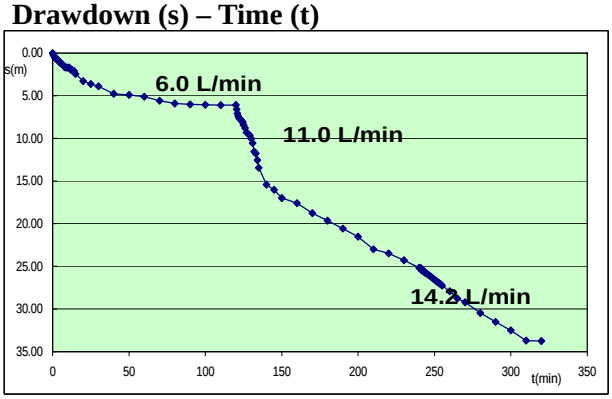


Drawdown (Log s) – Yield (Log Q)



Well No. J-4

Drawdown (s) – Time (t)



Drawdown (Log s) – Yield (Log Q)

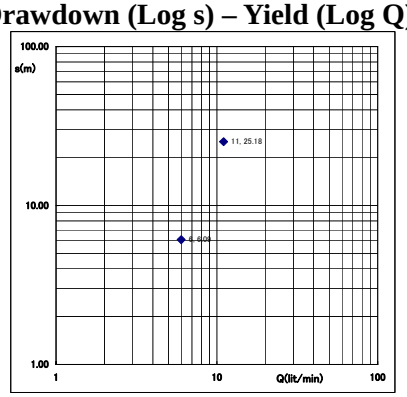


Figure 2.5-33 Multi-stage Pumping Test Graph

(2) Constant Discharge Pumping Test and Recovery Test

The drawdown(s)-time(t) graph, Theis's method graph, Cooper & Jacob's method graph, Hantush's method graph and Recovery method graph of the constant discharge pumping test and recovery test are shown in Figure 2.5-34 (1) to 2.5-34 (4). The estimation of hydraulic parameter by various methods is carried out using the software "Aquifer Test for Windows Version 2.56 of Waterloo Hydrogeologic Inc.". The estimated values of hydraulic parameters by various methods are shown in Table 2.5-42. Among values from various estimation methods, the average value without the maximum value and the minimum value is summarized at each parameter. The summarized hydraulic parameter of the constant discharge pumping test and recovery test is shown in Table 2.5-43.

Table 2.5-42 Hydraulic Parameters of Exploratory Wells estimated by Various Methods

Item		J-1	J-2	J-3	J-4
Transmissivity (m^3/sec/m)	Theis's method	1.02×10^{-4}	1.44×10^{-5}	3.31×10^{-5}	7.62×10^{-6}
	Cooper & Jacob's method	1.08×10^{-4}	1.50×10^{-5}	5.08×10^{-5}	4.80×10^{-6}
	Hantash's method	1.02×10^{-4}	1.14×10^{-5}	2.95×10^{-6}	4.59×10^{-6}
	Recovery method	1.06×10^{-4}	8.28×10^{-6}	2.91×10^{-5}	4.95×10^{-7}
Storativity	Theis's method	2.18×10^{-3}	2.18×10^{-3}	4.85×10^{-1}	9.99×10^{-3}
	Cooper & Jacob's method	2.73×10^{-3}	2.66×10^{-3}	2.02×10^{-1}	6.30×10^{-3}
	Hantash's method	1.98×10^{-3}	3.58×10^{-3}	4.32×10^{-1}	6.02×10^{-3}
Permeability Coefficient (m/sec)	Theis's method	4.86×10^{-6}	1.20×10^{-6}	3.31×10^{-6}	3.63×10^{-7}
	Cooper & Jacob's method	5.17×10^{-6}	1.25×10^{-6}	5.08×10^{-6}	2.28×10^{-7}
	Hantash's method	4.86×10^{-6}	9.53×10^{-7}	2.95×10^{-6}	2.18×10^{-7}
	Recovery method	5.05×10^{-6}	6.90×10^{-7}	2.91×10^{-6}	2.35×10^{-8}
Leakage factor	Hantash's method	Non leakage	7.62	0.762	

Remarks; Values of storativity of J-4 are calculated by Theis's equation after estimation of Aquifer Test.

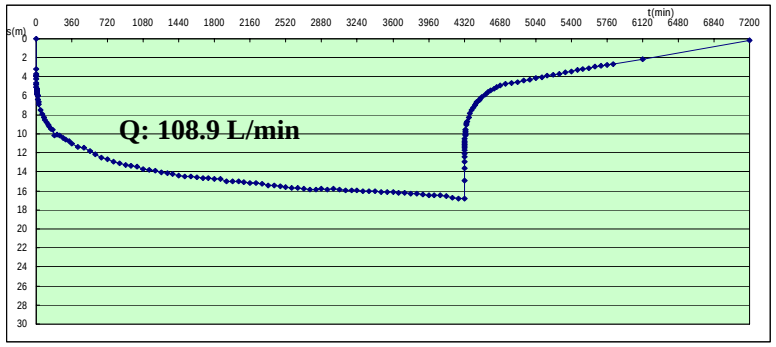
Table 2.5-43 Summarized Hydraulic Parameter of Exploratory Wells

Item		J-1	J-2	J-3	J-4
Transmissivity	(m^3/sec/m)	1.04×10^{-4}	1.29×10^{-5}	3.11×10^{-5}	4.70×10^{-6}
	(m^3/day/m)	8.99	1.11	2.69	0.41
Storativity		2.18×10^{-3}	2.66×10^{-3}	4.32×10^{-1}	6.30×10^{-3}
Permeability Coefficient (m/sec)		4.96×10^{-6}	1.08×10^{-6}	3.13×10^{-6}	2.23×10^{-7}

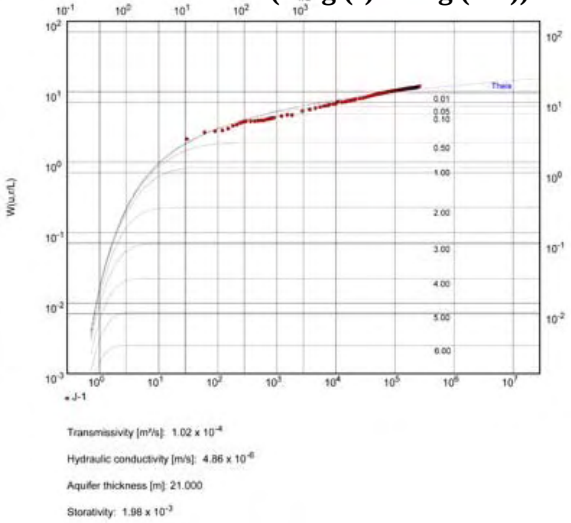
According to the summarized hydraulic parameters from pumping test, the transmissivity of J-1 shows 9.0 m^3/day/m, and J-2, J-3 and J-4 show 1.1, 2.7 and 0.4 m^3/day/m respectively. The permeability coefficient (hydraulic conductivity) of J-1, J-2, J-3 and J-4 shows 5.0×10^{-6}, 1.1×10^{-6}, 3.1×10^{-6} and 2.2×10^{-7} m/sec respectively. The storativity of J-1, J-2, J-3 and J-4 shows 2.2×10^{-3}, 2.7×10^{-3}, 4.3×10^{-1} and 6.3×10^{-3} respectively.

The transmissivity of J-1, J-2 and J-3 indicates a value with a single digit in unit m3/day/m. They show a value of smaller single digit than the existing LWSC's well No.2 and a value of smaller double digits than the existing LWSC's well No.1. The transmissivity of J-4 indicates a value of smaller single digit than J-1, J-2 and J-3.

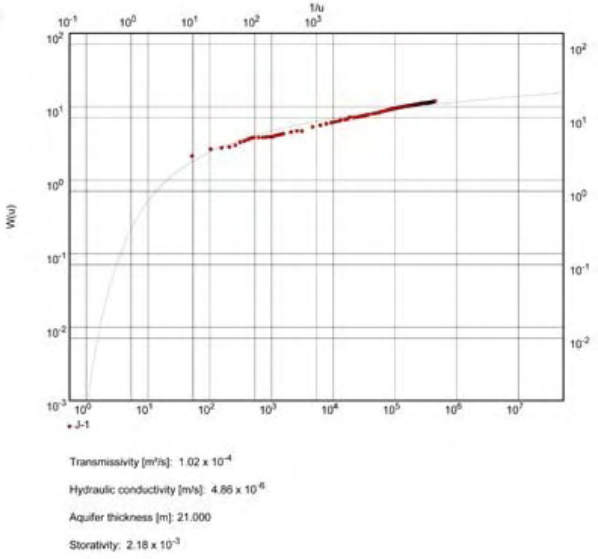
Drawdown (s) - Time (t)



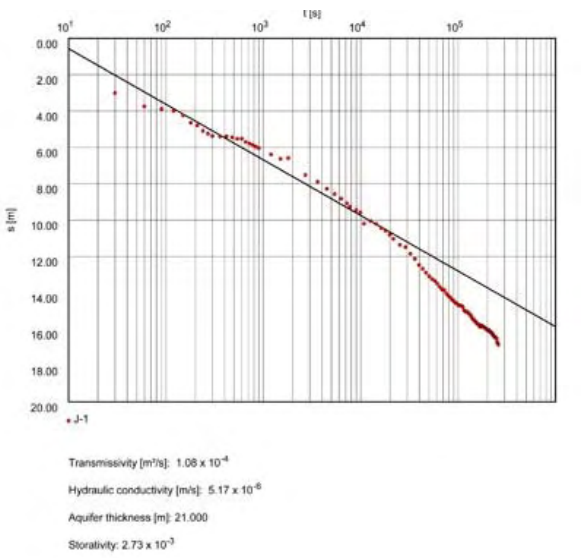
Hantush's Method (Log (s) – Log (r^2/t))



Theis's Method (Log(s) –Log(r^2/t))



Cooper & Jacob's Method (s – Log(t))



Recovery Method (s – Log(t/t'))

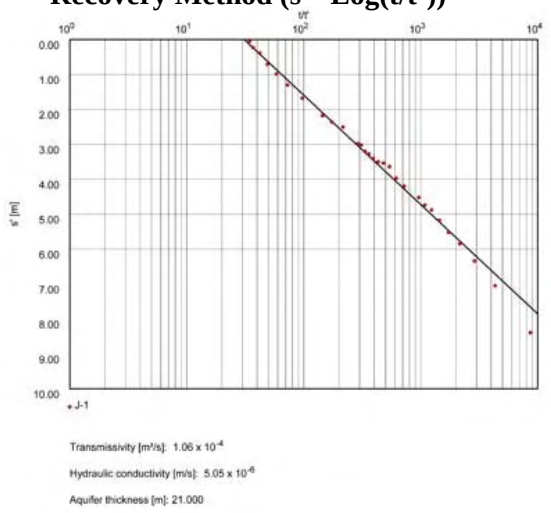
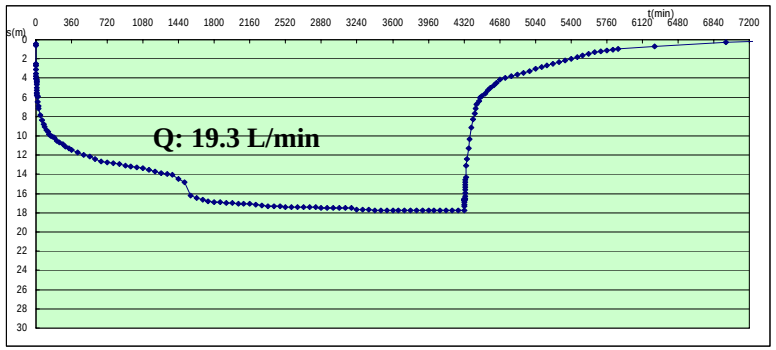
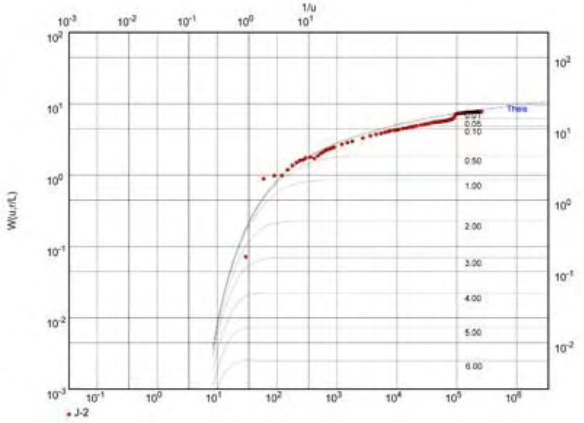


Figure 2.5-34 (1) Constant Discharge Pumping Test and Recovery Test Graph of J-1

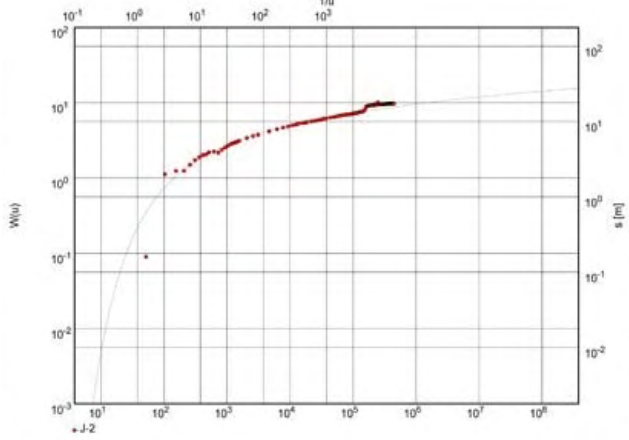
Drawdown (s) - Time (t)



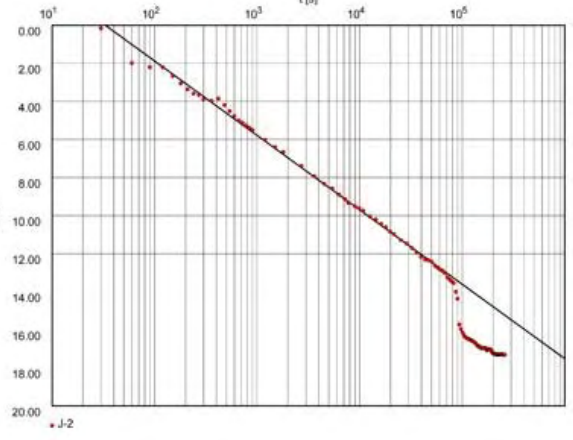
Hantush's Method (Log (s) – Log (r^2/t))



Theis's Method (Log(s) –Log(r^2/t))



Cooper & Jacob's Method (s – Log(t))



Recovery Method (s – Log(t'/t))

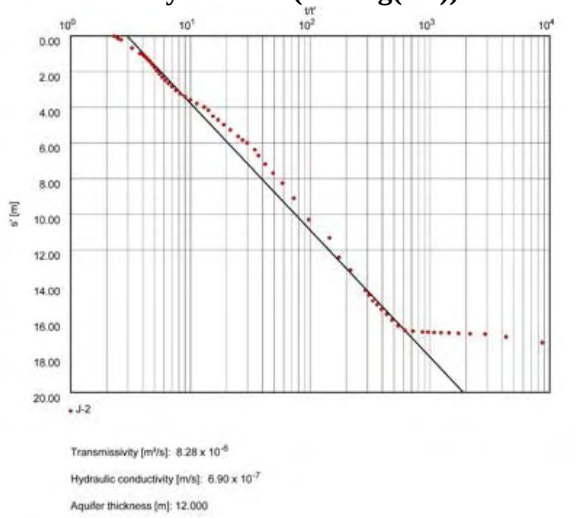
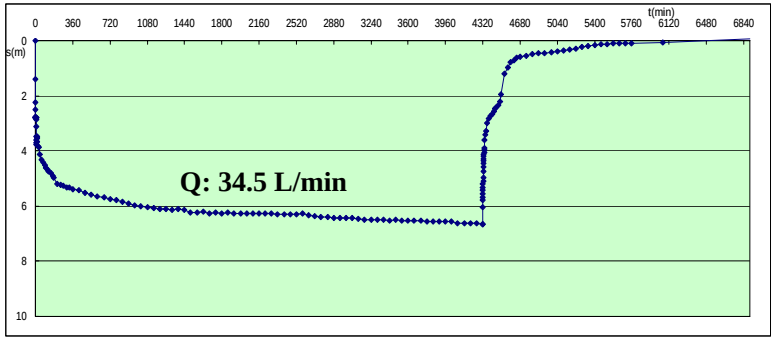
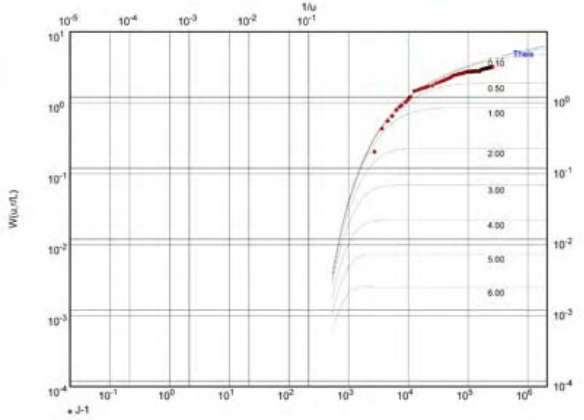


Figure 2.5-34 (2) Constant Discharge Pumping Test and Recovery Test Graph of J-2

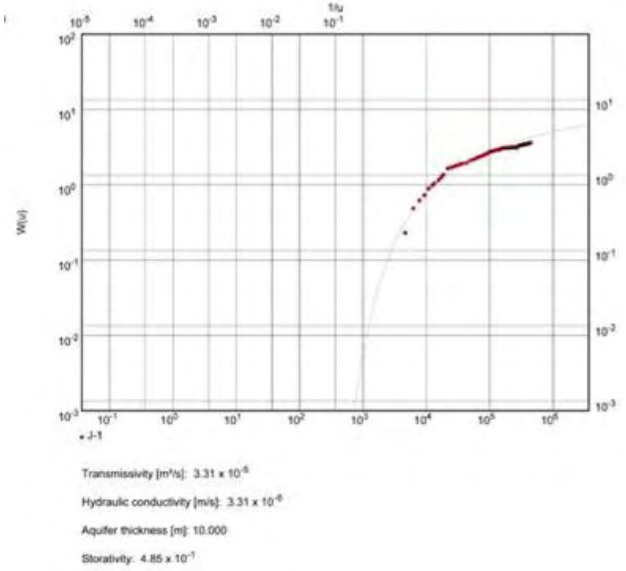
Drawdown (s) - Time (t)



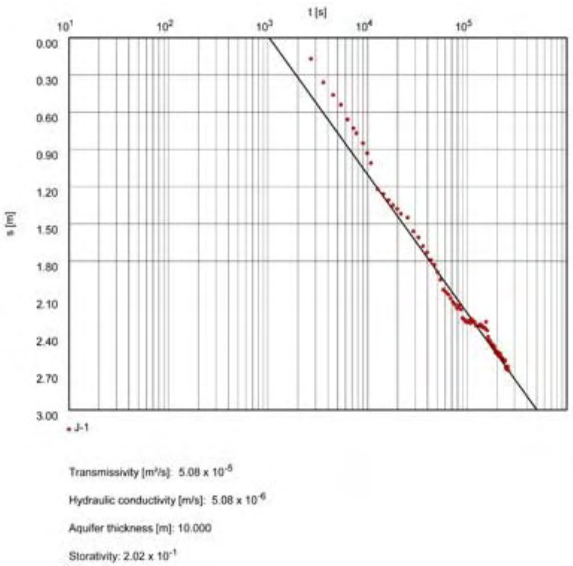
Hantush's Method (Log (s) – Log (r^2/t))



Theis's Method (Log(s) –Log(r^2/t))



Cooper & Jacob's Method (s – Log(t))



Recovery Method (s – Log(t'/t))

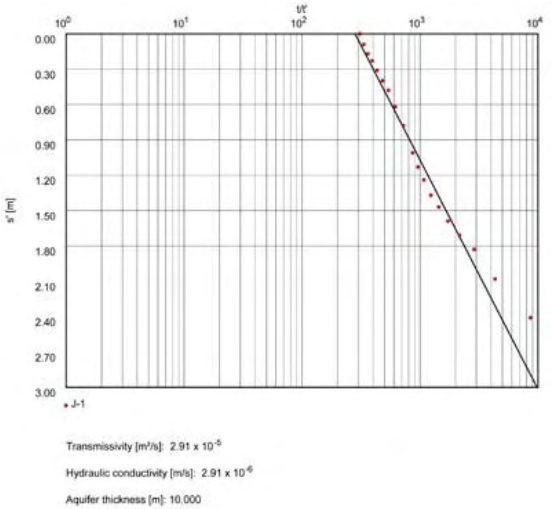
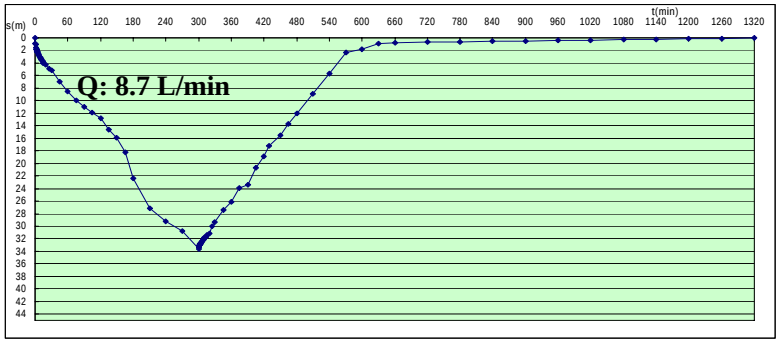
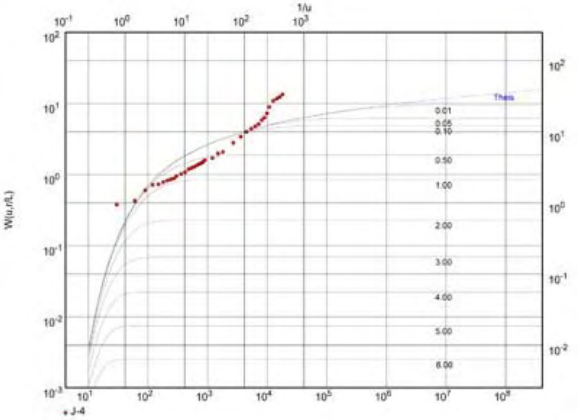


Figure 2.5-34 (3) Constant Discharge Pumping Test and Recovery Test Graph of J-3

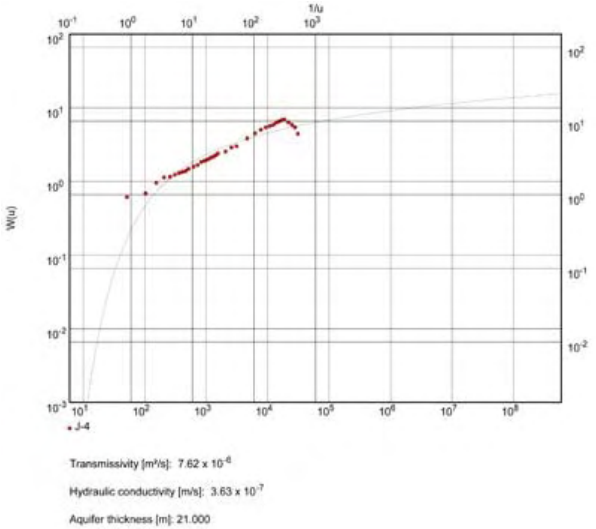
Drawdown (s) - Time (t)



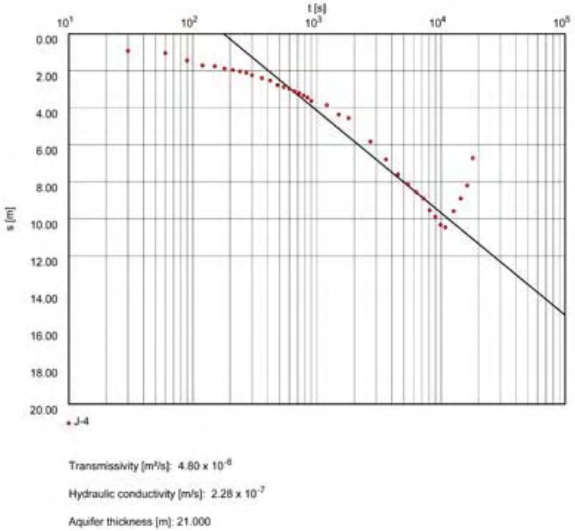
Hantush's Method (Log (s) – Log (r^2/t))



Theis's Method (Log(s) –Log(r^2/t))



Cooper & Jacob's Method (s – Log(t))



Recovery Method (s – Log(t'/t))

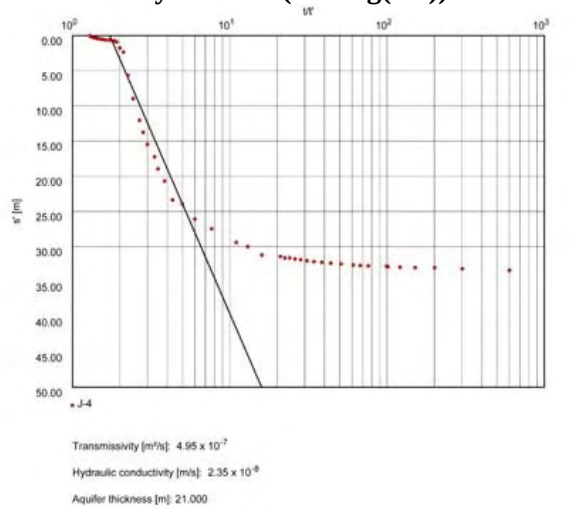


Figure 2.5-34 (4) Constant Discharge Pumping Test and Recovery Test Graph of J-4

2.5.6.3 Influence to Surrounding Shallow Wells during Pumping Test

At J-1, J-2 and J-3 sites, the observation of water level of surrounding shallow wells during the constant discharge pumping test and recovery test is carried out in order to confirm the situation of influence on existing shallow wells by pumping (see Figure 2.5-35). The influence on water level of existing shallow wells during pumping test at each site is as follows;

(1) Well No. J-1

The observation wells No.1, No.2 and No.4 show the rise of water level of 2-12cm during pumping test. The influence of infiltration and recharge of drainage water through road during pumping are considered. The observation well No.4 only shows the decent of the water level of 3cm by pumping, and the water level goes up during recovery test.

(2) Well No. J-2

The observation wells No.1-No.7 show the rise of water level of 5-35cm during pumping test, and the water levels go up again during recovery test. The rising up of water level of existing shallow wells during pumping is considered to be because of the infiltration and recharge of drainage water through dry field and road.

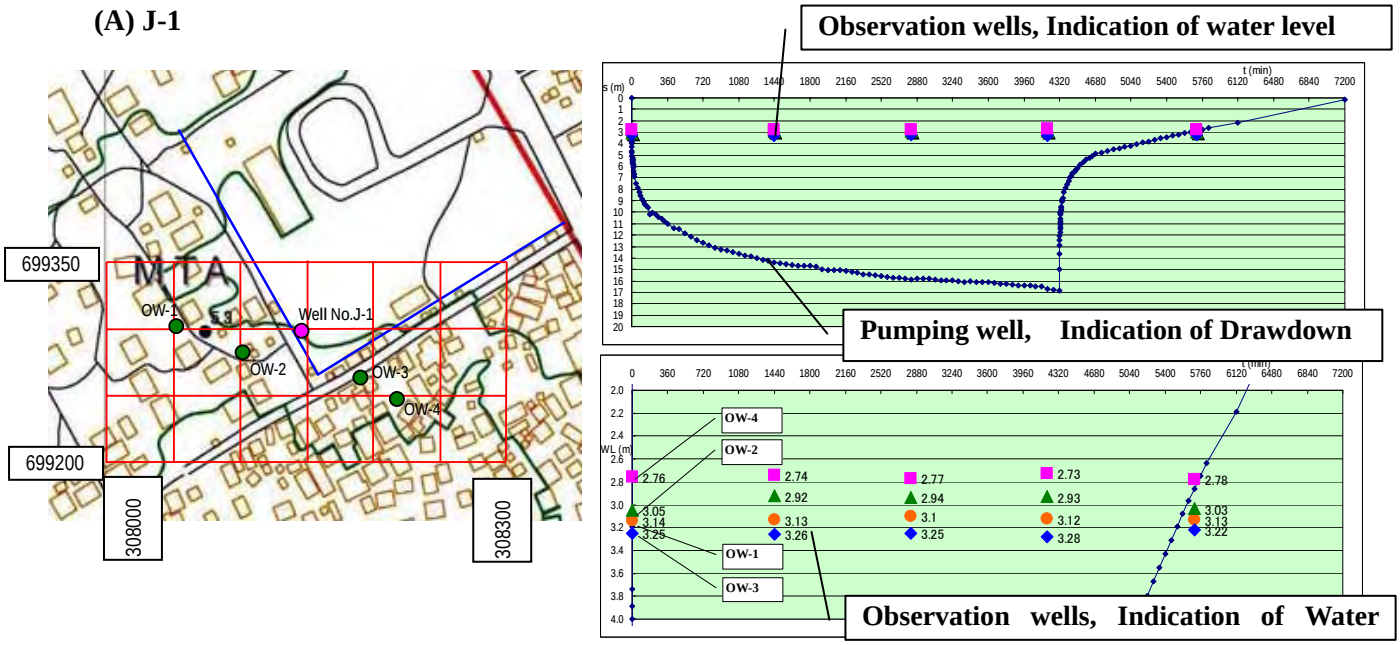
(3) Well No. J-3

The observation wells No.1 to No.3 show the water level decent of 26-41cm during pumping test, and water levels go up during recovery test.

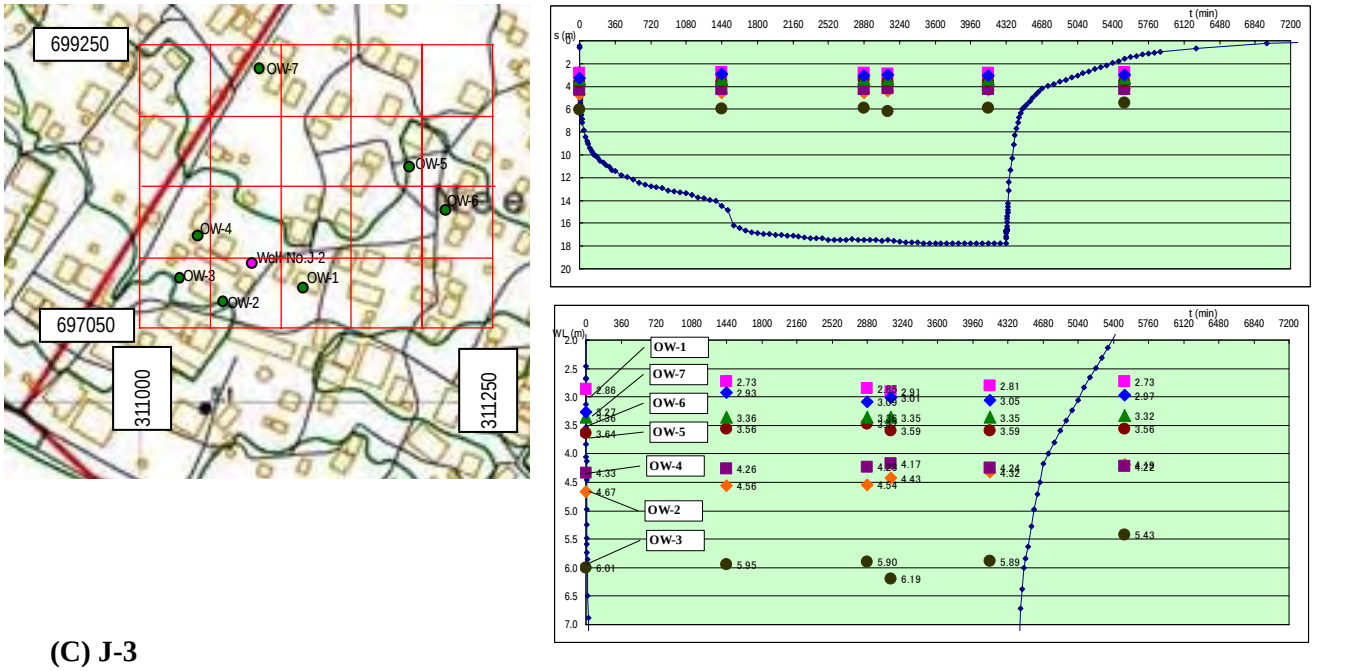
A part of existing shallow wells surrounding Well No.J-1 and existing shallow wells surrounding Well No.J-3 show some tiny water level decent during pumping test. Although such water level decline is seemed to have the large influence by pumping themselves by buckets for obtaining domestic water day by day, the influence of pumping of the exploratory well is considered. The observation of water level of existing shallow wells surrounding exploratory or new production wells is necessary to control the sustainable groundwater development.

At J-4 site, the observation of groundwater level of existing well is not carried out because of absence of shallow wells surrounding Well No.J-4.

(A) J-1



(B) J-2



(C) J-3

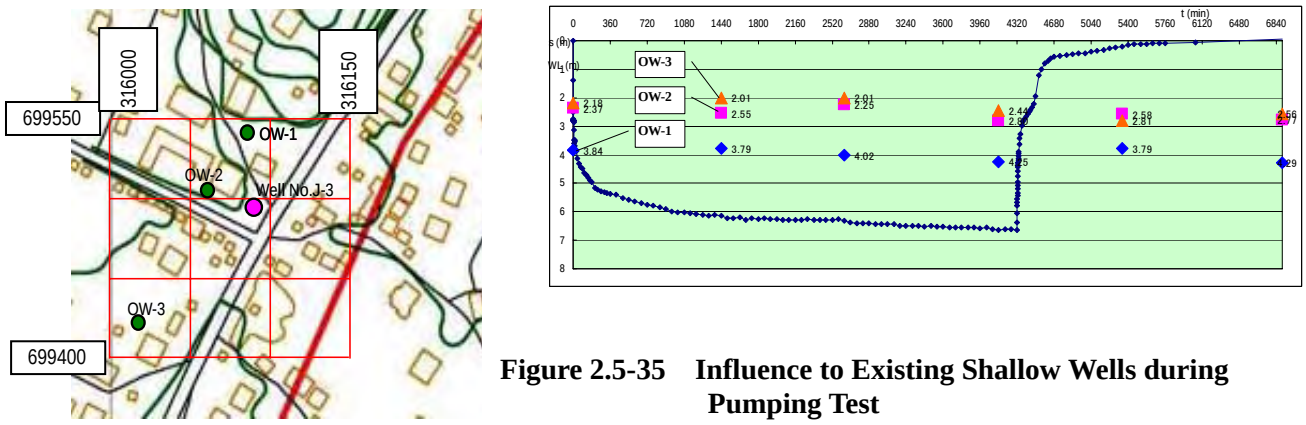


Figure 2.5-35 Influence to Existing Shallow Wells during Pumping Test

2.5.7 Results of Investigation of Oil Contamination

Since the oil contamination of surrounding area of the LPRC's old oil refinery was found out on the way of the project, the investigation of oil contamination was carried out. The well inventory investigation in detail with interview about oil contamination situation is conducted at 117 shallow wells. The investigation area is about 1.2km within the circle from the center of the old oil refinery. The area includes Chicken Soap Factory Community, Shoe Factory Community, MTA Community and Day Break Mouth Open Community.

2.5.7.1 Activity of LPRC's Oil Refinery

LPRC was established for oil refining and storing, and a refinery and stockpiling facilities were constructed at Chickin Soap Factory Community area in Gardnersville zone in 1978. The operation of the oil refining plant stopped because of lack of profit in 1983. Then the facility was used as oil stock piling facility. In 1990-1992 the oil plant was destroyed by on the civil war. At present the stock piling facility is empty. The location of the old oil refinery and the state of the facility at present is shown in Figure 2.5-36 and Figure 2.5-37 respectively.

2.5.7.2 Well Inventory Record and Summary Results

The 117 well inventory records for oil contamination and the summary table of oil contamination inventory record are arranged in GIS data base. An example of the record is shown in Figure 2.5-40. The present situation of the oil contamination and the well use condition based on the summary of the inventory tables are as follows;

(1) Present Situation of Oil Contamination

The rank classification of oil contamination is as follows;

1) Rank 1; Oil mixing in well water is always recognized.
2) Rank 2; Oil mixing in the well water is recognized at early morning almost every day, but disappears after withdrawals.
3) Rank 3; Oil mixing in well water is recognized at early morning in dry season or rainy season or sometimes, but disappears after withdrawals.
4) Rank 4; Oil mixing in well water is not recognized, but sometimes oil odor is felt.
5) Rank 5; Oil mixing in well water is recognized during well construction period, but disappears after concrete pipe installation or well completion.
6) Rank 6; Oil mixing or oil odor is not recognized at all.

The investigated wells are shown in Figure 2.5-39 with rank indication. The oil contamination is recognized in Chicken Soap Factory Community, some part of Shoe Factory Community and a very restricted part of MTA Community. The number and percentage of every contamination rank of investigated well is shown in Table 2.5-44 and Figure 2.5-40.

Table 2.5-44 Number and Percentage of Every Rank of Investigated Well

Rank	Description	Number of well	Percentage (%)	Remark
1	Oil mixing always	1	1	Total: 117 wells
2	Oil mixing every morning	15	13	
3	Oil mixing every season or sometimes	12	10	
4	Oil odor	3	3	
5	Oil mixing during construction period	1	1	
6	No oil contamination	85	72	

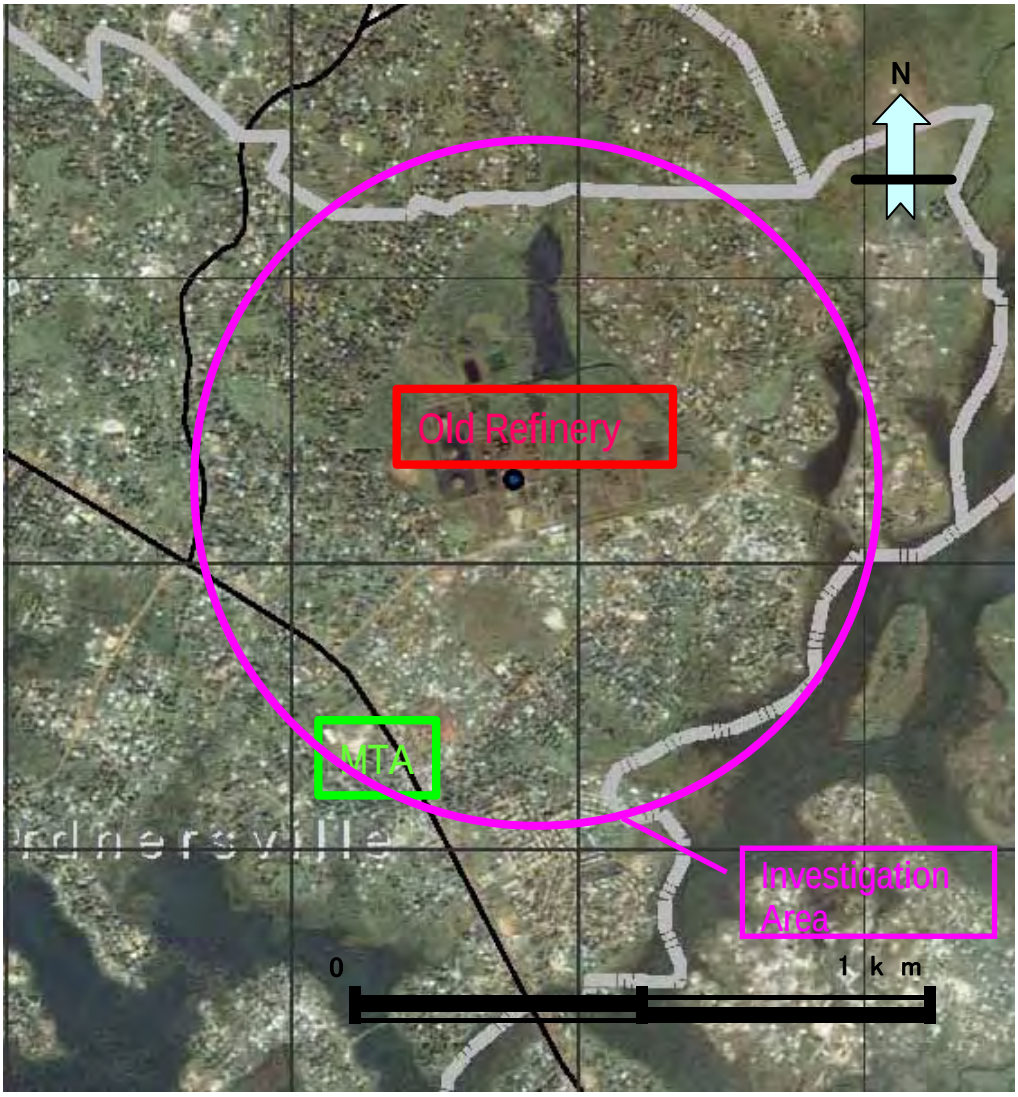


Figure 2.5-36 Location of Old Oil Refinery and Investigation Area

Figure 2.5-37 Present State of Old Refinery Facility

WELL INVENTORY (for Oil Contamination)					Z-1200 C-02-039	
					Survey Date	27th May 2009
Registered Well No.			Zone	Gardnersville	Community	Chikin Factory
Location	Easting	309189	Northing	700109	Elevation (m)	6
Construction	Year	2009	Provider	Rebecca		
Well Type/ Dimension	Type	(1.) Dug well/ 2. Drilled well/ 3. Others	Well Head	1. Nothing, (2.) Tire, 3. Drum, 4. Stone masonry, 5, Block, 6.Concrete	Well head hight (m)	0.20
	Casing	(1.) Nothing, 2. Tire, 3. Drum, 4. Block, 5. Concrete colgate, 6. PVC casing & Screen, 7. Steel casing & Screen			Equipment	1. Hand pump well, (2.) Draw well, 3. Others
	Diameter (cm)	100	Total Depth (m)	1.90	Water Level (m)	1.74
Water Use/ Yield	1. Drinking water, (2.) Washing water, 3. Others (Cooking & Bathing)					2
	No. of User	75	Volume	5 Gallon / day / person	Total	375 Gallon / day
Dry-up Condition	1. No dry-up, (2.) Dry-up in dry season ( ), 3. Sometimes dry-up by drawing, 4. Water level goes down in dry season ( ), 5. Water level goes down by drawing					2
Water Quality	Tempera-true	28.9 °C	pH	6.49	E.C	23.2 mS/m
	Others	1. Clean, 2. Cloudy, 3. Colored (Yellowish, Brownish, Reddish, Other ( )), 4. (Dirty), 5. Contaminated (0il), 6. Odor ( ), 7. Salty				
Oil Contamina-tion	(1.) Oil always mixes with well water. 2. Oil mixing is usarlly confirmed in early morning, it disapears by drawing. 3. At early morning oil mixising is confirmed sametimes or with season (Dry, Rainy), it disappears by drawing. 4. Oil oder is felt. 5.Oil contamination cannot be perceived.					1
	Countermeasure for contamination	Chlorination				
	Disease by water	(Not for drinking)				
Other Resident Conscious-ness						
<<Photoes>>	  					
Remarks						

Figure 2.5-38 Example of Well Inventory Record for Oil Contamination

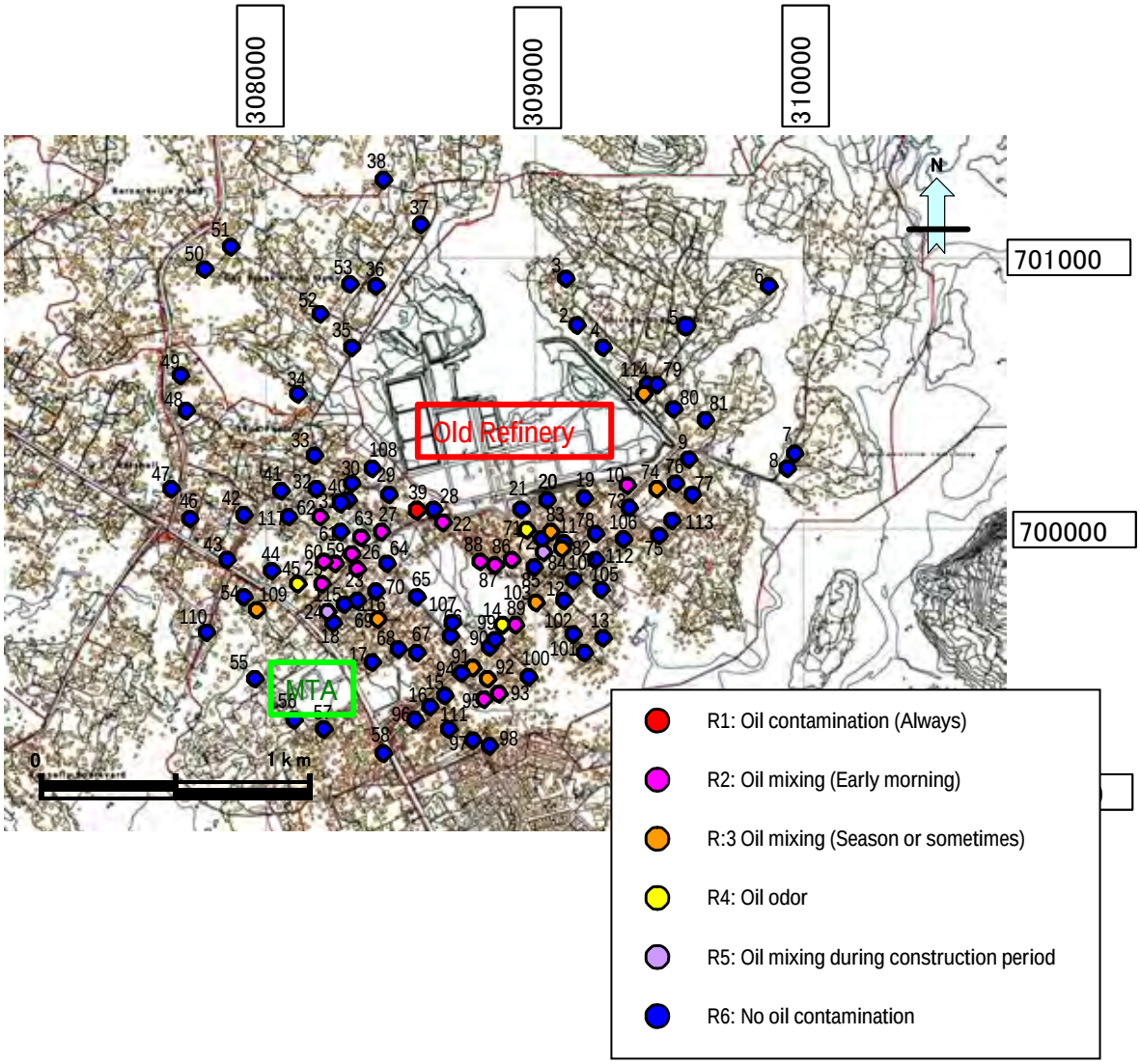


Figure 2.5-39 Distribution of Oil Contaminated Wells

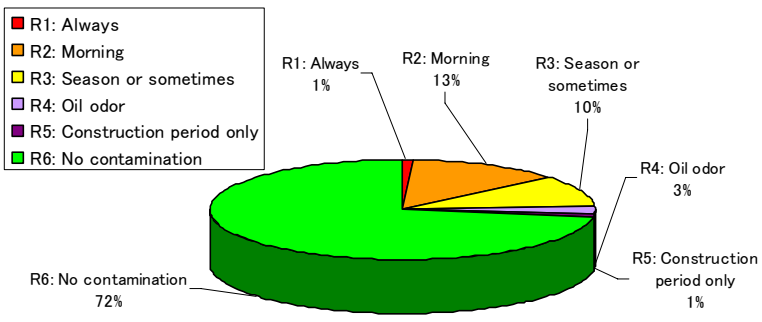


Figure 2.5-40 Percentage for Every Rank of Oil Contaminated Well in Investigation Area

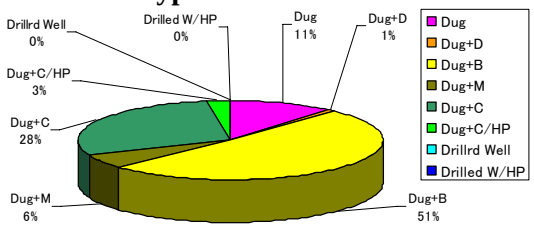
(2) Well Condition of the Investigation Area

(a) Well Equipment, Dimension and Water Level

Dug well without cover (Dug) and dug well with drum as mouth protection (Dug+D) are 12% of all the surveyed wells. It indicates that rather many wells of inferior circumstance still remain. Dug well

with block protection (Dug+B), dug well with masonry protection (Dug+M) and dug well with concrete protection (Dug+C) are 85%. Dug well with concrete cover and hand pump (Dug+C/HP) is 8%. It shows maintenance of well equipment is not so progressing. Dug well diameter is 0.9 to 1.2 m. Total depth is 1.8 to 19.8m (Average 4.9m). Water level is 0.9 to 8.1 m (Average 3.3m).

< Types of Wells >

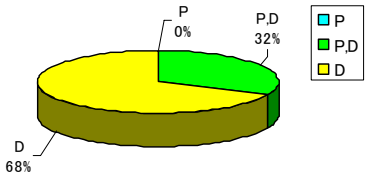


Well Dimension							
Ground Hight (m)		Total Depth (m)		Water Level (m)		WL(Elevation, m)	
Max.	10.0	Max.	19.8	Max.	8.1	Max.	4.7
Min.	1.0	Min.	1.8	Min.	0.9	Min.	-5.3
Average	4.5	Average	4.9	Average	3.3	Average	1.1
Median	4.0	Median	4.0	Median	2.9	Median	1.3
Mode	4.0	Mode	4.6	Mode	2.0	Mode	0.3
Total N	117	Total N	117	Total N	112	Total N	112

(b) Purpose of Groundwater Use and Volume

Portable and domestic use (P,D) is 32% of all the surveyed wells. It means that wells which can not be used as portable water are rather many. According to interview, water user per well is 10 to 1000 persons (Average 64 persons). Per capita water use volume is 5 to 40 gallons/day (Average 11.0 gallons/day).

< Purpose of groundwater use >

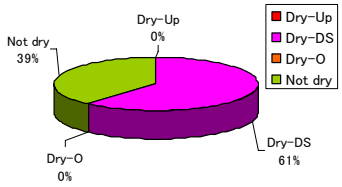


Water Use					
Person/ Well		Vol./ P. (Gal/day)		T. Volume (Zone) (X1,000 Gal/day)	
Max.	1000	Max.	40.0		
Min.	10	Min.	5.0		
Average	64	Average	11.0	Average	382
Median	35	Median	10.0		
Mode	30	Mode	10.0		
Total N	117	Total N	117		

(c) Dry-up Condition, Other Condition as Resident Consciousness and Water Quality

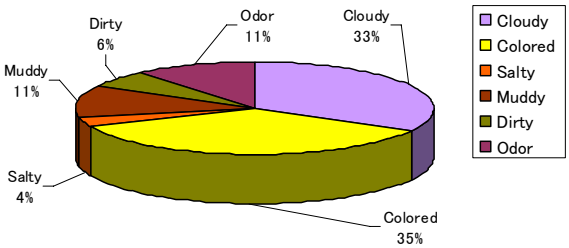
Dry-up in dry season (Dry-DS) is 61% of all the surveyed wells. It shows extremely severe condition. Other negative conditions as resident consciousness such as cloudy water, colored water, salty water, muddy water, dirty water and odor is 61%. The pH is low in some wells (pH<6.0), and the electric conductivity is high in some wells (EC>100mS/m).

< Dry-up condition >



Water Quolity					
Temp. (oC)		pH		EC (mS/m)	
Max.	30.9	Max.	8.7	Max.	197.0
Min.	27.2	Min.	4.5	Min.	1.9
Average	6.8	Average	6.8	Average	37.2
Median	28.8	Median	6.8	Median	30.5
Mode	28.8	Mode	6.1	Mode	6.3
Total N	117	Total N	117	Total N	117

< Other condition as resident consciousness >



2.5.7.3 Evaluation of Oil Contamination Area

The result of the oil contamination investigation is summarized as follows;

1) The oil contamination is recognized at shallow wells within about 1km circle of the old oil

refinery.

2) The oil contaminant is supposed to flow along the direction in which geographical feature mainly becomes low in the three directions of southwest, south-southeast, and east-northeast.
3) Since rather long time has passed after the occurrence of oil contamination, the present oil contamination area is recognized to be rather widely spread and separated with spots at some areas.
4) The oil contamination is not recognized around the MTA lot because of the location of relatively slightly high ridge portion comparing with surrounding area.

The present situation of oil contamination with zone indication is shown in Figure 2.5-43.

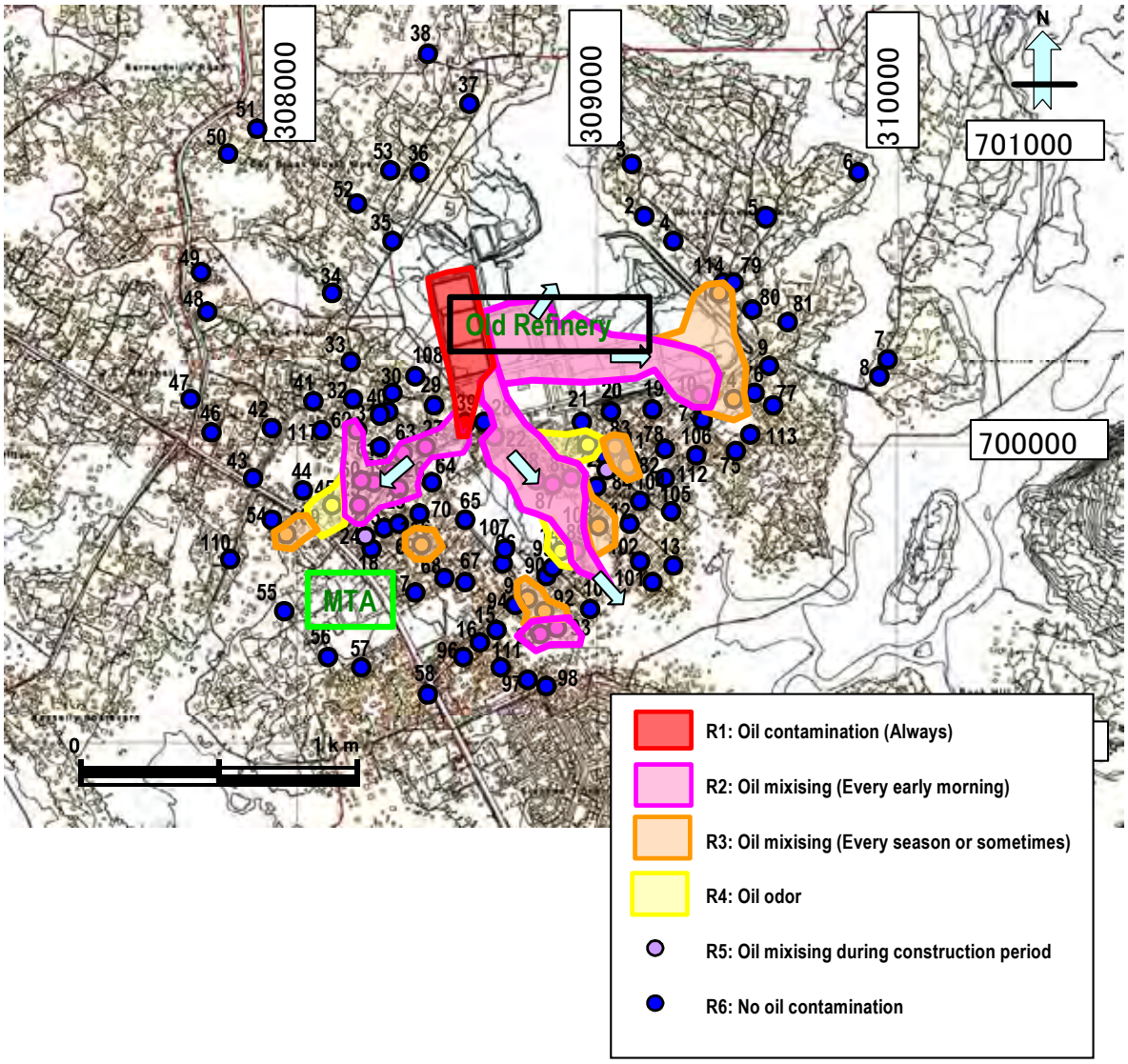


Figure 2.5-41 Zone Indication of Present Oil Contamination Condition

2.5.8 Issues on Water Supply Sector

2.5.8.1 General Issue

Beneficiaries that are covered by public water supply system of LWSC only make up about 37% of the overall population (about 1.0million) in Greater Monrovia. The rest dwellers depend on unsafe and/or instable water sources such as dug wells and shallow wells. This is because the existing pubic water supply system (White Plains Water Supply System) works less than 30% of the design capacity due to mechanical damages. It is summarized to be one of general issues that the water service

coverage ratio approaches 100% by 2019 due to the restoration of the existing White Plains water supply system or development of water supply system other than the White Plains water supply system.

2.5.8.2 Urgent Issue

Taking into account the above mentioned aspects, the problems and main issues for improvement of water supply services can be summarized as in the following table.

Table 2.5-45 Current Problems and Future Issues on Water Supply Services

Current Problems	Future Issues
Much deteriorated water supply facilities	➢ Large-scale replacement of rising main, distribution pipelines and service reservoirs
High water production cost	➢ Improvement of water supply system to be optimized (i.e. Not to use rising main for supplying water to dweller directly)
Low revenue water ratio	➢ Improvement of water tariff system (i.e. to reduce frat rate in tariff collection) ➢ Reduction of leakage ➢ Enhancement of individual water meter installation
Water supply for low income households	➢ Development of water supply facilities with low O&M cost
Lack of water quality parameter to be analyzed on the WHO standards	➢ Establishment of appropriate water laboratory in LWSC