PART 6

GROUNDWATER SIMULATION OF MASTER PLAN

Final Report

(Supporting Report)

PART 6 GROUNDWATER SIMULATION OF MASTER PLAN

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PART - 6. GROUNDWATER SIMULATION

CHAPTER 1. OUTLINE OF THE MODEL

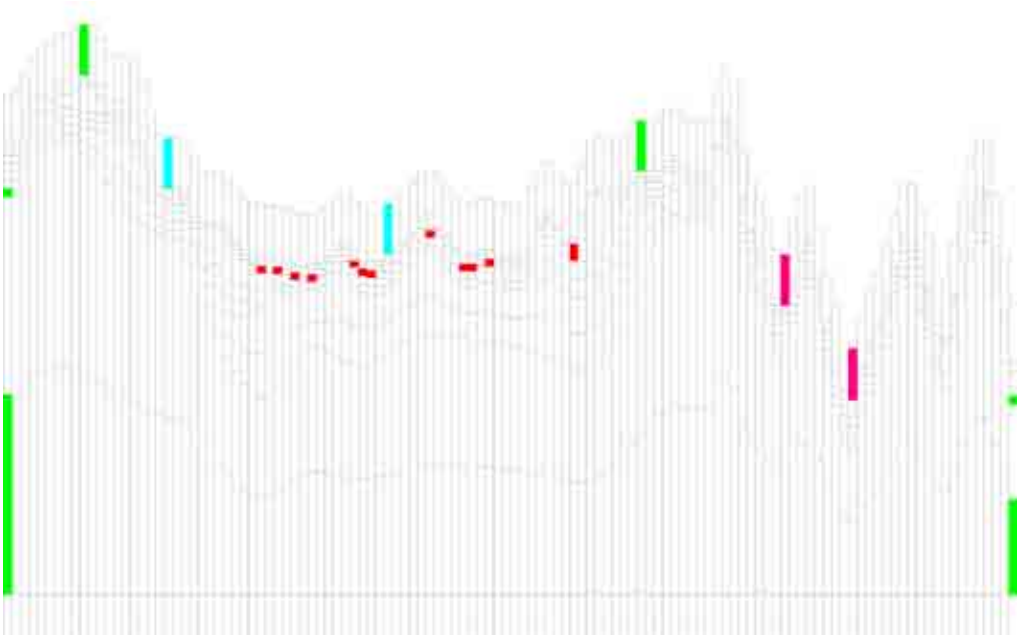
1.1. Boundary Conditions

The basic information (model structure, parameters, boundary conditions) of the model is given in Table 1 of the main report. The following table presents the details of the boundary conditions employed in this model.

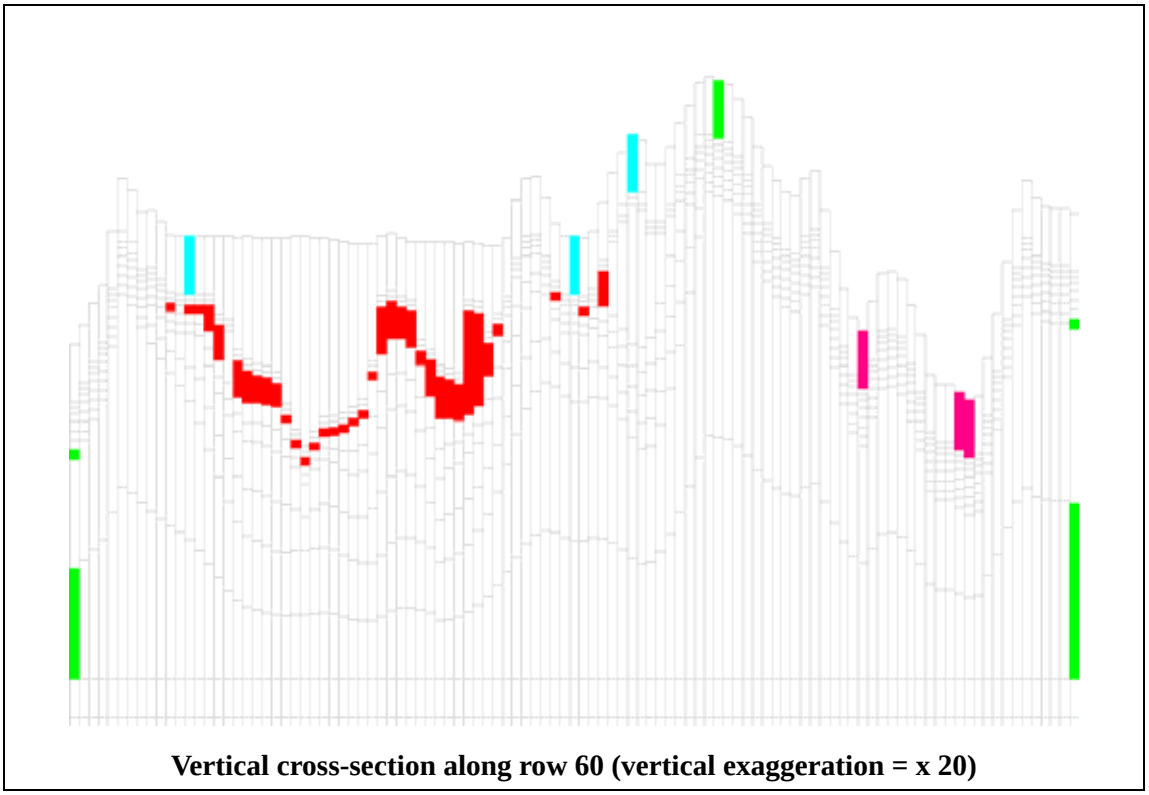
Table-6. 1 Details of Boundary Conditions

Structure	Boundary condition (BC)	
Layer	BC Type	Detail
1st layer: Quaternary	Constant Head Boundary	In basin: Fixed heads for rivers and dams,
	General Head Boundary	GHB for mountain ridges (see Figure 1 in main report) External Head = cell top – 50 m, Conductance = 1200m^2/day
	Recharge boundary	Groundwater recharge (see Figure 2 in main report)
	Drain boundary	Outside Bogota basin: Drain for major rivers Conductance = 2~10 m^2/day
3rd & 4th layer: Guadalupe	Constant Flux Boundary (Pumping well)	4897 existing wells, fully penetrated (see Figure 3 in main report) Pumping rate range 0.89~6684 m^3/day 59 newly planned wells (hypothetical)
8th layer Paleozoic	General Head Boundary	for outermost perimeter cells External Head = cell top + 15 m, Conductance = 400m^2/day
10th layer: Paleozoic	General Head Boundary	for outermost perimeter cells External Head = cell top + 100~500 m, Conductance = 400m^2/day
12th layer Paleozoic	No Flow Boundary	No groundwater is considered to move across the bottom of the model.

The vertical cross-section of the model showing grid/layer and major boundary conditions is shown in Figure-6.1.



Vertical cross-section along column 52 (vertical exaggeration = x 20)



Vertical cross-section along row 60 (vertical exaggeration = x 20)

Figure-6. 1 Cross-sectional Views of Grid/layer and Boundary Conditions of the Model

Note:

- The columns are vertical strips in the model plan view (Figure 1 in main report) and serially numbered 1 to 105 from the left.
- The rows are horizontal strips in the model plan view (Figure 1 in main report) and serially numbered 1 to 120 from the top.
- Red cells: well boundary, blue cells: constant head boundary, pink cells: drain boundary, green cells: general head boundaries.

1.2. Newly Planned Pumping Wells

The following table shows the list of the 59 pumping wells newly planned in this study. Some wells are located close together and thus integrated in one cell in the model. Such integrated result is shown in the right most two columns titled "Output Cell" and "No of wells per cell".

Table-6. 2 Details of Planned Wells in the Model

SN	Name (New)	Code	Row	Column	Pump rate (m3/d)	Output cell (m3/d)	No. of wells per cell
17	S-1	8743	84	28	5857.6		
18	S-2	8743	84	28	5857.6	-11715.2	2
19	S-3	8744	84	29	5857.6	-5857.6	1
14	S-4	8849	85	29	5857.6		
15	S-5	8849	85	29	5857.6		
16	EX-1	8849	85	29	5857.6	-17572.8	3
13	S-6	8954	86	29	5857.6	-5857.6	1
9	B-1	9061	87	31	5857.6		
10	B-2	9061	87	31	5857.6		
11	EX-2	9061	87	31	5857.6	-17572.8	3
8	B-3	9166	88	31	5857.6	-5857.6	1
12	U-103	9070	87	40	0	0	1
6	U-3	9385	90	40	5857.6		
7	U-4	9385	90	40	5857.6	-11715.2	2
4	U-2	9490	91	40	5857.6	-5857.6	1
2	EX-3	9595	92	40	5857.6		
3	U-1	9595	92	40	5857.6	-11715.2	1
1	U-101	9805	94	40	0	0	1
5	U-102	9491	91	41	0	0	1
23	-	8127	78	42	0	0	1
21	E-2	8337	80	42	5857.6	-5857.6	1
20	E-1	8757	84	42	5857.6	-5857.6	1
27	E-4	7918	76	43	5857.6	-5857.6	1
26	E-3	8023	77	43	5857.6	-5857.6	1
24	E-102	8128	78	43	0		
25	-	8128	78	43	0	0	2
22	E-101	8338	80	43	0	0	1
28	E-103	7814	75	44	0	0	1
58	Y-20	5296	51	46	5857.6	-5857.6	1
56	Y-18	5401	52	46	5857.6	-5857.6	1
54	Y-16	5506	53	46	5857.6		
55	Y-17	5506	53	46	5857.6	-11715.2	2
52	Y-14	5611	54	46	5857.6		
53	Y-15	5611	54	46	5857.6	-11715.2	2
51	Y-13	5716	55	46	5857.6	-5857.6	1
49	Y-11	5821	56	46	5857.6		
50	Y-12	5821	56	46	5857.6	-11715.2	2
47	Y-9	5926	57	46	5857.6		
48	Y-10	5926	57	46	5857.6	-11715.2	2
46	Y-8	6031	58	46	5857.6	-5857.6	1
44	Y-6	6136	59	46	5857.6		
45	Y-7	6136	59	46	5857.6	-11715.2	2
42	Y-4	6241	60	46	5857.6		
43	Y-5	6241	60	46	5857.6	-11715.2	2
39	Y-1	6346	61	46	5857.6		
40	Y-2	6346	61	46	5857.6		
41	Y-3	6346	61	46	5857.6	-17572.8	3
38	E-14	6451	62	46	5857.6	-5857.6	1
34	E-10	6766	65	46	5857.6		
35	E-11	6766	65	46	5857.6	-11715.2	2
33	E-9	6871	66	46	5857.6	-5857.6	1
32	E-8	6976	67	46	5857.6	-5857.6	1
31	E-7	7081	68	46	5857.6	-5857.6	1
29	E-5	7291	70	46	5857.6		
30	E-6	7291	70	46	5857.6	-11715.2	2
59	Y-21	5192	50	47	5857.6	-5857.6	1
57	Y-19	5402	52	47	5857.6	-5857.6	1
37	E-13	6662	64	47	5857.6	-5857.6	1
36	E-12	6767	65	47	5857.6	-5857.6	1
64	Y-26	4878	47	48	5857.6	-5857.6	1
62	Y-24	4983	48	48	5857.6		
63	Y-25	4983	48	48	5857.6	-11715.2	2
60	Y-22	5088	49	48	5857.6		
61	Y-23	5088	49	48	5857.6	-11715.2	2
67	Y-29	4564	44	49	5857.6	-5857.6	1
65	Y-27	4669	45	49	5857.6		
66	Y-28	4669	45	49	5857.6	-11715.2	2
					Total	-345,598	

<Note>
The numbers under "code" correspond to a cell in the model. Thus the wells that have the same code are located in the same model grid cell to produce a combined pumping rate under "Output cell".

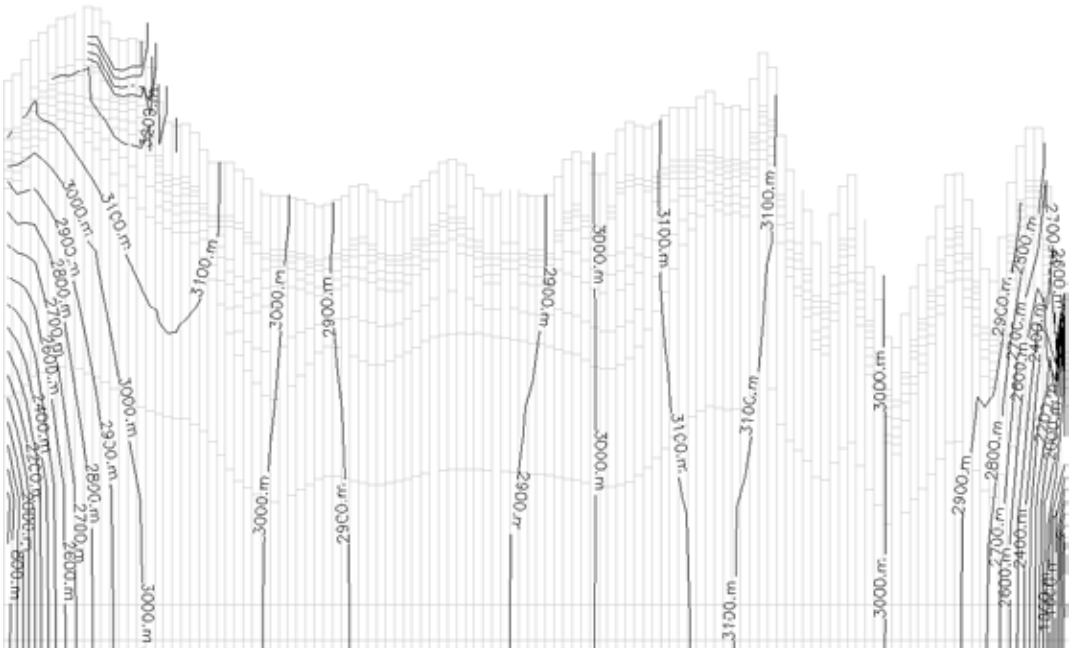
The pumping rate of wells are that for Scenario 4 in the drawdown forecast.

The pumping rate of a pumping well (wells taking water out of the model) is defined to have negative value in the model.

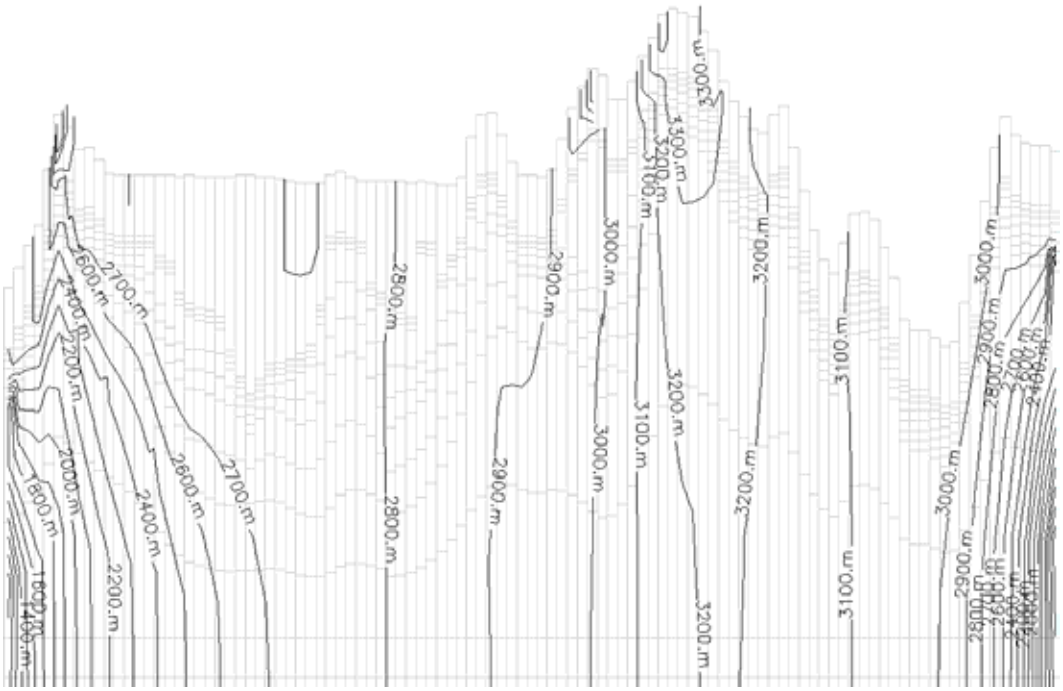
The shaded wells are temporality or permanently not in operation for some reasons.

1.3. Calibrated Model

The final outcome of the calibration under steady state condition as head distribution maps in plan view. The following Figures present head distribution in cross sectional views.



Head distribution in cross-section along column 52 (vertical exaggeration = x 20)



Head distribution in cross-section along row 60 (vertical exaggeration = x 20)

Figure-6. 2 Head Distribution of the Calibrated Steady State Model

CHAPTER 2. DRADOWN FORECAST

The influence of pumping from the 59 planned deep wells (from the Cretaceous aquifer) over the hydraulic head distribution of the surrounding aquifers was investigated using the calibrated model.

2.1. Head Observation Wells

The drawdown of water table and hydraulic heads due to pumping of newly planned wells were observed through hypothetical observation wells (only existing in the model) installed in the Cretaceous aquifer and in the Quaternary sediment layer above it. The following table summarizes details of the observation wells.

Table-6. 3 Detailed Location of Observation Wells

Well Name	Model Layer Screened	X (Easting)	Y (Northing)
OBW-Q-1	1	1003259	1031261
OBW-Q-2	1	998989	1032491
OBW-Q-3	1	992257	1034786
OBW-Q-4	1	999646	999461
OBW-Q-5	1	993406	1001838
OBW-Q-6	1	987331	1004379
OBW-1	3 to 5	1007392	1029531
OBW-2	3 to 5	1003382	1024430
OBW-3	3 to 5	1003473	1015414
OBW-4	3 to 5	996363	1009585
OBW-5	3 to 5	999507	1002572
OBW-6	3 to 5	991532	995422
OBW-7	3 to 5	997365	994603

Note that the locations of these hypothetical observation wells are determined on the map and do not consider actual site conditions.

2.2. Head Observation Results

The following table gives details of the observation results. .

Table-6. 4 Head Observation Data for the Cretaceous Aquifer

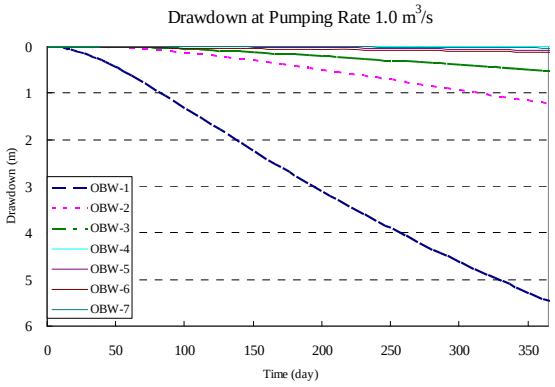
Head observation results at Pumping rate 2.0m^3/sec

Time (day)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5	0.02	0.00	0.00	0.00	0.00	0.00	0.00
6	0.02	0.00	0.00	0.00	0.00	0.00	0.00
7	0.03	0.00	0.00	0.00	0.00	0.00	0.00
9	0.04	0.00	0.00	0.00	0.00	0.00	0.00
11	0.06	0.00	0.00	0.00	0.00	0.00	0.00
13	0.08	0.00	0.00	0.00	0.00	0.00	0.00
15	0.11	0.00	0.00	0.00	0.00	0.00	0.00
17	0.13	0.00	0.00	0.00	0.00	0.00	0.00
19	0.16	0.01	0.00	0.00	0.00	0.01	0.00
21	0.19	0.01	0.00	0.00	0.00	0.01	0.00
24	0.25	0.01	0.01	0.00	0.00	0.01	0.00
27	0.30	0.01	0.01	0.00	0.00	0.01	0.00
30	0.37	0.02	0.01	0.00	0.00	0.01	0.00
33	0.44	0.02	0.01	0.00	0.00	0.02	0.00
36	0.51	0.03	0.01	0.00	0.00	0.02	0.00
39	0.58	0.03	0.02	0.00	0.00	0.02	0.00
42	0.66	0.04	0.02	0.00	0.00	0.02	0.00
45	0.75	0.05	0.02	0.00	0.00	0.03	0.00
48	0.83	0.05	0.03	0.00	0.00	0.03	0.00
51	0.92	0.06	0.03	0.00	0.00	0.03	0.00
61	1.25	0.09	0.04	0.00	0.00	0.04	0.00
71	1.59	0.13	0.06	0.00	0.00	0.05	0.00
81	1.94	0.17	0.08	0.00	0.00	0.06	0.00
91	2.30	0.22	0.10	0.00	0.00	0.06	0.00
101	2.67	0.27	0.12	0.00	0.01	0.07	0.00
111	3.04	0.33	0.14	0.00	0.01	0.08	0.00
121	3.41	0.39	0.17	0.00	0.01	0.08	0.00
131	3.78	0.46	0.20	0.00	0.02	0.09	0.00
141	4.15	0.52	0.23	0.00	0.02	0.10	0.00
151	4.51	0.60	0.25	0.00	0.02	0.10	0.01
161	4.87	0.67	0.29	0.00	0.03	0.11	0.01
171	5.22	0.75	0.32	0.00	0.03	0.11	0.01
181	5.57	0.83	0.35	0.00	0.04	0.12	0.01
191	5.91	0.91	0.38	0.00	0.04	0.13	0.01
201	6.24	0.99	0.42	0.00	0.05	0.13	0.01
211	6.57	1.08	0.45	0.00	0.05	0.14	0.02
221	6.90	1.16	0.49	0.00	0.06	0.14	0.02
231	7.21	1.25	0.53	0.00	0.07	0.15	0.02
241	7.53	1.34	0.56	0.00	0.07	0.16	0.02
251	7.83	1.42	0.60	0.00	0.08	0.16	0.03
261	8.13	1.51	0.64	0.00	0.09	0.17	0.03
271	8.43	1.60	0.68	0.00	0.10	0.18	0.03
281	8.71	1.69	0.72	0.00	0.10	0.18	0.04
291	9.00	1.78	0.76	0.00	0.11	0.19	0.04
301	9.27	1.87	0.80	0.00	0.12	0.20	0.04
311	9.54	1.97	0.84	0.00	0.13	0.21	0.05
321	9.81	2.06	0.88	0.00	0.14	0.21	0.05
331	10.07	2.15	0.92	0.00	0.15	0.22	0.05
341	10.33	2.24	0.97	0.00	0.15	0.23	0.06
351	10.58	2.33	1.01	0.00	0.16	0.24	0.06
361	10.83	2.42	1.05	0.00	0.17	0.24	0.07
371	11.07	2.51	1.09	0.00	0.18	0.25	0.07

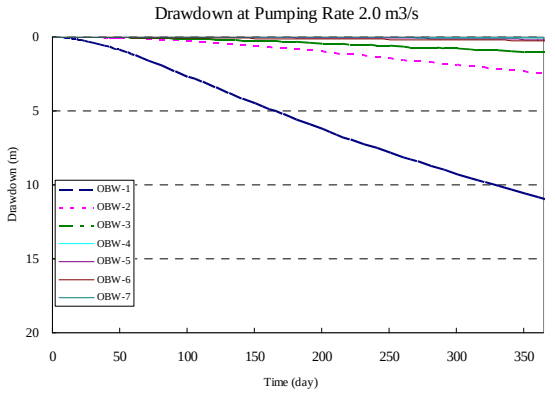
Head observation results at Pumping rate 4.0m^3/sec

Time (day)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3	0.02	0.00	0.00	0.00	0.00	0.00	0.00
4	0.02	0.00	0.00	0.00	0.00	0.00	0.00
5	0.03	0.00	0.00	0.00	0.00	0.00	0.00
6	0.04	0.00	0.00	0.00	0.00	0.00	0.00
7	0.06	0.00	0.00	0.00	0.00	0.00	0.00
9	0.09	0.00	0.00	0.00	0.00	0.00	0.00
11	0.12	0.00	0.00	0.00	0.00	0.00	0.00
13	0.17	0.00	0.00	0.00	0.00	0.00	0.00
15	0.21	0.01	0.00	0.00	0.00	0.01	0.00
17	0.27	0.01	0.00	0.00	0.00	0.01	0.00
19	0.32	0.01	0.01	0.00	0.00	0.01	0.00
21	0.39	0.01	0.01	0.00	0.00	0.01	0.00
24	0.49	0.02	0.01	0.00	0.00	0.02	0.00
27	0.61	0.03	0.01	0.00	0.00	0.02	0.00
30	0.74	0.04	0.02	0.00	0.00	0.03	0.00
33	0.87	0.04	0.02	0.00	0.00	0.03	0.00
36	1.01	0.05	0.03	0.00	0.00	0.04	0.00
39	1.17	0.07	0.03	0.00	0.00	0.04	0.00
42	1.33	0.08	0.04	0.00	0.00	0.05	0.00
45	1.49	0.09	0.04	0.00	0.00	0.05	0.00
48	1.67	0.11	0.05	0.00	0.00	0.06	0.00
51	1.84	0.12	0.06	0.00	0.00	0.06	0.00
61	2.49	0.18	0.09	0.00	0.00	0.08	0.00
71	3.17	0.26	0.12	0.00	0.00	0.10	0.00
81	3.88	0.34	0.16	0.00	0.01	0.11	0.00
91	4.61	0.44	0.20	0.00	0.01	0.12	0.00
101	5.34	0.55	0.24	0.00	0.01	0.14	0.00
111	6.08	0.66	0.29	0.00	0.02	0.15	0.00
121	6.82	0.78	0.34	0.00	0.03	0.16	0.01
131	7.56	0.91	0.40	0.00	0.03	0.17	0.01
141	8.29	1.05	0.45	0.00	0.04	0.19	0.01
151	9.02	1.19	0.51	0.00	0.05	0.20	0.01
161	9.73	1.34	0.57	0.00	0.06	0.21	0.02
171	10.44	1.50	0.64	0.00	0.06	0.22	0.02
181	11.13	1.65	0.70	0.00	0.07	0.23	0.02
191	11.82	1.82	0.77	0.00	0.09	0.24	0.03
201	12.49	1.98	0.84	0.00	0.10	0.25	0.03
211	13.15	2.15	0.91	0.00	0.11	0.26	0.03
221	13.80	2.32	0.98	0.00	0.12	0.28	0.04
231	14.43	2.50	1.05	0.00	0.14	0.29	0.04
241	15.05	2.67	1.13	0.00	0.15	0.30	0.05
251	15.66	2.85	1.21	0.00	0.16	0.31	0.06
261	16.26	3.03	1.28	0.00	0.18	0.33	0.06
271	16.85	3.21	1.36	0.00	0.19	0.34	0.07
281	17.43	3.39	1.44	0.00	0.21	0.35	0.07
291	17.99	3.57	1.52	0.00	0.23	0.36	0.08
301	18.55	3.75	1.60	0.00	0.24	0.38	0.09
311	19.09	3.93	1.68	0.00	0.26	0.39	0.09
321	19.62	4.11	1.77	0.00	0.28	0.40	0.10
331	20.14	4.30	1.85	0.00	0.29	0.42	0.11
341	20.66	4.48	1.93	0.00	0.31	0.43	0.11
351	21.16	4.66	2.02	0.00	0.33	0.45	0.12
361	21.65	4.84	2.10	0.00	0.35	0.46	0.13
371	22.14	5.02	2.19	0.00	0.37	0.47	0.14

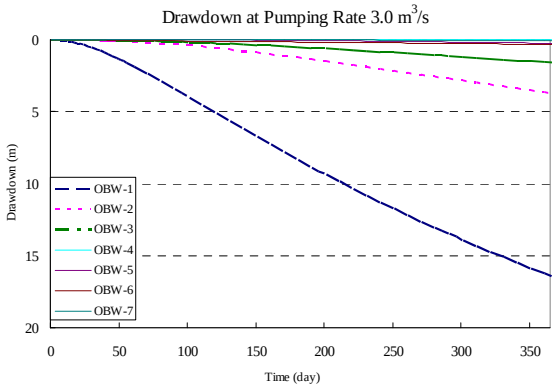
Drawdown graphs for the Cretaceous aquifer for different pumping rates of 1.0 to 6.0 m^3/sec (corresponding to Scenario 1 to 6) are presented below.



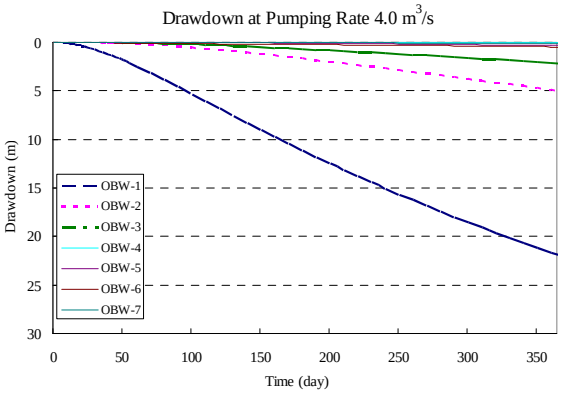
Scenario 1 (pumping rate at 1.0 m^3/sec)



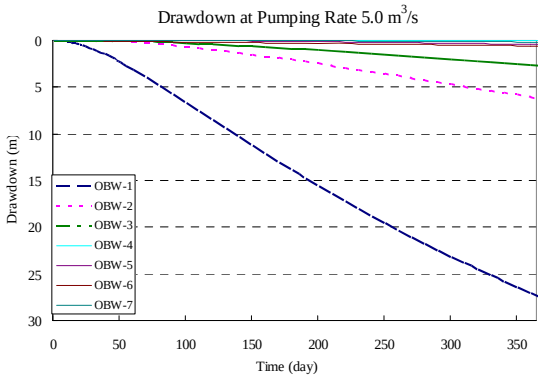
Scenario 2 (pumping rate at 2.0 m^3/sec)



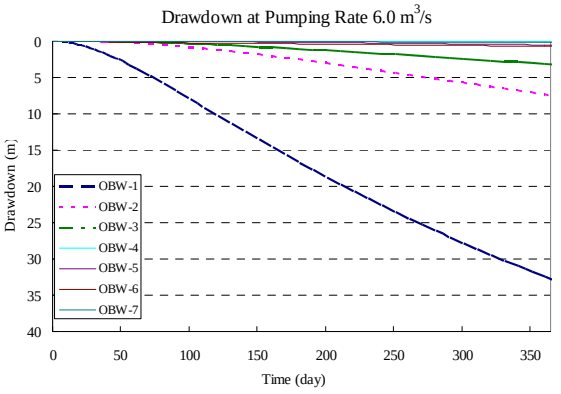
Scenario 3 (pumping rate at 3.0 m^3/sec)



Scenario 4 (pumping rate at 4.0 m^3/sec)



Scenario 5 (pumping rate at 5.0 m^3/sec)



Scenario 6 (pumping rate at 6.0 m^3/sec)

Figure-6. 3 Drawdown in the Cretaceous Aquifer at Different Pumping Rates

2.3. Discharge - Drawdown Relation

The relation between drawdown (s) observed at each observation wells and the collective pumping rate (Q) was investigated at the minimum and maximum pumping duration of one (1) month and nine (9) months respectively. The following tables correspond to the graphed representations.

Table-6. 5 Discharge (Q) - Drawdown (s) Relation

At Day 30 (1 month)

Q (m^3/s)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.09	0.00	0.00	0.00	0.00	0.00	0.00
1.0	0.18	0.01	0.00	0.00	0.00	0.01	0.00
1.5	0.28	0.01	0.01	0.00	0.00	0.01	0.00
2.0	0.37	0.02	0.01	0.00	0.00	0.01	0.00
2.5	0.46	0.02	0.01	0.00	0.00	0.02	0.00
3.0	0.55	0.03	0.01	0.00	0.00	0.02	0.00
3.5	0.64	0.03	0.02	0.00	0.00	0.02	0.00
4.0	0.74	0.04	0.02	0.00	0.00	0.03	0.00
4.5	0.83	0.04	0.04	0.00	0.00	0.03	0.00
5.0	0.92	0.04	0.02	0.00	0.00	0.03	0.00
5.5	1.01	0.05	0.02	0.00	0.00	0.04	0.00
6.0	1.10	0.05	0.03	0.00	0.00	0.04	0.00
At Day 271 (9 month)							
Q (m^3/s)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	2.11	0.40	0.17	0.00	0.02	0.04	0.01
1.0	4.21	0.80	0.34	0.00	0.05	0.09	0.02
1.5	6.32	1.20	0.51	0.00	0.07	0.13	0.02
2.0	8.43	1.60	0.68	0.00	0.10	0.18	0.03
2.5	10.53	2.00	0.85	0.00	0.12	0.21	0.04
3.0	12.64	2.41	1.02	0.00	0.14	0.25	0.05
3.5	14.74	2.81	1.19	0.00	0.17	0.29	0.06
4.0	16.85	3.21	1.36	0.00	0.19	0.34	0.07
4.5	18.96	3.61	1.53	0.00	0.22	0.38	0.08
5.0	21.06	4.01	1.70	0.00	0.24	0.43	0.08
5.5	23.17	4.41	1.87	0.00	0.27	0.47	0.09
6.0	25.28	4.81	2.04	0.00	0.29	0.52	0.10

* The drawdown is in meter

2.4. Head Recovery with Time

A simulation was conducted to see the recovery process of hydraulic heads at each observation wells after pumping is stopped after 9 months (271 days) of operation. The following tables show the data corresponding to the two graphs for Scenario 1 and 6.

Table-6. 6 Head Recovery with Time after Termination of Pumping for Scenario 1

Drawdown (m)

Time (day)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.26	0.02	0.01	0.00	0.00	0.01	0.00
60	0.67	0.07	0.03	0.00	0.00	0.02	0.00
90	1.16	0.13	0.06	0.00	0.00	0.03	0.00
120	1.68	0.22	0.09	0.00	0.01	0.04	0.00
150	2.20	0.32	0.14	0.00	0.01	0.04	0.00
180	2.72	0.43	0.18	0.00	0.02	0.05	0.01
210	3.21	0.55	0.23	0.00	0.03	0.06	0.01
240	3.68	0.67	0.29	0.00	0.04	0.07	0.01
270	4.12	0.80	0.35	0.00	0.05	0.07	0.02
300	4.28	0.92	0.39	0.00	0.06	0.07	0.02
330	4.27	1.00	0.44	0.00	0.07	0.07	0.03
360	4.15	1.07	0.47	0.00	0.08	0.06	0.03
390	3.99	1.12	0.50	0.00	0.09	0.06	0.03
420	3.81	1.15	0.52	0.00	0.10	0.06	0.03

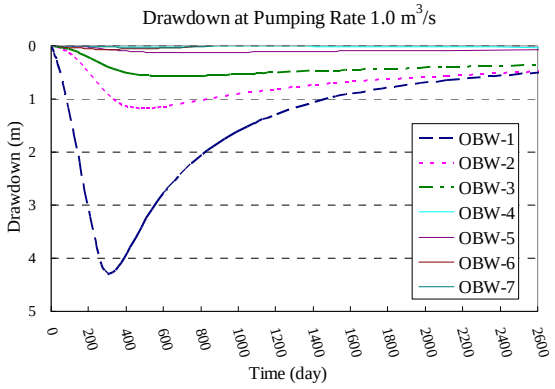
450	3.62	1.17	0.54	0.00	0.11	0.06	0.04
480	3.43	1.18	0.55	0.00	0.11	0.06	0.04
510	3.26	1.18	0.56	0.00	0.12	0.05	0.04
540	3.09	1.17	0.57	0.00	0.12	0.05	0.04
570	2.93	1.16	0.57	0.00	0.12	0.05	0.04
600	2.79	1.15	0.58	0.00	0.13	0.04	0.04
630	2.65	1.13	0.58	0.00	0.13	0.04	0.03
690	2.42	1.09	0.58	0.00	0.13	0.03	0.03
750	2.22	1.06	0.57	0.00	0.13	0.02	0.02
810	2.04	1.02	0.57	0.00	0.13	0.00	0.01
870	1.88	0.98	0.56	0.00	0.12	-0.01	0.00
930	1.75	0.94	0.55	0.00	0.12	-0.03	-0.01
990	1.63	0.91	0.54	0.00	0.12	-0.05	-0.03
1050	1.52	0.88	0.53	0.00	0.12	-0.07	-0.04
1110	1.42	0.85	0.52	0.00	0.11	-0.09	-0.06
1210	1.28	0.80	0.50	0.01	0.11	-0.13	-0.08
1310	1.16	0.76	0.49	0.01	0.11	-0.17	-0.11
1410	1.06	0.73	0.47	0.01	0.10	-0.22	-0.14
1510	0.97	0.70	0.46	0.01	0.10	-0.27	-0.17
1610	0.89	0.67	0.45	0.01	0.10	-0.32	-0.21
2110	0.65	0.57	0.40	0.02	0.08	-0.61	-0.37
2610	0.50	0.49	0.36	0.03	0.07	-0.90	-0.53

Table-6. 7 Head Recovery with Time after Termination of Pumping for Scenario 6

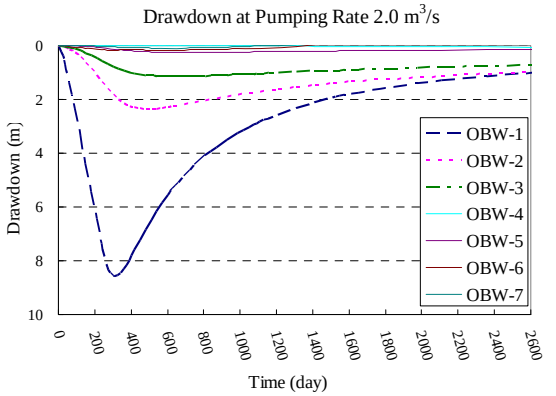
Drawdown (m)

Time (day)	OBW-1	OBW-2	OBW-3	OBW-4	OBW-5	OBW-6	OBW-7
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	1.57	0.12	0.06	0.00	0.00	0.05	0.00
60	4.04	0.39	0.18	0.00	0.01	0.11	0.00
90	6.97	0.79	0.35	0.00	0.03	0.18	0.01
120	10.09	1.30	0.56	0.00	0.05	0.24	0.02
150	13.23	1.90	0.81	0.00	0.09	0.29	0.03
180	16.29	2.57	1.10	0.00	0.13	0.35	0.04
210	19.24	3.29	1.40	0.00	0.18	0.41	0.06
240	22.05	4.04	1.73	0.00	0.24	0.46	0.08
270	24.72	4.82	2.07	0.00	0.31	0.52	0.11
300	25.67	5.49	2.37	0.00	0.38	0.54	0.14
330	25.60	6.02	2.62	0.00	0.44	0.53	0.17
360	24.93	6.43	2.82	0.00	0.50	0.53	0.20
390	23.96	6.71	2.98	0.00	0.56	0.54	0.23
420	22.85	6.90	3.11	0.00	0.61	0.55	0.25
450	21.72	7.01	3.22	0.00	0.65	0.57	0.27
480	20.61	7.06	3.30	0.00	0.68	0.58	0.29
510	19.54	7.06	3.36	0.00	0.71	0.60	0.31
540	18.54	7.03	3.41	0.00	0.73	0.62	0.32
570	17.60	6.97	3.44	0.00	0.74	0.64	0.34
600	16.73	6.89	3.46	0.00	0.76	0.65	0.35
630	15.92	6.79	3.47	0.00	0.76	0.67	0.35
690	14.52	6.57	3.46	0.00	0.77	0.70	0.36
750	13.30	6.34	3.43	0.01	0.76	0.72	0.36
810	12.24	6.11	3.39	0.01	0.75	0.75	0.36
870	11.31	5.88	3.34	0.01	0.74	0.76	0.36
930	10.48	5.67	3.29	0.02	0.73	0.78	0.35
990	9.75	5.46	3.23	0.02	0.71	0.79	0.34
1050	9.10	5.27	3.17	0.02	0.70	0.80	0.33
1110	8.51	5.09	3.11	0.03	0.69	0.80	0.31
1210	7.68	4.83	3.01	0.04	0.66	0.80	0.29
1310	6.97	4.59	2.92	0.05	0.64	0.80	0.26
1410	6.35	4.37	2.83	0.06	0.62	0.78	0.23
1510	5.82	4.18	2.75	0.07	0.60	0.76	0.19
1610	5.35	4.01	2.68	0.08	0.59	0.73	0.16
2110	3.90	3.39	2.40	0.13	0.53	0.50	-0.02
2610	2.97	2.93	2.18	0.18	0.48	0.22	-0.19

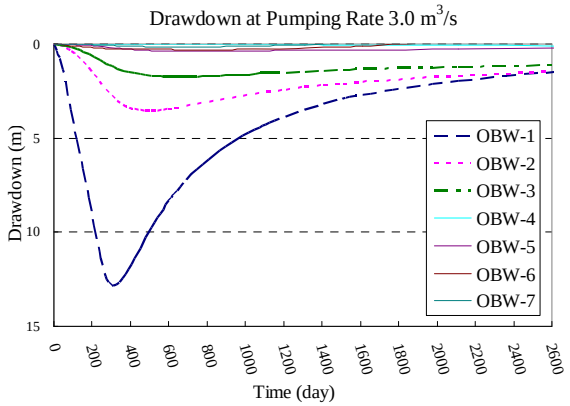
The result of head recovery observations for all Scenarios including 1 and 6 are presented in time-drawdown graphs below.



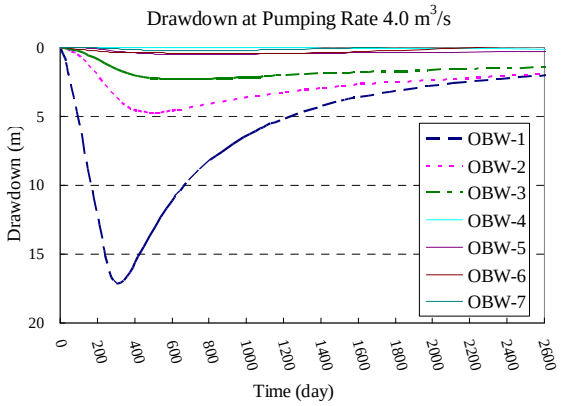
Scenario 1 (pumping at 1.0 m^3/sec)



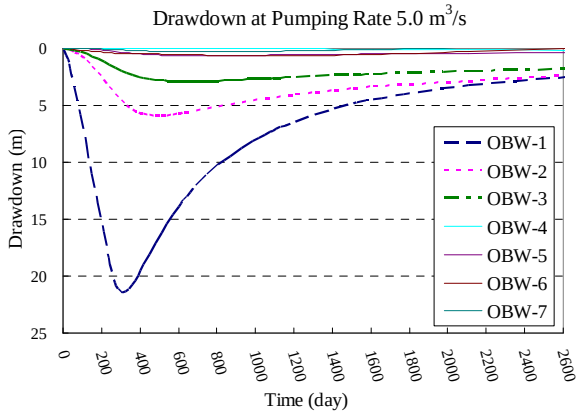
Scenario 2 (pumping at 2.0 m^3/sec)



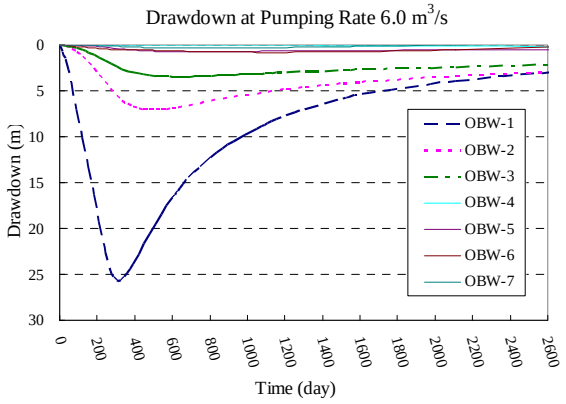
Scenario 3 (pumping at 3.0 m^3/sec)



Scenario 4 (pumping at 4.0 m^3/sec)



Scenario 5 (pumping at 5.0 m^3/sec)



Scenario 6 (pumping at 6.0 m^3/sec)

Figure-6. 4 Time-Drawdown relations for Scenario 1 to 6

2.5. Drawdown in Quaternary Sediment Layers

For the Quaternary sediment layers, the maximum drawdown was found to be very small. The following table is the time-drawdown data. The simulation time was extended up to 2600 days (approximately 7 years).

Table-6. 8 Drawdown in Quaternary Sediment Layers for Scenario 6

Drawdown (m)

Time (day)	OBW-Q-1	OBW-Q-2	OBW-Q-3	OBW-Q-4	OBW-Q-5	OBW-Q-6
0	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.02	0.00	0.00
60	0.00	0.00	0.00	0.04	0.00	0.00
90	0.00	0.00	0.00	0.06	0.00	0.00
120	0.01	0.00	0.00	0.07	0.00	0.00
150	0.01	0.00	0.00	0.09	0.00	0.00
180	0.02	0.00	0.00	0.11	0.00	0.00
210	0.03	0.00	0.00	0.12	0.00	0.00
240	0.03	0.00	0.00	0.13	0.00	0.00
270	0.04	0.00	0.00	0.14	0.00	0.00
300	0.05	0.00	0.00	0.15	0.00	0.00
330	0.06	0.00	0.00	0.15	0.00	0.00
360	0.08	0.00	0.00	0.15	0.00	0.00
390	0.09	0.00	0.00	0.15	0.00	0.00
420	0.10	0.00	0.00	0.15	0.00	0.00
450	0.11	0.00	0.00	0.15	0.00	0.00
480	0.12	0.00	0.00	0.15	0.00	0.00
510	0.14	0.00	0.00	0.15	0.00	0.00
540	0.15	0.00	0.00	0.15	0.00	0.00
570	0.16	0.00	0.00	0.15	0.00	0.00
600	0.17	0.00	0.00	0.14	0.00	0.00
630	0.18	0.00	0.00	0.14	0.00	0.00
690	0.20	0.00	0.00	0.14	0.00	0.00
750	0.22	0.00	0.00	0.13	0.00	0.00
810	0.23	0.00	0.00	0.13	0.00	0.00
870	0.25	0.01	0.00	0.12	0.00	0.00
930	0.26	0.01	0.00	0.12	0.00	0.00
990	0.27	0.01	0.00	0.12	0.00	0.00
1050	0.28	0.01	0.00	0.11	0.00	0.00
1110	0.29	0.01	0.00	0.11	0.00	0.00
1210	0.30	0.01	0.00	0.11	0.00	0.00
1310	0.31	0.02	0.00	0.10	0.01	0.00
1410	0.31	0.02	0.00	0.10	0.01	0.00
1510	0.31	0.02	0.00	0.09	0.01	0.00
1610	0.32	0.02	0.00	0.09	0.01	0.00
2110	0.30	0.04	0.00	0.06	0.01	0.00
2610	0.28	0.05	0.00	0.03	0.01	0.00

PART 7

GROUNDWATER SIMULATION OF FEASIBILITY STUDY

Final Report

(Supporting Report)

PART 7 GROUNDWATER SIMULATION OF FEASIBILITY STUDY

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List of Tables and Figures

PART 7 GROUNDWATER SIMULATION OF F/S

CHAPTER 1. OUTLINE OF THE MODEL

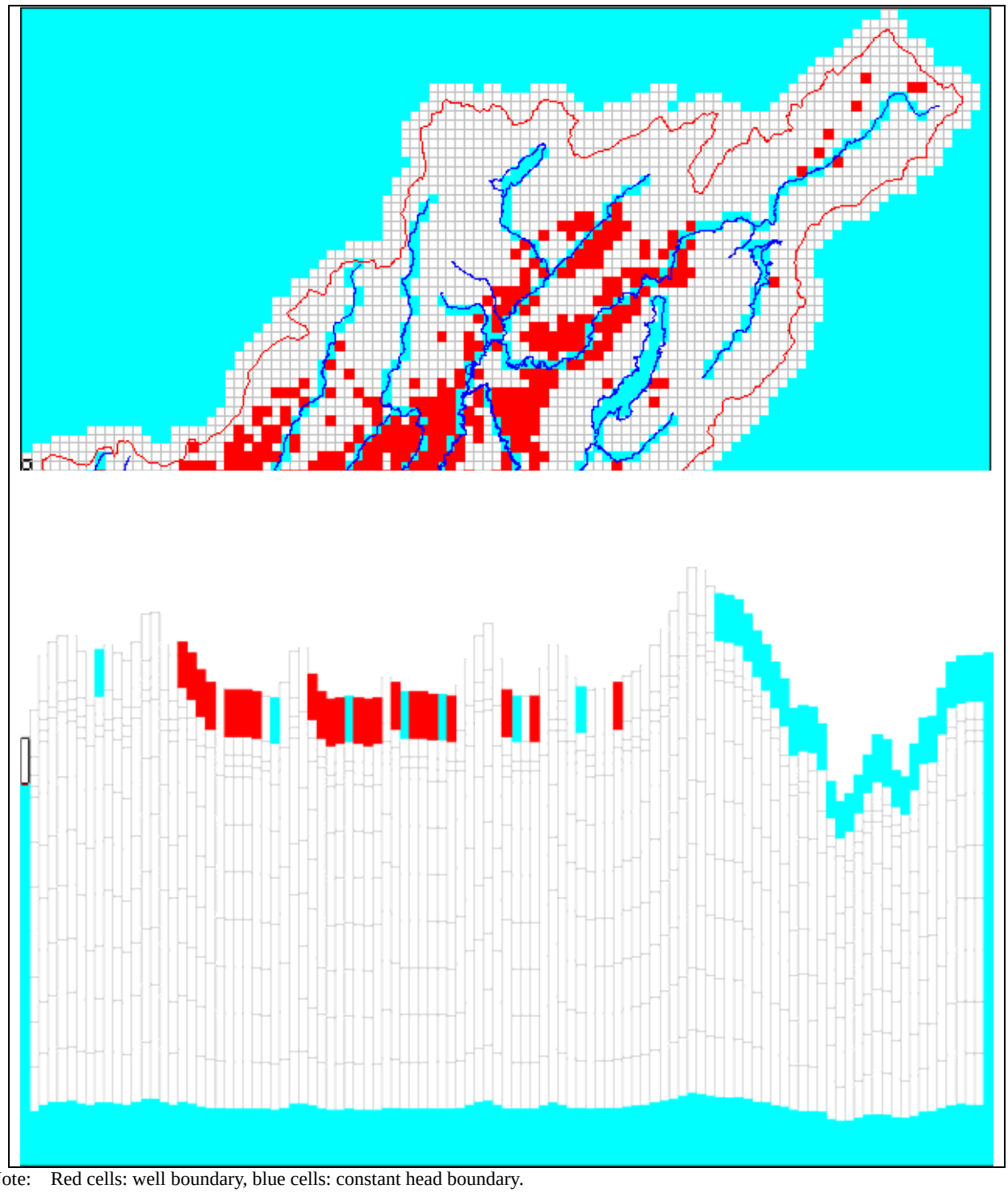
1.1. Boundary Conditions

The basic information (model structure, parameters, boundary conditions) of the model is given in Table-7.1 of the main report. The following table presents the details of the boundary conditions employed in this model.

Table-7. 1 Details of Boundary Conditions

Structure	Boundary condition (BC)	
Layer	BC Type	Detail
1st layer: Quaternary Plain area Tertiary Boundary of plain area and mountainous area. Guadalupe: Mountainous area arround the Bogota plain. (see Figure2 in main report)	Constant Head Boundary	In basin: Fixed heads for rivers, dams and area 2 km more out side of the Bogota basin.
	Recharge boundary	Groundwater recharge (see Figure 5 in main report)
	Evapotranspiration boundary	Evapotraspiration from groundwater Maximum ET rate: 0.0026 (m/day) Elevation of the ET Surface: 0.3m ET Extinction Depth: 1.5m
	Well boundary	Existing wells: 4918 existing wells are specified into 983 cells (see Figure 4 in main report) Projected wells: 65 projected wells are set for the three projects, 34 in the Easern Project side; 13 in the Southern Project side and 17 in the Yerbabuena Project side. (see Figure1 in main report 3.2.2)
2nd layer Tertiary Quaternary and Teriary area in layer 1 Guadalupe: The same as layer1	Constant Head Boundary	All the cells along the model domain boundary.
3rd and 4th layers Guadalupe	Constant Head Boundary	All the cells along the model domain boundary.
5th layer Cretaceous	Constant Head Boundary	All the cells along the model domain boundary.
6th to 11th layer Paleozoic	Constant Head Boundary	All the cells along the model domain boundary.
12th layer Paleozoic	Constant Head Boundary	All the cells within the 12th layer

The vertical cross-section of the model showing grid/layer and major boundary conditions is shown in Figure 7-1 and 7-2.



Note: Red cells: well boundary, blue cells: constant head boundary.

Figure-7. 1 Cross-sectional Views of Grid/layer and Boundary Conditions of the Model (along row 50)

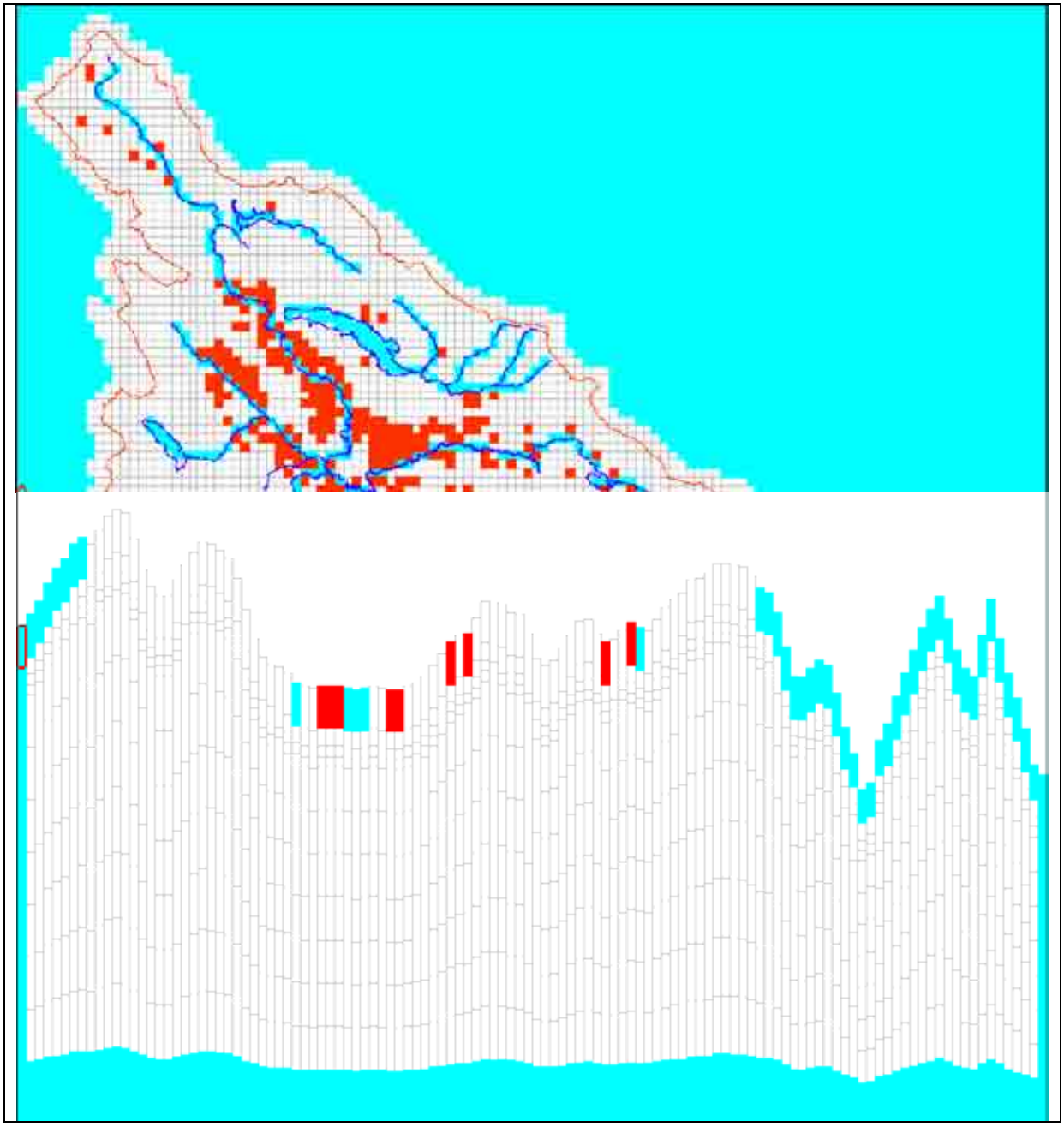


Figure-7. 2 Cross-sectional Views of Grid/layer and Boundary Conditions of the Model (along column 49)

1.2. Newly Planned Pumping Wells

The following table shows the list of the 64 pumping wells newly planned in this study.

Table-7. 2 Coordinates of 64 pumping wells

No_	Project	Latitude	Longitude	Site	Elavation	Yield_M3_D	Row	Column
E-1	Eastern	4.563	-74.065333	Vitelma	2810	2000	84	42
E-3	Eastern	4.627056	-74.055194	Chapinero	2825	2000	77	43
E-4	Eastern	4.634556	-74.05575	Chapinero	2768	2000	76	43
TS-2	Eastern	4.683917	-74.027722	Usaquen	2674	2000	71	46
TS-1	Eastern	4.685139	-74.029611	Usaquen	2621	2000	70	46
E-5	Eastern	4.69225	-74.024194	Usaquen	2688	2000	70	46
E-6	Eastern	4.692806	-74.025722	Usaquen	2643	2000	70	46
ST-1	Eastern	4.711722	-74.083389	Suba	2589	2500	68	40
ST-2	Eastern	4.712111	-74.084333	Suba	2588	2500	68	40
E-7	Eastern	4.712	-74.028972	Usaquen	2583	2000	68	46
ST-3	Eastern	4.7125	-74.084833	Suba	2589	2500	67	40
E-8	Eastern	4.722972	-74.025806	Usaquen	2583	2000	66	46
E-9	Eastern	4.727333	-74.022917	Usaquen	2597	2000	66	47
E-11	Eastern	4.736	-74.024	Usaquen	2577	2000	65	46
E-10	Eastern	4.733778	-74.023444	Usaquen	2587	2000	65	47
E-12	Eastern	4.740167	-74.022472	Usaquen	2583	2000	64	47
E-13	Eastern	4.745222	-74.022	Usaquen	2592	2000	64	47
E-14	Eastern	4.754833	-74.022917	Usaquen	2605	2000	63	47
E-15	Eastern	4.762639	-74.026889	Usaquen	2578	2000	62	46
CO-2	Eastern	4.764833	-74.024056	Usaquen	2643	2000	62	46
Y-1	Eastern	4.770583	-74.027333	Bogota Rural	2570	2000	61	46
Y-2	Eastern	4.774528	-74.026917	Bogota Rural	2571	2000	61	46
Y-3	Eastern	4.776278	-74.026611	Bogota Rural	2571	2000	60	46
Y-4	Eastern	4.784556	-74.028417	Bogota Rural	2575	2000	60	46
Y-5	Eastern	4.78625	-74.027889	Bogota Rural	2582	2000	59	46
Y-6	Eastern	4.78925	-74.028583	Bogota Rural	2571	2000	59	46
Y-7	Eastern	4.792278	-74.029417	Bogota Rural	2573	2000	59	46
E-16	Eastern	4.7575	-74.078389	Suba	2581	2500	63	40
E-17	Eastern	4.761111	-74.0815	Suba	2575	2500	62	40
Y-8	Eastern	4.795806	-74.031611	Bogota Rural	2581	2000	58	46
Y-9	Eastern	4.805694	-74.030139	Bogota Rural	2568	2000	57	46
Y-10	Eastern	4.809556	-74.030639	Bogota Rural	2570	2000	57	46
Y-11	Eastern	4.817278	-74.031	Bogota Rural	2569	2000	56	46
Y-12	Eastern	4.821583	-74.0315	Bogota Rural	2586	2000	55	46
B-4	Southern	4.531194	-74.168056	Ciudad Bolova	2945	1000	88	31
B-5	Southern	4.528528	-74.167778	Ciudad Bolova	2987	1000	88	31
B-1	Southern	4.539417	-74.160472	Ciudad Bolova	2835	1000	87	31
EX-2	Southern	4.537333	-74.164361	Ciudad Bolova	2867	1000	87	31
B-2	Southern	4.534083	-74.165583	Ciudad Bolova	2907	1000	87	31
B-3	Southern	4.532833	-74.167056	Ciudad Bolova	2918	1000	87	31
EX-1	Southern	4.556028	-74.179556	Soacha	2786	1000	85	29
S-5	Southern	4.552472	-74.180528	Soacha	2809	1000	85	29
S-6	Southern	4.550111	-74.182306	Soacha	2837	1000	85	29
S-1	Southern	4.562028	-74.189111	Soacha	2746	1000	84	28
S-2	Southern	4.561722	-74.185611	Soacha	2760	1000	84	29
S-3	Southern	4.562028	-74.182333	Soacha	2748	1000	84	29
S-4	Southern	4.559333	-74.179889	Soacha	2762	1000	84	29
Y-13	Yerbabuen	4.829278	-74.031028	Chia	2566	2000	55	46
Y-14	Yerbabuen	4.832611	-74.030111	Chia	2564	2000	54	46
Y-15	Yerbabuen	4.835306	-74.029917	Chia	2558	2000	54	46
Y-21	Yerbabuen	4.874861	-74.014944	Chia	2570	2000	50	47
Y-16	Yerbabuen	4.840889	-74.026722	Chia	2564	2000	53	46
Y-17	Yerbabuen	4.848778	-74.0265	Chia	2556	2000	52	46
Y-18	Yerbabuen	4.854194	-74.023778	Chia	2571	2000	52	46
Y-19	Yerbabuen	4.855944	-74.021556	Chia	2617	2000	52	47
Y-20	Yerbabuen	4.860778	-74.024667	Chia	2577	2000	51	46
Y-22	Yerbabuen	4.87875	-74.013444	Sopo	2566	2000	49	48
Y-23	Yerbabuen	4.881194	-74.012667	Sopo	2563	2000	49	48
Y-24	Yerbabuen	4.88925	-74.009667	Sopo	2557	2000	48	48
Y-25	Yerbabuen	4.893111	-74.007472	Sopo	2559	2000	47	48
Y-26	Yerbabuen	4.896333	-74.006278	Sopo	2559	2000	47	48
Y-27	Yerbabuen	4.91375	-73.997306	Sopo	2558	2000	45	49
Y-28	Yerbabuen	4.919028	-73.997528	Sopo	2554	2000	45	49
Y-29	Yerbabuen	4.922556	-73.996611	Sopo	2561	2000	44	49

1.3. Calibrated Model

The following Figures present head distribution in cross sectional view.

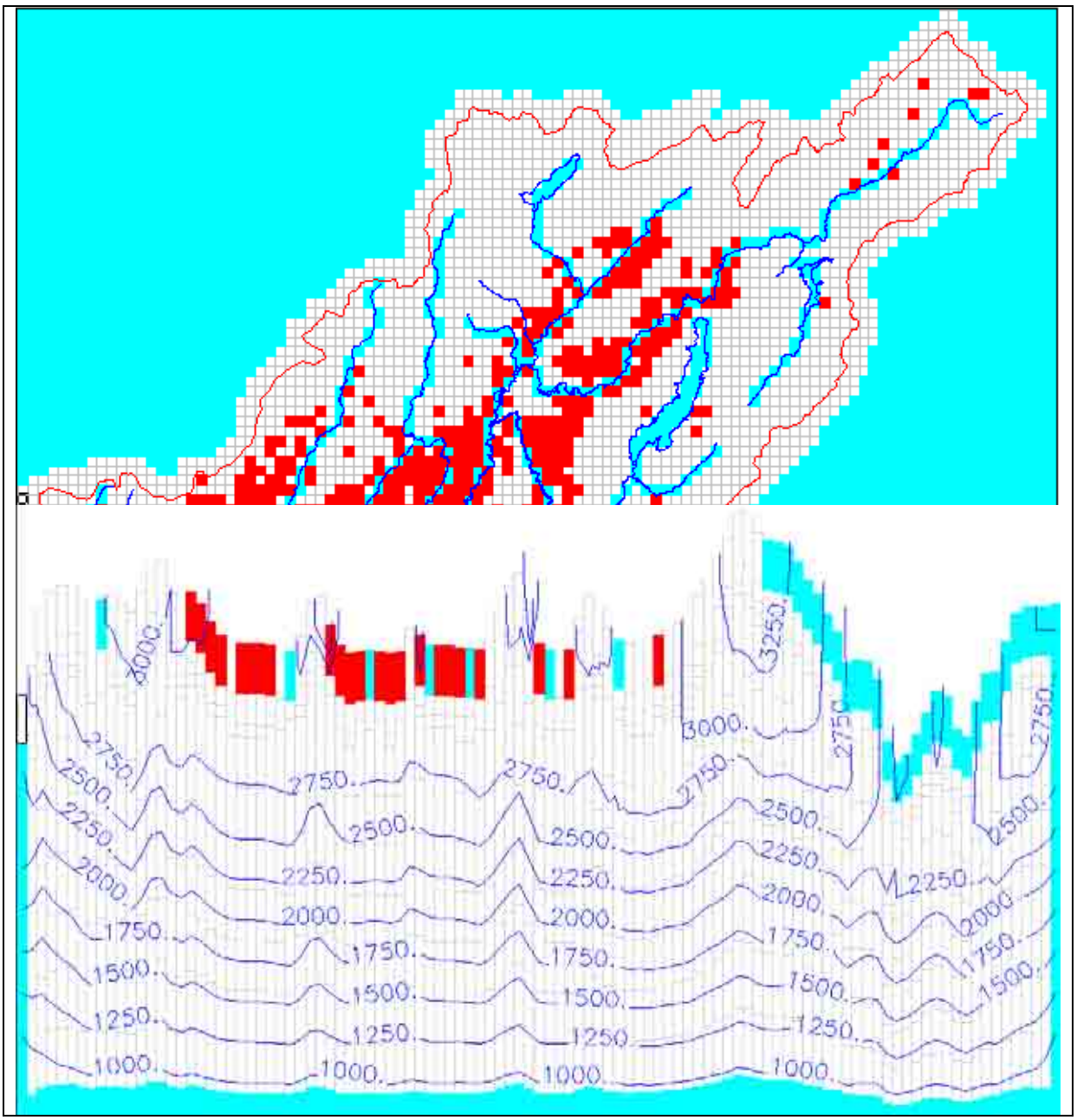


Figure-7. 3 Head Distribution of the Calibrated Steady State Model (along row 50)

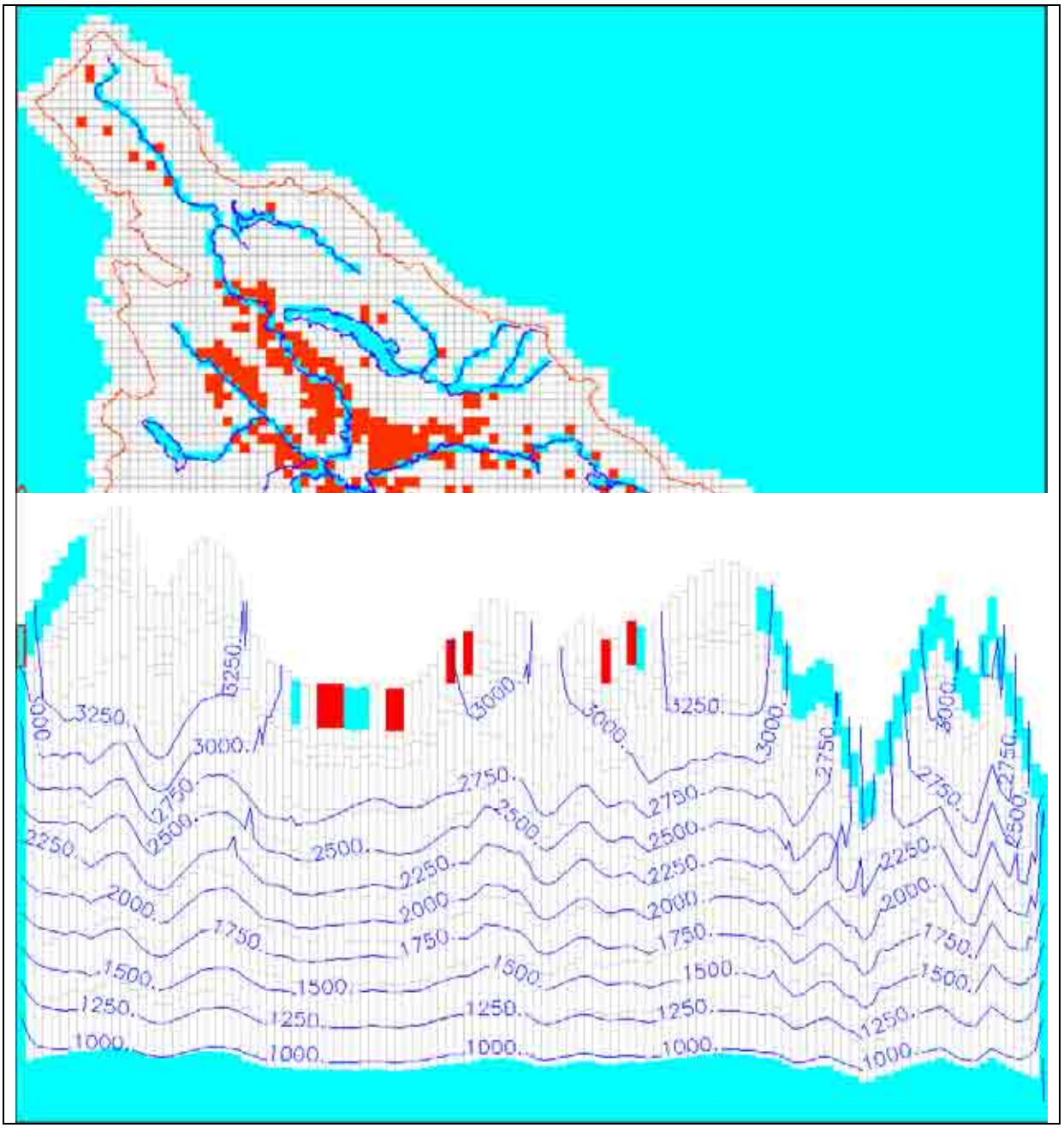


Figure-7. 4 Head Distribution of the Calibrated Steady State Model (along column 49)

CHAPTER 2. DRAWDOWN FORECAST

The influence of pumping from the 64 planned deep wells over the hydraulic head distribution of the surrounding aquifers was investigated using the calibrated model.

2.1. Head Observation Wells

The drawdown of water table and hydraulic heads due to pumping of newly planned wells were observed through hypothetical observation wells. The following table summarizes details of the observation wells.

Table-7. 3 Detailed Location of Observation Wells

No.	Borehole Name	Active	X (easting)	Y (northing)
1	South-1	☒	990322	993417
2	South-2	☒	989358	994291
3	South-3	☒	988453	995987
4	East-1	☒	1005777	1020268
5	East-2	☒	1002562	1004054
6	East-3	☒	1001584	996296
7	YBB-1	☒	1008896	1035781
8	YBB-2	☒	1007468	1032252
9	YBB-3	☒	1005535	1027444

Note that the locations of these hypothetical observation wells are determined on the map and do not consider actual site conditions.

2.2. Drawdown Observation Results

The following table gives details of the observation results.

Table-7. 4 Drawdown Observation Data for the Hypothetical Observation Boreholes

Time(day)	East-1	East-2	East-3	South-1	South-2	South-3	YBB-1	YBB-2	YBB-3
0	0	0	0	0	0	0	0	0	0
10	0.78	1.08	1.02	0.82	0	0.8	0.6	0.65	0.61
20	1.33	1.87	1.7	1.4	0.01	1.38	1.06	1.1	1.06
30	1.73	2.47	2.16	1.8	0.02	1.81	1.41	1.43	1.42
60	2.35	3.47	2.85	2.39	0.06	2.5	2.05	1.97	2.03
90	2.73	4.09	3.25	2.48	0.11	2.92	2.48	2.32	2.43
120	3	4.53	3.51	2.58	0.17	3.19	2.78	2.58	2.72
150	3.21	4.86	3.7	2.68	0.23	3.39	3.01	2.78	2.94
180	3.39	5.14	3.86	2.78	0.29	3.54	3.2	2.96	3.14
210	3.55	5.39	4	2.88	0.35	3.67	3.36	3.12	3.31
240	3.69	5.61	4.12	2.98	0.41	3.78	3.49	3.26	3.46
270	3.83	5.82	4.24	3.07	0.48	3.88	3.61	3.4	3.6
300	2.46	3.86	2.46	2.82	0.52	2.39	2.46	2.26	2.49
665	1.09	1.62	0.83	0.99	0.55	0.76	0.79	0.96	1.08
1030	0.81	1.14	0.54	0.56	0.49	0.48	0.42	0.63	0.75
1395	0.66	0.9	0.41	0.43	0.42	0.37	0.28	0.47	0.59
1760	0.55	0.73	0.34	0.35	0.36	0.3	0.21	0.37	0.48
2125	0.47	0.61	0.29	0.29	0.31	0.25	0.17	0.31	0.4
2490	0.41	0.52	0.25	0.24	0.27	0.21	0.14	0.26	0.34
2855	0.36	0.44	0.22	0.21	0.23	0.18	0.12	0.22	0.29
3220	0.32	0.38	0.2	0.18	0.2	0.15	0.1	0.19	0.25
3585	0.28	0.33	0.18	0.16	0.17	0.13	0.09	0.16	0.22
3950	0.25	0.29	0.16	0.14	0.15	0.12	0.08	0.14	0.19
4315	0.22	0.25	0.15	0.12	0.13	0.1	0.07	0.13	0.17
4680	0.2	0.22	0.13	0.11	0.12	0.09	0.06	0.11	0.15
5045	0.18	0.19	0.12	0.09	0.1	0.08	0.05	0.1	0.13
5410	0.16	0.17	0.11	0.08	0.09	0.07	0.05	0.09	0.12
5775	0.15	0.15	0.1	0.07	0.08	0.06	0.04	0.08	0.11
6140	0.13	0.14	0.09	0.06	0.07	0.05	0.04	0.07	0.1
6505	0.12	0.12	0.08	0.06	0.06	0.05	0.04	0.07	0.09

PART 8

LAND SUBSIDENCE

Final Report

(Supporting Report)

PART 8 LAND SUBSIDENCE

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PART 8 LAND SUBSIDENCE

CHAPTER 1. MODEL OF LAND SUBSIDENCE

(1) Analysis of land subsidence

Land subsidence by proposed project was analyzed in M/P Report. Mechanism of land subsidence was already explained in M/P Report. Therefore, in this part, supplemental explanation will be given regarding description of M/P Report/ Please refer to Main Report. Fundamental model of land subsidence by pumping is given by Figure-8.1 as explained in Main Report.

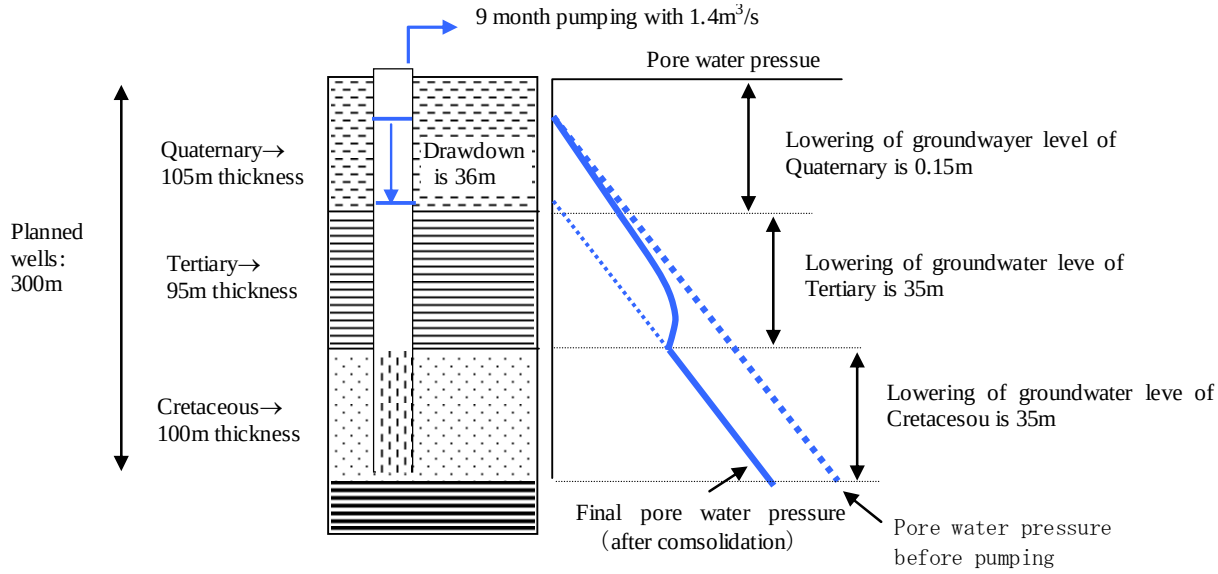

Figure-8. 1 Consolidation Model

(2) Speed of land subsidence

Consolidation of a layer will proceed in proportional to reduce in excess water pressure within the layer, which was caused by reduce in water pressure of a neighboring confined aquifer. Progress of consolidation can be predicted by formula of Terzaghi. As shown in the formula, speed of consolidation is proportional to coefficient of permeability of clay layer. Consequently, it will take long time until consolidation of clay layer finishes because of its low permeability.

$$\frac{\delta u}{\delta t} = \frac{k}{m_v \gamma_w} \times \frac{\delta^2 u}{\delta^2 z}$$

u: Excess water pressure of layer.

k: Coefficient of permeability.

m_v : Coefficient of volume compressibility.

γ_w : Unit weight of water.

(3) Consolidation model for Quaternary (Alluvial clay)

There is the existing consolidation model for alluvial clay in the northern part of Bogotá city (see Figure-8.2). This model was used for analysis. It was assumed that groundwater drained from clay layers by consolidation will go down and finally flow away from the bottom layer (layer No. 16 in Figure-8.2).

Symbol	Soil layer		Depth of layer (m)	Thickness of layer (m)	Unit weight (t/m^2)	Compression index (Cc)	Cv (cm^2/d)	Converted thickness (m)
	No.	Soil name						
	1	Fill	1.0	1.0	1.56	-	-	-
	2	Silt	2.5	1.5	1.38	1.72	2.59	1.2
	3	Clay	6.7	4.2	1.48	0.99	20.74	1.2
	4	Clay	20.1	13.4	1.34	1.48	0.86	19.0
	5	Clay	26.4	6.3	1.32	1.55	1.73	6.3
	6	Clay	30.5	4.1	1.46	1.37	117.07	0.5
	7	Clay	36.2	5.7	1.41	1.6	1.73	5.7
	8	Clay	39.7	3.5	1.33	3.77	1.73	3.5
	9	Clay	42.3	2.6	1.53	2.21	1.73	2.6
	10	Clay	50.5	8.2	1.46	1.16	1.73	8.2
	11	Clay	62.3	11.8	1.5	0.95	24.19	3.2
	12	Tuff	66.5	4.2	1.07	2.26	4.75	2.5
	13	Clay+sand	71.0	4.5	1.67	0.77	42.34	0.9
	14	Clay+sand	85.0	14.0	1.73	0.7	1.30	16.2
	15	Clay+sand	89.8	4.8	1.84	0.62	1.30	5.5
	16	Sandy clay	105.0	15.2	1.7	0.97	9.50	6.5
Total				105.0				83.0

Source: National University.

Figure-8. 2 Consolidation Model of alluvial Layers

(4) Coefficient of consolidation and thickness of layers

Speed of consolidation is dominated by coefficient of consolidation (Cv). The Quaternary layers consist of multiples layers with different Cv. For easy analysis, the Quaternary layers were unified into single layer with unified Cv by method bellow.

$$\text{Converted thickness of each layer} = \sqrt{\text{thickness each of layer} \times \text{Cv of each layer} \div \text{unified Cv}}$$

Unified Cv = 1.73 cm^2/day (Cv of layer No. 5, No. 7 – No. 10)

Thickness of unified layer = Total thickness of converted layers

On the other hand, coefficient of consolidation of Tertiary and Cretaceous layer can not be defined because they are expected elastic compression.

CHAPTER 2. RESULT OF ANALYSIS

(1) Result of Calculation

According top the result of groundwater simulation (see M/P Report), draw down of groundwater level of Quaternary aquifer is 0.15m. Based on this result, the final consolidation amount by draw-down of groundwater level of Quaternary aquifer was calculated, and its result is shown in Table-8.1. It must be noticed that consolidation amount in Table-8.1, 0.02m, means final value of consolidation under condition that pumping will continue for ever. But emergency well will not be operated forever but for only 9 month at longest. Consequently, to get exact value of consolidation after 9 month pumping, some modification must be done to the result, 0.02m.

Table-8. 1 Final Consolidated Length of Model Layer of Quaternary

Layer parameter					Before draw down of groundwater level				After draw down of groundwater level													
Layer	Depth of Bottom (m)	Thickness of layer (m)	Depth of center of layer (m)	Unit weight (t/m2)	Effective stress of layer(t/m2)	Effective stress in bottom (t/m2)	Effective stress of center (t/m2)	Reconsolidation stress of center (t/m2)	Effective stress of center (t/m2)	Reconsolidation stress of center	eo	Cc	Cr	Increase of effective stress(=P2-P1) (t/m2)	log(P2/P1)	H/(1+eo)	C*log(P2/P1)	dh(m)	Cv (cm2/s)	Cv (cm2/s)	Average Cv (cm2/s)	Average Cv (cm2/d)	Converted thickness of layer
fill	1	1.0	0.5	1.56	1.6	1.6	0.8	-1.1	0.8	-1.1				0.00	0	1.00	0.00	0.00					
Silt	2.5	1.5	1.8	1.38	2.1	3.6	2.6	-0.3	2.6	-0.3	2.84	1.72	0.24	0.00	0.00	0.39	0.00	0.00	0.00005	0.00001	0.00003	2.59	1.23
Clay	6.7	4.2	4.6	1.48	6.2	9.8	6.7	1.4	6.7	1.4	2.37	0.99	0.18	0.00	0.00	1.25	0.00	0.00	0.00043	0.00005	0.00024	20.74	1.21
Clay	20.1	13.4	13.4	1.34	12.9	22.7	16.3	6.6	16.3	6.6	3.1	1.48	0.3	0.00	0.00	3.27	0.00	0.00	0.00001	0.00001	0.00001	0.86	18.96
Clay	26.4	6.3	23.3	1.32	2.0	24.7	23.7	12.5	23.7	12.5	3.24	1.55	0.2	0.01	0.00	1.49	0.00	0.00	0.00003	0.00001	0.00002	1.73	6.30
Clay	30.5	4.1	28.5	1.46	1.9	26.6	25.7	15.6	25.7	15.6	3.72	1.37	0.22	0.02	0.00	0.87	0.00	0.00	0.00190	0.00081	0.00136	117.07	0.50
Clay	36.2	5.7	33.4	1.41	2.3	28.9	27.8	18.5	27.8	18.5	2.54	1.6	0.44	0.03	0.00	1.61	0.00	0.00	0.00003	0.00001	0.00002	1.73	5.70
Clay	39.7	3.5	38.0	1.33	1.2	30.1	29.5	21.2	29.6	21.2	3.6	3.77	0.15	0.04	0.00	0.76	0.00	0.00			0.00002	1.73	3.50
Clay	42.3	2.6	41.0	1.53	1.4	31.5	30.8	23.0	30.8	23.0	2.96	2.21	0.17	0.04	0.00	0.66	0.00	0.00	0.00003	0.00001	0.00002	1.73	2.60
Clay	50.5	8.2	46.4	1.46	3.8	35.2	33.4	26.2	33.4	26.2	2.28	1.16	0.37	0.05	0.00	2.50	0.00	0.00	0.00003	0.00001	0.00002	1.73	8.20
Clay	62.3	11.8	56.4	1.5	5.9	41.1	38.2	32.2	38.3	32.2	2.02	0.95	0.21	0.07	0.00	3.91	0.00	0.00	0.00054	0.00002	0.00028	24.19	3.16
Tuff	66.5	4.2	64.4	1.07	0.3	41.4	41.3	37.0	41.4	37.0	4.07	2.26	0.16	0.08	0.00	0.83	0.00	0.00	0.00010	0.00001	0.00006	4.75	2.53
Clay+sand	71	4.5	68.8	1.67	3.0	44.5	42.9	39.5	43.0	39.5	1.52	0.77	0.04	0.09	0.00	1.79	0.00	0.00	0.00097	0.00001	0.00049	42.34	0.91
Clay+sand	85	14.0	78.0	1.73	10.2	54.7	49.6	45.0	49.7	45.0	1.18	0.7	0.15	0.10	0.00	6.42	0.00	0.00	0.00002	0.00001	0.00002	1.30	16.18
Clay+sand	89.8	4.8	87.4	1.84	4.0	58.7	56.7	50.6	56.8	50.6	1.32	0.62	0.11	0.12	0.00	2.07	0.00	0.00	0.00002	0.00001	0.00002	1.30	5.55
Sandy clay	105	15.2	97.4	1.7	10.6	69.3	64.0	56.6	64.2	56.6	1.33	0.97	0.03	0.14	0.00	6.52	0.00	0.01	0.00014	0.00008	0.00011	9.50	6.49
Total	-	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	83

(2) Degree of consolidation

Emergency wells will be operated only for 9 month. Therefore, decrease of pore pressure (u) will finish after 9 month of pumping. Behavior of pore pressure (u) with time can be analyzed by formula below:

$$\frac{\delta u}{\delta t} = \frac{k}{m_v \gamma_w} \times \frac{\delta^2 u}{\delta^2 z}$$

Above equation can be approximated by finite difference equation below:.

cv(u1-2u0+u2)/(ΔZH)2=(ut-u0)/ Δt

cv(u1-2u0+u2)/(ΔZ)2=(ut-u0)/ (cv/H2t)= (ut-u0)/ ΔTv

（ΔZ=Δz/H）

Tv=cv/H2t

Degree of consolidation (Uz) is function of time factor (Tv). Tv is defined as shown below.

Time factor Tv = Cv/H2×t

Cv: Coefficient of Consolidation (cm^2/day)

H: Thickness of layer (cm)

t: Time after consolidation begins (day)

Calculation result by finite difference methods is shown in Figure-*

Decrease of pre pressure (u) will finish after 9 month (270days) of pumping. Therefore, Tv of that case is calculated for the model shown in Figure-7.27,

Tv =1.733/(8300)2×270=6.79×10-6

If pumping continues for 11 years, Tv=.0001 and Uz=5%. But emergency well will be pumped for 9 month only, and Tv=6.79×10-6 and Uz= must be much smaller than 5%. It means that it must be less than 5% when Tv=6.79×10-6. Therefore, applying Uz=5% for final land subsidence for Quaternary will give higher estimate of land subsidence for Quaternary.

Time constant (Tv)		0	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006
Degree of Consolidation (Uz)		0	5	5.09	5.19	5.29	5.38	5.47
Year after pumping		0	11	22	33	44	55	65
Soil Model	Calculation point	Initial u	0	0	0	0	0	0
1 Fill	0	1	1	1	1	1	1	1
2 Silt	1	1	1	1	1	1	1	1
3 Clay	2	1	1	1	1	1	1	1
4 Clay	3	1	1	1	1	1	1	1
5 Clay	4	1	1	1	1	1	1	1
6 Clay	5	1	1	1	1	1	1	1
7 Clay	6	1	1	1	1	1	1	1
8 Clay	7	1	1	1	1	1	1	1
9 Clay	8	1	1	1	1	1	1	1
10 Clay	9	1	1	1	1	1	1	1
11 Clay	10	1	1	1	1	1	1	1
12 Tuff	11	1	1	1	1	1	1	1
13 Clay+sand	12	1	1	1	1	1	1	1
14 Clay+sand	13	1	1	1	1	1	1	1
15 Clay+sand	14	1	1	1	1	1	1	1
16 Sandy clay	15	1	1	1	1	1	1	1
	16	1	0.99	0.98	0.97	0.961	0.952	0.943

Figure-8. 3 Land Subsidence

(3) Amount of land subsidence

Amount of land subsidence of the model layer in Figure-1 was finally calculated as shown in Table-8.2.

Table-8. 2 Amount of Land Subsidence

Geology	Darin condition for consolidation	Time factor (Tv)	Amount of land subsidence after 9 month pumping		
			Final land subsidence (m)	Degree of consolidation (%)	Land subsidence after 9 month pumping (m)
			(a)	(b)	(a)×(b)
Quaternary	One side	9.6×10^{-5}	0.02	5	0.001
Tertiary	-	-	0.003325	100	0.003325
Cretaceous	-	-	0.00105	100	0.00105
Total					0.0091

As shown in Table-8.2, amount of land subsidence after 9 month pumping is small and negligible. This is because intermediate Tertiary layers between Quaternary and Cretaceous layers prevent land subsidence of soft Quaternary layers.

PART 9

WELL PRODUCTION MANAGEMENT

Final Report

(Supporting Report)

PART 9 WELL PRODUCTION MANAGEMENT

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PART 9 WELL PRODUCTION MANAGEMENT

CHAPTER 1. WELL INTERFERENCE

1. Well Interference

Pumping from one well will cause lowering of the groundwater level of neighboring wells, as shown in Figure-9.1.

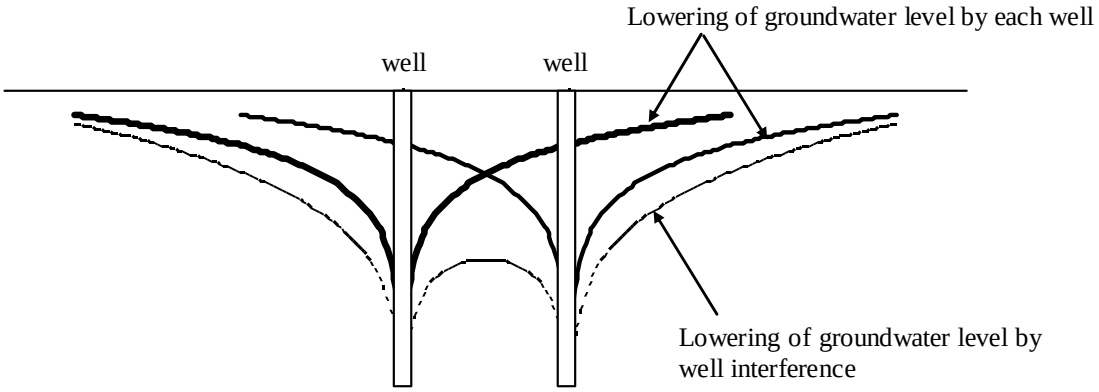

Figure-9. 1 Well Interference

2. Calculation of well interference

Drawdown of groundwater level by pumping with well interference was calculated by well formula below:

$$s_i=\sum Q_i/(2\pi T)\times Ln(R_i/r_{ij}) \quad (1)$$

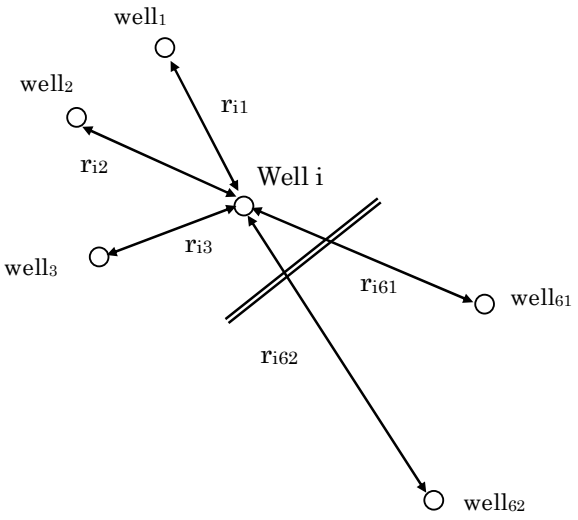

Figure-9. 2 Calculation Method of Draw-down of Well Interference

Where,

s_i: lowering of groundwater level of well No. i

R_i: Radius of influence of well No. i

Q_i: Yield from well No. i

r_{ij}: Distance between well No. i and well No. j

T_i: Transmissivity of well No. i

As example, calculation of well interference is explained below in well filed with 5 wells. Max draw down will be at the center of well filed (= well-3 in Figure-9.3) and minimum drawdown will be well at the end of well field (= well-1 and well-5 in Figuer-9.3).

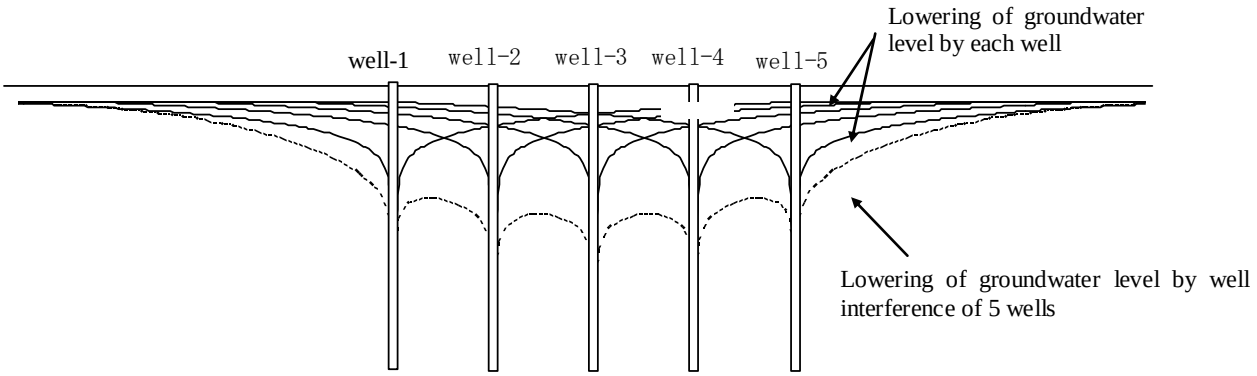

Figure-9. 3 Example of Well interference of Well field with 5 wells

If radius of influence (=R), yield (=Q) and transmissivity (=T) is the same among 5 wells, ratio of Maximum draw down/Minimum draw down of well filed is only function of well distance as shown in the next table.

Distance of well	Max/Min
50	2.35
100	2.07
150	1.91
200	1.79
250	1.70
300	1.63
350	1.56
400	1.51
450	1.46
500	1.43

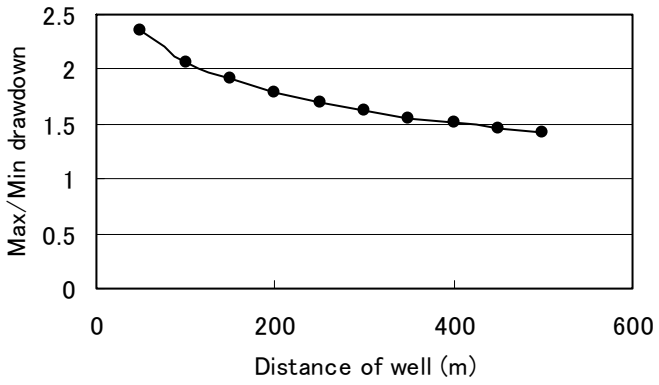

Figure-9. 4 Well Distance

CHAPTER 2. OPTIMUM YIELD FROM WELLS

1. Theory

Considering well interference of well filed comprising 5 wells, optimum yield from each well should satisfy condition below:

a) Total yield = $Q_1 + Q_2 + Q_3 + Q_4 + Q_5 \rightarrow$ Maximum

b) Lowering of groundwater level is same at every well

$$s_1 = s_2 = s_3 = s_4 = s_5$$

In M/P Study, total number of 62 wells was proposed. If well interference by 62 wells is taken into account, optimum yield of each 62 wells should satisfy condition below:

a) Total yield = $Q_1 + Q_2 + Q_3 + \cdots + Q_{60} + Q_{61} + Q_{62} \rightarrow$ Maximum

b) Lowering of groundwater level is same at every well

$$s_1 = s_2 = s_3 = \cdots = s_{60} = s_{61} = s_{62}$$

Above problem can be resoled by Simplex method. In general, Simplex method is expressed as below:

a) Objective function: $Z = \sum p_i x_i \quad (i=1,...n)$

b) Constraint: $\sum a_{ij} x_j \leqq b_i \quad (j=1,...,n \; i=1,....,m)$

$b_i \geqq 0$

$x_j \geqq 0 \qquad (j=1,\ldots,n)$

Solution of a) and b) can be solved by Simplex method by conversion of variables as below:

$p_i \rightarrow 1$

$x_i = \rightarrow Qi$

$a_{ij} \rightarrow 1/(2\pi T) \times Ln(R_i/r_{ij})$

2. Result of calculation

Parameter given is as follow:

- Transmissivity of well $T_i = 400m^2/day$
- Radius of influence of well $R_i = 10{,}000m$
- Draw-down si=20m, 30m, 40m, 50m, 60m, 70m

By Simplex method, optimum yield from each well for given draw-down was calculated. Result is shown in Table-9.1

Table-9. 1 Yield by Draw-down

No.	Well No.	Coordinate		Yield by Draw down (m^3/day)					
		x	**y**	20m	30m	40m	50m	60m	70m
1	S-1	987,615	996,222	853	1,279	1,705	2,131	2,558	2,984
2	S-2	988,003	996,189	686	1,029	1,372	1,715	2,058	2,401
3	S-3	988,367	996,222	669	1,004	1,338	1,673	2,007	2,342
4	S-4	988,638	995,924	618	928	1,237	1,546	1,855	2,164
5	S-5	988,567	995,165	607	911	1,215	1,518	1,822	2,125
6	S-6	988,370	994,904	705	1,057	1,409	1,762	2,114	2,466
7	EX-1	988,675	995,558	588	882	1,176	1,470	1,764	2,058
8	B-1	990,793	993,721	891	1,337	1,783	2,229	2,674	3,120
9	B-2	990,226	993,132	742	1,113	1,484	1,855	2,226	2,597
10	B-3	990,062	992,993	817	1,225	1,633	2,041	2,450	2,858
11	EX-2	990,361	993,491	750	1,125	1,500	1,875	2,249	2,624
12	EX-3	999,615	988,689	1,060	1,590	2,119	2,649	3,179	3,709
13	U-1	999,720	988,954	937	1,405	1,873	2,341	2,810	3,278
14	U-2	999,788	989,227	986	1,479	1,972	2,465	2,958	3,451
15	U-4	999,298	990,978	1,038	1,557	2,075	2,594	3,113	3,632
16	E-2	1,001,713	1,000,691	1,514	2,271	3,028	3,785	4,542	5,300
17	E-3	1,002,476	1,003,412	1,341	2,011	2,682	3,352	4,023	4,693
18	E-4	1,002,414	1,004,241	1,370	2,054	2,739	3,424	4,109	4,793
19	E-5	1,005,868	1,010,407	1,109	1,664	2,218	2,773	3,328	3,882
20	E-6	1,005,745	1,010,683	1,057	1,585	2,113	2,642	3,170	3,698
21	E-7	1,005,384	1,012,806	952	1,428	1,903	2,379	2,855	3,331
22	E-8	1,005,736	1,014,019	733	1,099	1,466	1,832	2,199	2,565
23	E-9	1,006,056	1,014,501	660	991	1,321	1,651	1,981	2,312
24	E-10	1,005,998	1,015,214	535	803	1,070	1,338	1,605	1,873
25	E-11	1,005,936	1,015,460	508	763	1,017	1,271	1,525	1,780
26	E-12	1,006,105	1,015,920	546	819	1,092	1,365	1,638	1,911
27	E-13	1,006,158	1,016,479	591	886	1,182	1,477	1,773	2,068
28	E-15	1,005,615	1,018,405	572	858	1,144	1,431	1,717	2,003
29	Y-1	1,005,566	1,019,284	495	742	990	1,237	1,485	1,732
30	Y-2	1,005,612	1,019,720	431	646	862	1,077	1,292	1,508
31	Y-3	1,005,646	1,019,914	442	663	884	1,105	1,326	1,547
32	Y-4	1,005,445	1,020,829	417	625	834	1,042	1,251	1,459
33	Y-5	1,005,504	1,021,016	397	595	794	992	1,191	1,389
34	Y-6	1,005,427	1,021,348	409	614	819	1,023	1,228	1,433
35	Y-7	1,005,334	1,021,683	438	657	876	1,095	1,314	1,532
36	Y-8	1,005,091	1,022,073	504	756	1,008	1,259	1,511	1,763
37	Y-9	1,005,254	1,023,167	543	814	1,086	1,357	1,628	1,900
38	Y-10	1,005,199	1,023,593	543	814	1,085	1,357	1,628	1,899
39	Y-11	1,005,159	1,024,447	551	826	1,102	1,377	1,653	1,928
40	Y-12	1,005,103	1,024,924	554	830	1,107	1,384	1,661	1,938
41	Y-13	1,005,155	1,025,774	537	805	1,073	1,342	1,610	1,878
42	Y-14	1,005,257	1,026,143	501	751	1,001	1,252	1,502	1,752
43	Y-15	1,005,279	1,026,441	529	793	1,058	1,322	1,587	1,851
44	Y-16	1,005,633	1,027,058	577	865	1,154	1,442	1,731	2,019
45	Y-17	1,005,658	1,027,931	582	872	1,163	1,454	1,745	2,035
46	Y-18	1,005,959	1,028,530	528	793	1,057	1,321	1,585	1,849
47	Y-19	1,006,206	1,028,723	548	822	1,096	1,370	1,644	1,918
48	Y-20	1,005,861	1,029,258	645	967	1,289	1,612	1,934	2,256
49	Y-21	1,006,939	1,030,815	646	969	1,293	1,616	1,939	2,262
50	Y-22	1,007,105	1,031,245	580	869	1,159	1,449	1,739	2,029
51	Y-23	1,007,192	1,031,516	600	900	1,200	1,500	1,800	2,100
52	Y-24	1,007,524	1,032,407	666	999	1,332	1,665	1,998	2,332
53	Y-25	1,007,768	1,032,834	673	1,009	1,346	1,682	2,019	2,355
54	Y-26	1,007,900	1,033,190	758	1,136	1,515	1,894	2,273	2,652
55	Y-27	1,008,895	1,035,116	976	1,464	1,952	2,440	2,928	3,416
56	Y-28	1,008,870	1,035,700	963	1,444	1,925	2,407	2,888	3,370
57	Y-29	1,008,972	1,036,090	1,089	1,634	2,179	2,723	3,268	3,813
58	E-1	1,001,405	996,374	1,552	2,329	3,105	3,881	4,657	5,433
59	E-14	1,006,064	1,017,515	619	928	1,238	1,547	1,857	2,166
60	E-17	999,554	1,018,241	1,245	1,867	2,489	3,111	3,734	4,356

No.	Well No.	Coordinate		Yield by Draw down (m^3/day)					
		x	y	20m	30m	40m	50m	60m	70m
61	E-16	999,911	1,017,843	1,180	1,769	2,359	2,949	3,539	4,128
62	U-3	999,332	990,801	1,010	1,516	2,021	2,526	3,031	3,536
Total yield (m^3/s)				0.53	0.80	1.07	1.34	1.60	1.87

Calculated result is summarized as shown in Table-9.2

Table-9. 2 Summary of Calculation

Draw down (m)	Total yield from 62 wells (m^3/s)
20	0.53
30	0.80
40	1.07
50	1.34
60	1.60
70	1.87

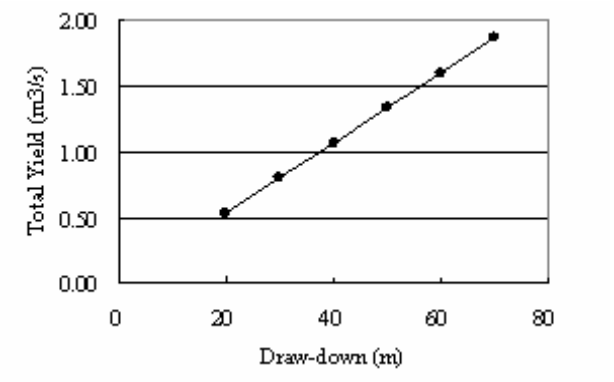

Figure-9. 5 Total Yield and Draw-down

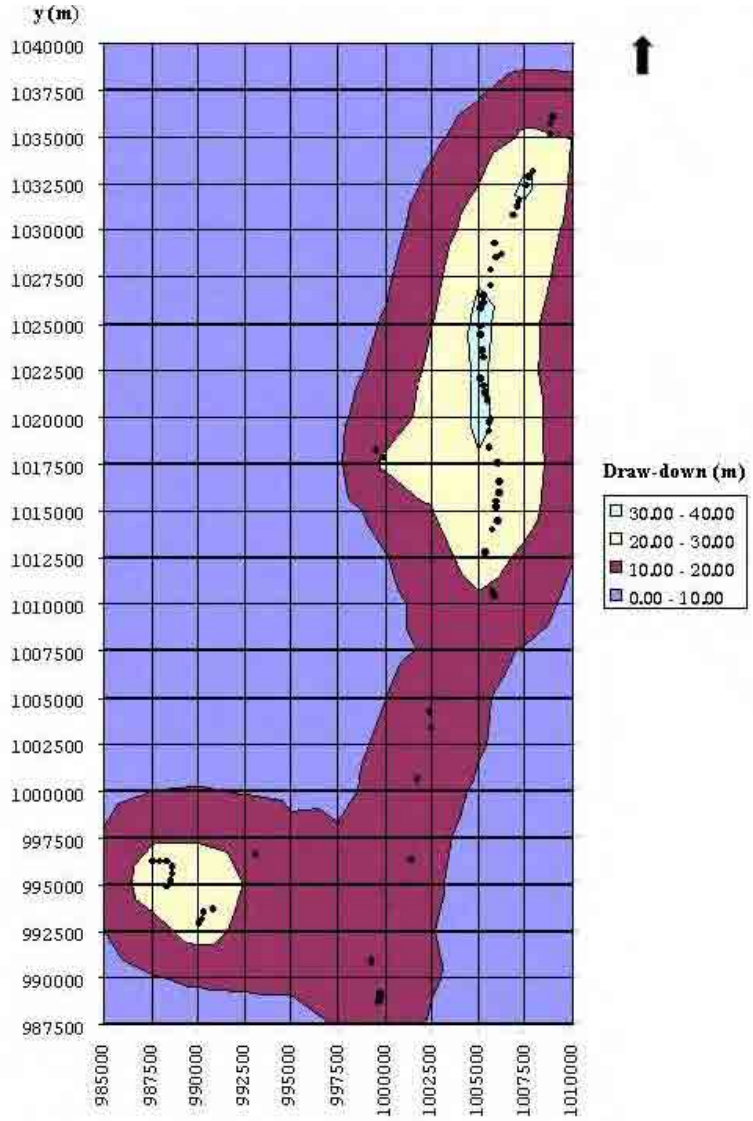

Figure-9. 6 Draw-down by Optimum Yield (Case: max draw-dawn=40m)

PART 10

WELLS IN FOREST PROTECTION AREA

Final Report

(Supporting Report)

PART 10 WELLS IN FOREST PROTECTION AREA

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PART 10 WELLS IN FOREST PROTECTION AREA

CHAPTER 1. EASTERN PROJECT WITH WELLS IN FOREST PROTECTION AREA

Any activity for economic development is prohibited within the forest protection area of the Eastern Hills. Therefore in M/P study, sites of emergency wells should be selected in the area out of the forest protection area. On the other hand, it is expected that drilling of emergency wells will be approved within the protection area in the near future, by reason below:

- Construction of emergency wells in the Eastern Hills is not economic activity but public activity to resolve water shortage and mountain fire.
- Impact to natural environment by construction and operation of emergency wells is negligible and easily recovered.
- Vegetation of the Eastern Hills is closely related to water/moisture in the soil. Pumping from emergency wells will be from deep aquifer, and has no effect to water/moisture of the soil. Therefore, pumping from emergency well will not affect vegetation in the Eastern Hills.

The Eastern Hills is located near the city center of Bogotá, to which it is easy to deliver water. Therefore, it is very effective to construct emergency wells in the Eastern Hills. However, number of wells proposed in the Eastern Project was limited, because wells sites were selected only from the area out of the forest protection area. Then, it was suggested from Colombia side that more wells are necessary in case of emergency. Following a change in institutional condition of the forest protection area, well sites were proposed even inside the forest protection area.

(1) Outline of Eastern Project with Wells inside Forest Protection Area

Outline of the Eastern Project with wells inside the forest protection area is shown in Table-10.1. Proposed wells inside the forest protection area are shown in Table-10.2 and Figure-10.1. Total amount of 52,000m^3/day of groundwater can be produced from 26 emergency wells inside the forest protection area.

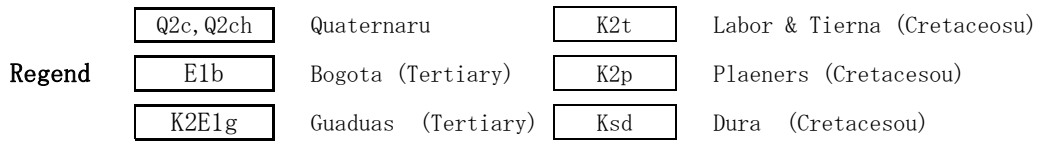
Table-10. 1 Outline of Eastern Project with Wells inside Forest Protection Area

Area	Number of wells	Water supplied (m^3/day)	Area for water supply	Population supplied
San Cristobal	4	8,000	Entire Bogotá	530,000
Santa Fe	8	16,000		1,066,000
Chapinero	11	22,000		1,466,000
Usaqunen	3	6,000		400,000
Total	26	52,000		3,462,000

Note-1)It is under condition of unit consumption rate of 15ℓ/person/day

Table-10. 2 Wells within Forest Protection Area

Site		No.	Coordinate		Elevation	Mark	Note
			Latitude	Longitude			
San Cristbal	Vitelma	VI-1	N 4°33' 33.5"	W 74°03' 48.0"	2,881	K2d	Acueducto site
		VI-2	N 4°33' 23.3"	W 74°03' 44.2"	2,911	K2d	Acueducto site
		VI-3	N 4°33' 19.1"	W 74°03' 37.3"	2,918	K2d	Acueducto site
		VI-4	N 4°33' 12.8"	W 74°03' 31.2"	2,921	K2d	Acueducto site
Santa Fe	Sant Isabel	SI-1	N 4°33' 08.1"	W 74°03' 26.0"	2,871	K2d	Acueducto site
	Casa Morino	CM-1	N 4°35' 07.1"	W 74°03' 44.3"	2,715	K2d	Acueducto site
		CM-2	N 4°36' 04.5"	W 74°03' 33.0"	2,728	K2d	Acueducto site
	Tank Silencio	TS-1	N 4°36' 01.6"	W 74°03' 31.5"	2,771	K2d	Acueducto site
		TS-2	N 4°36' 02.9"	W 74°03' 26.7"	2,774	K2d	Acueducto site
		TS-3	N 4°37' 06.2"	W 74°03' 28.4"		K2d	Acueducto site
	Olaya Herrera	OH	N 4°36' 42.168"	W 74°03' 31.645"		K2d	-
	Rio Arzobispo	RA-1	N 4°37' 10.8"	W 74°03' 25.8"	2,721	K2d	-
Chapinero	Unv. Poli-Technology	UP-1	N 4°37'37.4"	W 74°03'18.7"	2,725	K2d	-
	La Vieja Creek	VC-1	N 4°38'04.4"	W 74°03'20.7"	2,733	K2d	Acueducto site
		VC-2	N 4°38'16.0"	W 74°03'10.0"	2,757	K2d	Acueducto site
		VC-3	N 4°38' 57.6"	W 74°02' 48.9"	2,777	K2d	Acueducto site
	Rosales Creek	RC-1	N 4°38' 55.7"	W 74°02' 44.4"	2,722	K2d	-
		RC-2	N 4°38' 50.1"	W 74°02' 38.9"	2,774	K2d	-
		RC-3	N 4°39' 18.6"	W 74°02' 48.0"	2,827	K2d	-
		RC-4	N 4°39' 17.8"	W 74°02' 41.9"	2,857	K2d	-
	Chico	CH-1	N 4°39' 10.6"	W 74°02' 30.3"	2,709	K2t	Acueducto site
		CH-2	N 4°39' 05.2"	W 74°02' 22.8"	2,748	K2t	Acueducto site
		CH-3	N 4°40' 05.0"	W 74°02' 20.5"	2,757	K2t	-
Usaquen	Escuelade Caballeria(Military)	EC-1	N 4°39' 59.7"	W 74°02' 15.6"	2,600	K2t	Military site
		EC-2	N 4°39' 55.3"	W 74°02' 11.3"	2,613	K2t	Military site
		EC-3	N 4°40' 49.8"	W 74°02' 14.4"	2,618	K2t	Military site



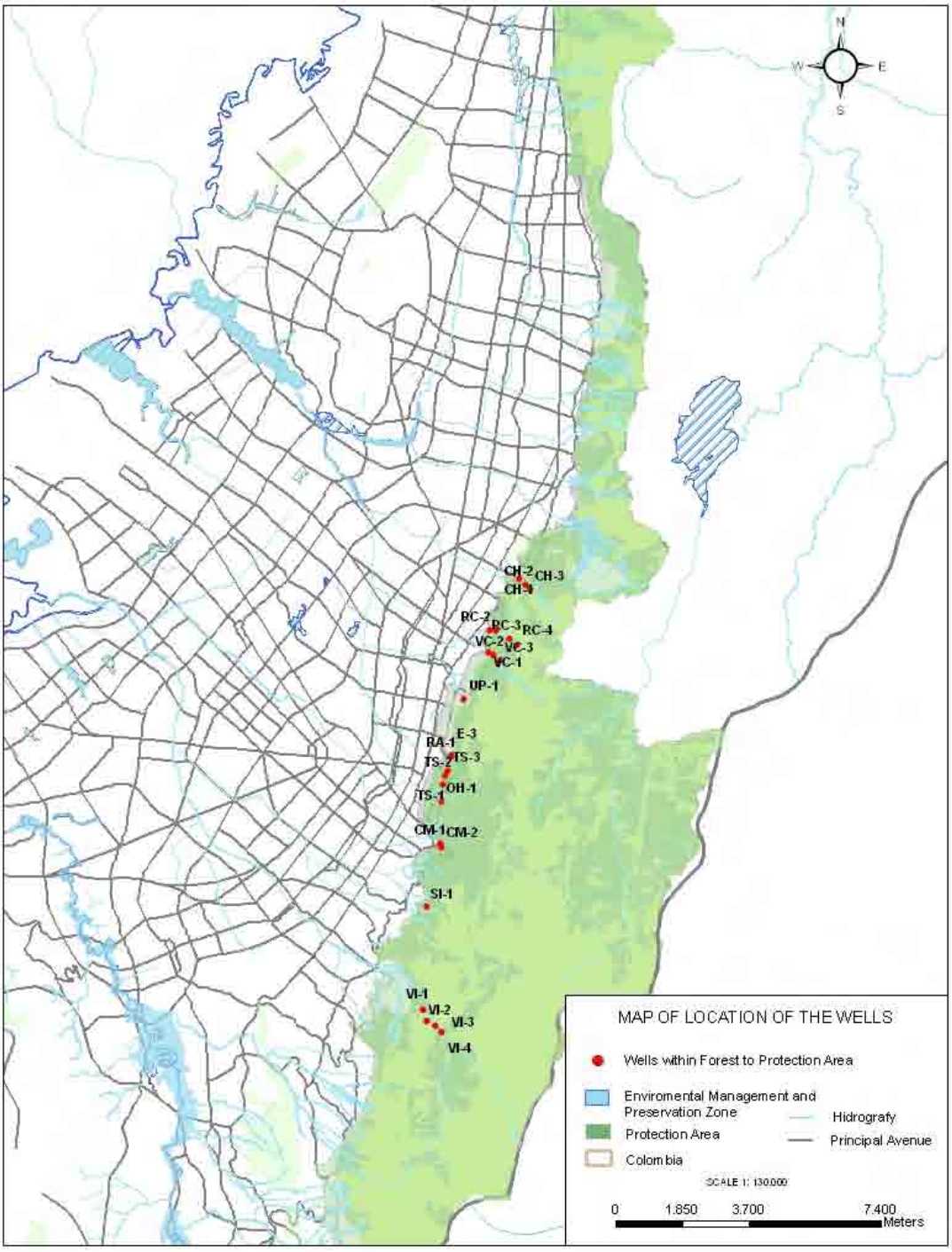


Figure-10. 1 Location of Wells

(2) Topographic Future of Forest Protection Area

Bogotá fault forms geological boundary between the Cretaceous and Tertiary. Moreover, it forms boundary of topographic future (see Figure-10.2). In the west of Bogotá fault, the Tertiary is distributed, of which slope is gentle, due to lower resistance of Tertiary rocks against erosion. On the other hand, in the east of Bogotá fault, the Cretaceous is distributed, of which slope is steep, due to higher resistance of Cretaceous rocks against erosion. As a result, area of the Tertiary is relatively flat, where residential area is developed. On the other hand, area of the Cretaceous is rugged, where only forest is spreading without development. So this area is regulated as the forest protection area.

Steep slopes with higher elevation are generally seen in the forest protection area. Consequently, it is not suitable for drilling wells in such area. However, there are some places where mountain streams cuts the wide and deep valley. Areas inside valleys are sometimes suitable for drilling. Drilling sites were selected from areas mentioned above.

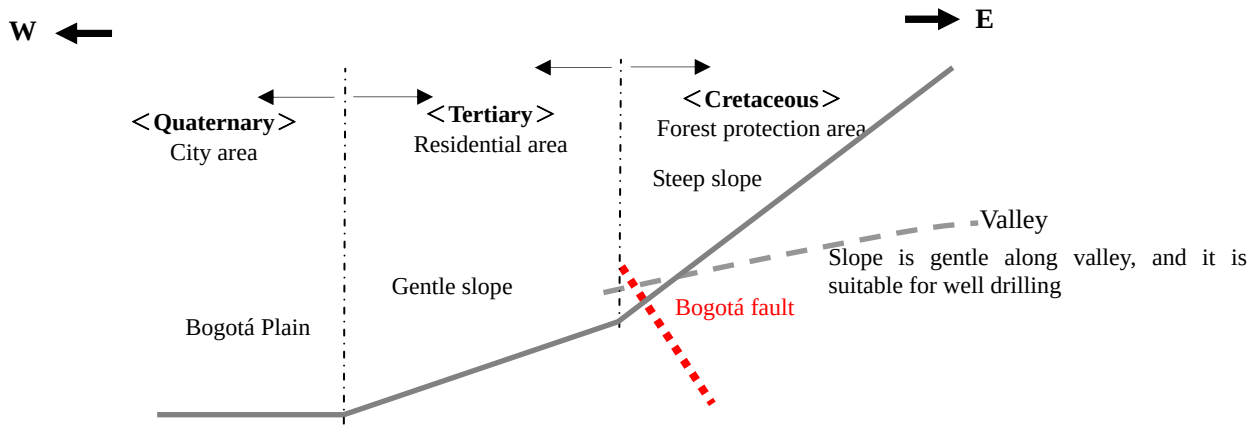


Figure-10. 2 Criteria of Drilling site in Eastern Hills

CHAPTER 2. FACILITY PLAN FOR PILOT PROJECT

(1) Facility Plan for Emergency Water Supply System

1) Composition and Connection Point for Emergency Water Supply Unit

The composition and the connection points for the emergency water supply unit on the pilot project are as shown in the following table.

Table-10. 3 Composition and Connection Point for Emergency Water Supply Unit (Pilot Project)

Project Name	Site		Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to (Exist Facility)	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)		
Pilot Project	Santa Fe	Casa Morino	PP-51	CM-1	New	8"+6"	300	4	190	75	6	45	2,000	Chlorine + Pressure Filtarlate	-	-	-	1

Note-1) Type of the supply is shown in the Figure-10.14.

2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the pilot project forms the unit which one (1) water treatment plant (WTP) consists on one (1) well. Therefore, the layout plan for each water supply unit is as shown in Figure-10.3.

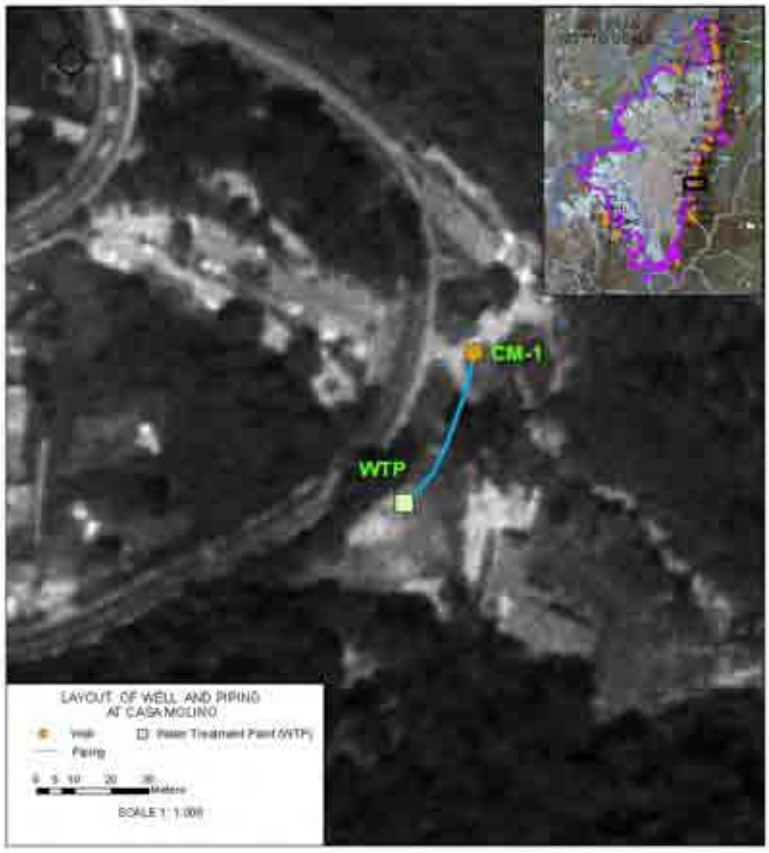


Figure-10. 3 Unit Lauout Plan for PP-51

CHAPTER 3. FACILITY PLAN FOR PROJECT OF WELLS INSIDE FOREST PROTECTION AREA

(1) Facility Plan for Emergency Water Supply System

The composition and the connection points for the emergency water supply unit on the 1st priority project are as shown in the following table.

Table-10. 4 Composition and Connection Point for Emergency Water Supply Unit (1st Priority Project)

Project Name	Site		Water Supply Unit No.	Well				Well Pump			Conveyance Line		Water Treatment Process		Transmission Line		Connection to	Type of Supply 1)
				No.	New/ Exist.	Dia (in.)	Depth (m)	Dia (in.)	Head (m)	PWR (kW)	Dia (in.)	Length (m)	Volume (m3/day)	Process	Dia (in.)	Length (m)	(Exist Facility)	
1st Priority Project	Vitelma	Vitelma	1-51	(E-1)	(Pilot)	–	–	–	–	–	–	–	8,000	(Exist. WTP)	–	–	Tank Vitelma	2
				VI-1	New	8"+6"	300	4	100	37	6	960						
				VI-2	New	8"+6"	300	4	100	37	6	1,370						
				VI-3	New	8"+6"	300	4	100	37	6	1,660						
				VI-4	New	8"+6"	300	4	100	37	6	1,970						
	Santa Fe	Sant Isabel	1-52	SI-1	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
		Casa Morino	1-53	(CM-1)	(Pilot)		–	–	–	–	–	–	(2,000)	(Chlorine + Pressure Filtarlate)	–	–	–	1
				CM-2	New	8"+6"	300	4	190	75	6	90	2,000	Chlorine + Pressure Filtarlate				
		Olaya Herrera	1-54	OH-1	New	8"+6"	300	4	190	75	6	955	8,000	Chlorine + Pressure Filtarlate	12	83	Tank Silencio	2
		Tank Silencio		TS-1	New	8"+6"	300	4	190	75	6	555						
				TS-2	New	8"+6"	300	4	190	75	6	25						
				TS-3	New	8"+6"	300	4	190	75	6	205						
		Rio Arzobispo	1-55	RA-1	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
	Chapinero	Unv. Poli-Technology	1-56	UP-1	New	8"+6"	300	4	190	75	6	25	2,000	Chlorine + Pressure Filtarlate	–	–	–	1
		La Vieja Creek	1-57	VC-1	New	8"+6"	300	4	190	75	6	25	6,000	Chlorine + Pressure Filtarlate	–	–	–	1
				VC-2	New	8"+6"	300	4	190	75	6	251						
				VC-3	New	8"+6"	300	4	190	75	6	711						
		Rosales Creek	1-58	RC-1	New	8"+6"	300	4	190	75	6	255	8,000	Chlorine + Pressure Filtarlate	–	–	–	1
				RC-2	New	8"+6"	300	4	190	75	6	25						
				RC-3	New	8"+6"	300	4	190	75	6	453						
				RC-4	New	8"+6"	300	4	190	75	6	760						
		Chico	1-59	CH-1	New	8"+6"	300	4	190	75	6	457	6,000	Chlorine + Pressure Filtarlate	12	25	Tank Chico	2
				CH-2	New	8"+6"	300	4	190	75	6	185						
				CH-3	New	8"+6"	300	4	190	75	6	65						
	Usaquen	Escuela de Caballeria (Military)	1-60	EC-1	New	8"+6"	300	4	190	75	6	25	6,000	Chlorine + Pressure Filtarlate	–	–	–	1
				EC-2	New	8"+6"	300	4	190	75	6	295						
				EC-3	New	8"+6"	300	4	190	75	6	475						

Note-1) Type of the supply is shown in the figure-10.14.

2) Layout Plan for Emergency Water Supply Unit

The emergency water supply unit for the 1st priority project forms the unit which one (1) water treatment plant (WTP) consists on one (1) to four (4) wells. Therefore, the layout plan for each water supply unit is as shown in Figure-10.4 to 10.13.

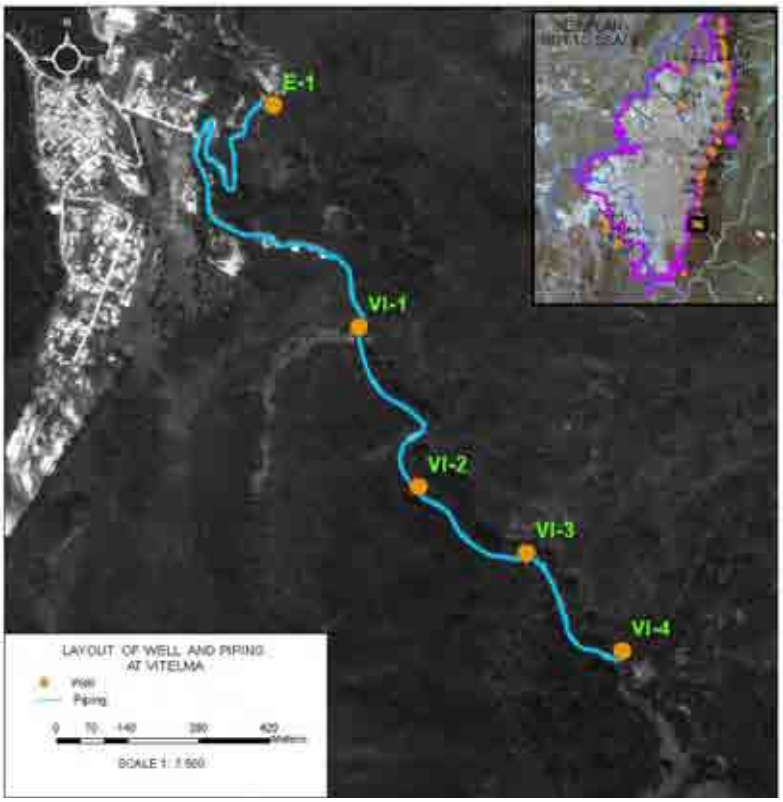


Figure-10. 4 Unit Layout Plan for 1-51

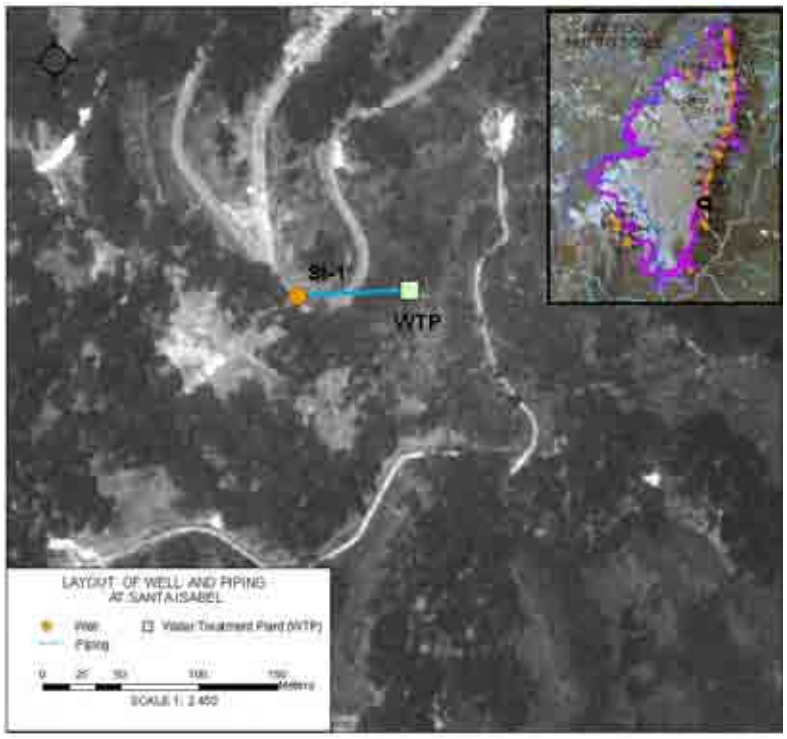


Figure-10. 5 Unit Layout Plan for 1-52

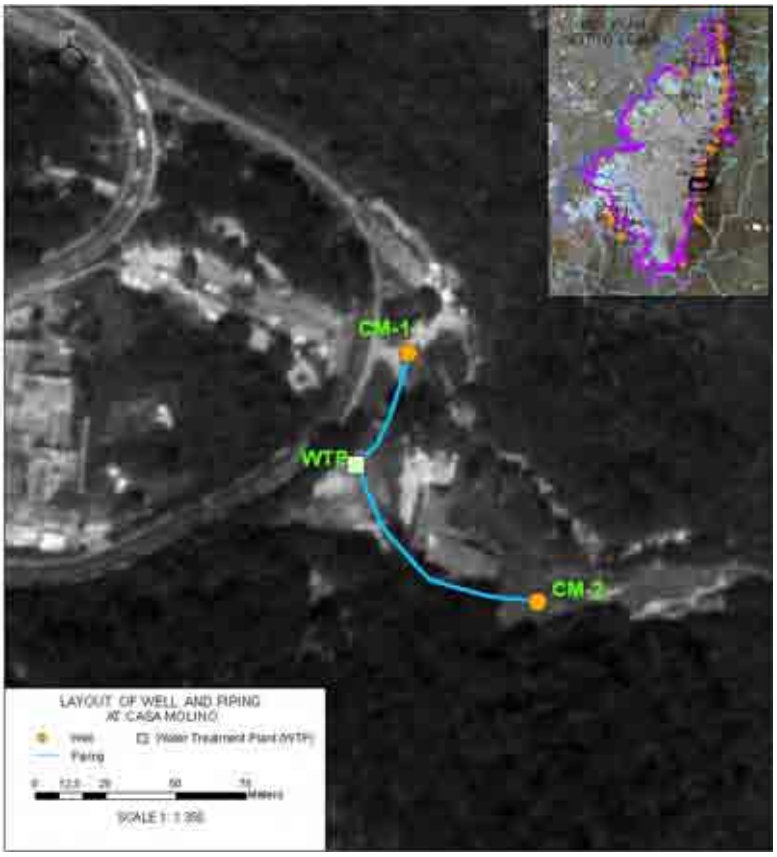


Figure-10. 6 Unit Layout Plan for 1-53

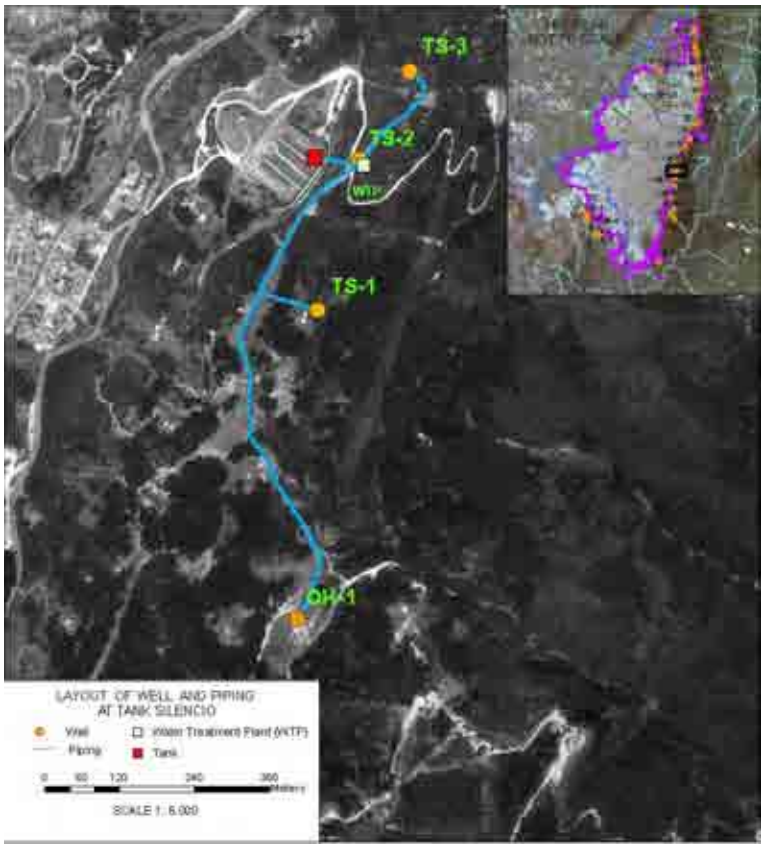


Figure-10. 7 Unit Layout Plan for 1-54

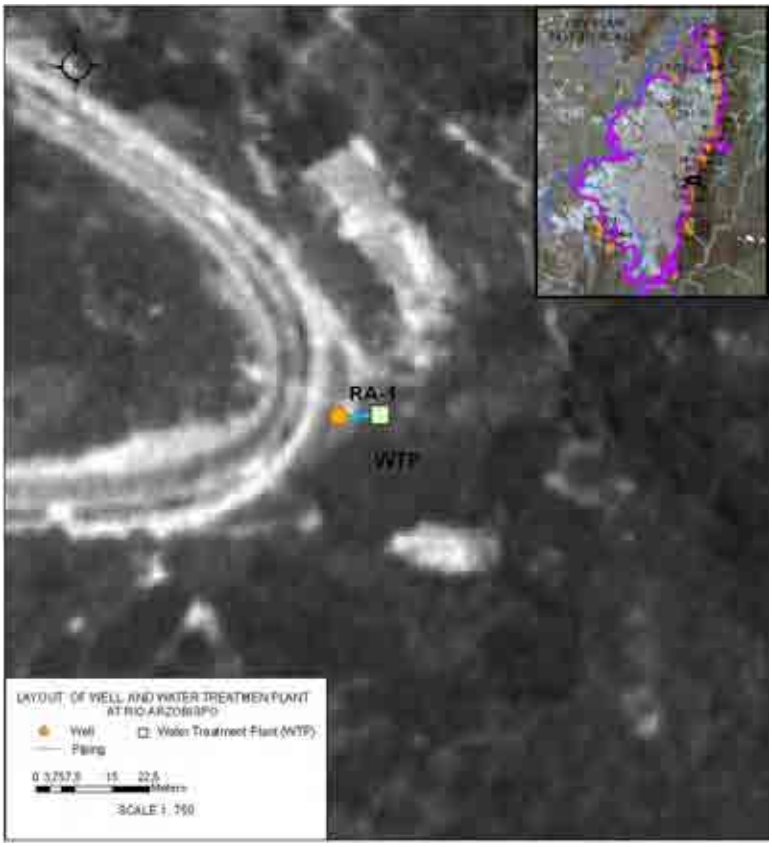


Figure-10. 8 Unit Layout Plan for 1-55

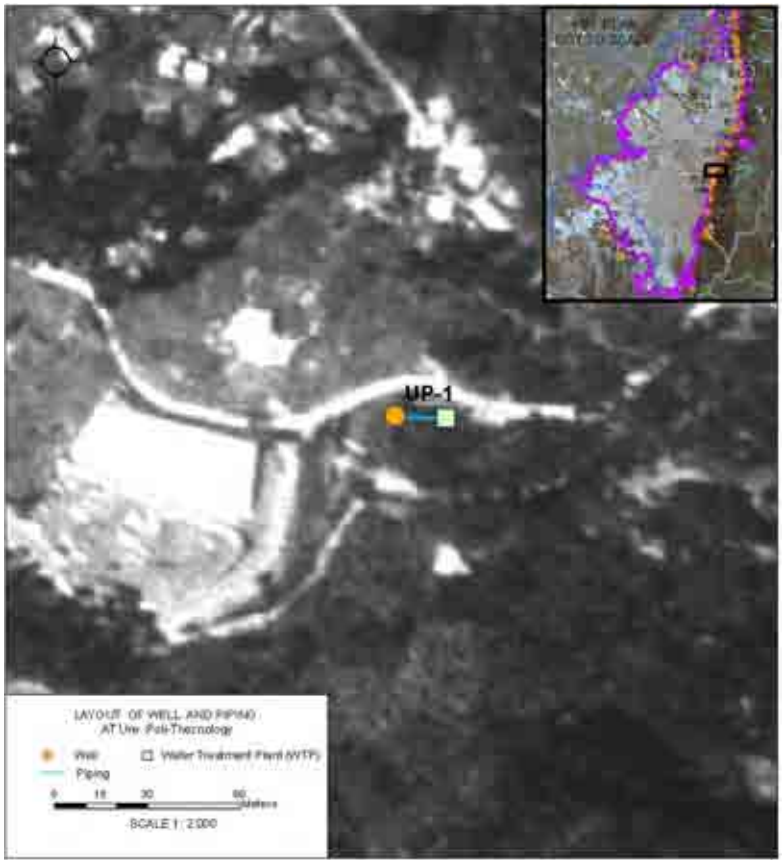


Figure-10. 9 Unit Layout Plan for 1-56

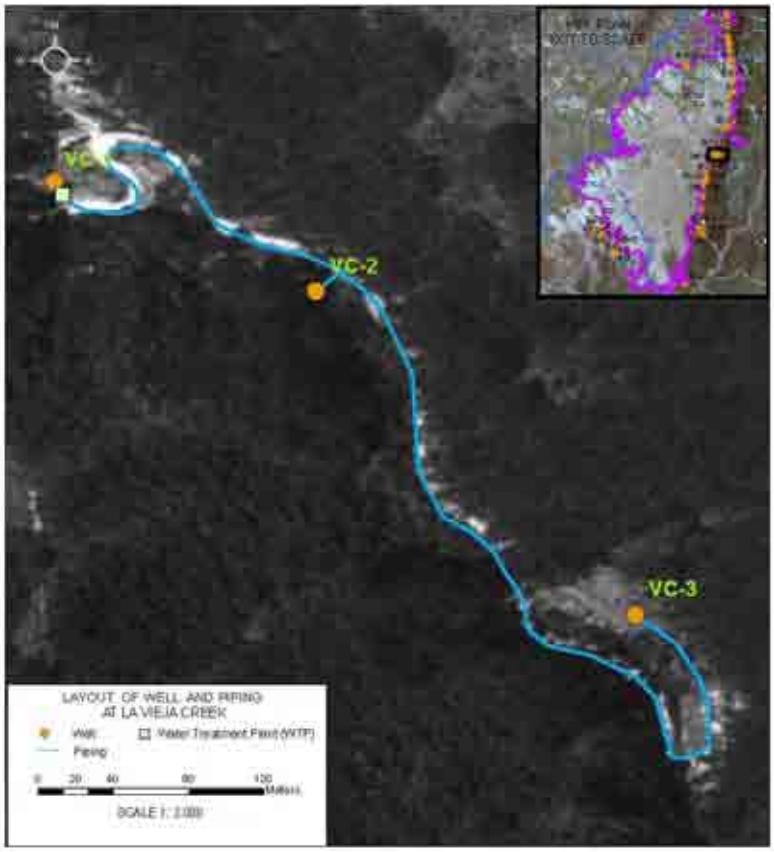


Figure-10. 10 Unit Layout Plan for 1-57

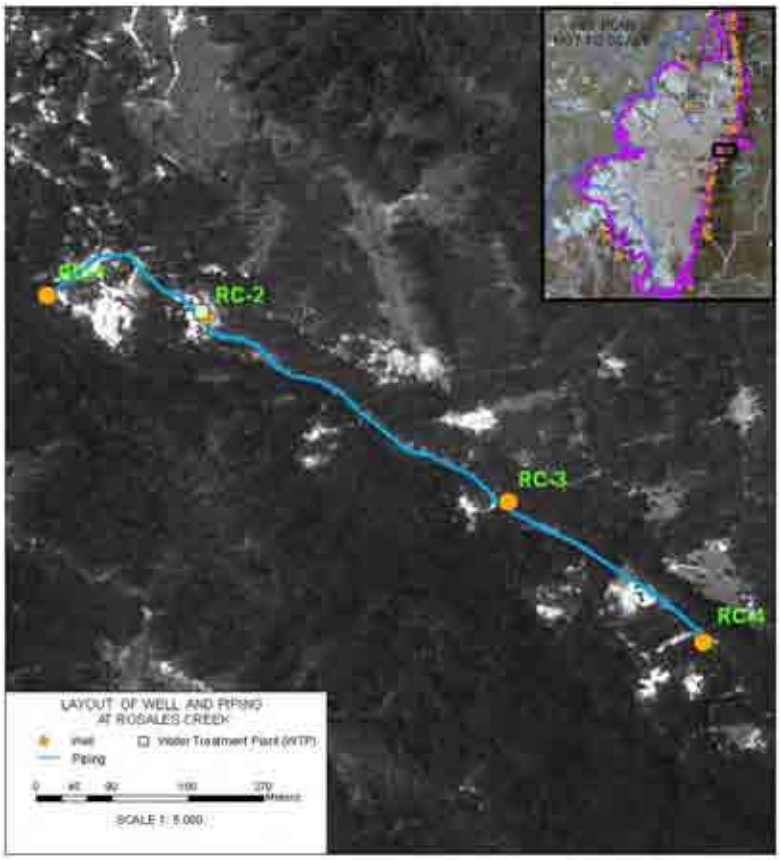


Figure-10. 11 Unit Layout Plan for 1-58

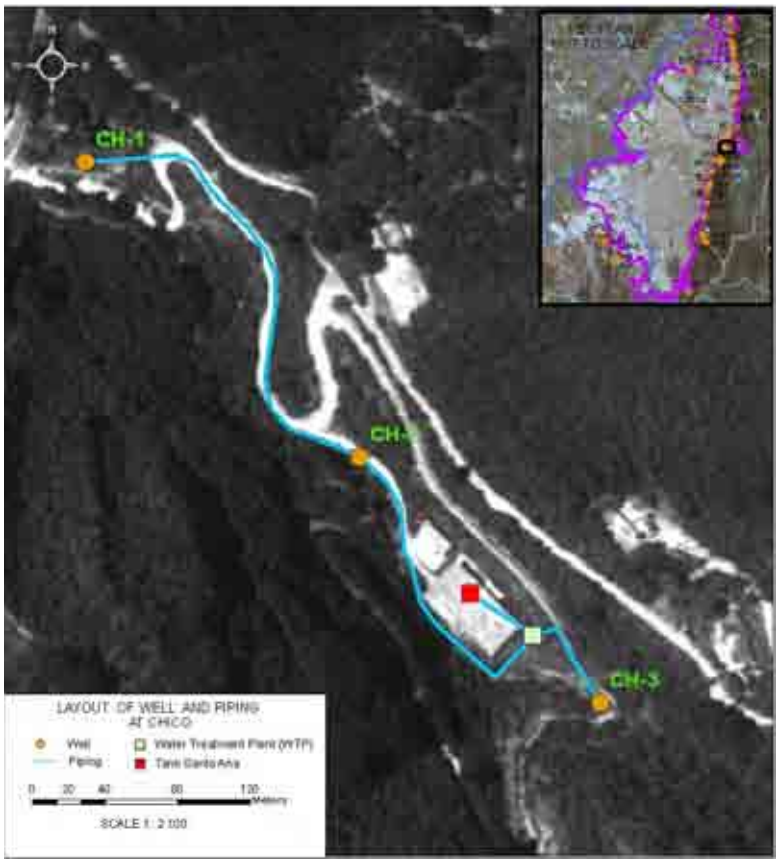


Figure-10. 12 Unit Layout Plan for 1-59

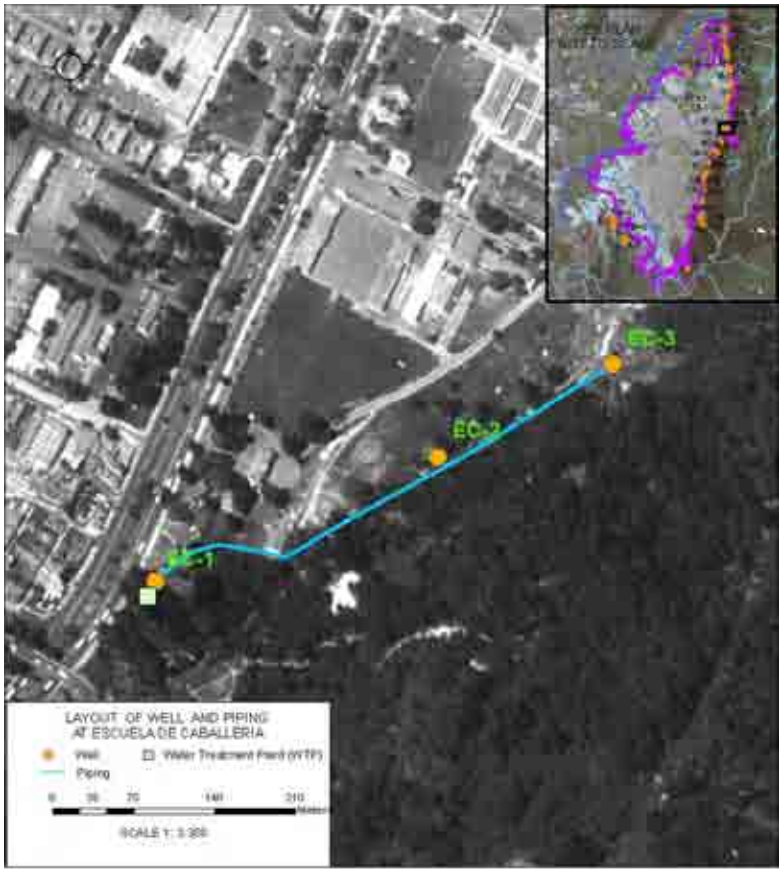
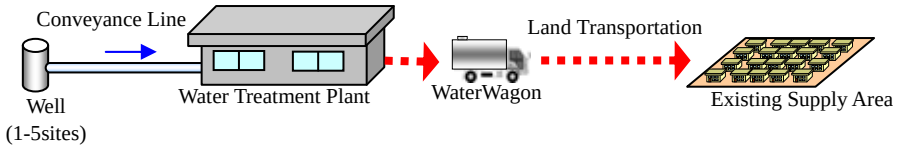
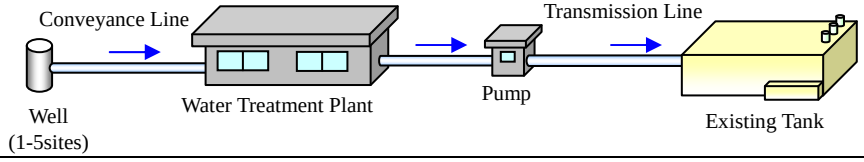
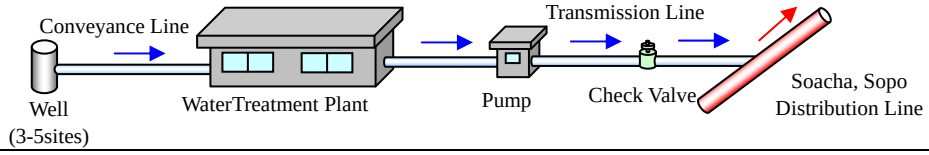


Figure-10. 13 Unit Layout Plan for 1-60

2) Plan for Water Supply Facility

As the composition of facilities for water supply, three (3) types of facilities are planned as shown in Figure-10.14. These facilities should be able to supply by the water wagon for the primary emergency in case of not only type-1 but also type-2 and type-3.

Type	Facilities composition for water supply for use of groundwater
Type-1	
Type-2	
Type-3	

(Source: JICA Study Team)

Figure-10. 14 Facilities Composition for Water Supply for Use of Groundwater

CHAPTER 4. COST ESTIMATE

Cost of Project inside the protection area was estimated as shown in Tabel 10.5.

Table 10.5 Cost of Project inside Forest Protection Area

Forest Protection Area Breakdown

No.	Description		Unit	San Cristbal (Vitelma)					Sant Isabel		Casa Morino			Tank Silencio				Olaya Herrera		Rio Arzobispo		Univ. Prli Tech		La Vieja Creek				Rosales Creek				Chico				Escuela Caballeria (Military)				Total	Installation Cost		Material & Equipment Cost		Amount
				VI-1	VI-2	VI-3	VI-4	WTP	SI-1	WTP	CM-1	CM-2	WTP	TS-1	TS-2	TS-3	WTP	OH-1	WTP	RA-1	WTP	UP-1	WTP	VC-1	VC-2	VC-3	WTP	RC-1	RC-2	RC-3	RC-4	WTP	CH-1	CH-2	CH-3	WTP	EC-1	EC-2	EC-3	WTP		Unit Price (Col$1,000)	Amount (Col$1,000)	Unit Price (Col$1,000)	Amount (Col$1,000)	
						E				E		E				E				E		E			E				E														
1	**Deep Well Pump**																																												
	(1) Well Construction	8in 150m + 6in 150m	well																																					0	427,600	0	0	0	
	(2) Well Construction	10in 150m + 8in 150m	well	1	1	1	1		1		1	1		1	1	1		1		1		1		1	1	1		1	1	1	1		1	1	1		1	1	1		24	525,120	12,602,880	0	0	
	(3) Well Construction	10in 200m + 8in 200m	well																																					0	652,000	0	0	0	
	(4) Pumping Test and Repot		lot																																					0	0	0	0	0	
	(5) Deep Well Submersible Pump	0.7m^3/min, 120m, 440V, 60Hz, 26KW	set																																					0	10,000	0	64,400	0	
	(6) Deep Well Submersible Pump	0.7m^3/min, 170m, 440V, 60Hz, 37KW	set																																					0	10,400	0	69,000	0	
	(7) Deep Well Submersible Pump	1.4m^3/min, 120m, 440V, 60Hz, 37KW	set																																					0	10,400	0	69,000	0	
	(8) Deep Well Submersible Pump	1.4m^3/min, 140m, 440V, 60Hz, 45KW	set	1	1	1	1		1		1	1		1	1	1		1		1		1		1	1	1			1	1	1				1		1	1	1		21	12,200	256,200	73,600	1,545,600	
	(9) Deep Well Submersible Pump	1.4m^3/min, 170m, 440V, 60Hz, 55KW	set																									1						1						2	13,400	26,800	81,000	162,000	
	(10) Deep Well Submersible Pump	1.4m^3/min, 190m, 440V, 60Hz, 75KW	set																													1								1	13,800	13,800	92,025	92,025	
																																										12,899,680		**1,799,625**	**14,899,305**
2	**Aqueduct**																																											
	(1) Piping, Above Ground	6in carbon steel	m					20	20	50	20	20		20		20					50		50		20	20		20	20	20	20		20	20	20		20	20	20		510	206	105,060	229	116,790	
		8in carbon steel	m					100					100		100		100									100					100				100				100	800	315	252,000	350	280,000	
	(2) Piping, Under Ground	6in PVC 1.38Mpa	m	10	10	10	400	50			80	120		25		25		25		25		25		50			100	300	50		300	100	420	220	100		50		200		2,475	150	371,250	46	113,850	
		8in PVC 1.38Mpa	m			350																																		350	162	56,700	78	27,300	
		10in PVC 1.38Mpa	m		450																				220	550				400							350		20	1,540	175	269,500	120	184,800	
		12in PVC 1.38Mpa	m	850																																				0	187	0	169	0	
		14in PVC 1.38Mpa	m																																					0	200	0	206	0	
		16in PVC 1.38Mpa	m																																					0	212	0	247	0	
		18in PVC 1.38Mpa	m																																					0	224	0	288	0	
		20in PVC 1.38Mpa	m																																					0	234	0	329	0	
		24in PVC 1.38Mpa	m																																					0	267	0	412	0	
	(2) Gate Valves	6in with flange, gasket etc.	sets	1	1	1	1	1	1	1	1	1		1	1	1		1		1	1	1	1	1	1	1		1	1	1	1		1	1	1		1	1	1		28	290	8,120	965	27,020	
		8in with flange, gasket etc.	sets																																					0	438	0	1,461	0	
		10in with flange, gasket etc.	sets										1																										1	2	676	1,352	2,254	4,508	
		12in with flange, gasket etc.	sets					1									1										1					1				1				5	1,551	7,755	5,170	25,850	
	(3) Check Valves	6in with flange, gasket etc.	sets	1	1	1	1		1		1	1		1	1	1		1		1		1		1	1	1		1	1	1	1		1	1	1		1	1	1		24	445	10,680	1,484	35,616	
		8in with flange, gasket etc.	sets																																					0	594	0	1,979	0	
		10in with flange, gasket etc.	sets																																					0	1,157	0	3,856	0	
		12in with flange, gasket etc.	sets																																					0	1,618	0	5,392	0	
																																										1,082,417		**815,734**	**1,898,151**
3	**Civil Works**																																											
	(1) Site Survey	10m x 20m	m^2	50	50	50	50	240	50	240	50	200	240	50	50	50	240	50		50	240	50	240	50	50	50	240	50	50	50	50	240	50	50	50	240	50	50	50	240	3,850	3	11,550	0	0	
	(2) Cutting Trees and bush	10m x 20m	m^2	50	50	50	50		50	240	50	200	240			50	240	50		50	240	50	240	50	50	50	240	50	50	50	50	240	50	50	50	240					3,120	8	24,960	0	0	
	(3) Development of Land	Excavation of Land (5m x 10m x 3mH)	m^3	50	50	50	50		50	240	50	200	240							50	240	50	240	50	50	50	240	50	50	50	50	240	50	50	50	240					3,020	25	75,500	0	0	
	(4) Site Grading	10m x 20m	m^3	50	50	50	50	240	50	240	50	200	240	50	50	50	240			50	240	50	240	50	50	50	240	50	50	50	50	240	50	50	50	240	50	50	50	240	3,800	40	152,000	0	0	
	(5) Road Construction, 5m wide	Gravel Road	m									100	20																												120	0	0	0	0	
	(6) Bridge Construction	Concrete Pipe 1m Dia., 6m	sets																																						800	0	0	0	
	(7) Concrete Pavement	H 100, base H 100	m^2							50			50		50		50																							50	250	80	20,000	0	0	
	(8) Security fence	Galvanized Fabric H=3.0m	m	25	25	25	25		25	100	25	25	120	25	25	25	120	25		25	80	25	80	25	25	25	120	25	25	25	25	120	25	25	25	120	25	25	25	120	1,630	150	244,500	150	244,500	
	(9) Gate for Fence	W= 5m, H=2.5m, Double Swing	sets	1	1	1	1		1	1	1	1	1		1		1																						1	12	3,500	42,000	0	0	
	(10) Out-Door Lighting	200V-200W, with concrete pole 11m	sets	2	2	2	2	8	2	4	2	2	8	2	2	2	8	2		2	4	2	4	2	2	2	8	2	2	2	2	10	2	2	2	8	2	2	2	4	118	300	35,400	500	59,000	
																																										605,910		**303,500**	**909,410**
4	**Architect Works**																																											
	(1) Pump Station: 96 m^2 for each site	L=12m, W=8m, H=4.0m, RC, block	m^2		96		96		96		96		96		96		96				96		96				192					192				192				192	1,536	850	1,305,600	750	1,152,000	
																																									1,305,600		**1,152,000**	**2,457,600**
5	**Diesel Engine Generator**																																											
	(1) Diesel Engine Generator-1	125kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets							(1)											(1)		(1)																	1	800	800	77,900	77,900	
	(2) Diesel Engine Generator-2	220kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets									(1)				(1)											(1)													1	800	800	106,780	106,780	
	(3) Diesel Engine Generator-3	400kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets					(1)																								(1)				(1)				1	900	900	159,000	159,000	
	(4) Diesel Engine Generator-4	500kVA, 440V 60Hz 3ph 4W, 1800 rpm	sets																																					0	1,000	0	326,000	0	
																																									2,500		**343,680**	**346,180**
6	**Power Receiving**																																											
	(1) Concrete Pole and Accessory	13m height, with arms and insulators	sets					1		1		1				1					1		1				1					1				1				10	1,000	10,000	1,000	10,000	
	(2) Step-Down Transformer-1	125kVA, 11.4kV-440V,	sets							1											1		1																	3	3,900	11,700	20,300	60,900	
	(3) Step-Down Transformer-2	200kVA, 11.4kV-440V,	sets									1															1									1				4	5,700	22,800	30,400	121,600	
	(4) Step-Down Transformer-3	300kVA, 11.4kV-440V,	sets					1								1																1								3	7,500	22,500	42,300	126,900	
	(5) Step-Down Transformer-4	400kVA, 11.4kV-440V,	sets																																					0	9,100	0	53,800	0	
	(6) Step-Down Transformer-5	500kVA, 11.4kV-440V,	sets																																					0	10,500	0	59,300	0	
	(7) Lightning Arrestor	11.4kV, 1 set = 3 units	sets					1		1		1				1					1		1				1					1				1				10	600	6,000	4,000	40,000	
	(8) Cut-out switch	11.4kV, 1 set = 3 units	sets					1		1		1				1					1		1				1					1				1				10	600	6,000	4,000	40,000	
	(9) Watt hour meter panel	WH, V, A, Hz,	sets					1		1		1				1					1		1				1					1				1				10	2,700	27,000	18,000	180,000	
	(10) Power Cable & Accessory	11.4kV,	sets					1		1		1				1					1		1				1					1				1				10	4,500	45,000	8,100	81,000	
	(11) 11.4kV, Over-Head Line,	connection to city power	m					100		300		300				300					300		300				300					300				300				2,800	35	98,000	45	126,000	
	(12) Commissioning and test operation		lots					1		1		1				1					1		1				1					1				1				10	1,000	10,000	0	0	
																																									259,000		**786,400**	**1,045,400**
7	**Electrical Works**																																											
	(1) Power Reciving Panel-1	125kVA, with changeover	panel							1											1		1																	3	9,600	28,800	19,000	57,000	
	(2) Power Reciving Panel-2	200kVA, with changeover	panel										1														1													2	15,200	30,400	30,000	60,000	
	(3) Power Reciving Panel-3	300kVA, with changeover	panel					1								1																								4	20,800	83,200	42,000	168,000	
	(4) Power Reciving Panel-4	400kVA, with changeover	panel																													1								1	24,800	24,800	50,000	50,000	
	(5) Power Reciving Panel-5	500kVA, with changeover	panel																																					0	30,000	0	60,700	0	
	(6) Distribution Panel	MCCB, V, A	panel																																					0	4,600	0	11,000	0	
	(7) Power Cable-1	XLPE/SWA/PVC/4c x 50mm2	m						50		80	120			120					50		50		50					50							70		50			690	4	2,760	23	15,870	
	(8) Power Cable-2	XLPE/SWA/PVC/4c x 70mm2	m	850										450		280								320			320							280				350			2,850	5	14,250	27	76,950	
	(9) Power Cable-3	XLPE/SWA/PVC/4c x 95mm2	m		1,300												920						640					500		550							600		4,510	6	27,060	36	162,360	
	(10) Power Cable-4	XLPE/SWA/PVC/4c x 120mm2	m			1,650																								850										2,500	8	20,000	44	110,000	
	(11) Power Cable-6	XLPE/SWA/PVC/4c x 185mm2	m				2,050																																		2,050	16	32,800	81	166,050	
	(12) Control Cable	PVC/SWA/PVC/10c x 2mm2	m	850	1300	1,650	2,050	200	100	100	80	120	100	450	120	280	100	920		50	100	50	100	50	320	640	100	320	50	500	850	100	550	280	70	100	50	350	600	100	13,750	15	208,250	66	907,500	
																																									470,320		**1,773,730**	**2,244,050**
8	**Water Treatment Plant**																																											
	(1) Chlorination Plant	2,000m3/day	sets																																					0	4,400	0	22,100	0	
	(2) Chlorination + Filterate Plant	2,000m3/day	sets							1											1		1																	3	71,700	215,100	286,700	860,100	
	(3) Chlorination + Filterate Plant	4,000m3/day	sets										1																											1	115,800	115,800	463,000	463,000	
	(4) Chlorination + Filterate Plant	6,000m3/day	lots																								1									1				1	3	159,800	479,400	639,300	1,917,900	
	(5) Chlorination + Filterate Plant	8,000m3/day	lots					1								1																1								3	203,900	611,700	815,600	2,446,800	
	(6) Chlorination + Filterate Plant	10,000m3/day	lots																																					0	248,000	0	991,900	0	
	(7) Chlorination + Filterate Plant	2,500m3/day	lots																																					0	82,700	0	330,800	0	
	(8) Chlorination + Filterate Plant	5,000m3/day	lots																																					0	137,800	0	551,200	0	
	(9) Chlorination + Filterate Plant	7,500m3/day	lots																																					0	192,900	0	771,500	0	
	(10) Aeration + Chlorination + Filterate Plant	100m3/day	lots																																					0	31,500	0	126,200	0	
																																									1,422,000		**5,687,800**	**7,109,800**
																																												30,709,896

PART 11

WATER QUALITY

Final Report

(Supporting Report)

PART 11 WATER QUALITY

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List of Tables and Figures

PART 11 WATER QUALITY

CHAPTER 1. RESULTS OF WATER QUALITY SURVEY

1.1. Water Quality Standard

Table-11. 1 Water Standards in Colombia

PARAMETERS	MINISTERIO DE PROTECCION SOCIAL DECRETO 1575 & 2115 De 2007 Potable Water regulations	DAMA RESOLUCION 250 De 1997 Groundwater regulations	MINISTERIO DE PROTECCION SOCIAL DECRETO 1594 De 1984 Water resource regulation	DAMA RESOLUCION 1074 De 1997 Waste water regulations
Al	2.0	0.2		
Sb	0.02	0.005		
As (mg/l)	0.05	0.01	0.05	0.1
Ba (mg/l)	1.0	0.5	1.0	5.0
B (mg/l)	1.0	0.3		
Cd (mg/l)	0.005	0.003	0.01	0.003
CN (mg/l)	0.1	0.05		
CNTotal (mg/l)	0.2	0.1	0.2	1.0
$CHCL_3$ (mg/l)	0.7	0.03		
Cr^{+6} (mg/l)	0.025	0.01	0.05	0.5
Cu (mg/l)	2.0	1	1	0.25
Phenol (mg/l)	0.01	0.001	0.002	0.2
Hg (mg/l)	0.002	0.001	0.002	0.02
Mo (mg/l)	0.2	0.07		
Ni (mg/l)	0.1	0.02		0.2
NO_2 (mg/l)	1.0	0.1	1.0	
NO_3 (mg/l)	10	10	10	
Ag (mg/l)	0.05	0.01	0.05	0.5
Pb (mg/l)	0.02	0.01	0.05	0.1
Se (mg/l)	0.015	0.01	0.01	0.1
ABS (mg/l)	0.7	0.5	0.5	20
THMs (mg/l)	≤ 1.0	0.1		
Ca (mg/l)	100	60		
$CaCO_3$ /Acidity (mg/l)	60	50		
$CaCO_3$ /Hydroxide	<LD	<LD		
$CaCO_3$/Alkalinity total (mg/l)	120	100		
Cl^- (mg/l)	300	250	250	
$CaCO_3$ /Hardness total (mg/l)	180	160		
Fe (mg/l)	0.5	0.3		

PARAMETERS	**MINISTERIO DE PROTECCION SOCIAL DECRETO 1575 & 2115 De 2007 Potable Water regulations**	**DAMA RESOLUCION 250 De 1997 Groundwater regulations**	**MINISTERIO DE PROTECCION SOCIAL DECRETO 1594 De 1984 Water resource regulation**	**DAMA RESOLUCION 1074 De 1997 Waste water regulations**
Mg (mg/l)	60	36		
Mn (mg/l)	0.15	0.1		0.12
SO_4 (mg/l)	350	250	400	
Zn (mg/l)	10	5	15.0	5.0
F^- (mg/l)	1.7	1.2		
PO_4 (mg/l)	0.4	0.2		
Color real (UPC)	<25	<15	<20	
Odor , Taste	Aceptable	Aceptable		
Turbility/UNT	≤5	<5	10/UJT	
TDS (mg/l)	<1000	<500		
Electric Conductivity (µS/cm)	≤1500	50-1000		
Ph			6.5-8.5	05-sep
Total Coniform (nmp)			1000	
NH_3 (mg/l)			1.0	
Total organic carbon				0.1
Chloroform (mg/l)				1.0
Organochlorine (mg/l)				0.05
Organophosphorus (mg/l)				0.1
Cr total (mg/l)				1.0
DBO_5 (mg/l)				1000
Ethylene dichloride				1.0
Polychlorinate binphenyl				No detectable
DQO (mg/l)				2000
Suspended Solid -SS (mg/l)				2.0
Total Suspended Solid (mg/l)				800
Hg organic (mg/l)				No detectable
Sulfate (mg/l)				1.0
Carbon tetrachloride (mg/l)				1.0
Trichioroethylene (mg/l)				1.0
Temperature (˚C9				<30
SAAM (mg/l)				0.5

Decreto 1575 & 2115 : Potable water regulation.

DAMA RESOLUCION 250 De 1997: Groundwater regulation, which defined the social and environmental costs to use..

DECRETO 1594 De 1984: Water use and control regulation for water resources as surface water, groundwater etc, to obtain the concessions, permits, licenses to use the water.

DAMA RESOLUCION 1074 De 1997: Waste water regulation which established environmental parameters.

1.2. Bogota River Water Quality

(1) The result of Water quality

Figure 1 to 18 indicate the Bogota River Water Quality along to the River

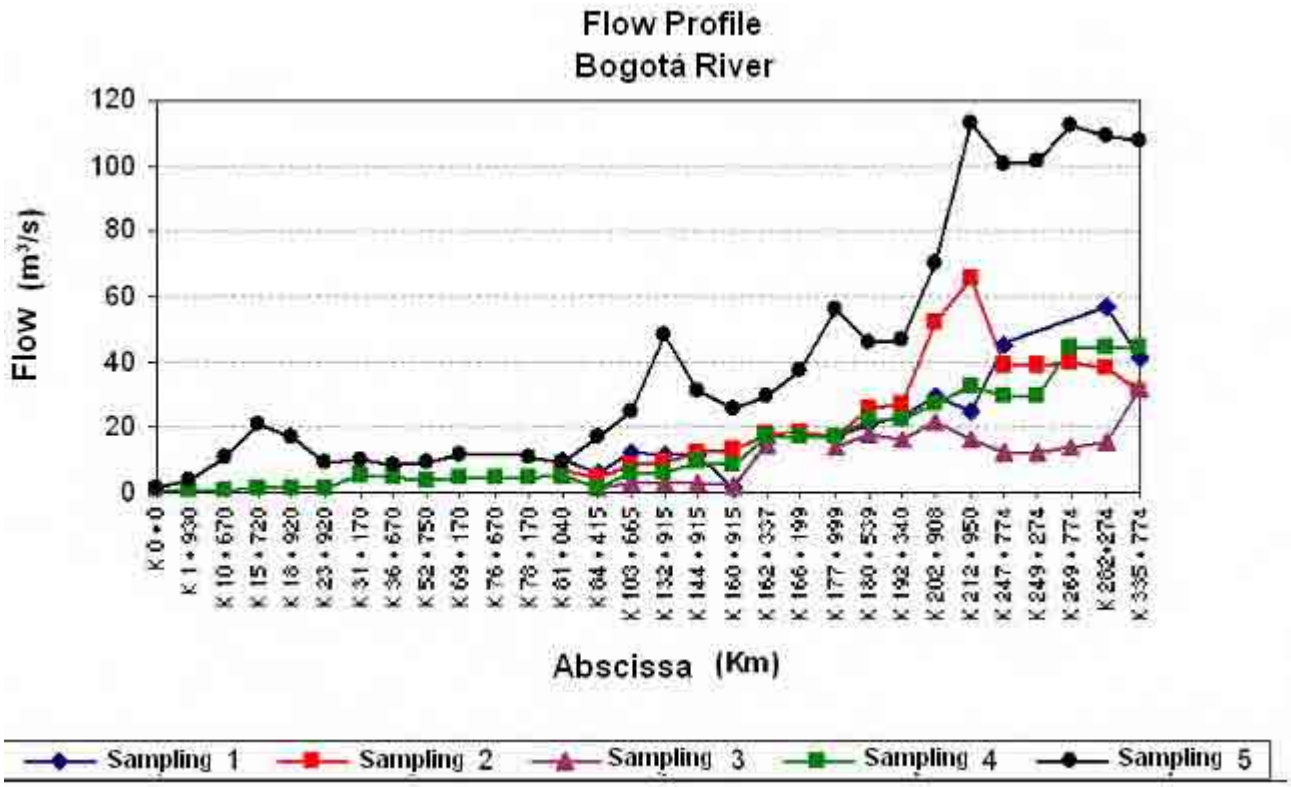


Figure-11. 1 Volume of the Bogota River

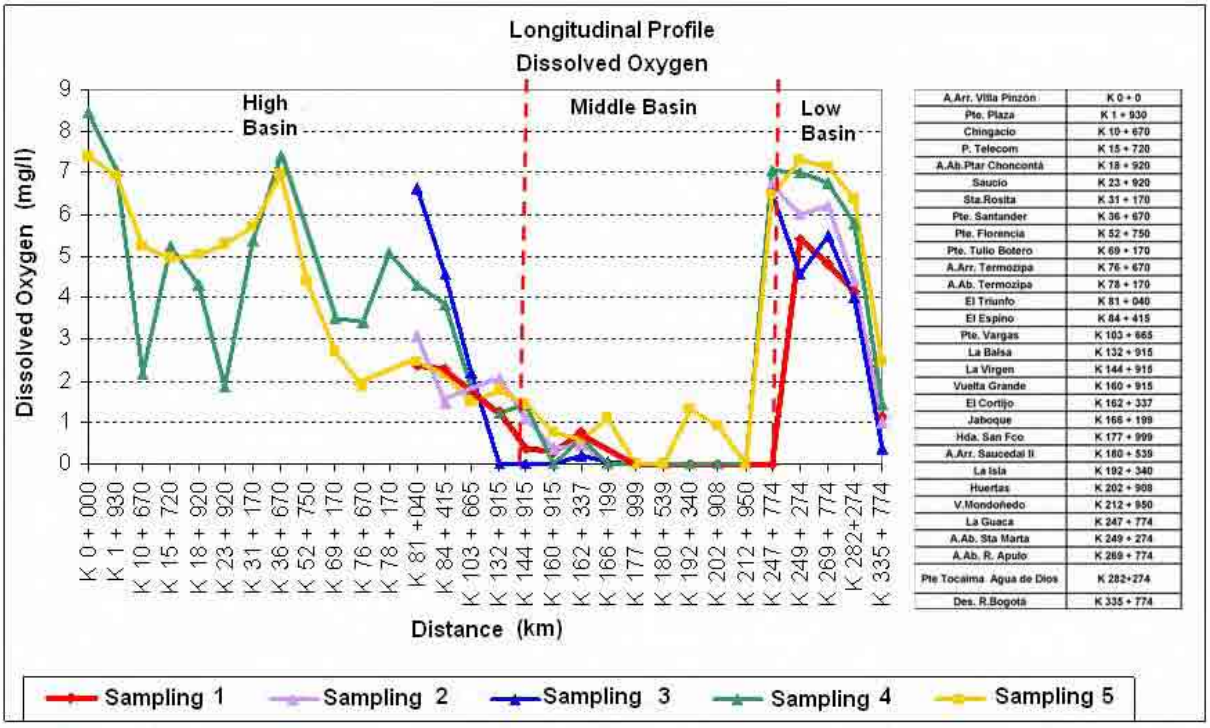


Figure-11. 2 DO (Dissolved Oxygen)

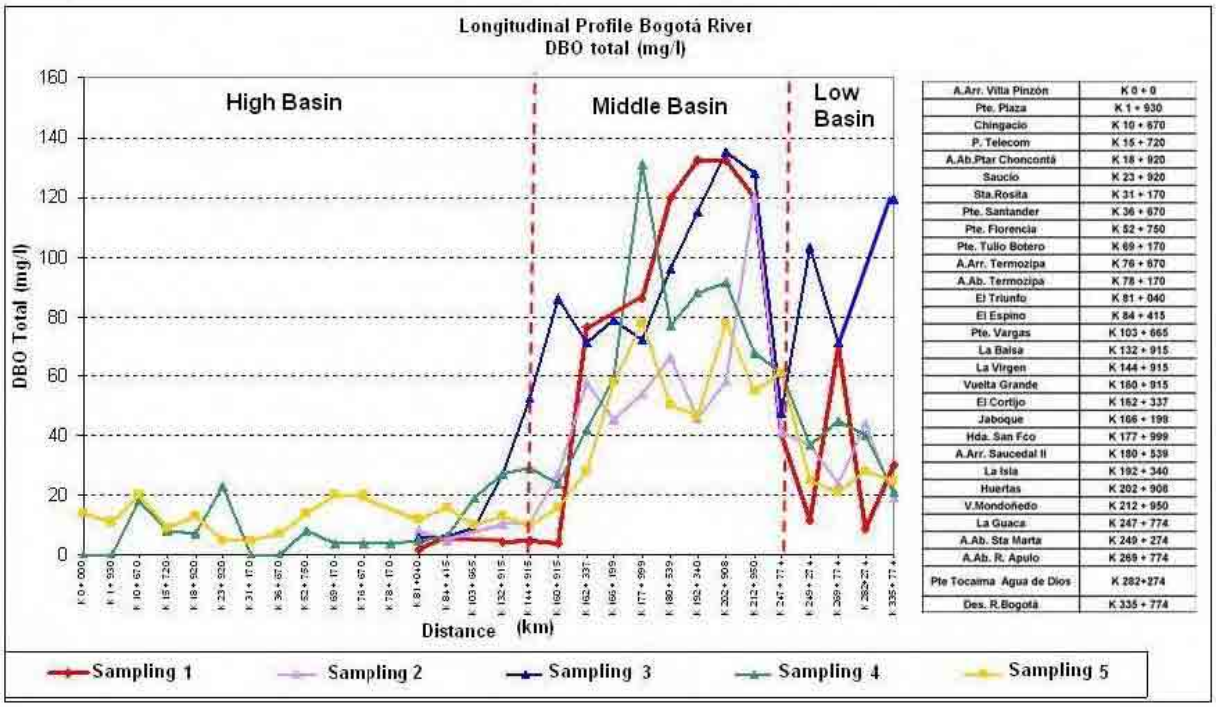


Figure-11. 3 BOD_5 total

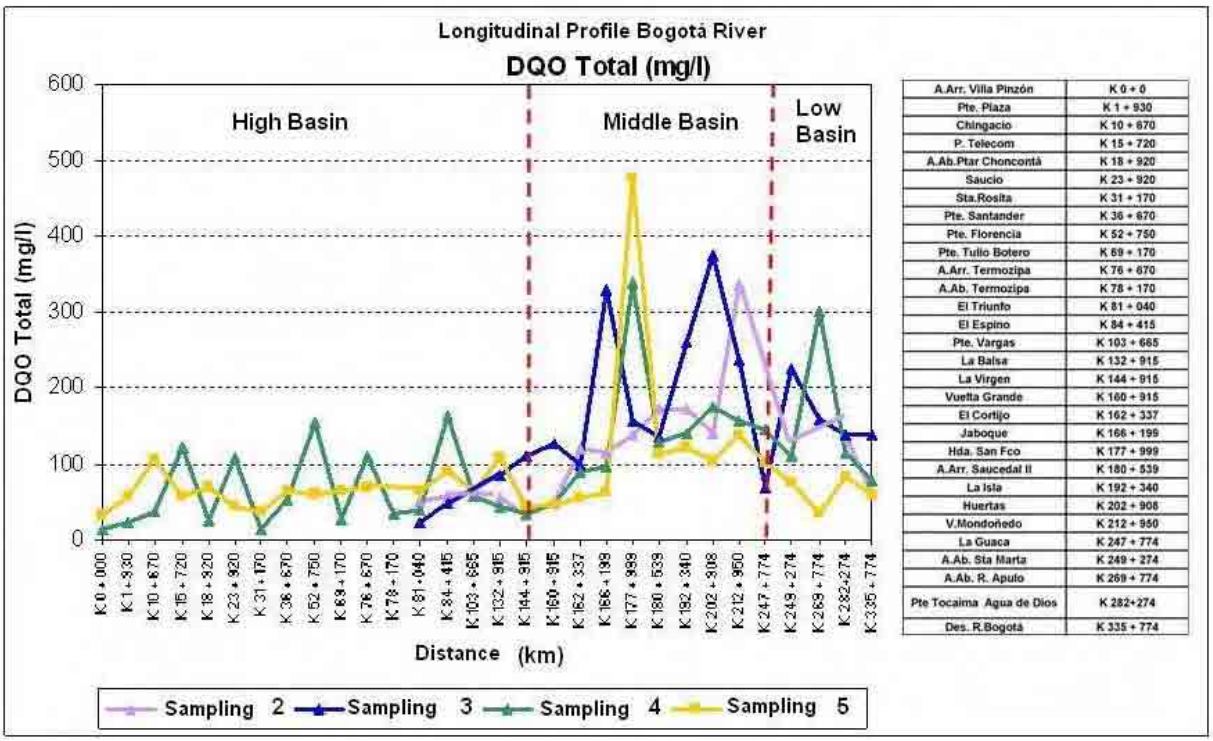


Figure-11. 4 COD Total

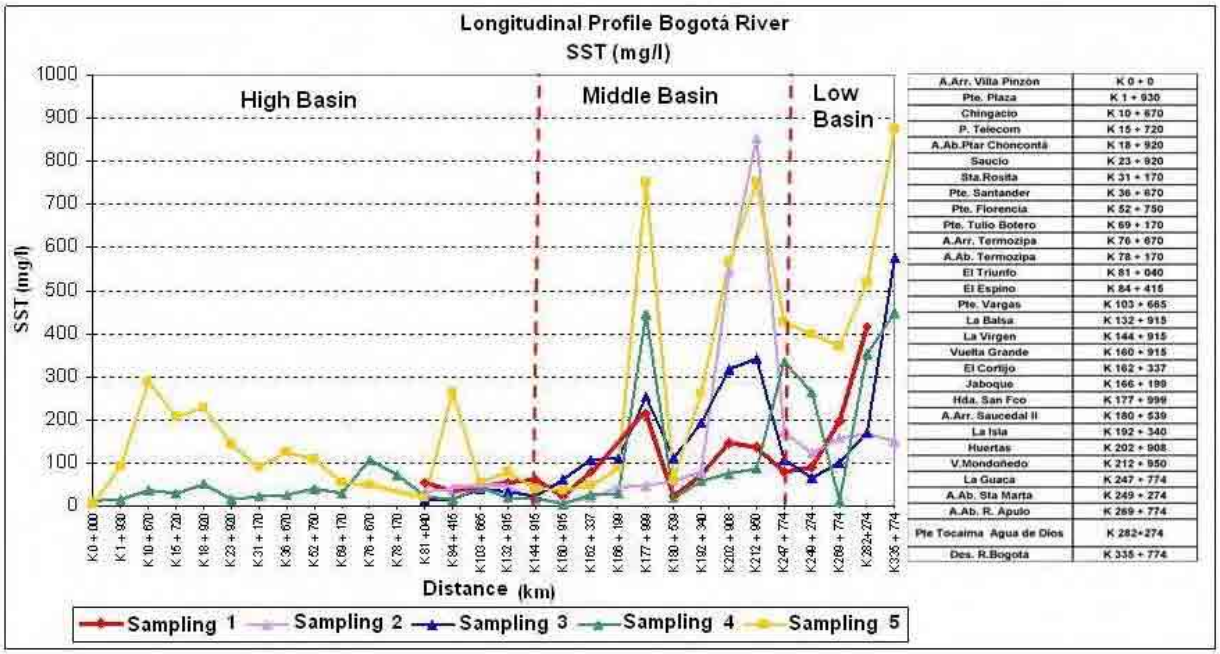


Figure-11. 5 SST

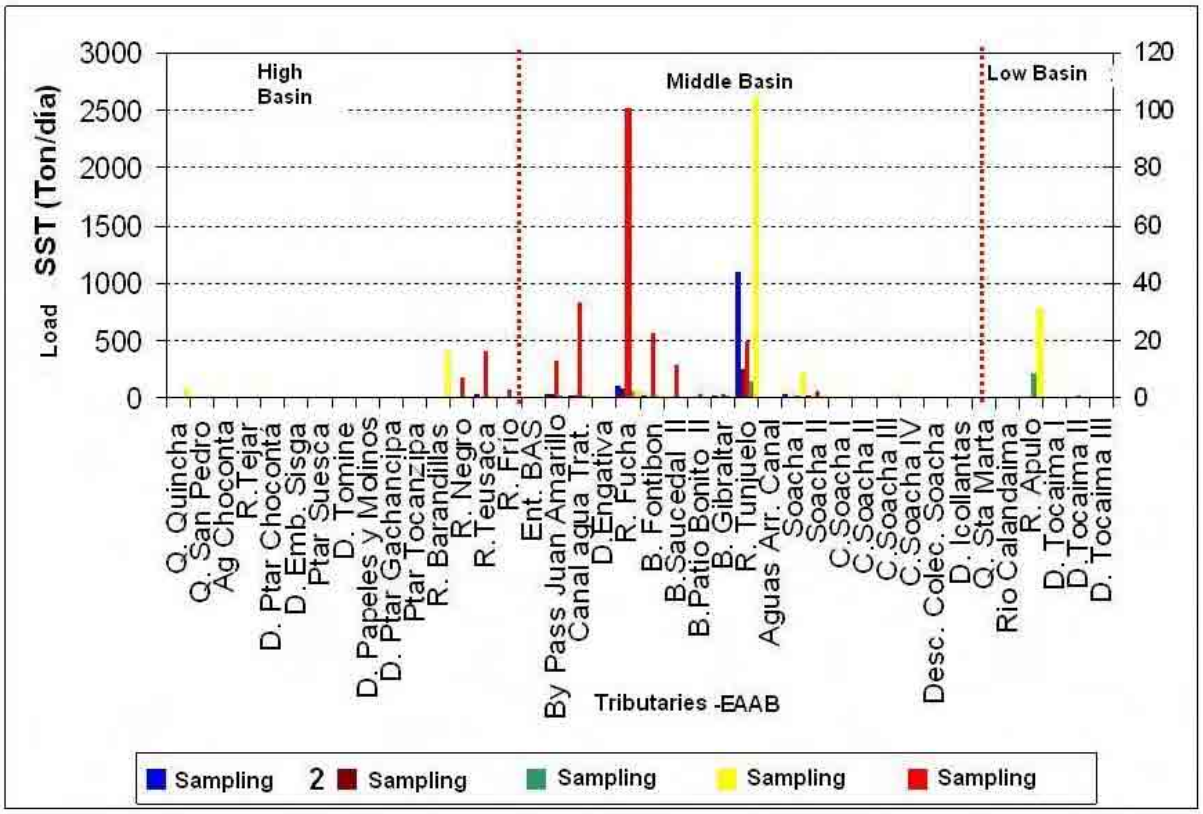


Figure-11. 6 SST Volumes

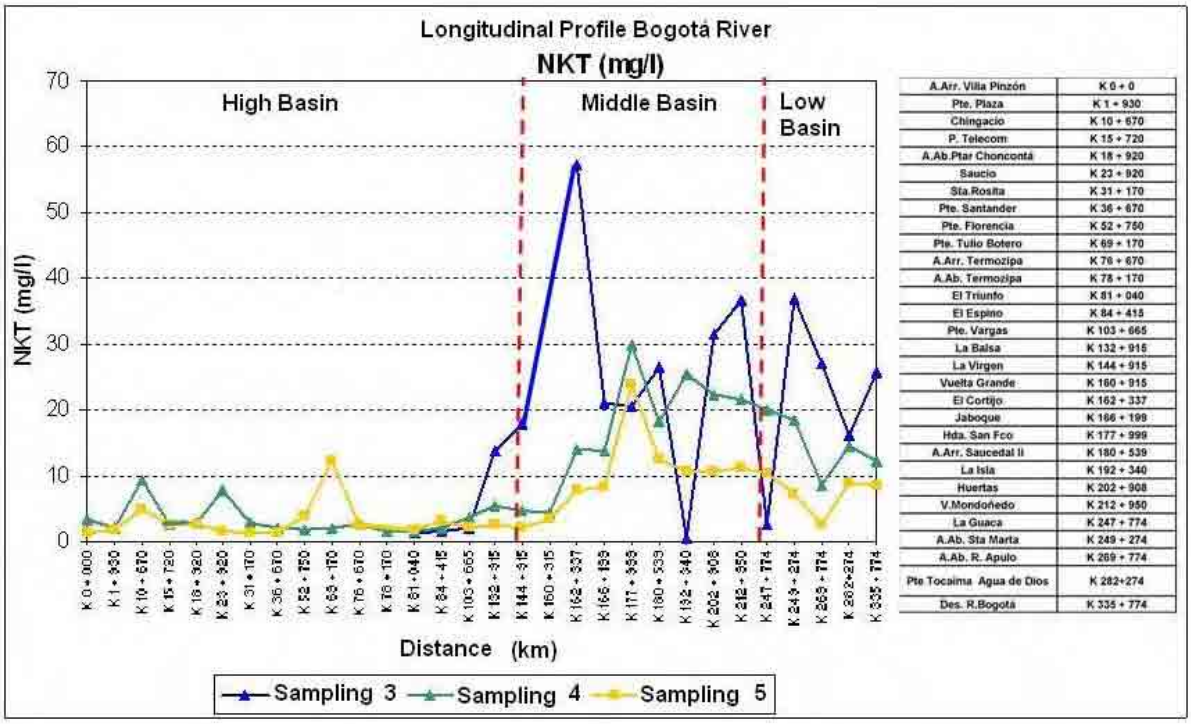


Figure-11. 7 NKT

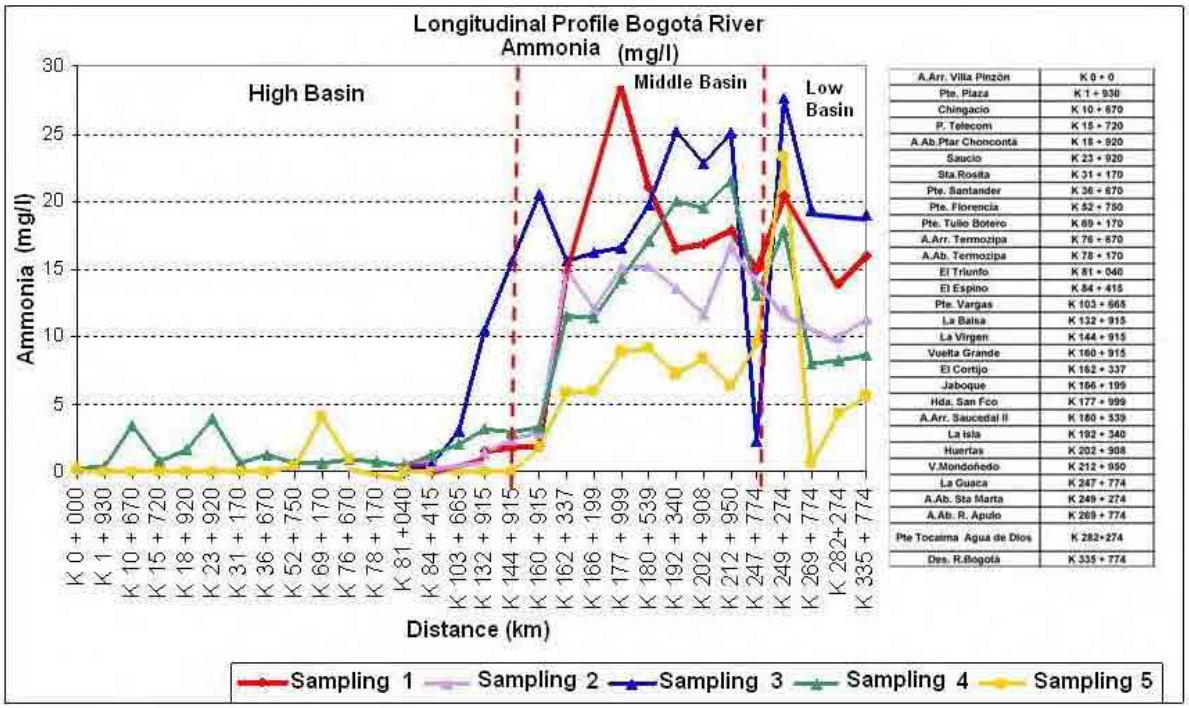


Figure-11. 8Ammonia

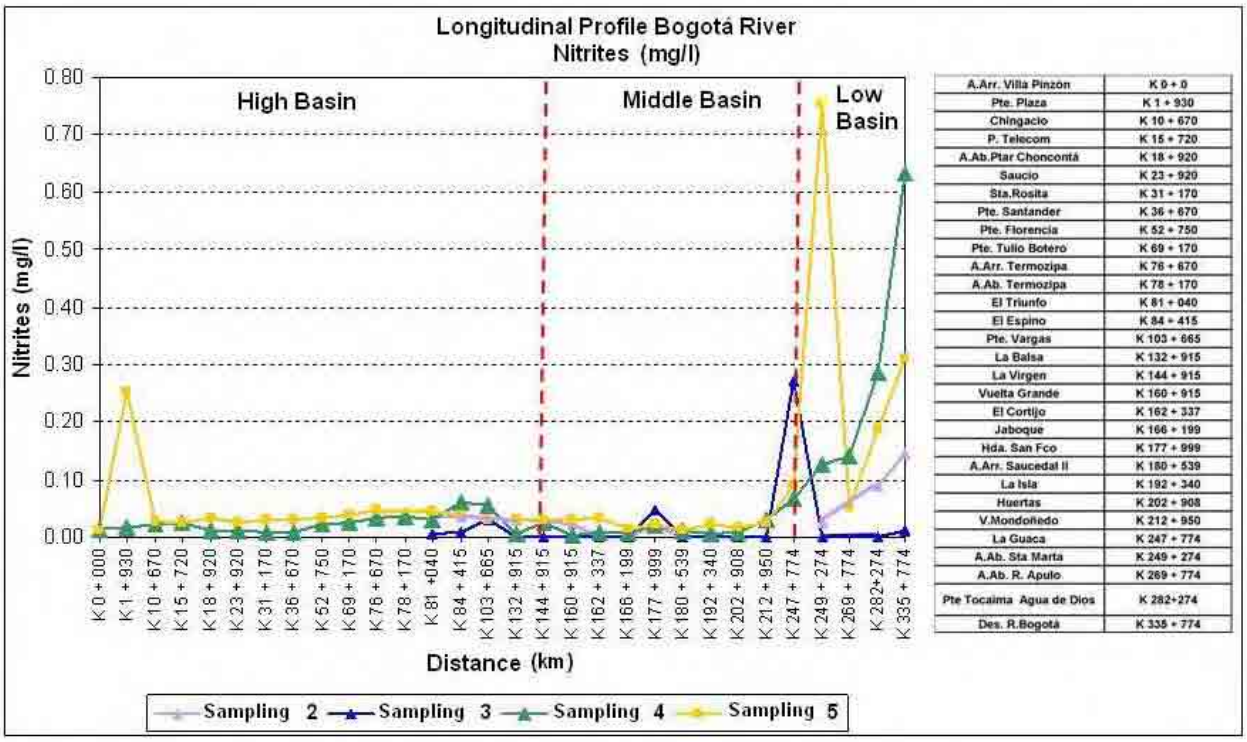


Figure-11. 9 Nitrite nitrogen

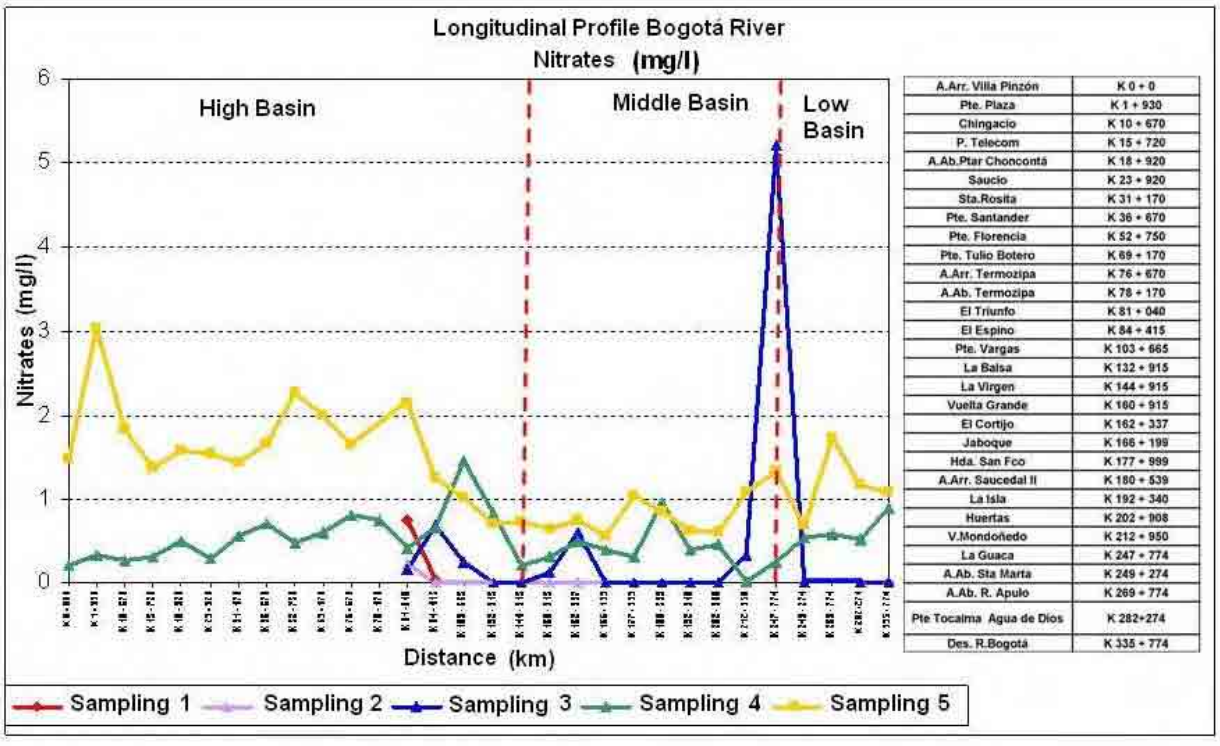
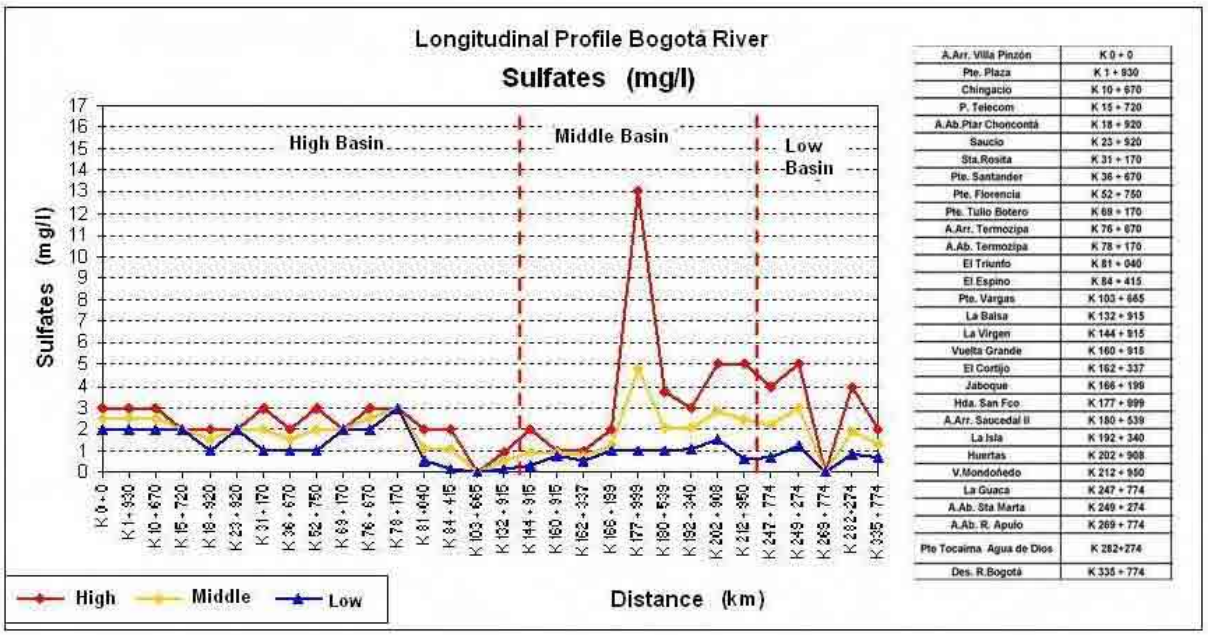
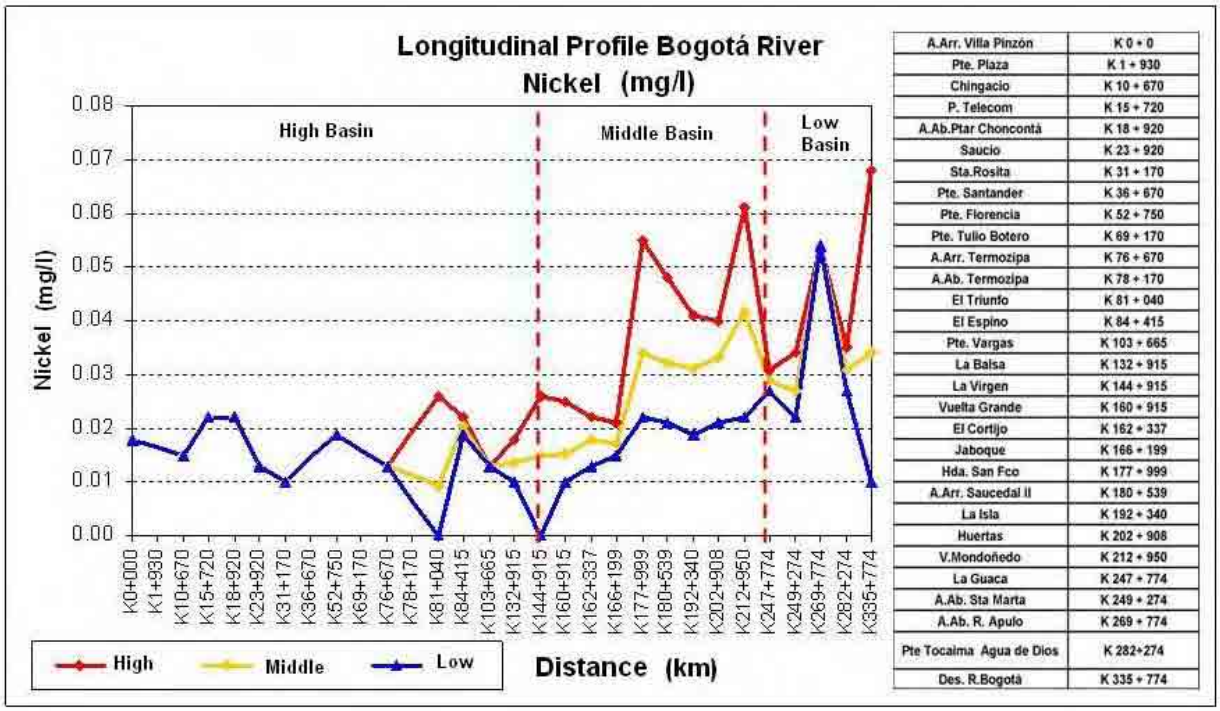


Figure-11. 10 Nitrate nitrogen



A.Arr. Villa Pinzón	K 0 + 0
Pte. Plaza	K 1 + 930
Chingacio	K 10 + 670
P. Telecom	K 15 + 720
A.Ab.Ptar Choncontá	K 18 + 920
Saucio	K 23 + 920
Sta.Rosita	K 31 + 170
Pte. Santander	K 36 + 670
Pte. Florencia	K 52 + 750
Pte. Tulio Botero	K 69 + 170
A.Arr. Termozipa	K 76 + 670
A.Ab. Termozipa	K 78 + 170
El Triunfo	K 81 + 040
El Espino	K 84 + 415
Pte. Vargas	K 103 + 665
La Balsa	K 132 + 915
La Virgen	K 144 + 915
Vuelta Grande	K 160 + 915
El Cortijo	K 162 + 337
Jaboque	K 166 + 199
Hda. San Fco	K 177 + 999
A.Arr. Saucedal II	K 180 + 539
La Isla	K 192 + 340
Huertas	K 202 + 908
V.Mondoñedo	K 212 + 950
La Guaca	K 247 + 774
A.Ab. Sta Marta	K 249 + 274
A.Ab. R. Apulo	K 269 + 774
Pte Tocaima Agua de Dios	K 282+274
Des. R.Bogotá	K 335 + 774

Figure-11. 11 Sulfate



A.Arr. Villa Pinzón	K 0 + 0
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Chingacio	K 10 + 670
P. Telecom	K 15 + 720
A.Ab.Ptar Choncontá	K 18 + 920
Saucio	K 23 + 920
Sta.Rosita	K 31 + 170
Pte. Santander	K 36 + 670
Pte. Florencia	K 52 + 750
Pte. Tulio Botero	K 69 + 170
A.Arr. Termozipa	K 76 + 670
A.Ab. Termozipa	K 78 + 170
El Triunfo	K 81 + 040
El Espino	K 84 + 415
Pte. Vargas	K 103 + 665
La Balsa	K 132 + 915
La Virgen	K 144 + 915
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El Cortijo	K 162 + 337
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A.Arr. Saucedal II	K 180 + 539
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La Guaca	K 247 + 774
A.Ab. Sta Marta	K 249 + 274
A.Ab. R. Apulo	K 269 + 774
Pte Tocaima Agua de Dios	K 282+274
Des. R.Bogotá	K 335 + 774

Figure-11. 12 Nickel

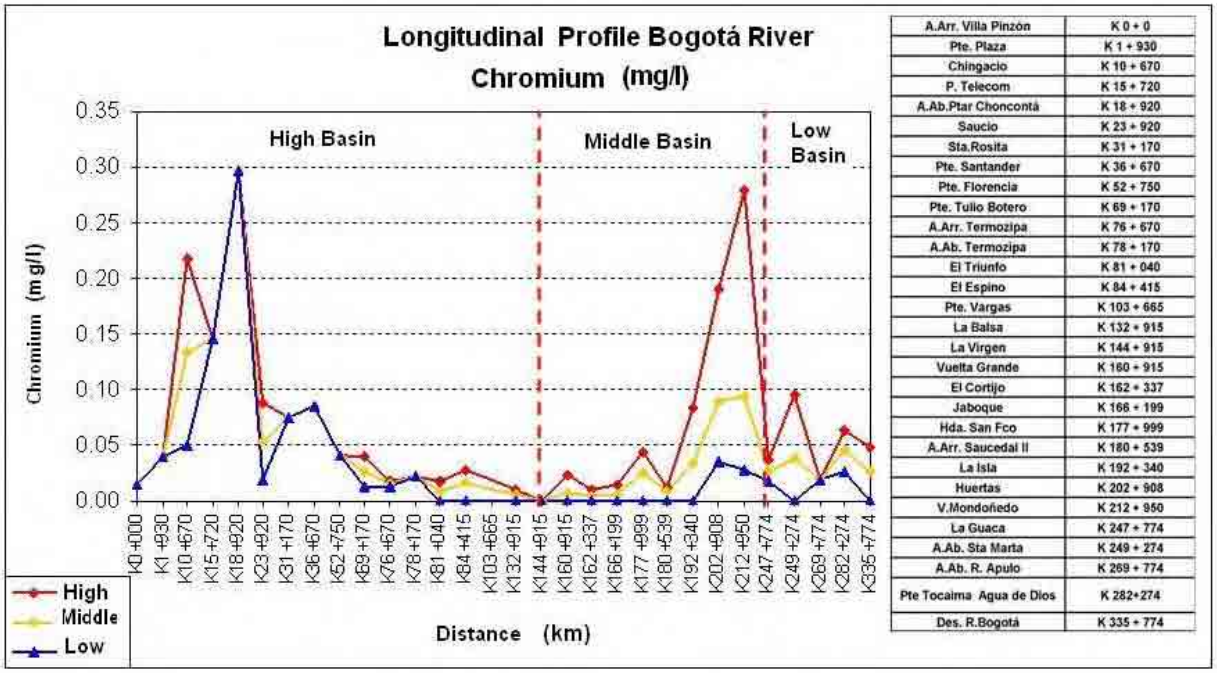

Figure-11. 13 Chromium

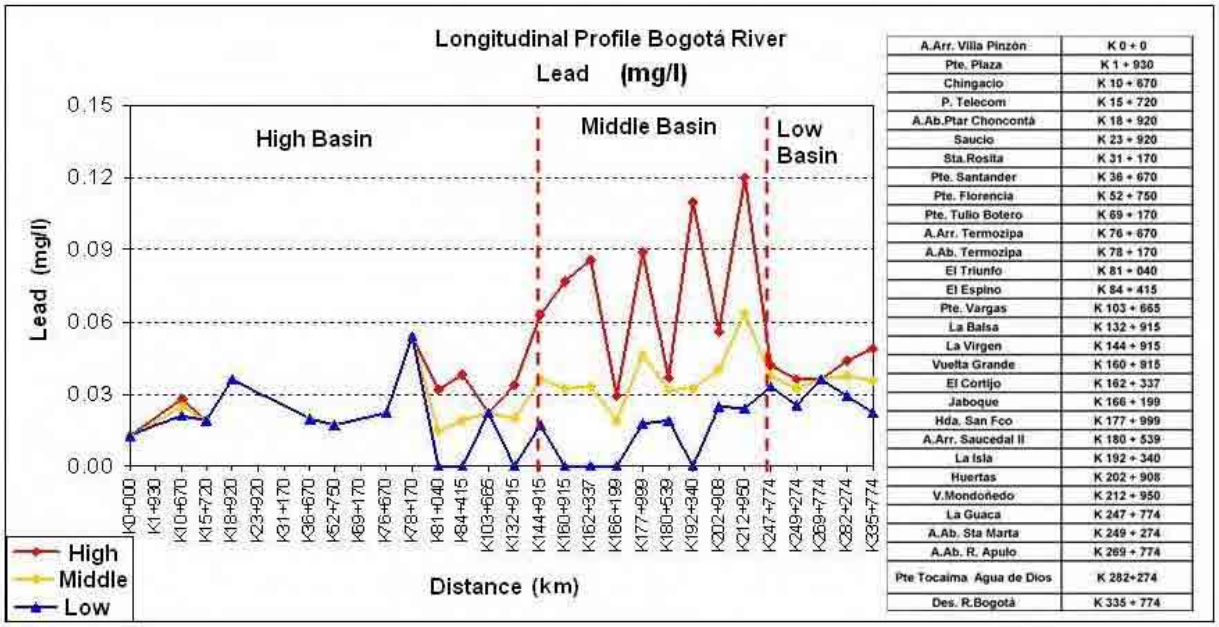

Figure-11. 14 Lead - Pb

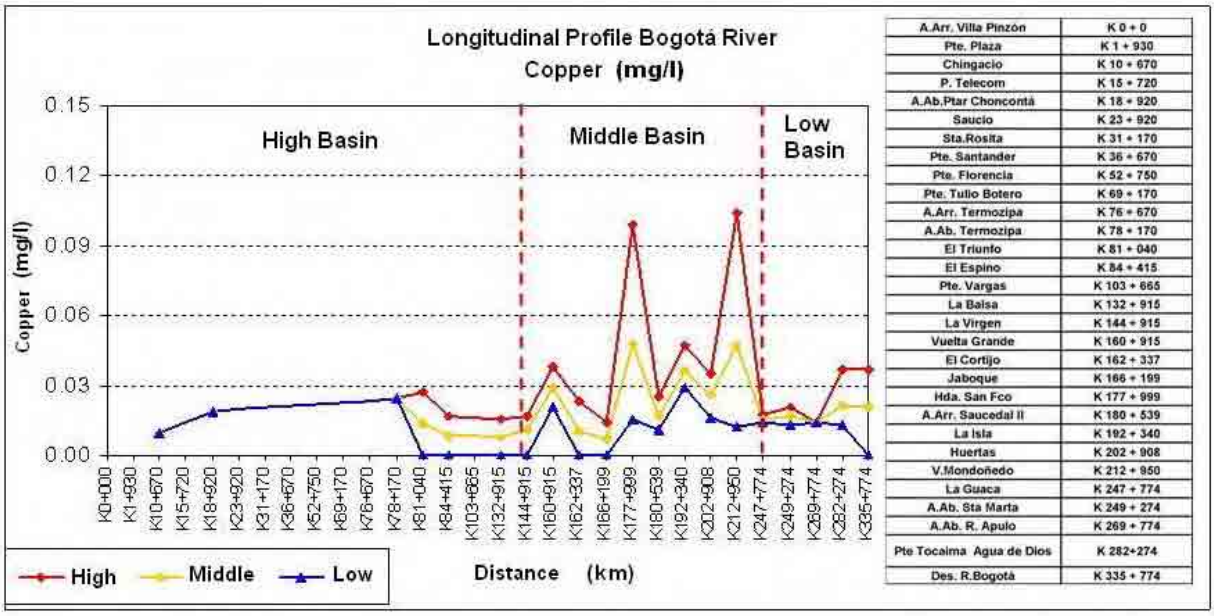

Figure-11. 15 Copper

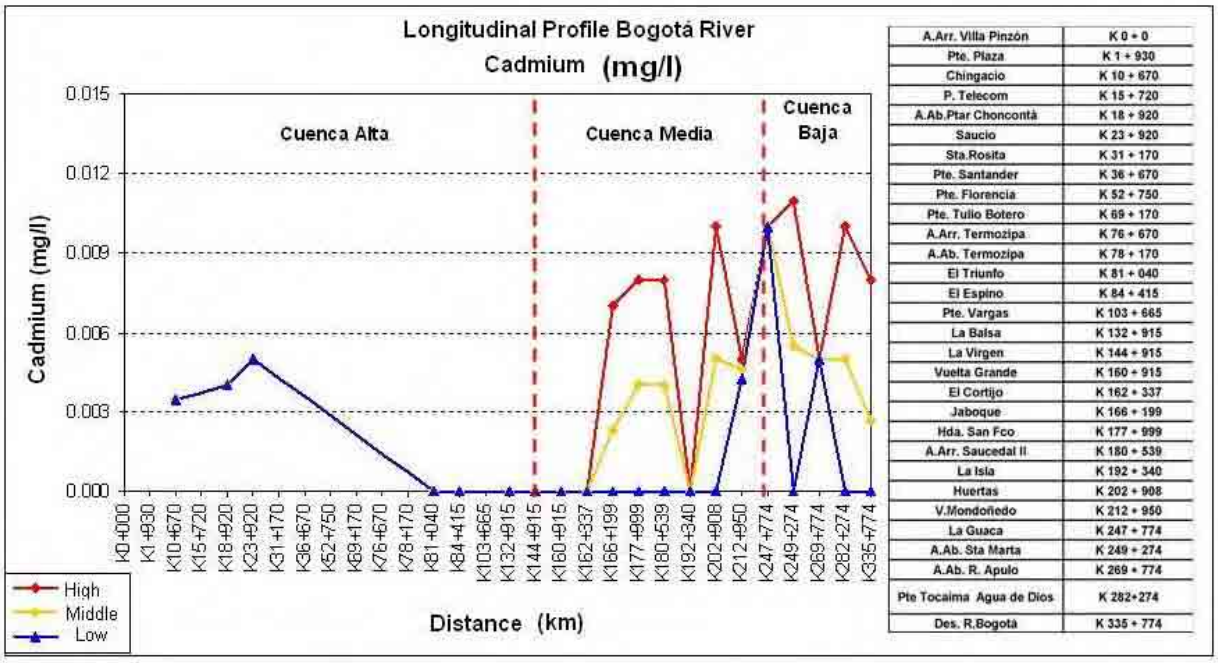

Figure-11. 16 Cadmium

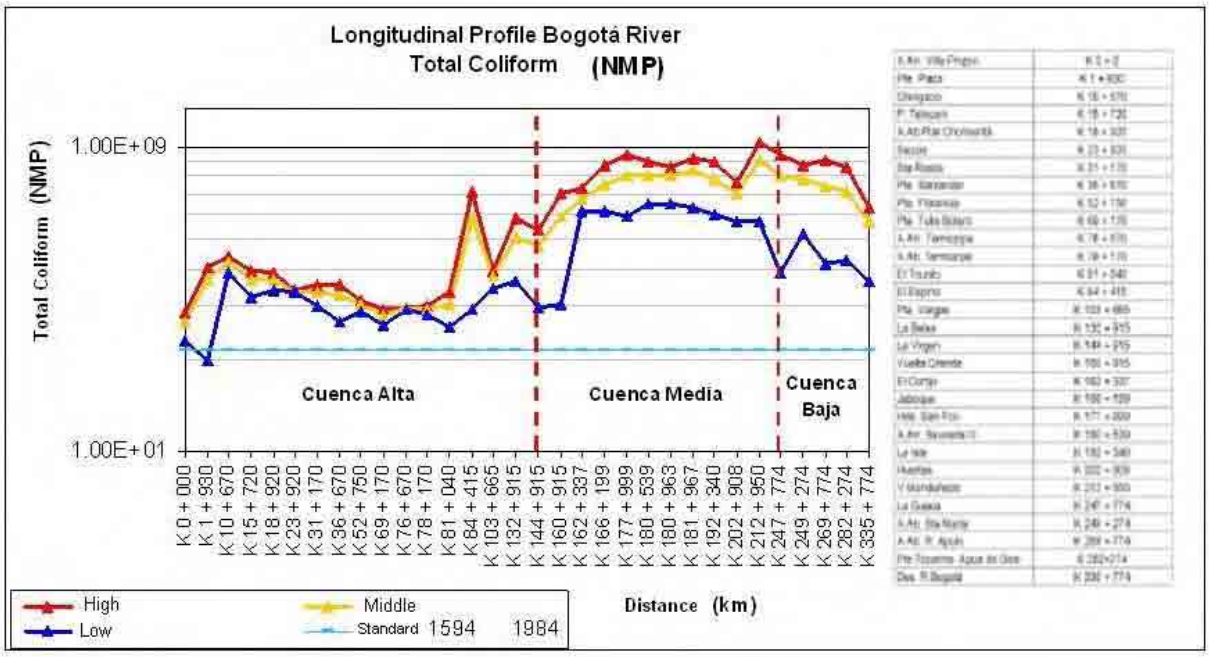

Figure-11. 17 Total Coliform (NMP)

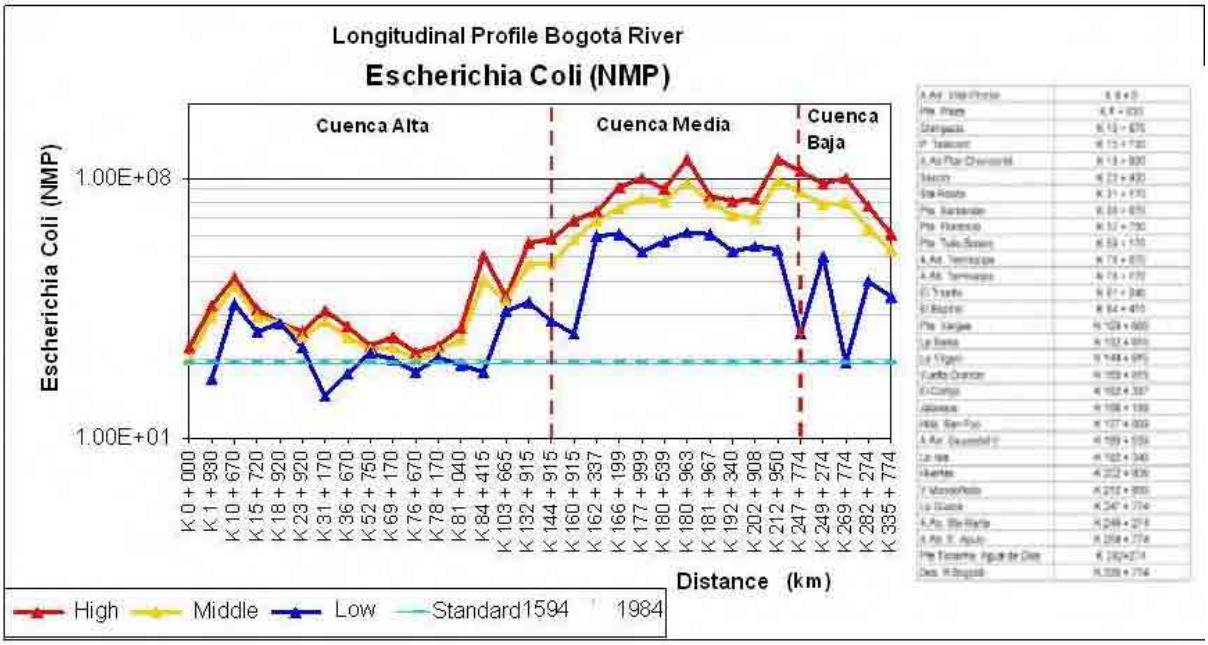

Figure-11. 18 Escherichia Coli (NMP)

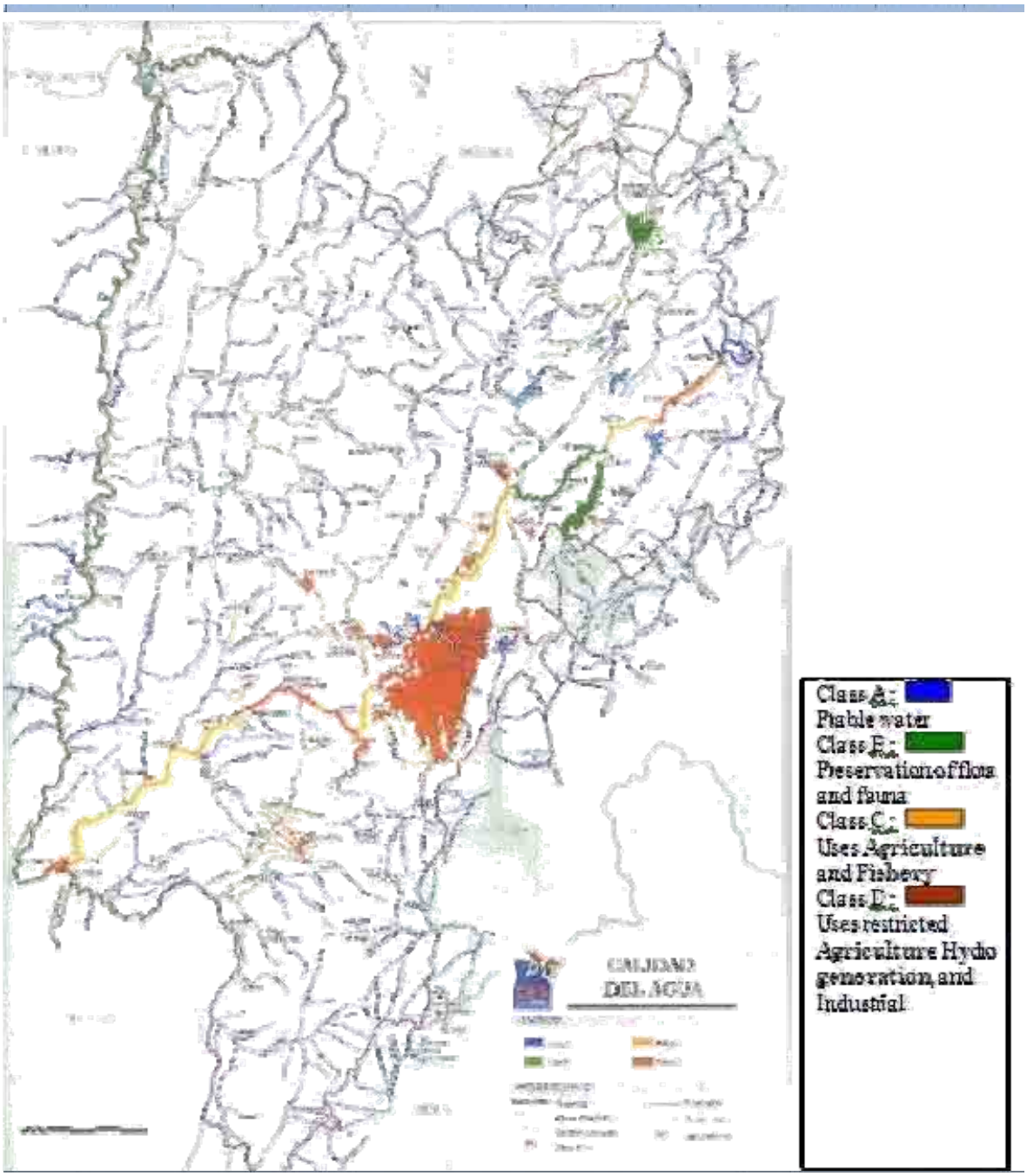

Figure-11. 19 Summary of Water Quality in Bogota River Basin

1.3. Considerations on Characteristics of Water Quality of Bogota River

In relation to the water pollution aspect of the Bogotá River, there are detected 4 distinct characteristics.

The first characteristic is the good quality of the water in the area starting of the Bogotá River up to Villapinzon, where the BOD is lower than 2 ㎎/ℓ. The OD (Dissolved Oxygen) also registers a level below 6 ㎎/ℓ and the amount of organic substances is also at level of only 0.1tonO_2/day.

The second characteristic refers to the stretch between Villapinzon and Choconta.

In this area, there are 171 tanneries, of which 121 are located in Villapinzon and 50 in Choconta.

The wastes of these companies are flushed untreated into the Bogotá River, polluting it immensely.

Due to this industrial waste, the DO is reduced 2 ㎎/ℓ, and, not only increase of BOD (10 ㎎/ℓ) but sodium sulphate, hydrated lime, ammonium sulphate, formic acid, sulphuric acid, sodium carbonate, besides the post-treatment oils are also flushed away. Another significant aspect is the detection of harmful heavy metals such as chrome and lead. Ten years ago, mercury was also detected but currently, there is no information about its presence. The explanation given by CAR was that mercury is no longer used in tanning processes. At the La Virgen metrological point, an average of 13 ㎎/ℓ of BOD is registered. It is said, however, that the fact of many branch rivers into the Bogotá River increases its flow and the auto-purification effect restores the quality of the water.

In the Furio River which is the limit of the initial of the medium Bogotá River Basin, the average flow quantity of 13 ㎥/s. At the Purification Station of Tibitoc Water Treatment Plant (WTP) which intake 4 ㎥/s, at proximity 40 km downstream from Villapinzon. From Villapinzon to the Juan Amarillo River (The Salitre River is the name given to the initial part of the Juan Amarillo River and are the same river. Hereinafter, we will refer to it only as the Salitre River), which is the river closest to the urban area of Bogotá, the water is mainly used as irrigation for crops and fields. The agricultural and cattle breeding waste runs directly to the Bogotá River. The waste standards for these agricultural and cattle breeding wastes was established, but, in reality, neither examination of water nor the regulation is done.

The third characteristic refers to the quality of water in the urban area of Bogotá which corresponds to the medium basin of the Bogotá River. When Bogota River is in a town area, the water turns worse dramatically. The domestic waste water of the entire population of Bogotá, which is 6.4 million, is discharged into the Bogotá River. The main rivers flowed into Bogotá River are the Salitre River, the Fucha River, and the Tunjuelo River.

In the urban area of Bogotá, there is only the Salitre WWTP which operates only the primary treatment, with a low index of elimination of BOD since the organic treatment is not operated.

Untreated waste water into the Bogotá River also through another two important rivers, the Fucha and the Tunjuelo

At the Salitre River point, the BOD is on average 120 ㎎/ℓ, 130 ㎎/ℓ are registered at the Fucha River and 140 ㎎/ℓ at the Tunjuelo River. The contamination of the water quality is caused by the sewage inflow (domestic and industrial waste) from urban area of the Bogotá. It is registered that the volume of organic substances is, on average, 482tonO_2/day. The water quality of the Bogotá River, at the joint of the Tunjuelo River, is awful and it has a grayish color, is cloudy and foul smelling. It is confirmed that a chemical material and heavy metal from Tunjuelo River are extremely big by water examination. It is much bigger than pollution of hides factory of the Villapinzon described as the second characteristic. There are a lot large-scale hides factories, a metal factory of a car in a Tunjuelo River sub-basin, and industrial waste water flows into Bogotá River as most non-tratment.

The volume of waste from the rivers in the urban area of Bogotá is approximately 23 ㎥/s, which corresponds to 2/3 of the entire average flow 37 ㎥/s of the Bogotá River.

The impact of the waste of the urban area on the contamination of the quality of the Bogotá River is very considerable. The bacterial contamination content is also extremely high along this stretch.

There is information that at the Salitre River and in Lake Muña the Total Coliform bacteria 10～28 million/100㎖, of which 3～7 million/100㎖ correspond to the faecal coliform bacteria.

On the other hand, in much the same way that the contamination of the water quality in the Bogotá river is very important, the pollution of the waters in Lake Muña, which originate from the Bogotá River for the purpose of generating electrical power is also very important. The existence of any type of fish has not been confirmed.

The fourth characteristic is the quality of the water on the stretch between Subachoque River, at the final stretch of the Bogotá River, and the Magdalena River.

From the urban area up to the Tequendama Falls, the course of the river is slow and, even though a

recovery in the quality of the water is not expected, the BOD there is at a level of 18～34 ㎎/ℓ and the DO at 2～7 ㎎/ℓ.

Summary of the water quality in the River Basin of Bogotá is shown. in Figure 19. The water quality of Middle Bogotá River Basin presents an inferior aspect as above. However, a sewer system plan is already devised by ACUEDUCT and CAR, and it is a stage conducted to enforcement. A fund supply of a Salitre WWPT expansion plan was already prepared, and construction from 2008 is planned. In addition, now sewage intercepting system is under construction. Canoa WWPT is still planning, but the water quality of Bogotá River will be improved greatly at a complete the system.

1.4. Chingaza River Basin

Principal Water quality examination results of Chingaza River Basin are as follows.

Table-11. 2 shows the results of water quality of Chingaza River Basin

Parameters	Water quality	Remark
Hardness	50mg/ℓ	Ministry of Health of Colombia Decret 475 : 160 mg/ℓ、Japanese Water Quality standard : 300 mg/ℓ
Turbidity	‹1.25NT	WHO Guideline : 5NTU
PH	6.3-7.6	Neutral
Alkalinity	5-17 mg/l	Ministry of Health of Colombia Decret 475 : 100 mg/ℓ
Mg	0.2 – 0.9 mg/l	Ministry of Health of Colombia Decret 475 : 60 mg/ℓ
Mn	0.02 – 0.08	Ministry of Health of Colombia Decret 475 : 0.15 mg/ℓ
Fe	0.2 – 1.1 mg/l	Ministry of Health of Colombia Decret 475 : 0.5 mg/ℓ
Total Coliform Bacteria	50-500	Ministry of Agriculture Decret 1594/1984 : ‹1000
Nitrato	0.004～0.09 mg/ℓ	WHO: ‹50
Ammonia	0.11～0.4 mg/ℓ	Ministry of Agriculture Decret 1594/1984 : ‹10
Chloride	1.7～7.36 mg/ℓ	Not indicated in WHO Guideline. Generally minor than 250
Nitrito	0.006～0.14 mg/ℓ	Ministry of Agriculture Decret 1594/1984 : ‹10
Conductibity	30 - 60	Ministry of Health of Colombia Decret 475 : 1500μS/cm
TDS	30 – 115 mg/l	Ministry of Health of Colombia Decret 475 : 1000mg/ℓ
		Not indicated in WHO Guideline

By the above results it can be judged it to be clean river water as the source of drinking water (Class A)

Table-11. 3 Water Quality of CHINGAZA River Basin

M0NITOREO	EMBALSE CHUZA				EMBALSE SAN RAFAEL				EMBALSE CHISACA				EMBASE REGADERA			
PARAMETROS	MARZO	JUNIO	SEPTIEMBRE	DICIEMBRE	MARZO	JUNIO	SEPTIEMBRE	DICIEMBRE	MARZO	JUNIO	SEPTIEMBRE	DICIEMBRE	MARZO	JUNIO	SEPTIEMBRE	DICIEMBRE
Turbiedad UNT	1.99	3.72	2.58	2.05	3.07	3.33	2.53	10.23	7.67	93.33	7.77	9.67	14.23	118.33	8.10	12.00
CONDUCTIVIDAD/µS/cm	30.7	37.50	34.50	35.33	52.18	64.17	57.75	54.67	31.73	31.67	23.67	23.00	33.50	27.17	15.33	23.00
pH	6.31	7.09	7.59	755	6.99	6.82	7.41	7.57	6.93	6.67	7.63	6.97	7.18	6.65	7.48	6.98
ALCALINIDAD/mg$CaCO_3$/L	13.7	13.16	14.3	15.4	15.7	14.6	17.3	15.3	12.3	5.7	7.7	7.7	16.3	4.5	6.7	7.7
DUREZA TOTAL/mg$CaCO_3$/L	29.2	19.04	15.00	12.58	24.33	18.80	27.92	21.58	23.33	11.03	13.67	8.33	17.00	12.35	6.33	8.67
CALCIO mg!L	10.9	6.04	5.09	3.09	9.05	6.16	6.95	6.12	8.60	3.34	3.54	2.28	6.29	3.68	2.96	2.21
MAGNESIO mg/L	0.95	0.79	0.67	0.49	0.47	0.82	0.92	0.77	0.46	0.65	0.60	0.38	0.27	0.77	0.60	0.39
HIERRO TOTAL mg/L	0.52	0.33	0.31	0.24	0.48	0.53	0.48	0.41	0.94	1.14	0.65	0.46	3.36	2.12	0.76	0.54
MANGANESO mg/L	0.04	0.03	0.17	0.01	0.03	0.04	0.03	0.02	0.07	0.05	0.04	0.02	0.08	0.07	0.04	0.04
FOSFORO TOTAL mg/L	0.04	0.03	0.02	0.01	0.48	0.53	0.48	0.41	0.06	0.13	0.03	0.04	0.09	0.15	0.06	0.09
NKT mg/L	0.43	0.37	0.34	0.43	0.82	0.45	0.95	0.66	0.63	1..34	0.67	0.63	0.93	1.17	1.87	1.03
COT mg/L	2.98	2.78	2.44	1.86	2.78	1.86	2.90	3.11	2.93	4.90	5.27	4.70	5.33	4.90	3.83	4.10
SOLIDOS mg/L	37.9	30.67	32.08	28.58	46.5	48.67	42.50	48.05	64	117	32	38	40.3	115.67	33.67	21.67
COLIFORMES TOTALE	258.50	429.03	469.62	367.51	1007.73	527.01	10108.95	638.25	51.13	1060.67	6.67	151.83	316.87	2683.83	261.83	931.89

Font：ACUEDUCT 2004-2005 Annual Report of Water Quality

CHAPTER 2. SUPPLEMENTARY WATER QUALITY TEST

2. 1. Test sites

(1) Test sites

This Study placed emphasis on surveying the Cretaceous layer groundwater in the Bogota plain. Specifically, the Study area covered the Bogota metropolitan area and the southern hill zone. The previous JICA study revealed a paucity of groundwater quality data with regard to the southern hill zone of the Bogota metropolitan area. Cretaceous layer is distributed over the southern hill zone, within which 20 well sites were selected for water quality survey under this Study.

(2) Number of water quality tests

Sampling for water quality testing is divided into two phases. The goal of this testing is to identify long-term changes in water quality. In addition, by identifying water quality in wells located in Cretaceous layer distributed over the Bogota city eastern area and the southern hill zone, a sanitizing method is to be determined to enable this water to be effectively potable. In this regard, water quality testing is as follows:

- Phase 1 (January 2007 ~ March 2007):
  - Water quality testing is carried out during the dry season. This enables subsequent comparison with and identifying of groundwater characteristics during the rainy season.
- Phase 2 (August 2007 ~ December 2007):
  - Water quality testing is carried out during the rainy season, enabling confirmation of groundwater characteristics during the rainy season.

Groundwater quality is linked to factors including topographical well location, target aquifer and production amount.

(3) Sampling sites

Representative aquifers, rivers and wells are selected.

- Rivers and wells for sampling are selected in the Bogota river surrounding area. The status of groundwater contamination and the effect of river pollution on groundwater is then identified.
- To the extent possible, samples are taken from wells in Cretaceous layer within the Bogota metropolitan area.
- From the standpoint of water quality change, sampling wells are selected to enable an accurate estimation of groundwater flow conditions.
- On the basis of water quality testing results, study and proposal is made with regard to the necessity for chlorination treatment to render groundwater safe for potable water supply.
- Sampling sites are indicated in Figure-20.

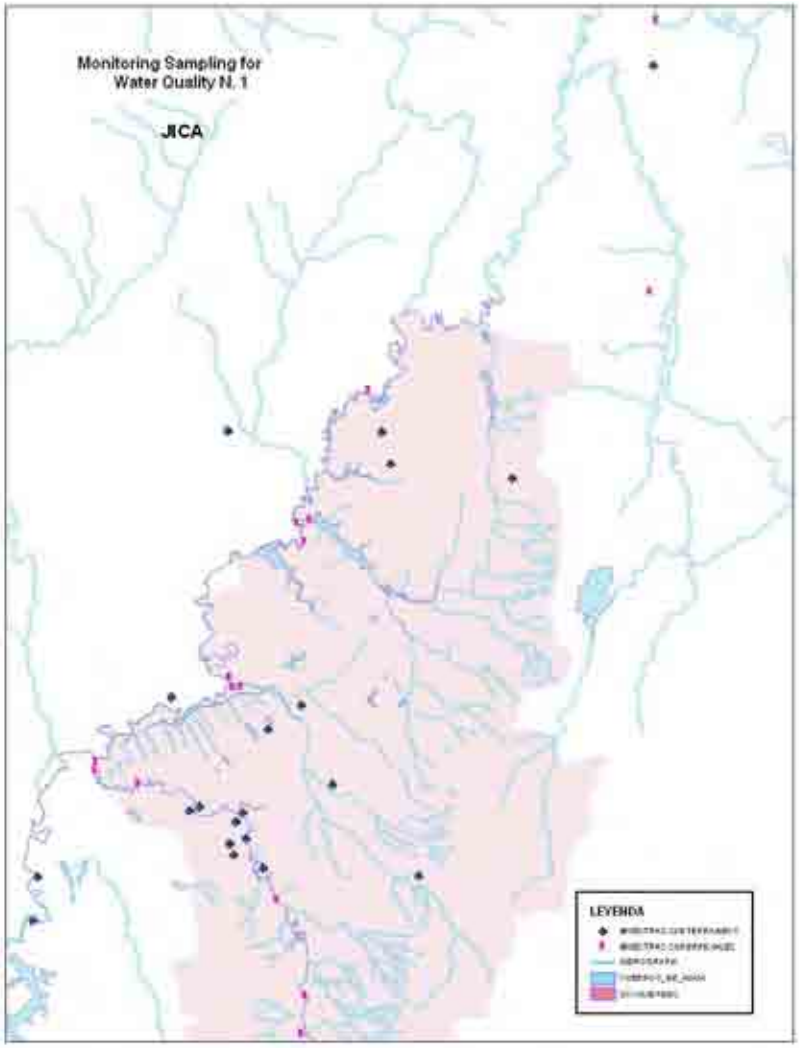

Figure-11. 20 Sampling sites Map

2. 2. Results of supplementary water quality testing

Results of river and well water quality testing are indicated in Table-○○ for the river and Table-○○ for the wells. Specifically, the tables compare the results of supplemental water testing with water quality standards set by the Colombian government, with those items marked where values are in excess of standard values.

Table-11. 4 The results of well water quality testing

POZO	HORA	PH	TEM AMB	TEM AGUA	CONDUCTIVIDAD	OD	TURBIEDAD NTU	Zn mg/L Zn	Ba mg /L	Cr^{+6} mg/L	CN mg/L	F mg/L	Ag mg/L	Mn mg/L
Bavaria	10:30	5,85	13,1	22,6	95,7	0,64	4	0.04	3	0.035	0.004	0.74	0.00	0.047
Carboquimica	11:45	5,95	20	21	24,8	0,6	0	0.02	2	0.004	0.009	0.48	0.032	0.106
Dersa	10:00	6,67	17,8	19,2	32,2	3,97	2	0.00	0	0.000	0.000	0.00	0.00	0.733
Districarnazas luna	14:45	5,54	20	18,3	19,3	1,59	3	0.00	0	0.067	0.000	0.18	0.00	0.217
Frigorifico guadalupe	15:30	6,52	21,6	19,1	37	2,1	20	0.00	3	0.020	0.018	0.00	0.00	0.166
Gaseosas colombiana 2	12:10	6,06	20,9	20,2	34,3	1,8	0	0.00	3	0.002	0.009	0.08	0.00	0.103
Gibraltar	12:20	5,94	15,6	18,7	49,9	3,5	10	0.06	4	0.046	0.007	0.00	0.00	0.042
Gm colmotores	15:00	7,2	21,9	20,1	80,7	1,78	7	0.00	3	0.000	0.012	0.21	0.00	0.255
Indumil	15:30	6,07	22,4	19,9	22,6	0,87	2	0.00	4	0.039	0.003	0.32	0.00	0.698
Jardines apogeo	12:10	7,14	20,7	20,7	25,7	1,6	6	0.00	2	0.000	0.003	0.00	0.00	0.150
La diana	11:30	6,61	20,8	19,3	30,6	2,5	11	0.01	0	0.000	0.004	0.04	0.00	0.114
La salle	11:12	6,28	20	19,5	22,2	2,3	5	0.00	2	0.000	0.003	0.16	0.00	0.034
Manufacturas eliot	16:20	7,61	17,8	18	61,2	1,6	14	0.00	1	0.029	0.011	0.41	0.00	0.091
Mariscal sucre	12:45	6,68	19,8	20	54	2,16	13	0.07	1	0.126	0.000	0.24	0.00	0.024
Parque tunal	09:05	6,12	18,3	18,6	37,9	0,3	7	0.02	2	0.000	0.005	0.40	0.026	0.081
Petco	13:00	5,34	22,8	18,7	21,3	1,15	1	0.00	1	0.000	0.000	0.29	0.00	0.265
Quintas de santa ana	13:00	7,09	23,4	23,5	13,5	3,41	0	0.04	2	0.006	0.001	0.23	0.00	0.176
Siberia	14:45	6,65	18,3	19,4	157,4	1,71	23	0.00	0	0.000	0.003	0.00	0.045	0.147
Suba	12:00	6,01	21,5	23,6	50	2	7	0.00	1	0.216	0.012	0.00	0.00	0.378
Vitelma	10:20	6,38	10,6	13	19,5	2,6	20	0.03	3	0.111	0.00	0.18	0.00	0.356

POZO	Cu mg/Lcu	Fe mg/L	Dureza mg/L$CaCO_3$	SO_4 mg/L	S^- µg/L	$NO_{3ml\,NO3}$	Mo mg/Lmo	NH_4 mg/L	Fenol mg/L	NO_2 mg/L	Al mg/L	Cu mg/L	B mg/L	Mn mg/L	Cl mg/L	Cl libre mg/L	Cl total mg/L
Bavaria	0.02	6.21	12.73	1	15	2.0	0.02	10.35	0.002	0.000	0.211	0.02	0.0	0.047	12.7	0.00	0.03
Carboquimica	0.02	10.52	10.68	2	6	1.0	0.02	0.81	0.005	0.000	0.171	0.02	0.0	0.106	6.0	0.01	0.07
Dersa	3.33	10.28	2.21	0	14	34.5	0.13	8.36	0.006	0.00	0.137	3.33	0.0	0.756	42.8	0.00	0.14
Districarnazas luna	0.82	2.93	13.59	0	7	0.0	0.03	0.92	0.003	0.00	0.194	0.82	0.0	0.217	12.4	0.02	0.02
Frigorifico guadalupe	0.07	3.87	14.57	2	2	0.9	0.03	2.12	0.002	0.000	0.315	0.07	0.0	0.166	44.8	0.00	0.02
Gaseosas colombiana 2	0.03	6.52	8.71	5	7	0.3	0.08	0.26	0.002	0.000	0.042	0.03	0.0	0.103	17.3	0.00	0.02
Gibraltar	0.02	1.74	14.06	0	43	0.7	0.02	12.61	0.010	0.008	0.050	0.02	0.0	0.042	10.2	0.00	0.02
Gm colmotores	0.04	15.72	11.04	3	10	0.00	0.13	0.23	0.003	0.000	0.048	0.04	0.2	0.255	45.8	0.00	0.06
Indumil	0.33	10.84	9.55	18	5	0.0	0.03	0.79	0.002	0.000	0.042	0.33	0.0	0.698	2.1	0.02	0.04
Jardines apogeo	0.04	4.61	10.74	0	4	0.0	0.00	0.85	0.003	0.000	0.181	0.04	0.0	0.150	14.2	0.00	0.01
La diana	0.01	2.21	12.52	0	5	0.0	0.01	19.06	0.004	0.000	0.000	0.01	0.0	0.114	0.8	0.02	0.04
La salle	0.04	0.25	9.96	0	1	1.3	0.00	0.00	0.000	0.002	0.000	0.04	0.0	0.034	2.2	0.01	0.02
Manufacturas eliot	0.03	0.45	10.25	1	5	0.1	0.00	4.91	0.003	0.000	0.379	0.03	0.0	0.091	14.0	0.00	0.02
Mariscal sucre	0.04	0.12	18.44	0	103	0.4	0.00	1.36	0.003	0.058	0.045	0.04	0.0	0.024	21.2	0.05	0.07
Parque tunal	0.03	5.01	12.03	14	11	1.0	0.01	0.24	0.006	0.00	0.005	0.03	0.0	0.081	26.9	0.02	0.06
Petco	0.23	8.48	14.83	1	2	0.00	0.01	0.15	0.001	0.000	0.201	0.23	0.0	0.265	12.8	0.00	0.00
Quintas de santa ana	0.08	1.11	12.01	0	6	0.0	0.00	0.00	0.001	0.00	0.036	0.08	0.2	0.176	1.9	0.00	0.07
Siberia	0.04	0.95	3.13	0	19	0.2	0.00	50.22	0.002	0.002	0.089	0.04	0.0	0.147	81.2	0.04	0.08
Suba	0.04	4.31	12.58	1	76	0.0	0.01	0.30	0.002	0.000	0.029	0.04	0.0	0.378	13.9	1	0.01
Vitelma	0.04	1.06	11.23	0	80	1.1	0.00	0.00	0.002	0.000	0.030	0.04	0.0	0.356	2.1	0.01	0.05

Table-11. 5 The results of river water quality testing

RIO	ident	HORA	PH	TEM_AMB	TEM_AGUA	CONDUCTIVI	OD	TURBIEDAD_	Zn mg/L	Ba mg/L	Cr+6 mg/L	CN mg/L	F mg/L	Ag mg/L	Mn mg/L	Cu mg/L	Fe mg/L
BOGOTA CIERRE	1	7.30	7.12	12.9	17.7	76.9	0	105	0.00	14.00	0.300	0.009	0.24	0.00	0.172	0.00	1.10
BOGOTA CIERRE	1	8.00	7.03	12.7	17.7	77.8	0	99	0.01	14.01	0.300	0.009	0.24	0.00	0.172	0.00	1.11
BOGOTA CIERRE	1	8.30	7.02	13	17.7	77.9	0	105	0.02	14.02	0.300	0.009	0.24	0.00	0.172	0.00	1.12
BOGOTA CIERRE	1	9.00	7	15.3	17.7	77.1	0	90	0.03	14.03	0.300	0.009	0.24	0.00	0.172	0.00	1.13
BOGOTA CIERRE	1	9.30	6.99	15.9	17.8	76.9	0	100	0.04	14.04	0.300	0.009	0.24	0.00	0.172	0.00	1.14
BOGOTA CORTIJO	2	7.50	6,62	11,2	16,8	37,7	1,22	45	0.03	3.00	0.00	0.004	0.48	0.013	0.061	0.04	0.06
BOGOTA CORTIJO	2	8.20	6,58	11,6	17,1	37,4	1,77	45	0.04	3.01	0.00	0.004	0.48	0.013	0.061	0.04	0.06
BOGOTA CORTIJO	2	8.50	6,71	12,5	17,2	28,2	1,9	47	0.05	3.02	0.00	0.004	0.48	0.013	0.061	0.04	0.06
BOGOTA CORTIJO	2	9.20	6,82	13,4	17,7	44,1	1,68	75	0.06	3.03	0.00	0.004	0.48	0.013	0.061	0.04	0.06
BOGOTA CORTIJO	2	9.50	6,76	13,7	17,7	50,6	1,41	77	0.07	3.04	0.00	0.004	0.48	0.013	0.061	0.04	0.06
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	3	11.10	6	14.2	18.5	78.4	0	190	0.00	10.0	0.303	0.00	0.09	0.00	0.154	0.00	1.31
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	3	11.40	6.2	15.5	18.7	76.8	0.01	220	0.01	10.1	0.303	0.00	0.09	0.00	0.154	0.00	1.32
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	3	12.10	6.1	17.1	19	78.8	0	210	0.02	10.2	0.303	0.00	0.09	0.00	0.154	0.00	1.33
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	3	12.40	6.04	18.9	19.2	79.8	0.02	227	0.03	10.3	0.303	0.00	0.09	0.00	0.154	0.00	1.34
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	3	13.10	6.14	18.9	19.3	81.2	0	217	0.04	10.4	0.303	0.00	0.09	0.00	0.154	0.00	1.35
BOGOTA LISBOA	4	13.30	7.49	20.2	19.7	19.9	2	5	0.02	0.00	0.59	0.004	0.00	0.00	0.010	0.00	0.04
BOGOTA LISBOA	4	14.00	7.27	20.3	19.2	25.3	1.7	6	0.02	0.00	0.59	0.004	0.00	0.00	0.010	0.00	0.04
BOGOTA LISBOA	4	14.30	7.83	19.1	19.4	24.9	1.6	6	0.02	0.00	0.59	0.004	0.00	0.00	0.010	0.00	0.04
BOGOTA LISBOA	4	15.00	7.4	18.2	19.4	25	1.57	6	0.02	0.00	0.59	0.004	0.00	0.00	0.010	0.00	0.04
BOGOTA LISBOA	4	15.30	6.89	19.5	19.4	25	1.81	7	0.02	0.00	0.59	0.004	0.00	0.00	0.010	0.00	0.04
BOGOTA PTE CUNDINAMARCA	5	8.00	5.95	11.2	17.2	58	0.01	205	0.00	9.00	0.101	0.001	0.00	0.000	0.109	0.04	0.08
BOGOTA PTE CUNDINAMARCA	5	8.30	5.84	11.2	17.4	59	0	230	0.01	9.01	0.101	0.001	0.00	0.000	0.109	0.04	0.08
BOGOTA PTE CUNDINAMARCA	5	9.00	6.07	12.1	17.7	59.2	0	248	0.02	9.02	0.101	0.001	0.00	0.000	0.109	0.04	0.08
BOGOTA PTE CUNDINAMARCA	5	9.30	6.06	12.6	17.8	56.2	0	220	0.03	9.03	0.101	0.001	0.00	0.000	0.109	0.04	0.08
BOGOTA PTE CUNDINAMARCA	5	10.00	6.34	12.6	18	57	0	230	0.04	9.04	0.101	0.001	0.00	0.000	0.109	0.04	0.08
BOGOTA PTE LA VIRGEN	6	11.00	6.5	17.8	17.4	22.7	2.11	17	0.00	2.00	0.035	0.001	0.18	0.017	0.016	0.03	0.93
BOGOTA PTE LA VIRGEN	6	11.30	6.42	17.9	17.6	22.9	2.11	17	0.01	2.01	0.035	0.001	0.18	0.017	0.016	0.03	0.93
BOGOTA PTE LA VIRGEN	6	12.00	6.45	18	17.8	23	1.43	18	0.02	2.02	0.035	0.001	0.18	0.017	0.016	0.03	0.93
BOGOTA PTE LA VIRGEN	6	12.30	6.44	19.4	18.1	23.3	1.54	17	0.03	2.03	0.035	0.001	0.18	0.017	0.016	0.03	0.93
BOGOTA PTE LA VIRGEN	6	13.00	6.47	18.5	18.2	23.4	2.46	18	0.04	2.04	0.035	0.001	0.18	0.017	0.016	0.03	0.93
BOGOTA SAN BERNARDINO	7	13.30	6.36	23.1	18.9	61.8	0.01	208	0.00	10.00	0.088	0.003	0.00	0.000	0.155	0.01	1.25
BOGOTA SAN BERNARDINO	7	14.00	6.52	22.8	18.8	59.6	0.02	212	0.01	10.01	0.088	0.003	0.00	0.000	0.155	0.01	1.26
BOGOTA SAN BERNARDINO	7	14.30	6.69	20.3	18.8	61.8	0	226	0.02	10.02	0.088	0.003	0.00	0.000	0.155	0.01	1.27
BOGOTA SAN BERNARDINO	7	15.00	6.53	20.3	18.9	61.6	0	233	0.03	10.03	0.088	0.003	0.00	0.000	0.155	0.01	1.28
BOGOTA SAN BERNARDINO	7	15.30	6.56	20.1	18.7	61.4	0	258	0.04	10.04	0.088	0.003	0.00	0.000	0.155	0.01	1.29
BOGOTA TIBITOC	8	13.45	6.29	18.9	18.8	11.3	5.58	21	0.05	4.00	0.073	0.002	0.09	0.016	0.026	0.03	0.66
BOGOTA TIBITOC	8	14.15	6.64	18.7	18.6	11.1	5.49	21	0.06	4.01	0.073	0.002	0.09	0.016	0.026	0.03	0.66
BOGOTA TIBITOC	8	15.45	6.24	18.2	18.6	10.5	5.41	21	0.07	4.02	0.073	0.002	0.09	0.016	0.026	0.03	0.66
BOGOTA TIBITOC	8	15.15	6.36	18.4	18.8	9.3	4.02	26	0.08	4.03	0.073	0.002	0.09	0.016	0.026	0.03	0.66
BOGOTA TIBITOC	8	15.45	6.41	17.4	18.4	9	4.02	24	0.09	4.04	0.073	0.002	0.09	0.016	0.026	0.03	0.66
FUCHA CON ALAMEDA	9	13.10	6.28	21.3	20.6	105.3	0.5	129	0.00	20.00	0.313	0.002	0.00	0.00	0.264	0.00	1.54
FUCHA CON ALAMEDA	9	13.40	6.68	19	20.7	108.3	0.3	141	0.01	20.01	0.313	0.002	0.00	0.00	0.264	0.00	1.55
FUCHA CON ALAMEDA	9	14.10	6.7	20.2	20.7	110.9	0.2	163	0.02	20.02	0.313	0.002	0.00	0.00	0.264	0.00	1.56
FUCHA CON ALAMEDA	9	14.40	6.47	19.3	20.9	112.7	0.1	174	0.03	20.03	0.313	0.002	0.00	0.00	0.264	0.00	1.57
FUCHA CON ALAMEDA	9	15.10	6.51	20.2	21	111.2	0.2	167	0.04	20.04	0.313	0.002	0.00	0.00	0.264	0.00	1.58

RIO		HORA	PH	TEM_AMB	TEM_AGUA	CONDUCTIVI	OD	TURBIEDAD_	Zn mg/L	Ba mg/L	Cr+6 mg/L	CN mg/L	F mg/L	Ag mg/L	Mn mg/L	Cu mg/L	Fe mg/L
TUNJUELO 100m ABAJO DE YOMASA	10	11.30	5.81	19.6	17.8	46.8	0.89	851	0.00	5.00	0.055	0.00	0.00	0.00	0.254	0.00	1.92
TUNJUELO 100m ABAJO DE YOMASA	10	12.00	6.09	20.1	17.8	46	1.05	832	0.00	5.00	0.055	0.00	0.00	0.00	0.254	0.00	1.92
TUNJUELO 100m ABAJO DE YOMASA	10	12.30	6.24	20.1	18	48.1	1.04	814	0.00	5.00	0.055	0.00	0.00	0.00	0.254	0.00	1.92
TUNJUELO 100m ABAJO DE YOMASA	10	13.00	6.17	20.2	18.2	47.3	0.91	820	0.00	5.00	0.055	0.00	0.00	0.00	0.254	0.00	1.92
TUNJUELO 100m ABAJO DE YOMASA	10	13.30	6.19	21	18.6	49.1	1.01	755	0.00	5.00	0.055	0.00	0.00	0.00	0.254	0.00	1.92
TUNJUELO SAN BENITO	11	6.30	6.12	10.8	14.2	65.9	0.06	231	0.00	6.00	0.133	0.00	0.01	0.00	0.171	0.06	0.73
TUNJUELO SAN BENITO	11	7.00	6.02	11.1	14.3	65.5	0.08	372	0.00	6.00	0.133	0.00	0.01	0.00	0.171	0.06	0.73
TUNJUELO SAN BENITO	11	7.30	6.12	12.4	14.6	64.3	0.08	311	0.00	6.00	0.133	0.00	0.01	0.00	0.171	0.06	0.73
TUNJUELO SAN BENITO	11	8.00	6.21	12.9	14.7	64.7	0.02	292	0.00	6.00	0.133	0.00	0.01	0.00	0.171	0.06	0.73
TUNJUELO SAN BENITO	11	8.30	6.14	14.6	14.7	64.7	0.08	488	0.00	6.00	0.133	0.00	0.01	0.00	0.171	0.06	0.73
TUNJUELO USME	12	7.00	6.08	9.7	12.7	23.6	2.28	82	0.00	3.00	0.103	0.002	0.00	0.00	0.101	0.07	0.99
TUNJUELO USME	12	7.30	6.05	10.4	12.4	24.3	1.9	80	0.00	3.00	0.103	0.002	0.00	0.00	0.101	0.07	0.99
TUNJUELO USME	12	8.00	5.93	11.3	12.8	25.9	2	80	0.00	3.00	0.103	0.002	0.00	0.00	0.101	0.07	0.99
TUNJUELO USME	12	8.30	5.73	11.9	13.3	25.2	1.91	80	0.00	3.00	0.103	0.002	0.00	0.00	0.101	0.07	0.99
TUNJUELO USME	12	9.00	5.6	13.2	13.7	26.5	1.78	80	0.00	3.00	0.103	0.002	0.00	0.00	0.101	0.07	0.99
TUNJUELO ISLA PONTON SAN JOSE	13	10.00	6.79	16.7	16.4	159.1	0.3	164	0.00	16.00	0.320	0.003	1.11	0.00	0.234	0.00	1.27
TUNJUELO ISLA PONTON SAN JOSE	13	10.30	7.06	15	16.3	179.5	0	158	0.00	16.00	0.320	0.003	1.11	0.00	0.234	0.00	1.27
TUNJUELO ISLA PONTON SAN JOSE	13	11.00	6.87	14.8	16.5	169.7	0.6	116	0.00	16.00	0.320	0.003	1.11	0.00	0.234	0.00	1.27
TUNJUELO ISLA PONTON SAN JOSE	13	11.30	6.86	15.4	16.9	156.8	0.3	126	0.00	16.00	0.320	0.003	1.11	0.00	0.234	0.00	1.27
TUNJUELO ISLA PONTON SAN JOSE	13	12.00	7	17	16.9	172.1	0.1	126	0.00	16.00	0.320	0.003	1.11	0.00	0.234	0.00	1.27
QUIBBA	14	7.15	7.83	10.4	10.4	21.4	8.53	15.9	0.00	3.00	0.022	0.002	0.20	0.00	0.011	0.02	0.16
QUIBBA	14	7.45	7.55	10.4	10.4	23.2	9.48	13.6	0.00	3.00	0.022	0.002	0.20	0.00	0.011	0.02	0.16
QUIBBA	14	8.15	7.43	11.3	11.3	22.3	10.67	10.4	0.00	3.00	0.022	0.002	0.20	0.00	0.011	0.02	0.16
QUIBBA	14	8.45	7.29	11.2	11.2	22.3	8.76	15.4	0.00	3.00	0.022	0.002	0.20	0.00	0.011	0.02	0.16
QUIBBA	14	9.15	7.15	11.7	11.7	22.4	11.9	11.1	0.00	3.00	0.022	0.002	0.20	0.00	0.011	0.02	0.16
JUAN AMARILLO	15	11.00	8.5	20.5	19.5	61.1	0.02	76	0.02	6.00	0.091	0.015	0.05	0.006	0.141	0.08	0.86
JUAN AMARILLO	15	11.30	8.21	18.4	19.6	69.7	0.35	77	0.02	6.00	0.091	0.015	0.05	0.006	0.141	0.08	0.86
JUAN AMARILLO	15	12.00	7.19	21.2	19.5	69.1	0.67	79	0.02	6.00	0.091	0.015	0.05	0.006	0.141	0.08	0.86
JUAN AMARILLO	15	12.30	7.68	20.3	19.5	70	0.43	80	0.02	6.00	0.091	0.015	0.05	0.006	0.141	0.08	0.86
JUAN AMARILLO	15	13.00	7.29	20.8	20.5	71	0.37	81	0.02	6.00	0.091	0.015	0.05	0.006	0.141	0.08	0.86

RIO	Dureza mg/LCaCO3	SO4 mg/L	S- µg/L	NO3 mg/L	Mo mg/L	NH4	Fenol mg/L	NO2 mg/L
BOGOTA CIERRE	0.00	33	510	9.0	0.16	60.19	0.073	0.021
BOGOTA CIERRE	0.01	33	510	9.1	0.17	60.20	0.073	0.021
BOGOTA CIERRE	0.02	33	510	9.2	0.18	60.21	0.073	0.021
BOGOTA CIERRE	0.03	33	510	9.3	0.19	60.22	0.073	0.021
BOGOTA CIERRE	0.04	33	510	9.4	0.20	60.23	0.073	0.021
BOGOTA CORTIJO	15.01	21	120	2.4	0.00	14.28	0.016	0.027
BOGOTA CORTIJO	15.02	21	120	2.5	0.01	14.29	0.016	0.027
BOGOTA CORTIJO	15.03	21	120	2.6	0.02	14.30	0.016	0.027
BOGOTA CORTIJO	15.04	21	120	2.7	0.03	14.31	0.016	0.027
BOGOTA CORTIJO	15.05	21	120	2.8	0.04	14.32	0.016	0.027
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	4.17	30	400	8.8	0.00	96.05	0.092	0.064
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	4.18	30	400	8.9	0.01	96.06	0.092	0.064
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	4.19	30	400	8.10	0.02	96.07	0.092	0.064
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	4.20	30	400	8.11	0.03	96.08	0.092	0.064
BOGOTA DESPUES DE LA DESCARGA PTE METALICO	4.21	30	400	8.12	0.04	96.09	0.092	0.064
BOGOTA LISBOA	9.79	7	9	0.3	0.00	1.01	0.004	0.012
BOGOTA LISBOA	9.80	7	9	0.3	0.00	1.02	0.004	0.012
BOGOTA LISBOA	9.81	7	9	0.3	0.00	1.03	0.004	0.012
BOGOTA LISBOA	9.82	7	9	0.3	0.00	1.04	0.004	0.012
BOGOTA LISBOA	9.83	7	9	0.3	0.00	1.05	0.004	0.012
BOGOTA PTE CUNDINAMARCA	11.52	25	202	3.4	0.00	24.19	0.020	0.067
BOGOTA PTE CUNDINAMARCA	11.53	25	202	3.5	0.01	24.20	0.020	0.067
BOGOTA PTE CUNDINAMARCA	11.54	25	202	3.6	0.02	24.21	0.020	0.067
BOGOTA PTE CUNDINAMARCA	11.55	25	202	3.7	0.03	24.22	0.020	0.067
BOGOTA PTE CUNDINAMARCA	11.56	25	202	3.8	0.04	24.23	0.020	0.067
BOGOTA PTE LA VIRGEN	11.29	7	20	1.6	0.01	4.80	0.006	0.064
BOGOTA PTE LA VIRGEN	11.30	7	20	1.7	0.02	4.81	0.006	0.064
BOGOTA PTE LA VIRGEN	11.31	7	20	1.8	0.03	4.82	0.006	0.064
BOGOTA PTE LA VIRGEN	11.32	7	20	1.9	0.04	4.83	0.006	0.064
BOGOTA PTE LA VIRGEN	11.33	7	20	1.10	0.05	4.84	0.006	0.064
BOGOTA SAN BERNARDINO	9.3	27	258	6.1	0.00	18.49	0.087	0.144
BOGOTA SAN BERNARDINO	9.4	27	258	6.2	0.01	18.50	0.087	0.144
BOGOTA SAN BERNARDINO	9.5	27	258	6.3	0.02	18.51	0.087	0.144
BOGOTA SAN BERNARDINO	9.6	27	258	6.4	0.03	18.52	0.087	0.144
BOGOTA SAN BERNARDINO	9.7	27	258	6.5	0.04	18.53	0.087	0.144
BOGOTA TIBITOC	10.85	0	23	1.1	0.01	0.40	0.002	0.076
BOGOTA TIBITOC	10.86	0	23	1.2	0.01	0.40	0.002	0.076
BOGOTA TIBITOC	10.87	0	23	1.3	0.01	0.40	0.002	0.076
BOGOTA TIBITOC	10.88	0	23	1.4	0.01	0.40	0.002	0.076
BOGOTA TIBITOC	10.89	0	23	1.5	0.01	0.40	0.002	0.076
FUCHA CON ALAMEDA	7.85	45	680	69.5	0.00	56.99	0.114	0.136
FUCHA CON ALAMEDA	7.86	45	680	69.6	0.01	56.99	0.114	0.136
FUCHA CON ALAMEDA	7.87	45	680	69.7	0.02	56.99	0.114	0.136
FUCHA CON ALAMEDA	7.88	45	680	69.8	0.03	56.99	0.114	0.136
FUCHA CON ALAMEDA	7.89	45	680	69.9	0.04	56.99	0.114	0.136

RIO	Dureza mg/LCaCO3	SO4 mg/L	S- µg/L	NO3 mg/L	Mo mg/L	NH4	Fenol mg/L	NO2 mg/L
TUNJUELO 100m ABAJO DE YOMASA	1.88	10	352	8.6	0.29	22.83	0.040	0.224
TUNJUELO 100m ABAJO DE YOMASA	1.88	10	352	8.6	0.29	22.83	0.040	0.224
TUNJUELO 100m ABAJO DE YOMASA	1.88	10	352	8.6	0.29	22.83	0.040	0.224
TUNJUELO 100m ABAJO DE YOMASA	1.88	10	352	8.6	0.29	22.83	0.040	0.224
TUNJUELO 100m ABAJO DE YOMASA	1.88	10	352	8.6	0.29	22.83	0.040	0.224
TUNJUELO SAN BENITO	9.3	32	138	3.9	0.00	9.75	0.032	0.005
TUNJUELO SAN BENITO	9.3	32	138	3.9	0.00	9.75	0.032	0.005
TUNJUELO SAN BENITO	9.3	32	138	3.9	0.00	9.75	0.032	0.005
TUNJUELO SAN BENITO	9.3	32	138	3.9	0.00	9.75	0.032	0.005
TUNJUELO SAN BENITO	9.3	32	138	3.9	0.00	9.75	0.032	0.005
TUNJUELO USME	11.8	10	85	2.4	0.00	9.74	0.085	0.006
TUNJUELO USME	11.8	10	85	2.4	0.00	9.74	0.085	0.006
TUNJUELO USME	11.8	10	85	2.4	0.00	9.74	0.085	0.006
TUNJUELO USME	11.8	10	85	2.4	0.00	9.74	0.085	0.006
TUNJUELO USME	11.8	10	85	2.4	0.00	9.74	0.085	0.006
TUNJUELO ISLA PONTON SAN JOSE	7.48	69	941	15.3	0.00	42.38	0.137	0.146
TUNJUELO ISLA PONTON SAN JOSE	7.48	69	941	15.3	0.00	42.38	0.137	0.146
TUNJUELO ISLA PONTON SAN JOSE	7.48	69	941	15.3	0.00	42.38	0.137	0.146
TUNJUELO ISLA PONTON SAN JOSE	7.48	69	941	15.3	0.00	42.38	0.137	0.146
TUNJUELO ISLA PONTON SAN JOSE	7.48	69	941	15.3	0.00	42.38	0.137	0.146
QUIBBA	8.29	0	19	1.3	0.00	0.00	0.002	0.001
QUIBBA	8.29	0	19	1.3	0.00	0.00	0.002	0.001
QUIBBA	8.29	0	19	1.3	0.00	0.00	0.002	0.001
QUIBBA	8.29	0	19	1.3	0.00	0.00	0.002	0.001
QUIBBA	8.29	0	19	1.3	0.00	0.00	0.002	0.001
JUAN AMARILLO	0.00	25	266	11.0	0.00	41.96	0.064	0.226
JUAN AMARILLO	0.00	25	266	11.0	0.00	41.96	0.064	0.226
JUAN AMARILLO	0.00	25	266	11.0	0.00	41.96	0.064	0.226
JUAN AMARILLO	0.00	25	266	11.0	0.00	41.96	0.064	0.226
JUAN AMARILLO	0.00	25	266	11.0	0.00	41.96	0.064	0.226

2. 3. Considerations

(1) Rivers

Supplemental water quality results were confirmed as being essentially identical to those obtained by ACUECTO testing. In the case of the Bogota river, Cr+6 (hexavalent chromium) has been detected around Tibitoc due to inflow of tannery effluents. Other items are generally satisfactory. Cr+6 is not detected upstream of urban area. Although some items are slightly above standards for wastewater, actual overall river discharge pollution is at a satisfactory level. Nevertheless, water quality degrades dramatically as river discharge passes through urban area. For example, although turbidity value is 6~50 upstream of urban area, this value rises to 200 by the time river discharge has traversed urban area. Dissolved oxygen (OD) value is zero due to the fact that wastewater is released untreated into rivers from Bogota urban area. The Juan Amarillo river flows through the northern part of Bogota urban area (residential district) and exhibits a high turbidity value of 50. Nevertheless, the presence of other contaminants is within standard values for wastewater. The Tujuelo river on the other hand flows through the southernmost part of urban area and exhibits turbidity values of 200 in its middle reaches. This zone has a heavy presence of industrial establishments including tanneries, metal processing plants and food processing plants. Cr+6 values are a high 0.1~0.3 mg/ℓ. NH_4 values are also high; and this is attributed to the anaerobic characteristic of river sedimentation.

(2) Wells

A large number of the wells exceeds the standard value for the items of Fe, Mn and NH_4 throughout the Study area. For Fe, although 0.5 mg/ℓ is set as the water standard, almost all sampled wells in the Study area exhibited a value of 1~10. For Mn, 0.15 mg/ℓ is set as water standard, several wells exhibited a value of 0.05～0.3 mg/ℓ. It is clear the Fe and Mn content area a result of the geology of the area. By the comparison of geographical condition, the water quality of Mn in the Quaternary is much larger value exhibited than that in the Cretaceous.

Evenif groundwater quality in the tributary upstream areas (Cretaceous layer) exhibits a high concentration of Fe and Mn, overall, water quality is good.

Methods for treating this are oxidation, oxidation-reduction, or absorption. Specific method to be applied will be studied in more detail at the feasibility study stage.

Other hand NH_4 value is high, but this is not considered due to river pollution. Surface water permeation is not on a scale commensurate with the amount of sulfur (hydrogen sulfide) exhibited by groundwater samples. Furthermore, sulfur content is detected in locations located at considerable distance from sources of river contamination. In general, there are almost no specific guidelines or standards for potable water and this item must be studied in the future. Also, Ba (barium) has been detected in high concentrations throughout the Study area. Barium content has been categorized as an item requiring further study in light of the fact that toxicity evaluation standards have not been established, as well as the fact that the existing content within treated water remains unclear.

Cr+6 has been detected from wells in the vicinity of the Tunjuelo river, indicating that contamination from river discharge has permeated into groundwater aquifer.

PART 12

FACILITIES FOR SEWAGE SYSTEMS

Final Report

(Supporting Report)

PART 12 FACILITIES FOR SEWAGE SYSTEMS

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PART 12 FACILITIES FOR SEWAGE SYSTEMS

CHAPTER 1. Facilities for Sewage Drainage and Treatment

1.1 Summary

In the case of the Bogota river basin which is the target area under the Study, wastewater treatment for urban area as stipulated under the Urban Maintenance Project (POT) falls within the jurisdiction of ACUEDUCTO. Remaining area is under the jurisdiction of the Autonomous Regional Corporation of Cundinamarca (Corporación Autonoma Regional de Cundinamarca – CAR). Between ACUEDUCTO and CAR, there is not mutual cooperation system as the public sewerage. The sewage service coverage in Bogota urban area is 85%~90%. However, the definition of sewage service coverage rate in Colombia is the number of persons availing of sewage service divided by the total population of the area. In other words, this is equivalent to the wastewater collection rate for sewers. Nevertheless, not all collected sewage is subsequently treated. Main sewage pipeline and wastewater treatment facilities exist only within the Salitre system. The Salitre Station of Sewage Treatment Plant (Salitre WWTP), the only sewage treatment station in the area of the city of Bogotá, was built with an investment made by DAMA and its management was consigned to ACUEDUCTO.

DAMA is responsible for the maintenance control costs, and ACUEDUCTO is responsible for operation, administration and maintenance of the Salitre Waste Water Treatment Plant (WWTP). It is decided that CAR bears expansion of a Salitre WWTP and a construction of a Canoa WWTP as a future plan.

In addition, ACUEDUCTO performs the sewage maintenance of the urban area of Bogotá (sewage piping grid, sewage trunk line) using its own funds (derived from the collection of taxes for water and sewage) and it invests on equipment, operation and maintenance.

On the other hand, CAR has built and managed small-scale sewage treatment stations at 2 locations using its own funds and at 27 locations using the funds of the Interamerican Development Bank (IDB), distributed over 24 of the main municipalities.

However, in relation to the rural areas that are managed by CAR, the sewage treatment is carried out on onsite (septic well, septic tank and outhouses).

By taking into consideration the population density, the installation of a sewage service would not be feasible in terms of cost but since the largest part of the sewage is being treated in unsuitable septic tanks, we believe that this is leading to the contamination of the rivers and the groundwater.

1.2 Actual Situation of Sewage System in the urban area of Bogotá.

The sewer spread rate (tasa de servicio de alcantarillado) in a urban area of Bogotá is called 85%～90%. The sewage maintenance service in the urban area of Bogotá is being adequately performed but the definition of the index of penetration of the sewage (tasa de servicio de alcantarillado) should be the “population that is benefited by the sewage/population”, which means that it relates to a sewage collection index and this does not mean that all the collected sewage is being treated. The most collection sewage water is discharged into a river as non-treated directly. The main trunk and the treatment station are only ready in the Salitre System. However the Salitre WWPT system is only primary processing , the BOD removal rate of it is around 40%.

Although sewage pipelines are under construction within other delineated treatment sectors, sewage at present runs untreated into tributaries of the Bogota River. Even in the case of the Salitre treatment plant, BOD elimination rate is around 40%.

Figure -12.1 indicate the situation of the sewage system in the urban area of Bogotá.

The following three main tributaries within the Bogota urban area as well as the Soacha area are under the sewage treatment jurisdiction of ACUEDUCTO. Specifically, the Soacha area was transferred to ACUEDUCTO control in 2005 and ACUEDUCTO has subsequently not yet completed a sewage pipe

inventory.

(a) Salitre System
(b) Fucha System
(c) Tunjuelo System
(d) Soacha System

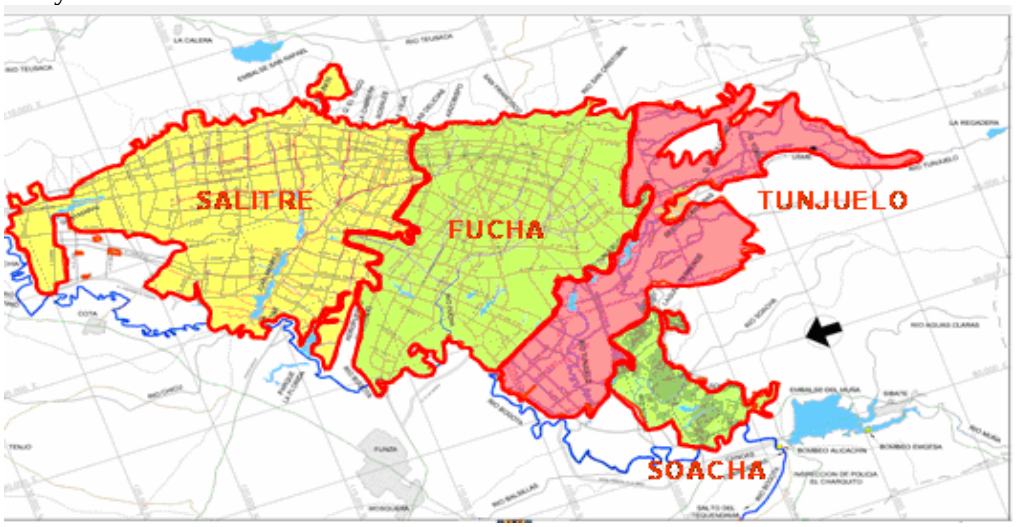


Figure-12. 1 The sewage system in the urban area of Bogotá

Table -12.1 and Table -12.2 indicate the projected target population and sewage volume within the respective wastewater treatment sectors.

Table-12. 1 Projected population

Treatment sector	2000	2005	2010	2015	2020	Saturation value
Salitre	2,038,102	2,246,180	2,490.869	2,800,546	3,171,965	3,306,934
Fucha	2,287,190	2,611,238	2,767,524	2,933,240	3,153,876	3,496,275
Tunjuelo	2,117,618	2,448,870	2,775,736	3,047,517	3,298,957	3,422,820
Soacha	353,026	434.528	506,890	568,670	617,775	793,255
Total	6,795,936	7,740,816	8,541,019	9,349,973	10,242,572	11,019,284

Unit: persons

Table-12. 2 Average sewage volume

Treatment sector	2000	2005	2010	2015	2020	Saturation value
Salitre	5.9	6.4	7.1	7.8	8.5	10.8
Fucha	7.5	8.3	9.0	9.5	9.9	10.7
Tunjuelo + Soacha	5.7	6.4	7.2	7.8	8.2	8.3
Total	19.1	21.1	23.3	25.1	26.6	29.8

Source: ACUEDUCTO, Aspetos Técnicos Análisis del Saneamiento del Río Bogotá, May 2006. Unit: m^3/sec

Sewage systems are basically separate. Because existing sub-main sewage pipelines are combined sewer systems, rainwater gets mixed in with sewage. As a result, system design is such that in cases where discharge increases during periods of rain, discharge is subsequently diverted to rivers or regulating ponds by means of overflow facilities constructed along the sewage pipeline (intercepting sewer). Numerous instances of problems as a result of pipe connection method have be confirmed, including cases where sewage collector pipes are connected to rain drainage pipes and vice versa. Table–12.3 shows the actual states of collection pipe.

Table-12. 3 Actual states of Collection pipe

Treatment sector	Sewage collector pipes are connected to Rain drainage	Rain drainage are connected to sewage collector pipes
Salitre	37%	42.5%
Fucha	22.4%	56%
Tunjuelo	15.2%	90%

CHAPTER 2. SALITRE WASTEWATER TREATMENT PLANT

The Salitre wastewater treatment plant (WWTP) is the only one in the Bogota city area. The Bogota D.C. (SDA) holds the ownership rights for the treatment plant. The SDA has subsequently consigned responsibility for operation, administration and maintenance of the plant to ACUEDUCTO. A general description of the Salitre WWPT is given below.

- Served population: 2.1 million
- Treatment method: First degree primary treatment (through chemically induced precipitation and basin sedimentation)
- Treatment capacity: 4m³/s on average; maximum of 9.94 m³/s
- Treatment efficiency: 40% BOD (biochemical oxygen demand) elimination (220 ㎎/l → 130 ㎎/l); TTS (total soluble solids) elimination of 60% (150 ㎎/l → 60 ㎎/l)
- Sludge treatment: 135 tons/day by anaerobic treatment
- Biogas production: 15,000 m³/day

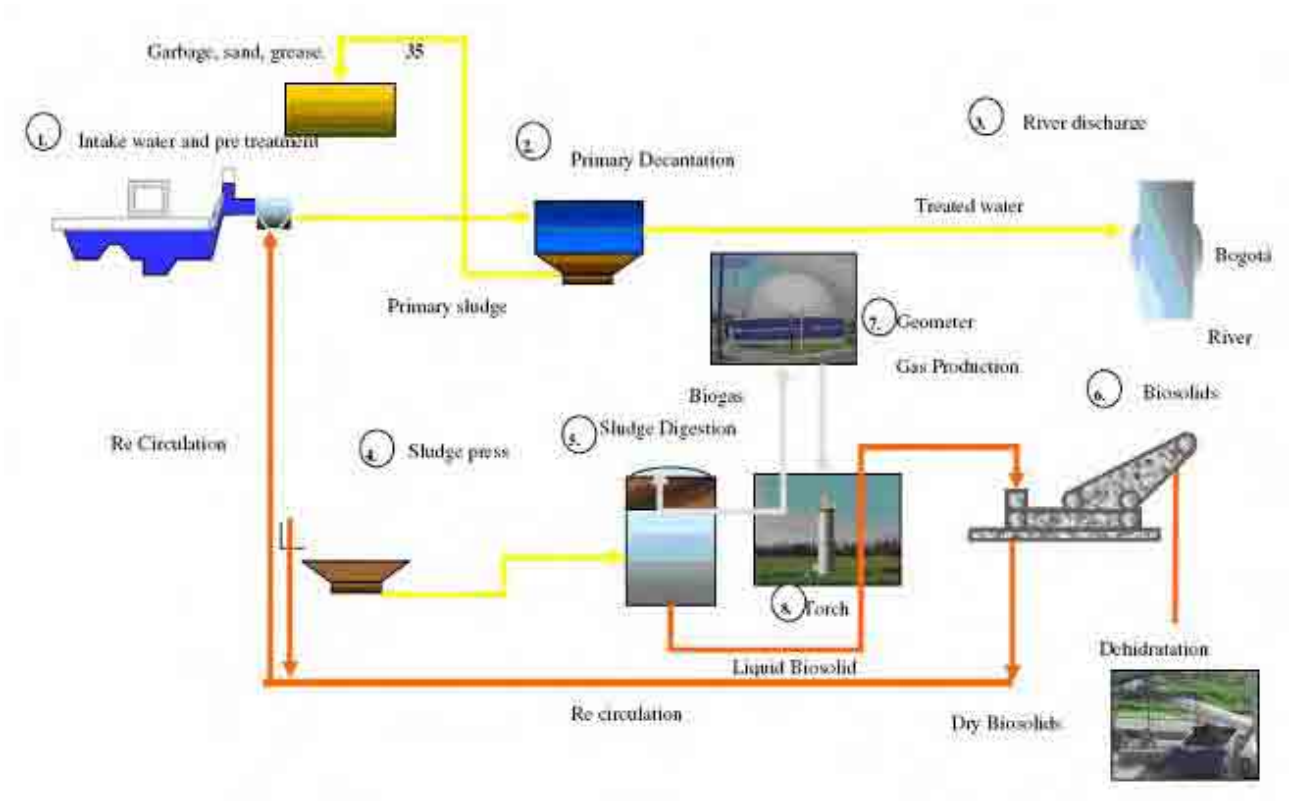
The Salitre Sewage Treatment Station operates twenty-four hours a day; its operational system is divided into three shifts with sixty-five employees. The monthly operational and maintenance cost is COL Peso $1,200 million (around US$ 600,000 per month). This amount is paid to ACUEDUCTO by SDA.

An expense breakdown is as follows：

Operation Cost : 70% (Chemical 63%, Transportation and Disposal 22%, Electricity, fuel 14%, Labor and Water analysis1%), Administration Cost : 25% (Personnel expenses 54%, Articles of consumption 25%, Insurance 11%, Tax 0%), Maintenance: 4%

Source: ACUEDUCTO

Figure-12. 2 Overview of the WWTP Salitre



Source: ACUEDUCTO

Figure-12. 3 El Salitre WWTP

The following problems of the Salitre System are already known by ACUEDUCTO

- Inability to control the water collection volume when it rains
- Inability to collect all the sewage during periods of the dry season
- Significant mix of soil and sand due to the Intake structure and slowness velocity
- Low capacity of IRB and Tibabuyes Interceptors, and this continues to be an issue to be seen to in the future.

The following factors are considered to be the causes of the problems pointed out:

- The sewage collection pipelines are connected to the rainwater and the rainwater pipelines are connected to the sewage collection pipelines
- Lack of capacity of the Intake pumps of WWTP, besides the fact that they are placed too high and this hinders the collection of sewage in times of the dry season.
- During the rainy season, the level of the water in the Bogotá River rises, which pressures the level of the water of the Salitre River hindering the outflow of the sewage.

The main sewage trunk has already been concluded and is now an open water circuit of approximately 800m alongside the Intake point of the Salitre WWTP.

The main trunk branches into 4 lines, the first line (tramo 1) and the second line (tramo 2) is mainly combination system pipelines. During the rainy season when the volume increases, the water volume to be collected is controlled through its outflow

CHAPTER 3. ONGOING AND FUTURE SEWAGE INFRASTRUCTURE PROJECTS

In order to upgrade measures to cope with sewage from the Bogota metropolitan area, ACUEDUCTO is either currently executing, or planning for the future, the projects described below. Figure-12.4 gives an overview of the target area, and Table-12.4 gives an overview of projects as well as implementation status.

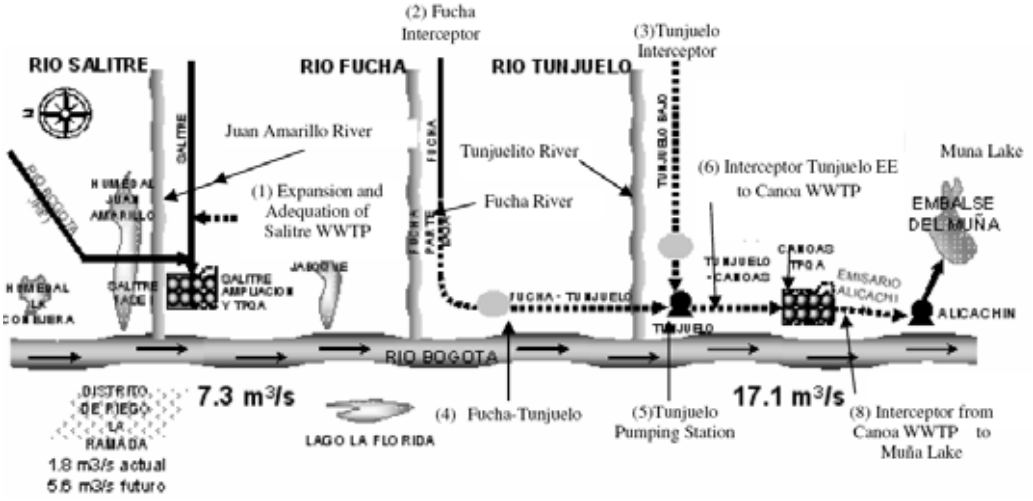


Figure-12. 4 Overview of sewage infrastructure projects

Table-12. 4 Overview of sewage infrastructure projects and status of progress

No.	Facilities	Project overview	Estimated construction cost (million US $)	Progress
(1)	Expansion of Salitre treatment plant	(1) Facility expansion from current primary treatment capacity of 4 m³/s to 8 m³/s. (2) Construction of secondary treatment facilities with a capacity of 8 m³/s.	200 CAR funding	Construction scheduled for 2008~2010. Design and construction combined under a single turnkey contract. Owner of the existing facility is SDA; construction funding is to be provided by CAR. Facility is operated by ACUEDUCTO. Institutional agreement among the concerned agencies has not yet been finalized.
(2)	Fucha interceptor	Sewage main line construction to connect collector pipeline to the Fucha sector.	ACUEDUCTO funding	Completed
(3)	Tunjuelo interceptor	Sewage mainline construction to connect a collector pipeline to the Tunjuelo sector.	ACUEDUCTO funding	There are four sectors: of which the upstream 1st and 2nd sectors are completed. The 4th sector down river is currently under construction and construction for the 3rd sector is scheduled for completion in 2008~2009.
(4)	Fucha-Tunjuelo interceptor	Connects the Fucha sewage system with Tunjuelo pump station.	70 ACUEDUCTO funding	Construction scheduled for early 2007 to 2009 (33 months).
(5)	Tunjuelo pump station	Sewage from the Fucha and Tunjuelo sectors is conveyed to the Canoa WWTP. Capacity: 17.1 m³/s.	90 ACUEDUCTO funding	Bidding procedures in 2007. Construction start at the end of 2007; completion planned in 2011.
(6)	Tunjuelo interceptor	Conveyance pipe from Tunjuelo pumping station to Canoa WWTP.	100 ACUEDUCTO funding	Preparatory works for bidding in 2007. Basic design completed in fiscal 2007. Tendering in 2008. Contract is to include both detailed design and construction.
(7)	Canoa WWTP	(1) Primary treatment facilities: 18 m³/s capacity. (2) Secondary treatment facilities: 18 m³/s capacity.	(1)350 (2)350 CAR funding planned	CAR project. Basic design scheduled for completion in 2007. Construction scheduled for 2009~2014. However, funding source has not yet been finalized.
(8)	Canoa pumping station (conveyance from Canoa WWTP to Muña lake)	A pump station is to be constructed at the treatment plant, and discharge for hydropower generation is to be diverted to Muña lake.	50 CAR funding	CAR project. Muña lake environment restoration plan has been drafted.

Source: ACUEDUCTO presentation, 2007

CHAPTER 4. SEWAGE SERVICE SUPPLY SITUATION IN AREAS OUTSIDE THE CITY OF BOGOTÁ

In the outskirts of Bogotá, CAR directly executes the construction and control of the management and maintenance. CAR performed in 1991, the "CAR-BID Water Improvement Quality Project for the waters of the Bogota plain." This project was executed with funding from the Interamerican Development Bank (IDB) and cost 55.6 million U.S. dollars. In relation to the sewage service supply, 27 small-scale sewage treatment stations were built in 24 municipalities.

The planning of the project, the undertaking and the construction of the premises were carried out by CAR and after the conclusion of the setup, the management and the control of the conservation were handed over to the jurisdiction of each city (municipality). The treatment methods are many since they were not standardized. An average scale of the treatment capacity is about 50ℓ/s. The areas benefited by the sewage service supply are only the urban areas of each municipality and, outside these (farming areas) the treatment is carried out onsite (septic wells and tanks, outhouses, external, etc.)

The following problems, however, were pointed out in the setup situation:

- The area that receives treatment is small.
- The preparation of the pipeline grid for the collection of sewage is delayed.
- The small treatment capacity of the treatment station adds to the problem of low treatment efficiency.
- There are installations whose projects have technical problems.
- Since the management and control of conservation require a considerable amount of money, the municipality will not allow the sewage treatment installations.

Due to these problems and the inability of the municipality to cover the expenses, besides not being able to address the technical aspect, the installations are now practically abandoned.

Therefore, CAR signed an agreement with ESSERE, a privately-owned company, for the management and conservation of the sewage treatment stations in October of 2005. The mature system in the contract is 2 years with the option to renew every year after that. The management company will only be responsible for management and conservation, and the interceptors and setup of the trunks are the responsibility of each municipality. The configurations of the grids are all of the junction kind.

Figure-12.5 indicates the location of the sewage treatment plants.

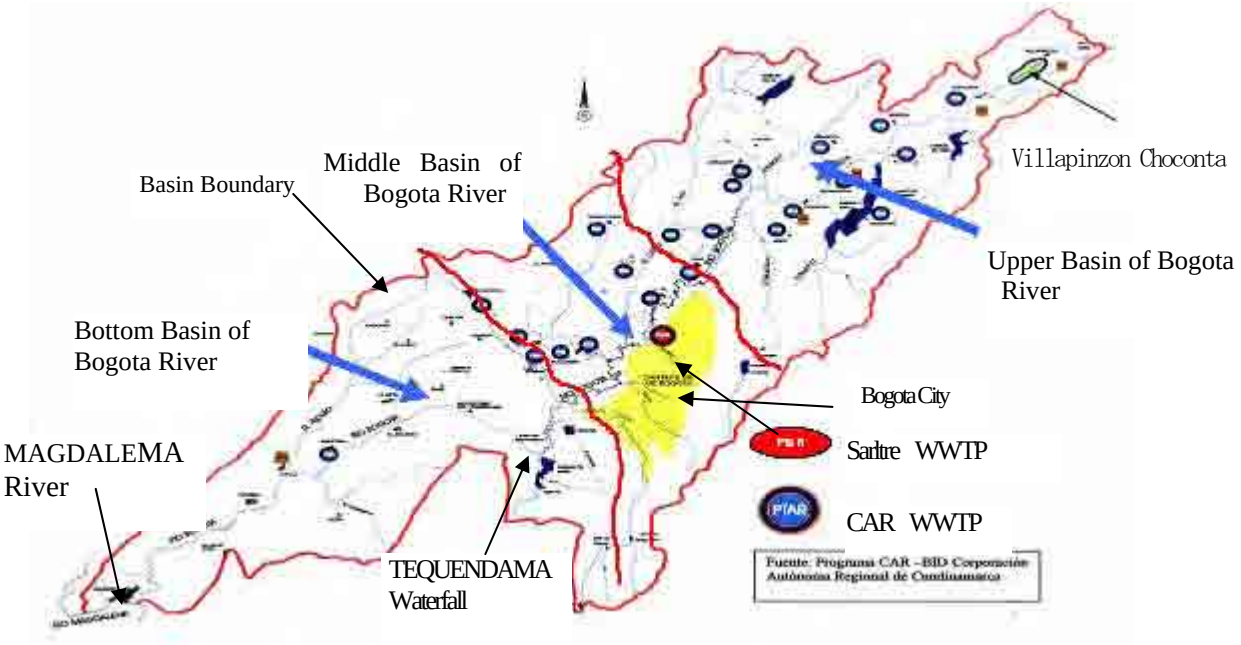


Figure-12. 5 The location of the sewage treatment plants

The Waste Water Treatment Plant of CAR and the current situation are shown in Table -12.5.

Table-12. 5 The Waste Water Treatment Plant of CAR and the current situation

No.	Municipality	Serviced Population	Construction Cost by IDB ≅ mil US$	Treatment system and Capacity (l/s)	Current Situation
1	Anapoima	10,000	5000	Combination of UASB system and Stabilization Pond. Designed treatment capacity : 38 (ℓ/s)、BOD elimination of 85%～90%、Pond Area : 20,000 ㎡	Completed in 1991. It was no management before transferred to the private company. After improvement of the facilities., operation capacity has 12 (ℓ/s)（1/3 of designed capa.）Actual attend population : 6,500. Furthermore on planning improvement of the facilities..
2	Bojaca	———	500	OD system.. Treatment capacity : 8(ℓ/s)	Constructed by CAR, management by municipality. Operation state is good.
3	Cajicá	41,000	500	Stabilization Pond method Designed treatment capacity : 115(ℓ/s) Pond area : 13,000 ㎡	Completed in 1996. Actual operation : 13(ℓ/s). Operation and maintenance state are also not good. An aquatic flora grows thick
4	Chia I	23,500	200	Stabilization Pond system. Designed treatment capacity : 100(ℓ/s) Pond area : 33,000 ㎡	Completed in 1990. Actual operation : 35(ℓ/s). There is a structural problem On planning improvement of the facilities.
5	Chocontá	15,000	1000	Stabilization Pond system. Designed treatment capacity : 18 (ℓ/s)	Completed in 1997. Actual operation : 136 (ℓ/s). DBO elimination of 110→37 ㎎/ℓ) 68%. There is a channel design problem.
6	Cogua	6,100	700	Stabilization Pond system. Designed treatment capa. : 17.5(ℓ/s)	Actual operation : 16(ℓ/s). Operation state is good.
7	Cota	4,500	160	OD system. Designed treatment capa. : 5(ℓ/s)	Completed in 1981, before CAR-IDB program. Management by Municipality. Acutual operation : 5(ℓ/s). BOD elimination of 80%
8	El Rosal	--------	450	OD system. Designed treatment capa. : 26.4(ℓ/s)	Actual operation : 18.5(ℓ/s)
9	Facatativá	120,000	7000	OD system. Designed treatment capa. : 560 (ℓ/s)、	Completed in 1997. On construction of improvement of the facilities. Actual attending population : l61,600. actual operation : 359(ℓ/s). DBO elimination of 65%
10	Funza	122,000	8500	OD system. 6 channels Designed treatment capa. : 240(ℓ/s)	Completed in 1997. Aeration efficiency is not good. On construction improvement of the facilities. Actual attending population : 23,900. Actual operation : 60(ℓ/s), DBO elimination of 90-95%
11	Gachancipá	5,000	500	Stabilization Pond system. Designed treatment capa. : 20(ℓ/s) Pond area : 36,000 ㎡	Actual attending population : 2,300. Actual operation : 6(ℓ/s) BOD elimination of 70%. Operation state is good.
12	Guatativa	6,000	400	OD system Designed treatment capa. : 8 (ℓ/s)	Complete operation. There is no problem. BOD elimination of 95%. Operation cost is high.
13	La Calera	2,100	2200	SBR system. Designed treatment capa. :	Actual operation : 24(ℓ/s). Operation state is good.

				32(ℓ/s)	
14	Madrid I	25,000	1900	Stabilization Pond system. Designed treatment capa. : 50(ℓ/s)	Completed in 1998. Actual operation : 25(ℓ/s). BDO elimination of 86% On improvement construction. Be completed in 2008. Operation state is good.
15	Madrid II	25,000	1300	Idem	Idem
16	Mosquera	――	4000	Stabilization Pond system. Designed treatment capa. : 120(ℓ/s)、	Completed in 1997. Actual operation : 50(ℓ/s). BOD elimination of 80%
17	Nemocon	7,500	850	OD system. Designed treatment capa. : 12(ℓ/s)	――――
18	Sesquilé	1,400	400	Sedimentation pond. Designed treatment capa. : 5.8(ℓ/s) Pond area : 10,000 ㎡	Actual operation : 5(ℓ/s)
19	Sopó	7,000	550	Stabilization Pond system. Designed treatment capa. : 20(ℓ/s)	Actual attending population : 5,400. Actual operation : 8(ℓ/s), BOD elimination of 75%
20	Subachoque	4,200	350	Stabilization Pond system. Designed treatment capa. : 14.6(ℓ/s)	Completed in 1996. Actual operation : 7(ℓ/s). BOD elimination of 76%
21	Suesca	8,000	500	Sedimentation pond.（SS elimination）、Designed treatment capa. : 18(ℓ/s)	Actual attending population : 1,500. Actualoperation : 6 (ℓ/s) Operating 1 pond of 2. No maintenance state. Algae grows thick.
22	Tabio	8,000	500	Sedimentation pond. Designed treatment capa. : 17(ℓ/s)	Financed by CAR-IDBprogram
23	Tenjo	5,900	800	RAP（Anaerobic Reactor a Piston） Designed treatment capa. : 12.7(ℓ/s)	Completed in 1990. Actual operation : 8(ℓ/s)
24	Tocancipá	5,300	1200	Stabilization Pond system. Designed treatment capa. : 26(ℓ/s) Pond area : 16,700 ㎡	Completed in 1991 Financed by CAR-IDBprogram. Actual atending population : 3,600. Actual operation : 10(ℓ/s)
25	Zipaquira I	39,500	650	Stabilization Pond system. Designed treatment capa. : 132(ℓ/s) Pond area : 66,500 ㎡	Completed in 1991. Financed by CAR-IDB program. Actual operation : 44(ℓ/s). A rate of operation is not good
26	Zipaquira II	50,000	700	Stabilization Pond system. Designed treatment capa. : 200(ℓ/s) Pond area : 67,700 ㎡	Completed in 1992. Actual operation : 29(ℓ/s) A rate of operation is not good.
27	Ubaté	18,000		RAP（Anaerobic Reactor a Piston） Designed treatment capa. : 60(ℓ/s)	Completed in1997. Actual operation : 40(ℓ/s)
28	Cucunbá	900		Stabilization Pond system. Designed treatment capa. : 2(ℓ/s)	Completed in 1990. Actual operation : 2(ℓ/s)
29	Saboyá	700		Stabilization Pond system. Designed treatment capa. : 4(ℓ/s)	
30	San Miguel de Sema	400		Stabilization Pond system. Designed treatment capa. : 1(ℓ/s)	BOD elimination of 76%
31	Lenguazaque	1,200		Activated sludge method. Facility area : 120 ㎡ Designed treatment capa. : 2.5(ℓ/s)	BOD elimination of 98%
Total					

Most of WWTP facilities were built by the middle in 1990. However, Operation rate is not satisfactory, it depends on low sewage collection network to WWPT, and luck of a maintenance management, because a construction of sewage collection water pipe and sewage main line are burdens of each municipality.

An important aspect is that the industrial waste of the area of Villapinzon alongside the Bogotá River is being disposed of untreated into the Bogotá River.

IDB financed a new loan to CAR in October, 2006 as a Improvement of water quality of Bogota river. In this project, the improvement of the WWTPs which built in the first CAR-IDB program is included.

PART 13

ENVIRONMENTAL AND SOCIAL STUDY

Final Report

(Supporting Report)

PART 13 ENVIRONMENTAL AND SOCIAL STUDY

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PART 13 ENVIRONMENTAL AND SOCIAL STUDY

Table-13.1 Current Environmental and Social Conditions in and the Project sites

Region				No.	Location Conditions	Environmental and Social Consideration Requirements
astern Project Eastern Project	Bogota City	San Cristobal	Vitelma	E-1	Vitelma distribution reservoir. A well already exists and is owned by ACUEDUCTO. Treatment facilities required.	Owned by ACUEDUCTO. An area suitable to locate a decontamination facility exists. Residents do not reside near to the site, therefore environmental and social considerations minimized.
				VI-1	The area covers from the Vitelma distribution reservoir to the southeast (mountainside) forest area. Many old unpaved roads exist. The entire project area owned by ACUEDUCTO. The project area includes "Ranger house". Deforestation not required. Electricity available. The existing roads are suitable for transporting well drilling equipment. However, along the roadside area construction space is inadequate.	All the project areas are owned by ACUEDUCTO. Procurement of land is therefore not required. However, the areas are located within a Forest Protection Area, and therefore an environmental permit will be required. The manager of ACURDUCTO is the sole resident within the entire area. The project areas are roadside or grassland areas around the ranger's residence. Deforestation not required.
				VI-2	Same as above	Same as above
				VI-3	Same as above	Same as above
				VI-4	Same as above	Same as above
				VI-5	Same as above	Same as above
	Bogota City	Santa Fe	Santa Isabel	SI-1	Owned by ACUEDUCTO. Roadside. Access to the area not an issue. However, earthwork required for securing space and conserving the mountain.	The site is owned by ACUEDUCTO, but it is located within a Forest Protection Area and therefore a drilling permit needs to be obtained. The area is generally open field, grasslands, but some trees will need to be cut down.
			Casa Morino	CM-1	The area is near to the intake of the San Diego water purification plant. Roadside. Owned by ACUEDUCTO. Grassland.	Owned by ACUEDUCTO. Located in a Forest Protection Area. A drilling permit required. Deforestation not required.
				CM-2	Located about 150 meters along the eastside (mountainside) of the CM-1 area. Grassland and wooded area. The construction area is adequate and suitable, although access roads are unpaved.	Owned by ACUEDUCTO. Located in a Forest Protection Area. A drilling permit required. Resettlement not required.
				CM-3	Located about 300 meters along the eastside (mountainside) of the CM-1 area. Conditions for equipment transport are not good. The mountain slope is nearly adjacent to the road. Deforestation not required. However, to secure space and conserve the mountain, earthwork is required.	Owned by ACUEDUCTO. Located in a Forest Protection Area. A drilling permit required. Deforestation (secondary forest) and earthwork required for the access road and construction works. Resettlement not required.
			Tank Silencio	TS-1	Located about 50 meters along the eastside (mountainside) of the Silencio distribution reservoir (storage capacity: 30,000 m3) area. Grassland. Unpaved road exists and can be used for access. Construction works space is adequate.	The area is located in the Silencio distribution reservoir. Owned and well maintained by ACUEDUCTO. The project area is located within a Forest Protection Area. A drilling permit required. Resettlement not required. No other environmental and social considerations required.
				TS-2	Same as above	Same as above
				TS-3	Located in the Silencio distribution reservoir (storage capacity: 30,000 m3) area. Located 400 meters south and about 100 meters east (mountainside) from an unpaved road. An access road needs to be constructed. The area is flat grassland. Deforestation not required. Close proximity to the mountain slope.	Same as above
			Rio Arzobispo	RA-1	The opposite side and across the road from a National Park. Located in a Forest Protection Area. The road is rather congested with traffic. The site is along the roadside but there is an insufficient working area. Owned by ACUEDUCTO. "Ranger's house" is located within the area.	Construction in a National Park is not possible. The area is located next to a heavily trafficked road and also close to the mountain slope, and therefore there is little space for construction. Earthwork to secure working space and mountain conservation would be required.
	Bogota City	Chapinero	Paraiso	E-3	The site is located just down from the Paraiso lll distribution reservoir and is owned by ACUEDUCTO. The site is forested, and runs along side the steep slope of the mountain. A paved road runs and leads up to an unpaved road. Legally owned properties of Residences of low-income group in the area. Electricity and gas are available. Each household treats water separately.	The site is within the boundary of the distribution reservoir of ACUEDUCTO. Resettlement not required. Some deforestation required. The area is 2825 meters above sea level and not located in a Forest Protection Area. The site is far from the residential area. It is assumed that construction works will not cause negative impact.

			Rubio	E-4	The site is located near the Pardo Rubio III distribution reservoir (storage capacity: 90 m3). A high-voltage electric transmission line is located near the site. There is a loose gravel road about 100 meters long that feeds off a paved road. The road is usable for construction work access.	Deforestation not required. Some houses are scattered near the site, but resettlement will not be required. All the residences are legally owned. No other environmental and social considerations required. In close proximity to the site, a postmortem facility once existed.
			University Politecnica	UP-1	The site is located within the university campus, concrete paved and used as a parking lot and soccer field.	Owned by the university. Adequate space for construction works cannot be secured. Reexamination required.
			La Vieja Creek	VC-1	A vacant , wide and flat land area. Sufficient space available. Deforestation not required. Resettlement not required. An access road is maintained for operation and maintenance an aqueduct that runs though the area.	Owned by ACUEDUCTO. Located in a Forest Protection Area. A drilling permit required. There is an upper-class residential area near to the site, and therefore noise prevention measures are required to be considered.
				VC-2	Roadside. Deforestation not required. The site abuts alongside a steep mountain stream, but there is sufficient space for construction works.	Same as above
				VC-3	Located within the boundary of ACUEDUCTO. Near to a tunnel used for administrate an aqueduct leading to Chinguaza-Usaquen. The space is wide open. Deforestation not required. Flat grassland. Resettlement not required. An existing well-maintained road for operation and maintenance of the aqueduct can be used to access the area.	Owned by ACUEDUCTO. Located within a Forest Protection Area. A drilling permit required. Construction works and a building area are to be considered so that the operation and maintenance of the aqueduct is not hindered. Residential areas do not exist within the vicinity.
			Rosales Creek	RC-1	Located in front of the Metropolitan Club. Private property. Presently vacant land. Sufficient space for construction works available. Deforestation not required. The site is close to 5th Avenue and lies close to upper-class condominiums.	The area is located within a Forest Protection Area that has been turned into a residential area. Noise prevention and safety needs are to be a consideration when constructing. Deforestation not required.
				RC-2	Private property. About 100 meters from the road. The road is unpaved but can be used for accessing. Vacant land. Sufficient space available for construction and storage. Deforestation not required. A devastated house whose construction has been stopped exists on the site.	Land procurement required. The area is located in a Forest Protection Area. A drilling permit required. Deforestation required. The area is significantly distanced from the residential area, consequently environmental and social considerations not at issue.
				RC-3	Private property. Adjacent to a paved road. Deforestation not required. Sufficient space available, but the site runs alongside the mountainside and requires some earthwork.	Located within a Forest Protection Area. A drilling permit required. No other environmental and social considerations required.
				RC-4	Private property. Sufficient flat space for construction available. One house is standing close to the site. The owner of the house has a cooperative attitude. The project area is grassland, but about 20 trees are to be cleared. Close to a stream.	Located within a Forest Protection Area. A drilling permit required. Only one house is in the area. The owner is cooperative, but noise prevention and safety measures are needed. The road has little traffic.
			Chico	CH-1	Adjacent to the road (Carreteria la Carrela). An access road leading from this road is required. The opposite side of the road runs along a stream. Sufficient space for construction works available.	Private property. Located within a Forest Protection Area. A drilling permit required. Construction of an access road, some deforestation and earthwork required. No resettlement.
				CH-2	Located about 20 meters west from the entrance of the Chico distribution reservoir. Adjacent to a paved road. Sufficient space for construction works available.	Private property. Located within a Forest Protection Area. A drilling permit required. Resettlement not needed. Other social and environmental considerations not required.
				CH-3	Located about 70 meters to the east (mountainside) from the Chico distribution reservoir. An unpaved road for maintenance exists. The road is somewhat suitable for the transport of drilling equipment. The site lies in a gradual slope manner. Deforestation and earthwork are needed for securing construction works space.	Owned by ACUEDUCTO. Located within a Forest Protection Area. A drilling permit required. Deforestation (secondary forest) and earthwork are needed for construction space. Resettlement not required. The area is located within the boundary of distribution reservoir. No apparent problem exists for construction works.
		Usaquen	Escuela de Caballeria (Military)	EC-1	Located within the property of the military school. Sufficient construction works space available. The area is close to Route 7. This road is convenient for carrying equipment. The location is advantageous in terms of emergency water distribution as well. The area also has the best geological condition compared to other sites.	Drilling permit of the military required. Not located in a Forest Protection Area. There is sufficient space for construction works. If these works do not hinder military training, environmental and social considerations not required.
				EC-2	Same as above	Drilling permit of the military required. The project area is located in a Forest Protection Area.
				EC-3	Same as above	Same as EC-1

	Bogota City	Usaquen	Tank Santana	TA-1	The distribution reservoir of ACUEDUCTO had earlier existed within the area. Within property owned by ACUEDUCTO. Adjacent to an upper income residential area and the property of a military school. Access by a paved road is possible. Sufficient construction works space available.	Not located within a Forest Protection Area. Noise prevention and safety measures are needed for the adjacent residential area.
				TA-2	Owned by ACUEDUCTO. Separated by the other area from TA-1. Adjacent to upper class residences. Limited construction works space available.	Same as above
			La Aguadora	E-5	As a pilot project, drilling has started. The project area is located about 300 meters from the Santa Ana distribution reservoir, on flat land (downside) side. Owned by ACUEDUCTO. Close to a well-maintained road that is good for accessing the site. Located in a wooded area. Adjacent to a upper class condominiums.	Owned by ACUEDUCTO. As a pilot operation, drilling has started. Not located within a Forest Protection Area. A drilling permit has been obtained from SDA. Deforestation was undertaken in an area of 15m x 30m. Earthwork and drilling to the depth of about 1 meter has also been carried out. No effect on the locate traffic. Construction is carried out during the daytime. Complaints from the residences have not been reported. Waste dump from drilling is treated by a mud pit. The waste dump from drilling treatment standard of IDEAM is being fulfilled.
				E-6	Located beside the Entrance house of Santa Anna Reservoir. Near to a middle and upper class residential area and towards the mountainside. There are no houses in the area. Construction works is planned to be close to the paved road. Deforestation of secondary forest is required.	Owned by ACUEDUCTO. Sufficient space available. Because of the site is near the residential area, the safety measures and noise and vibration measures during construction are to be carefully planned.
			Bosque Medina	E-7	Located within Bogotá city. Along Route 7, the main street leads to the central part of the city from a residential area. Very congested traffic. A concrete plant had earlier stood in the area; however, the area is now a vacant land. A guard is stationed there. High-rise office buildings and up-scale condominiums are neighboring the area. This location is the central area of the northern regional development zone.	The project area is privately owned. Presently a construction plan for a new building, etc. has not been filed, but it is assumed that in the future a building will be constructed on the site. In the immediate vicinity four large-scale buildings are under construction. Considering the construction of these buildings, the noise and vibration caused by drilling is not an issue.
			Boeque de Pinos	E-8	Within the property exists a nursing school (Colegio Pureza de Maria). Located along Route 7. The project area is well maintained and located in a vacant land, behind a soccer field. Adjacent to an upper-class residential area.	The nursing school owns the site. The agreement on land procurement or a lease agreement is required The availability of electricity and road access is not an issue, but safety measures and the prevention of noise and vibration for students in class, and the treatment of waste dumps from drilling are to be carefully planned.
				E-9	A graveled road about 100 meters in length leads to the area from Route 7. Used as a building materials yard. The area is about 1,000 m2. The mountain, on the backside of the area, was formerly a rock quarry, while steep cliffs are also close by. There are no houses at the bottom of mountain.	The site is privately owned. An access road and the availability of electricity is not a problem. The area is about 100 meters from the road and there is only one house near the site. No issues are expected with regards to construction, and the measures to satisfy the residents are easy.
		Usaquen	Cerro Norte	E-10	Along Route 7. Formally a rock quarry. A steep cliff is adjacent to the property. The site is a large empty space. In the vicinity new office buildings and apartments are being built. On the slope of the mountain, residences of low-income group are prevalent.	The project area is privately owned. The agreement on land procurement or a lease agreement is required. It is quite certain that new construction works will occur in the area in the future. On the opposite side of Route 7, low- to mid-income housing is prevalent.
				E-11	The area is located in the same rock quarry as above mentioned.	Same as above
			Soratama	E-12	Along Route 7. The site is used as a yard to store building materials such as gravel. Owned by a company (named Servita) and co-managed by 5 individuals. Next to the site a former rock quarry exist and a steep cliff. The mountain surface is laid bare.	A company owns the site. The agreement on land procurement or a lease agreement is required Resettlement not required. Access and the transport of building materials to the site are possible. Residents do not reside around the area and thus only slight consideration of construction works is required.
			Soratama	E-13	Formally a rock quarry. Located along Route 7. The mountainside of the road is not very steep. On the slope of the mountain, low- to mid-income housing is prevalent.	The site is privately owned. The agreement on land procurement or a lease agreement is required On the opposite side of Route 7 a middle-income house is being built. The road has a lot of traffic.
			La Salle	E-14	The site includes the pilot operation known as La Salle. It is located on a wide, privately owned land facing Route 7. Fifty meters to the east (mountainside) from the entrance the land is owned by ACUEDUCTO, an artesian well (Jumping Well) is already located. Treatment facilities are to be built using this well.	It is assumed that a condominium will be built in this area in the future, but ACUEDUCTO already holds the land around the well. Therefore, land procurement is not needed. Resettlement not required. A well is already drilled. Treatment facilities are to be built on the site. Sufficient space is available. Environmental and social considerations not required.

			Codito	E-15	Vacant land in the middle of a densely built residences area of low-income group. Near to the Condito l distribution reservoir. Private property. Roadside. Grassland. Across the road, houses are also densely built.	Land procurement required. The road has a lot of traffic. A residential area neighbors the site. Social and environmental considerations required, with regards to traffic, noise and vibration, safety measures, and installation of equipment during construction.
				CO-2	Located about 2 kilometers from Route 7 to the east (mountainside). Roadside. The road has a lot of traffic. The project area is on the west side (down side of the mountain) of the road. Maintained, vacant land. About 20 trees with the diameter of 30 cm are planned. Sufficient construction space is available. Low-income housing (from level 2 to 3) along the mountainside exist. The project is located in the middle of Codito distribution reservoir II and III. Under the sidewalk, a distribution pipe network under the ownership of ACUEDUCTO exists.	The project area is privately owned. Surrounded by a wire mesh fence, the site is maintained. Some trees need to be cut. Due to the heavy traffic in the vicinity, consideration for the residents residing in the area is also required. Sufficient space is available at the site and thus construction works do not appear to be an issue.
		Suba	Suba	E-16	Planned as a Pilot Project. A well owned by ACUEDUCTO (Suba Well) already exists. Located in the parking lot of a restaurant.	The well can be used “as is”, but a Treatment facilities (WTP) is required. Sufficient construction space is available. The site is located on the property of a restaurant, and safety measures and noise prevention during construction will be required.
	Bogota City	Suba	Mariscal Sucre	E-17	Planned as a Pilot Project. Locate on the property of a primary, college, and high school of Military. A well already exists, but it is not suitable in its present state. A Treatment facilities (WTP) is needed. Construction access is good. The best location for Pilot Project.	A land usage permit of the school needed. No resettlement. Other social and environmental considerations not required.
			Suba Tank	ST-1	Planned as a Pilot Project. Owned by ACUEDUCTO. Located in the Suba distribution reservoir about 90,000 m3 . Located nearby an administrative building exist. Grassland. Earthwork is slightly needed, but sufficient space is available Adjacent to a heavy-trafficked road, but an access road can be laid to the site.	The site lies within in the property owned by ACUEDUCTO, but adjacent to upper class condominiums. Noise and vibration prevention required.
				ST-2	Same as above. Not planned as a Pilot Project.	No environmental and social considerations required.
				ST-3	Same as above. Not planned as a Pilot Project.	Same as above
	Bogota Rural	Bogota Rural	Bogota Rural	Y-1	Located alongside Route 7. A yard for the storage of concrete pipes with a 3m diameter exists. Sufficient construction space is available, but the site is owned by a privately held company (American Pipe). Located in the vicinity, low-income housing is densely built.	Land procurement or a land lease agreement required. Sufficient construction space is available. Environmental and social considerations not required.
				Y-2	A wooded area. Toward the south side, low-income housing is spread around. The site is located 50 meters to the west from Route 7. The eastside of the road is designated as a Forest Protection Area, but logging has been carried out. Pastureland, after logging, lies on the left side of the area.	The project area is privately owned. Divided with a brick wall, and a maintained pasture. Environmental and social consideration not required except an agreement with the landowner under a land lease agreement.
				Y-3	A wide pasture area neighboring a substation. Located on the west side of Route 7. On the east side there is a suitable site, but designated as a Forest Protection Area. Confirmation required.	Land procurement or a lease agreement required. Environmental and social considerations not required.
				Y-4	Located on the west side of Route 7. Neighboring to a playground (grassland) for war games (paint ball). Insufficient area available. Adjacent to a car garage, horse stable and a restaurant.	Heavily trafficked. The area is too small for construction. The land is privately owned. Land procurement or a lease agreement required.
	Bogota Rural			Y-5	Located on the west side of Route 7. The project site is located within a flat pasture. The opposite side of the road gradually slopes. Residents do not reside in the area.	The land is privately owned. Environmental and social considerations not required.
				Y-6	Located on the west side of Route 7. The project site is within a flat pasture.	The land is privately owned. Environmental and social considerations not required.
				Y-7	Located on the west side of Route 7. The project site is within a flat pasture.	The land is privately owned. There are signs in the area writing “No venta” (No sale), “No arrenda” (No lease) and “No permuta” (No swap). No other environmental and social considerations required.
				Y-8	Located on the west side of Route 7. The project site is located within a flat and wide pasture area.	The land is privately owned. No other social and environmental considerations required.
				Y-9	Located on the west side of Route 7. The project site is located within a flat and wide pasture area. Cattle are pastured. Adjacent to “Casa de Eventos”. Along the east side of the road the mountain is steeply sloped.	The land is privately owned. No other social and environmental considerations required.

				Y-10	Located on the west side of Route 7. Private property. People are living in a hut. Adjacent to a soccer field and BABARIA (a beer factory). In the neighborhood there is a bus station and a school (Colegio Miguel Antonio Caro).	The land is privately owned. Insufficient construction space. Neighboring to commercial buildings and a school. Social consideration during construction required.
				Y-11	Located on the west side of Route 7. The site is a deserted area. Neighboring a maintained pasture. There are signs writing "No venta" (No sale), "No arrenda" (No lease) and "No permuta" (No swap).	The landowner is unknown. Land preparation (earthworks) for construction works required.
				Y-12	Located on the west side of Route 7. The site is a vacant land near the road. Adjacent to a storage house, truck yard, etc.	The land is privately owned, a vacant grassland but not for pasture. There are no residents. No other social and environmental considerations required.
		Additor	Olaya Herrera	OH-1	Located unpaved road. The access is good. However, the distance to the site is long. Located in 10m right under the high-voltage electric transmission line. A site is grassland and no deforestation. The neighboring peace and order are bad.	Located within a Forest Protection Area. The landowner is unknown. A drilling permit required. Also needs a construction permit because of the construction near the high-voltage electric transmission line. No resettlement. No other social considerations required.
	Bogota City	Ciudad Bolivar	Ciudad Bolivar	B-1	Grassland by a stream and an unpaved road.	Little environmental and social consideration during construction needed. The site is not located in a Forest Protection Area, but on privately owned land. the agreement on land procurement or a lease agreement is required
				EX-2	Planned as a Pilot Project. Drilling was completed by JICA. Condition of location is the same as B-1 above.	A well is already drilled. Environmental and social consideration problems did not occur.
				B-2	Same as B-1	Same as B-1
				B-3	Same as above	Same as above
				B-4	Same as above	Same as above
				B-5	Same as above	Same as above
	Soacha	Soacha	Soacha	S-1	Residence area of low-income group. Densely built in the south hill area. However the site is located in the pasture, along the upper side of the city. One person owns this pasture. The densely built low-income houses reach to the vicinity of the project area, but in the pasture area no illegally built houses exist. ACUEDUCTO distributes water to some parts of the Soacha city, but the city holds control of the water supply network. Water is always in short supply.	Minor environmental and social considerations required during construction. The site is privately owned, and the agreement on land procurement or a lease is required
				EX-1	Cancelled. Located in the south hill area same as S-1 to 6. This site is the best local of the Project. Pasture, sufficient space, best hydro geological condition. However no agreement with landowner.	Planned for test well drilling, but due to disagreement with the landowner the activity was cancelled. As in S-1, no other environmental and social considerations required.
				S-2	Same as S-1	Same as S-1
				S-3	Same as above	Same as above
				S-4	The owner is the same as S-1, 2 and 3, above. The project site is located further to the center of the hill. There is no illegally built houses on the property.	Same as above
				S-5	Same as above	Same as above
				S-6	Same as above	Same as above
	Chia	Chia	Chia	Y-13	Located on the west side of Route 7. Adjacent to a restaurant. The project area is within a pasture surrounded by a wire mesh fence.	The land is privately owned. A restaurant is neighboring the site; construction management consideration is required.
				Y-14	Located on the west side of Route 7. The project site is located within grassland. Residents do not reside in the area.	Environmental and social considerations not required.
	Chia			Y-15	Pasture land located close to a tollbooth. Located on the west side of Route 7.	Same as above
				Y-16	Located on the west side of Route 7. Next to a soccer field and grassland. A gradual piedmont area.	A company owns the land. Resettlement not required. An access road near to the site exists. Environmental and social considerations not required.
				Y-17	Located on the west side of Route 7. Roadside. Grassland.	The land is privately owned. Resettlement not required. An access road near to the site exists. Environmental and social considerations not required.
Yerbabuena Project				Y-18	Located on the east side of Route 7, about 300 meters towards the mountainside, at the bottom of a bare rock mountain. From here towards the north, the slope of the mountain area becomes gradually gentle.	Environmental and social considerations not required.
				Y-19	Located on the east side of Route 7, a grassland, about 600 meters from the road. Located within the area designated for agricultural testing by Rasagi university.	The site is located within the property of the university. Safety measures during construction works need to be consider and implemented. No other social and environmental considerations required.

				Y-20	Located on the east side of Route 7. Located within the property of a women's theological university next to Catolica university.	The site is located within the property of the university. Safety measures during construction works need to be consider and implemented. No other social and environmental considerations required.
				Y-21	Located on the east side of a road (freeway). Grassland across a hill. Streamside. Surrounded by walls.	The land is privately owned. Resettlement not required. No other social and environmental considerations required.
	Sopo	Sopo	Sopo	Y-22	Located on the east side of the road (freeway). Within the property of Instituto Caro y Cuerva, behind a soccer field.	Land lease agreement required. The site is located within the institute's property and safety measure during construction need to be considered and implemented.
				Y-23	Located on the east side of the road (freeway). About 500 meters towards the mountainside. A grassland neighboring Colegio Trinidad del Monte.	The land is privately owned. Resettlement not required. No other social and environmental considerations required.
				Y-24	Located about 250 meters to the east from the road (freeway). A pasture.	A company owns the land. Resettlement not required. No other social and environmental considerations required.
Yerbabuena Project Yernabuena				Y-25	Located about 250 meters to the east from the road (freeway). A pasture.	The project area is a pasture. Deforestation not required. A company owns the land. No other social and environmental consideration required.
				Y-26	Located in a crop field, about 200 meters to the east from the road (freeway). In front of a school.	The project site is a crop field. Deforestation not required. The land is privately owned. No other social and environmental considerations required.
				Y-27	Located about 400 meters to the east from the road (freeway). An unpaved road is available for service. The land area is grassland located at the bottom of a mountain. There is a flowing well.	The land is privately owned. No other social and environmental considerations required.
				Y-28	Located about 150 meters to the east from the road (freeway). Access by an unpaved road. Vacant grasslands.	The land is privately owned. No other social and environmental considerations required.
				Y-29	Located about 100 meters to the east from the road (freeway). Roadside. A pasture.	The land is privately owned. No other social and environmental considerations required.