付録 B.　河川流量データ

Table 3.1 : Monthly Flow (m^3/sec)

S. No.	River Name	Location	Catchment Area (km^2)	Month											
				Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	Gundu Khola	Gundu Gaon	4.30	0.07	0.06	0.05	0.05	0.05	0.19	0.68	0.86	0.67	0.30	0.11	0.08
2	Sipadol Khola	Pikhel	2.85	0.05	0.05	0.04	0.03	0.04	0.13	0.50	0.63	0.49	0.22	0.08	0.05
3	Gadgade Khola	Foothill of Deurali Bhanjyang	11.64	0.17	0.15	0.12	0.11	0.13	0.54	1.74	2.17	1.69	0.75	0.32	0.22
4	Sali Nadi	Sankhu	12.50	0.18	0.15	0.13	0.12	0.14	0.58	1.86	2.31	1.81	0.80	0.35	0.23
5	Manohara	Mulpani	62.75	0.83	0.71	0.62	0.61	0.78	2.77	8.50	10.36	7.96	3.53	1.52	1.01
6	Mahadev Khola	Intake Site	6.40	0.10	0.09	0.07	0.06	0.07	0.30	1.01	1.27	1.00	0.44	0.18	0.12

Table 3.2 : Minimum Flow (m^3/sec)

S. No.	River Name	Location	Catchment Area (km^2)	Return Period								
				2 years			10 years			20 years		
				1 day	7 days	Month	1 day	7 days	Month	1 day	7 days	Month
1	Gundu Khola	Gundu Gaon	4.30	0.029	0.034	0.094	-	0.001	0.035	-	-	0.026
2	Sipadol Khola	Pikhel	2.85	0.020	0.024	0.076	-	-	0.025	-	-	0.017
3	Gadgade Khola	Foothill of Deurali Bhanjyang	11.64	0.079	0.089	0.179	0.008	0.019	0.086	0.001	0.009	0.070
4	Sali Nadi	Sankhu	12.50	0.085	0.095	0.188	0.009	0.021	0.092	0.001	0.011	0.075
5	Manohara	Mulpani	62.75	0.453	0.485	0.694	0.202	0.252	0.448	0.144	0.206	0.398
6	Mahadev Khola	Intake Site	6.40	0.040	0.050	0.120	-	0.005	0.031	-	0.001	0.038

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Table 3.6 : Discharge Measurements

Date	Sources																	
	Mahadev Khola			Manohara River			Gadgade Khola			Gundu Khola			Sipadol Khola			Sali Nadi		
	m^3/sec	lps	mld	m^3/sec	lps	mld	m^3/sec	lps	mld	m^3/sec	lps	mld	m^3/sec	lps	mld	m^3/sec	lps	mld
02/10/96	0.377	377	32.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11/10/96	-	-	-	-	-	-	0.660	660	57.02	-	-	-	-	-	-	-	-	-
15/10/96	-	-	-	1.763	1763	152.32	-	-	-	0.084	84	7.26	0.084	84	7.26	-	-	-
28/10/96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.403	403	34.82
02/11/96	-	-	-	-	-	-	0.389	389	33.61	-	-	-	-	-	-	-	-	-
18/11/96	0.133	133	11.49	-	-	-	0.351	351	30.33	-	-	-	-	-	-	-	-	-
19/11/96	-	-	-	0.970	970	83.81	-	-	-	0.042	42	3.63	0.047	47	4.06	-	-	-
23/12/96	0.073	73	6.31	0.595	595	51.41	0.184	184	15.90	-	-	-	-	-	-	-	-	-
22/01/97	0.067	67	5.79	0.713	713	61.60	0.143	143	12.36	-	-	-	-	-	-	-	-	-
23/02/97	-	-	-	-	-	-	-	-	-	0.0195	20	1.73	0.0065	7	0.60	-	-	-
24/02/97	0.064	64	5.53	0.504	504	43.55	0.113	113	9.76	-	-	-	-	-	-	-	-	-
19/03/97	0.049	49	4.23	0.0294	29	2.51	0.0735	74	6.39	-	-	-	-	-	-	-	-	-
20/03/97	-	-	-	-	-	-	-	-	-	0.011	11	0.95	0.0035	4	0.35	-	-	-
22/04/97	0.052	52	4.49	0.358	358	30.93	-	-	-	-	-	-	-	-	-	-	-	-
28/04/97	-	-	-	-	-	-	0.1554	155	13.39	0.017	17	1.47	0.0136	14	1.21	-	-	-
04/06/97	0.043	43	3.72	0.033	33	2.85	-	-	-	-	-	-	-	-	-	-	-	-
13/06/97	-	-	-	-	-	-	0.0236	24	2.07	0.0043	4	0.35	0.0047	5	0.43	-	-	-
15/06/97	0.038	38	3.28	0.0109	11	0.95	-	-	-	-	-	-	-	-	-	-	-	-

The dry weather flows of this river is fully utilized for irrigation and Sankhu area is dependent on water from this river. Hence, it is most likely that the riparian issue will arise in the use of water from this river if diverted for Bhaktapur. Besides, a very long transmission main of 12 km length is needed to supply water from this source to Bhaktapur. Preliminary cost estimates showed that this scheme does not compare favourably with the alternative dugwell scheme. Hence, it is not considered as the additional source of water supply to Bhaktapur.

3.6.4 Gadgade Khola

The Gadgade Khola sub-basin belongs to the Manohara basin and is located just adjacent to Mahadev Khola basin on its north side. As given in Table 3.3, a discharge of 95 % probability of exceedance for this stream amounts to 60 lps i.e. 5.18 mld.

The measured discharges in this stream as given in Table 3.6 shows that the flow in this stream is always greater than 60 lps except one measurement on 13 June 1997 of 23.6 lps. Thus a preliminary techno-economic analysis had been carried out to consider the viability of diverting water from this stream. But this preliminary cost estimate showed that this scheme did not compare favourably with the alternative dugwell scheme from cost consideration.

3.6.5 Manohara River

The hydrological analysis carried out on this river, as tabulated in Tables 3.1 to 3.3, shows that the following flows could be made available from this river below Bode :

	Flows in mld
For 75% of time	45
Average annual minimum	25
Minimum 1 in 10 year	17

But the discharge measurements carried out in this river as given in Table 3.6 showed that the flows were very low on 19 March 1997, 4 June 1997 and 15 June 1997.

Taking into consideration of the size of its catchment area at this point, it is not likely to have discharges so low in its natural condition. The Consultant, made a walkover survey along the river course upstream of this point and found that the water from this river was being diverted at several places for irrigating the potato fields thus giving the unnatural low flows at the time of measurement.

Thirty canal systems along the course of Manohara River and one in Ghatte Khola upstream of Bode have also been identified. These systems divert water as and when needed. During the dry season, they divert water in rotation basis as there is not enough water in the river to fulfill the demand of all at one time.

Thus the only reason of so low discharge in Manohara river on those dates is the diversion of water in the upstream reach.

STAFF GAUGE'S RECORD

Station No.: 15
Name of Station: Balkhu Khola, Kiltipur

Date	March 1989		April		May		June		July		August		September		October		November		December		January, 1990		February	
	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q
1															0.66	1.26	0.57	0.81	0.53	0.62	0.49	0.47		
2															0.68	1.38	0.57	0.79	0.53	0.62	0.49	0.47		
3															0.65	1.22	0.57	0.79	0.52	0.58	0.49	0.47		
4															0.63	1.09	0.57	0.79	0.51	0.54	0.49	0.47		
5															0.62	1.07	0.58	0.84	0.51	0.54	0.49	0.47		
6															0.61	1.00	0.58	0.84	0.50	0.51	0.49	0.47		
7															0.60	0.95	0.57	0.79	0.50	0.51	0.49	0.48		
8															0.59	0.90	0.57	0.79	0.51	0.54	0.52	0.59		
9															0.62	1.04	0.57	0.81	0.51	0.56	0.54	0.68		
10															0.61	0.99	0.57	0.79	0.51	0.54	0.56	0.76		
11															0.60	0.95	0.57	0.79	0.51	0.54	0.56	0.76		
12															0.61	1.00	0.55	0.72	0.51	0.54	0.56	0.76		
13															0.59	0.90	0.55	0.72	0.51	0.54	0.56	0.76		
14													0.67	1.32	0.58	0.86	0.55	0.70	0.51	0.54				
15													0.64	1.15	0.59	0.90	0.54	0.66	0.51	0.54				
16													0.62	1.04	0.59	0.90	0.55	0.70	0.51	0.54				
17													0.64	1.16	0.60	0.95	0.55	0.70	0.51	0.54				
18													0.77	2.00	0.59	0.90	0.54	0.66	0.50	0.51				
19													0.69	1.44	0.58	0.86	0.54	0.66	0.50	0.51				
20													0.63	1.13	0.58	0.87	0.54	0.66	0.50	0.51				
21													0.79	2.17	0.58	0.86	0.54	0.66	0.50	0.51				
22													0.70	1.50	0.57	0.81	0.54	0.68	0.50	0.51				
23													0.70	1.50	0.57	0.81	0.54	0.66	0.50	0.51				
24													0.65	1.24	0.58	0.86	0.54	0.66	0.50	0.51				
25													0.74	1.78	0.58	0.86	0.54	0.68	0.50	0.52				
26													0.65	1.22	0.58	0.84	0.54	0.66	0.50	0.51				
27													0.68	1.42	0.58	0.84	0.54	0.66	0.50	0.51				
28													0.66	1.28	0.58	0.86	0.54	0.66	0.50	0.51				
29													0.90	3.05	0.57	0.81	0.54	0.66	0.50	0.51				
30													0.77	2.00	0.57	0.79	0.53	0.62	0.49	0.47				
31															0.57	0.81			0.49	0.47				

Remarks: H : Gauge Height (m), average of the gauge reading at 8:00, 12:00 and 17:00
Q : Discharge (m3/sec)

出展：JICA. 1990. Groudwater Management Project in the Kathmandu Valley

Table C-2.3 Discharge Measurement in the Field

R. Basin	Stn.No	Location	River	C.A (km2)	Dry Season *1 Measured Dis.(l/s)	Dry Season *1 Spec.Dis. (l/s/km2)	Rainy Season *2 Measured Dis.(l/s)	Rainy Season *2 Spec.Dis. (l/s/km2)
I. Bisunumati	20	Budhanilkantha	Bisnumati	6.5	20.2	3.1	935	143.8
	23	Baniyatar	Bisnumati	14.0	1.4	0.1	1,543	110.2
	24	Baniyatar	Bisnumati	14.5	2.1	0.1	1,863	128.5
	25	Nepaltar	Bisnumati	60.9	51.1	0.8	-	-
	10	Bisnumati Ring Road Bridge	Bisnumati	61.2	34.2	0.6	6,316	103.2
II. Dhobi Kh.	26	Bhangai	Dhobi	10.2	18.5	1.8	1,944	190.6
	27	Bhangaltar	Dhobi	11.4	23.3	2.0	2,084	182.8
	28	Dhumbaharai	Dhobi	23.3	4.1	0.2	4,285	183.9
	14	Dhobi Ring Road Bridge	Dhobi	23.7	8.4	0.4	5,039	212.6
III.Bagmati	19	Gokarna	Bagmati	56.9	233	4.1	7,467	131.2
	5	Gokarna, Sakhu Road Bridge	Bagmati	57.8	246,	4.3	7,783	134.7
	18	Gauri Gat	Bagmati	66.6	259	3.9	5,885	88.4
	38	Chobar	Bagmati	588.3	1850	3.1	32,679	55.5
IV. Manohara	21	Multipani	Manohara	58.2	99.9	1.7	3,284	56.4
	22	Nitbarahi	Manohara	62.5	74.2	1.2	3,100	49.6
	6	Manohara Bridge	Manohara	73.8	24	0.3	7,489	101.5
	7	Manohara Ring Road Bridge	Manohara	255.2	177	0.7	18,737	73.4
V. Hanumante	41	Nagarkot Intake	Tabya Kushi	6.8	-	-	682	100.3
	42	Bromhayani Bridge	Tabya Kushi	21.5	-	-	506	23.5
	29	Taikabun	Suidi	2.5	2.4	1.0	37	14.8
	30	Taikabun	Suidi	2.9	6.5	2.2	28	9.7
	16	Hanumante Bridge	Hanumante	78.2	15.5	0.2	1,374	17.6
	13	Sagu Confluence	Godavari	17.2	74.8	4.3	659	38.3
VI. Khodu Kh.	11	Kodku Head Work	Kodku	16.7	154	9.2	479	28.7
	12	Kodku, Lubhu Road Crossing	Kodku	33.5	81.9	2.4	1,535	45.8
VII.Nakhu Kh.	17	Tikabairab No.1 Head Work	Lele	14.8	152	10.3	1,312	88.6
	8	Tikabhairab	Nakhu	42.1	349	8.3	3,418	81.2
	9	Jaulakhel	Nakhu	54.4	166	3.1	3,622	66.6
VIII.Balkhu Kh.	15	Kirtipur-Tinthana Bridge	Balku	36.4	33	0.9	1,869	51.3
	39	Ring Road Bridge	Balku	41.3	-	-	2,094	50.7
IX. Bosan Kh.	40	Parphin Road Crossing	Bosan	7.2	-	-	558	77.5

Remarks: *1 carried out during the period from Feb.28 to Mar.13, 1989
*2 carried out during the period from Sep.16 to Sep.30, 1989

付録C　カトマンズ盆地のNWSCの水道システムの概要

出典：WB, NWSC, PSPC. Preparation of a Contract for the Urban Water Supply and Sanitation Services in the Kathmandu Valley. Volume I NWSC Asset Assessment – Kathmandu Valley. 1998.

飲料水供給施設の概要

<u>システム 1- Balaju</u>

この給水システムは、ほぼ一年を通して多岐にわたる表流水源から、カトマンズの北西部へ 5～10 MLD の水を供給している。システムの大半は 30 年以上前に建設された。沈澱池、急速ろ過池を有する浄水場はあるが、現行では運転可能な状態ではなく、修復が必要である。 滅菌はさらし粉による。配水池は老朽化が著しく危険な状態である。

<u>システム 2-Bansbari</u>

この給水システムは地下水と表流水の混合利用により 10～30 MLD の水を供給する。地下水は過去 30 年間に建設された Bansbari 井戸群から来ている。井戸のいくつかは、水位が低下しており、改善・改修を必要としている。いくつかの井戸では現在改善事業が進行中である。

表流水源はカトマンズ北部の丘陵地にあり、減圧水槽を経由して導水されてくる。

当初全ての水は Maharajgunj にある旧式の浄水場と配水池に流れていたが、その後浄水場は放棄されてしまっている。ただし、さらし粉殺菌用の設備のみがいまだに使用されている。

深刻な地下水源の水質問題に注視するため、近代的な浄水場が Bansbai に 1990 年代に建設された。この浄水場には、井戸水のための生物処理、沈殿、急速ろ過が設置されている。浄水場は良好な状態で運転中である。ただし、硫酸アルミニウム塊破砕機が故障しており、硫酸アルミニウム注入は正確に行われていない。

雨期の増水量を導水するための新しい導水管もまた Muhan Pokhari / Bishnumati 取水口から Bansbari 浄水場まで敷設された。

<u>システム 3-Sundarijal</u>

このシステムはカトマンズ盆地で最大の給水システムである。地下水と表流水の混合利用により最大 48 MLD まで供給している。

地下水は過去 30 年間に設置された Gokarna と Dhobi Khola 井戸群からきている。いくつかの井戸は水位が低下しており、改善・改修を必要としている。いくつかの井戸では現在改善事業が進行中である。

表流水源は Bagmati 川の最上流部にある。当初、全ての水は Sundarjal 水力発電所の

放水路から流れてきていた。タービンが稼動していない際に給水を可能にする側管は 1990 年代に設置されたが、切断されたままになっている。機械の機能不全のせいで利用されていないためと判断される。

これと同時期に Bagmati 川からの直接取水口が設置された。これは発電所バイパスラインから自然水路へと放流されている水を取り入れることによって発電所を迂回することができる。

浄水場（曝気、沈澱、急速ろ過）は Sundarijal（容量 20 MLD）に 1965 年に建設された。浄水場はいまなお稼働中であるが、維持管理状況は劣悪である。計器による運転は作動不能で、初期の塩素ガス装置の代わりにさらし粉滅菌装置が利用されている。

カトマンズ市に近い２番目の浄水場は井戸群の水質問題に対処すべく（システム 2 における Bansbari に近似）Mahankal Chaur に 1990 年代に建設された。ここは概ね良好な運転状態であるが、次亜塩素酸ソーダ生成装置は電極の未交換のため使用されていない。その代わりとしてさらし粉注入機が機能している。

二条目のバイパスラインが表流水源からの直接導水を可能にするために、Mahankal Chaur 浄水場と同時期に Sundarijal 浄水場にも建設された。

<u>システム 4-Bhaktapur</u>

この給水システムは Bhaktapur と Thimi に給水している。以下の二つのサブシステムからなる。

- Bhaktapur の北西部に臨む Mahadev Khola 表流水源：約 4MLD 供給
- Bode 内に複雑に配置されている様々な井戸：最大 3MLD 供給

Mahadev Khola は Bansbari（Bhaktapur）浄水場と配水池に給水している。浄水場は 1980 年代に建設された。野外設備の中に、複雑に入り組んだ凝集・フロック形成タンク、沈降タンク、急速ろ過が設置されている。フロック形成タンクは漏水のため使用されておらず、薬品注入設備はごく初歩的なものである。滅菌はさらし粉による。浄水場は修復が必要な状況にある。

さらし粉滅菌は Bode 配水池で使われてはいるものの、井戸水のための水処理は存在しない。

２番目の配水池が西部のサブシステム中の Katunje にある。現在は使用されてはおらず、送水管中の水理的な問題、またおそらくは送水量不足に起因すると理解されている。

西部サブシステムは Bode 配水池に隣接した実験的な太陽パネル主導井戸から導水する。状態は良好で運転可能と判断される。

<u>システム 5-Dudh Pokhari/Sundarijal</u>

このシステムは Dudh Pokhari と Lunkot における湧水と、Kathmandu 南西部に臨む

Nakhu Khola 川の取水口によって給水される複合システムである。 総容量は 3 MLD である。

主要水源は Dudh Pokhari にあり、取水口はコンクリートで保護されている。水は自然流下によって Bhajangal 配水池へ流れる。そこから一部はカトマンズに流れ、残りは Kirtipur と Chauvar の二方面へポンプを通して給水される。そこでは小規模配水池が地域配水システムに給水している。Kirtipur はまた、より小規模の Lunkot 湧水からも給水されている。そこでは水源が完全には保護されておらず、表流雨水によって汚染される危険にあるが、塀で仕切られた囲いの内側にある。

Nakhu Khola 川の取水口には小規模の沈殿槽がある。沈殿槽は使用されてはいないと思われ、河川は重度の汚染が懸念される。原水は二つの屋外水平ポンプと井戸ポンプによって浄水場まで揚水されている。

Sundarighat 浄水場には沈殿、緩速砂ろ過（現在は使用されておらず迂回されている)、圧力式ろ過装置、さらし粉注入装置がある。浄水場は 劣悪な状態・管理にあると思われ、沈殿槽は漏水すると報告されている。

<u>システム 6-Shaibhu</u>

このシステムは総容量が 20MLD ある。

主要な給水は 100 年ほど前 Pharping に建設された水力発電所から来ている。集水管、ヘッドポンド、発電所に連接する導水管は現在 NWSC によって維持管理がなされている。いくつか小程度の漏水が（埋設もしくは高架管）で発見されてはいるが、利用年数の長さにもかかわらず、これらは全体的に良好な状態にあるように思われる。

Pharping には過去 20 年間のうちに建設された近代的なポンプ場がある。浄水場は杜撰な管理がされているように見えるが、一般的に運転可能である。Pharping 発電所にある二つの井戸からの少量の導水もある。井戸のひとつは操業しておらず、代わりの井戸が穿孔されたがまだポンプ装備が完了していない。

ポンプ場から Shaibhu へ続く二本の導水管がある。ポンプ場建設以前に建設された導水管は漏水するとの報告があり、水源からの地域配水のためのみに使用されている。

Shaibhu においては配水池の屋根上に簡易浄水施設がある。沈殿槽、砂ろ過、比較的新しいさらし粉装置から構成されており、塩素ガス機の代わりに利用されている。

<u>システム 7-Chapagaon</u>

このシステムはカトマンズ盆地南部（Nallu, Basuki, Mul, Debaki Mul）を臨む丘陵地内のコンクリート保護された湧水（Chapagaon）と河川取水の混合利用により Lalitpur へ最大 7MLD まで給水する。表流水源は自然流下によって給水される。Chapagaon 水源を揚水するため 3 つのポンプ場が建設された。小規模の最初のポンプ場はもはや利用されていない。2番目のポンプ場は管理は杜撰であるが未だに機能している。3 番目のポンプ

場は井戸において水中ポンプを使っており、新しい装置である。

バイパス管と代替ルートが完備されたシステムにより、水源は二つの配水池に供給している。古い下流の配水池にはさらし粉滅菌装置がある。他に浄水装置は存在しない。

河川取水口には河川砂礫層（Nakhu Khola）に埋設された集水管があり、これにより集水している。取水点は村の下流であるが比較的汚染されていない。これは、砂礫層がろ過機能を果たしているためと考えられる。Chaurghare の井戸中には水中ポンプ装置があるが、これは調査時に更新中であったため、運転していなかった。

付録 D.　財務・水道料金データ

NEPAL WATER SUPPLY CORPORATION
Profit & Loss A/C (2054/2055)

	Annex	This year at 2055/3/32 Nrs.	Last year at 2054/3/31 Nrs.
Income:			
Water Revenue (After Rebate)	12	270136954.19	256492918.36
Expenditure:			
Production	13	92853288.65	80171654.19
Distribution	13	59908551.60	47578533.48
Quality Control	13	7958792.75	9915245.30
Electro-mechanical	13	12348648.94	9855434.04
Sewerage	13	12921418.93	9435240.38
Consumer's Account	13	23942922.21	20524654.03
Administrative Expenses	13	74262957.90	61624744.48
Provision for D/D		290076.04	3640334.39
Total		284486657.02	242745840.29
Operating Surplus (Deficit)		-14349702.83	-13747078.07
Other Income	12	70556774.03	47588597.24
Net Operating Surplus (deficit)		56207071.20	61335675.31
Interest Payable		-10555228.48	-2977815.96
Depreciation Provided		-80224379.26	-73371330.66
Depreciated Fund Transferred from Capital Reserve		46901913.90	46901913.90
Net Profit (Loss)		12329377.36	31888442.59
Last year Adjustment		-50751858.72	-
Accumulated Loss up to Last Year		-66512473.85	-98400916.44
Net Loss Transferred to B/S		-104934955.21	-66512473.85

NEPAL WATER SUPPLY CORPORATION
Balance Sheet (2054/2055)

	Annex	This year at 2055/3/31 Nrs.	Last year at 2054/3/31 Nrs.
Capital & Liabilities			
Capital Investment	1	1,088,376,298.66	998,376,298.66
Capital Reserve	2	850,202,759.60	871,280,427.29
Long Term Loan	3	1,417,774,569.31	1,164,890,773.21
Total		**3,356,353,627.57**	**3,034,547,499.16**
Assets & Properties			
Net Fixed Assets	4	1,947,386,082.89	1,863,592,669.98
Work In Progress	5	479,316,167.13	481,034,966.94
Share Investment		100,000.00	100,000.00
Total (A)		2,426,802,250.02	2,344,727,636.92
Current Assets			
Debtors	6	204,180,734.44	198,669,289.63
Advance & Deposit	7	216,030,537.98	72,576,149.57
Stock Inventories	8	130,500,863.15	139,445,824.34
Bank & Cash Balance	9	417,539,389.17	340,768,972.87
		968,251,524.74	751,460,236.41
Current Liabilities (-)	10	(143,635,102.40)	(128,152,848.02)
Total (B)		824,616,422.34	623,307,388.39
Profit & Loss			
Net Loss (C)		104,934,955.21	66,512,473.85
TOTAL (A+B+C)		3,356,353,627.57	3,034,547,499.16

NEPAL WATER SUPPLY CORPORATION
INCOME AND EXPENDITURE STATEMENT
FOR THE YEAR ENDING JULY 15 , 1997
F.Y. 1996 / 97

(~~UN~~AUDITED)

PARTICULARS	SCHEDULE	F.Y. 1996 / 97	F.Y.1995 / 96
INCOME			
WATER REVENUE (AFTER REBATE)	12	256,492,918.36	225,251,364.[illegible]
TOTAL		256,492,918.36	225,251,364.2
EXPENDITURES			
PRODUCTION	13	80,171,654.19	69,199,922.2
DISTRIBUTION		47,578,533.48	49,065,401.7
QUALITY CONTROL		9,915,245.30	4,665,448.4
ELECTRO MECHANICAL		9,855,434.04	9,790,461.8
SEWERAGE SYSTEM OPERATION		9,435,240.38	13,604,326.4
BILLING AND CONSUMER ACCOUNTING		20,524,654.03	16,516,577.3
ADMINISTRATIVE EXP.		61,624,744.48	48,437,750.6
DOUBTFUL DEBTS		3,640,334.39	1,028,844.0
TOTAL		242,745,840.29	212,308,732.77
TOTAL INCOME		13,747,078.07	12,942,631.50
OTHER INCOME		47,588,597.24	52,798,947.37
PROFIT		61,335,675.31	65,741,578.87
LESS INTEREST PAYABLE		(2,977,815.96)	(3,532,130.25)
LESS DEPRECIATION	4	(73,371,330.66)	72,755,676.10
DEDUCTION FROM CAPITAL RESERVE FOR DEPRECIATION		46,901,913.90	46,901,913.90
NET PROFIT		31,888,442.59	36,355,686.42
ADJUSTMENT FOR CAST YEAR		-	1,042,376.52
NET LOSS (UP TO THE LAST YEAR)		(98,400,916.44)	(135,798,979.38)
NET LOSS TRANSFERED TO BALANCE SHEET		(66,512,473.85)	(98,400,916.44)

As per our attached Report

(D.K. Bajimaya) Finance Manager

(K.N. Bhattarai) General Manager

(Khagendra Basnyat) ChairMan

(K.K. Singh) C.A.

(B.B.K.C) A.G.

Members

Kathmandu

Date

EPAL WATER SUPPLY CORPORATION
BALANCE SHEET
FOR THE YEAR ENDING JULY 15 , 1997
F.Y. 1996 / 97

(~~UN~~AUDITED)

PARTICULARS	SCHEDULE	F.Y. 1996 / 97	F.Y.1995 / 96
CAPITAL AND LIABILITY			
SHARE CAPITAL FUND AND FUND	1	998,376,298.66	948,376,298.66
CAPITAL RESERVE	2	871,280,427.29	891,658,172.26
LONG TERM LOAN	3	1,164,890,773.21	1,038,114,559.39
TOTAL FUND :		3,034,547,499.16	2,878,149,030.31
ASSETS AND PROPERTIES			
FIXED ASSETS	4	1,863,592,669.98	1,659,110,173.62
WORK IN PROGRESS	5	481,034,966.94	611,299,571.43
SHARE INVESTMENT		100,000.00	
TOTAL A :		2,344,727,636.92	2,270,409,745.05
CURRENT ASSETS			
RECEIVABLES (DEBTORS)	6	198,669,289.63	129,502,936.24
ADVANCES AND DEPOSIT	7	72,576,149.57	76,847,279.90
STORES INVENTORIES	8	139,445,824.34	129,201,214.87
BANK AND CASH BALANCES	9	340,768,972.87	313,200,389.41
		751,460,236.41	648,751,820.42
LESS CURRENT LIABILITY	10	128,152,848.02	139,413,451.60
NET CURRENT ASSETS TOTAL B :		623,307,388.39	509,338,368.82
PROFIT AND LOSS ACCOUNT :			
NET LOSS TOTAL C :		66,512,473.85	98,400,916.44
TOTAL A+B+C		3,034,547,499.16	2,878,149,030.31
Notes of Accounts	11		

As per our attached Report

(D.K. Bajimaya)	(K.N. Bhattarai)	(Khagendra Basnyat)	(K.K. Singh)	(B.B.K.C.)
Finance Manager	General Manager	Chair Man	C.A.	A.G.
(D.K. Bajimaya)	(K.N. Bhattarai)	(Khagendra Basnyat)	(K.K. Singh)	(B.B.K.C.)
Finance Manager	General Manager	Members	C.A.	A.G.

Kathmandu
Date :

Table D.1 Current Monthly Water Tariff for Metered Connections by Size of Connection Pipe and Types of Users

Connection Size (Inch)	Basic Allowance (M3)		Minimum Water Tariff by Types of Users (NRs)			Additional Water Tariff Beyond Basic Allowance by Types of Users per M3 (NRs)		
	Domestic	GVT Industrial	Domestic	Gvt/Semi-Govt/Corp	Industrial/Commercial	Domestic	Gvt/Semi-Govt/Corp	Industrial/Commercial
0.5 (a)	10.000	8.000	40.00	35.50	38.60	9.70		
(b)		8.001 – 15.000					8.95	10.80
(c)		15.001 – 30.000					10.50	11.90
(d)		30.001 – 50.000					12.10	14.80
(e)		50.001 – 100.000					14.60	17.50
(f)		100.001 –					17.80	19.85
0.75	27.000	27.000	590.00	647.10	590.00	21.20	23.30	26.40
1	50.000	50.000	1030.00	1132.40	1030.00	21.80	24.00	27.10
1.5	140.000	140.000	2883.00	3171.00	2883.00	22.15	24.45	27.80
2	235.000	235.000	4840.00	5322.70	4840.00	22.75	25.05	28.45
3	700.000	700.000	14415.00	15855.00	14415.00	23.35	25.65	29.30
4	1400.000	1400.000	28830.00	31710.00	28830.00	24.00	26.45	29.90

Table D.1 Current Monthly Water Tariff for Metered Connections by Size of Connection Pipe and Types of Users

Tap size	水道料金（1）	水道料金（2）
1/2	148	56
3/4	1258	420
1	2046	700
1 1/2	5590	1860
2	9222	3075
3	27386	9125
4	54772	18585

Table D.2 Current Monthly Water Tariff for Non-Metered Connections by Size of Connection Pipe and Types of Users

Connection Size (Inch)	Domestic Users		Govt. Semi-Govt Organizations and Corporations		Industrial and Commercial Users	
	Main Connection (NRs)	Branch Connection (NRs)	Main Connection (NRs)	Branch Connection (NRs)	Main Connection (NRs)	Branch Connection (NRs)
0.5	176.50	59.00	194.00	64.70	294.15	103.00
0.75	1323.60	442.00	1456.00	485.35	1485.50	500.00
1	2206.00	736.00	2426.80	808.90	2780.00	927.00
1.5	5883.00	1956.00	6471.30	2151.60	7780.00	2574.00
2	9707.00	3236.00	10677.80	3559.20	13060.00	4353.00
3	28827.00	9604.00	31710.00	10564.45	38916.00	12972.00
4	57654.00	19561.00	63420.00	21517.25	77833.00	25930.00

Table D.3 Current Monthly Water Tariff for Water Tanker

タンク容量 (L)	料金 (Rs.)
4000	725
5000	850
6000	900
7000	1090
8000	1210
9000	1330
10000	1450

付録E.　マノハラ川付近での浅井戸揚水テスト及び土質データ

Source : N W S C

Annex 3.1

Date : Feb. or. Mar 1997

Drawdown Test

(Existing Manohar Infiltration gallary)

Time	Elapsed time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec	Remarks
	0	0.60	0.00	12.90	SWL = 0.60 m
	1	1.03	0.43		
	2	1.21	0.61		
	3	1.30	0.70		
	5	1.38	0.78		
	10	1.42	0.82		
	15	1.45	0.85		
	20	1.50	0.90		
	25	1.54	0.94		
	30	1.55	0.95		
	35	1.55	0.95		
	40	1.55	0.95		
	60	1.57	0.97		
	90	1.57	0.97		
	120	1.57	0.97		

Recuperation Test (Recovery)

Time	Elapsed time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec	Remarks
	0	1.57	0.00	12.90	SWL =0.60m
	1	1.22	0.35		
	2	1.00	0.57		
	3	0.89	0.68		
	4	0.83	0.74		
	5	0.79	0.78		
	10	0.71	0.86		
	15	0.67	0.90		
	20	0.66	0.91		
	30	0.65	0.92		
	60	0.64	0.93		

Specific yield

$$C = \frac{2.303}{t} \log \frac{S1}{S2}$$

Where, S1 = 0.97, S2 = 0.04 and t = 1 hr

Therefore, C = 3.19

Annex 3.2

Drawdown Test

Time	Elapsed time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec	Remarks
	0	0.60	0.00	14.66	SWL = 0.60m
	1	1.08	0.48		
	3	1.36	0.76		
	4	1.48	0.88		
	5	1.55	0.95		
	10	1.71	1.11		
	15	1.72	1.12		
	20	1.73	1.13		
	25	1.74	1.14		
	30	1.75	1.15		
	45	1.78	1.18		
	60	1.80	1.20		
	90	1.82	1.22		
	120	1.84	1.24		
	150	1.85	1.25		
	180	1.85	1.25		

Recuperation Test (Recovery)

Time	Elapsed time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec	Remarks
	0	1.85	0.00	14.66	SWL = 0.60m
	1	1.38	0.47		
	2	1.14	0.71		
	3	0.99	0.86		
	4	0.92	0.93		
	5	0.87	0.98		
	10	0.76	1.09		
	15	0.71	1.14		
	20	0.69	1.16		
	30	0.66	1.19		
	45	0.65	1.20		
	60	0.64	1.21		

Specific yield

$$C = \frac{2.303}{t} \log \frac{S1}{S2}$$

Where, S1 = 1.25, S2 = 0.04 and t = 1 hr

Therefore, C = 3.44

Annex 3.3

Drawdown Test

Time	Elapsed time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec	Remarks
1.00	0	0.60	0.00	22.50	SWL=0.60m
	1	1.24	0.64		
	2	1.74	1.14		
	3	2.00	1.40		
	4	2.16	1.56		
	5	2.27	1.67		
	10	2.31	1.71		
	15	2.46	1.86		
	20	2.55	1.95		
	30	2.60	2.00		
	45	2.66	2.06		
	60	2.70	2.10		
	90	2.72	2.12		
	120	2.74	2.14		
	150	2.75	2.15		

Recuperation Test (Recovery)

Time	Elapsed time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec	Remarks
	0	2.75	0.00	22.50	SWL=0.60m
	1	2.08	0.67		
	2	1.59	1.16		
	3	1.33	1.42		
	4	1.17	1.58		
	5	1.08	1.67		
	10	0.89	1.86		
	15	0.82	1.93		
	20	0.77	1.98		
	25	0.74	2.01		
	35	0.69	2.06		
	45	0.66	2.09		
	60	0.65	2.10		

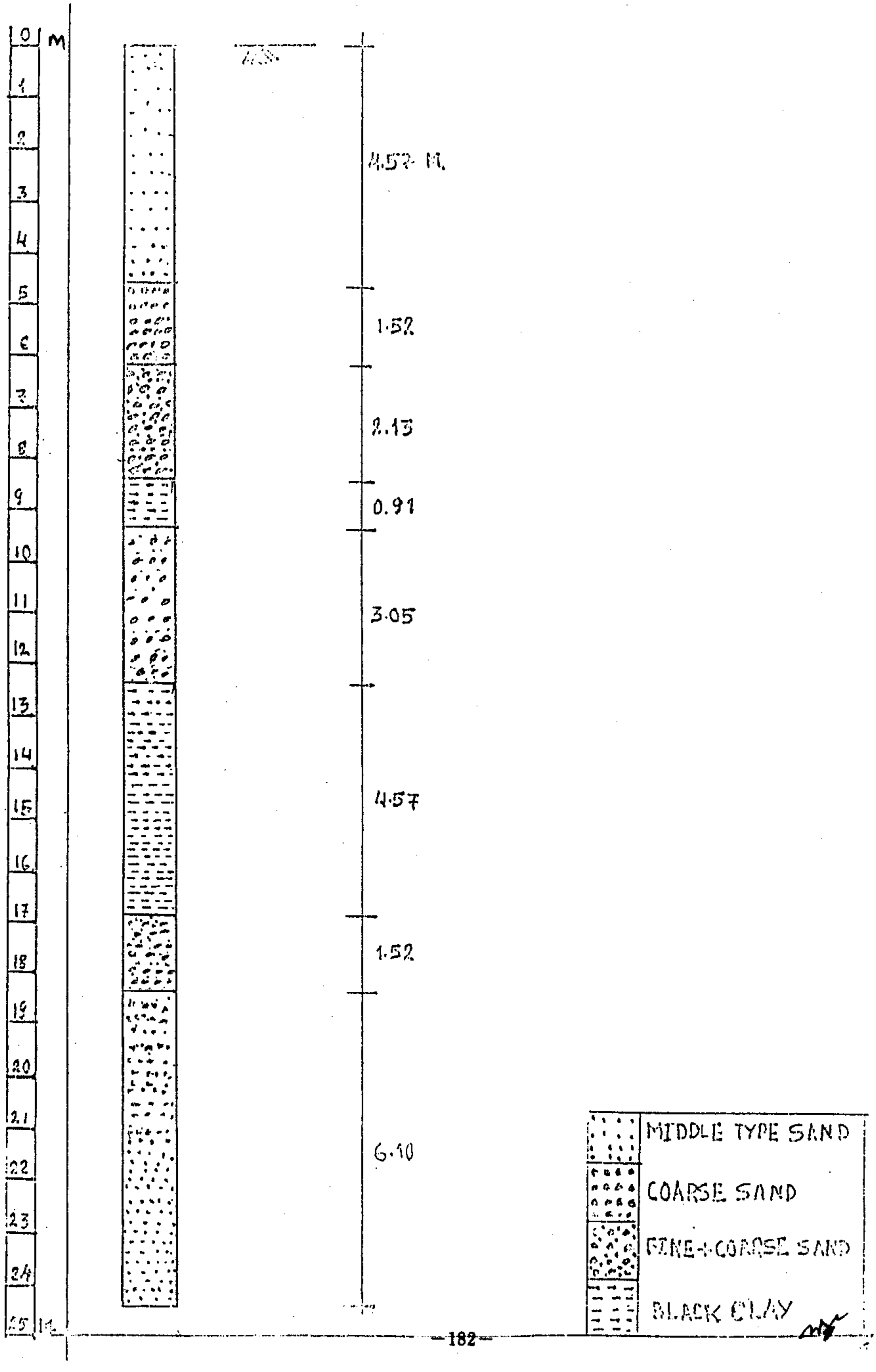
<u>Specific yield</u>

$$C = \frac{2.303}{t} \log \frac{S1}{S2}$$

Where, S1 = 2.15, S2 = 0.05 and t = 1 hr

Therefore, C = 3.76

LITHOLOGICAL LOG OF BORE HOLE AT BANK OF MANOHARA RIVER



4 HYDROGEOLOGICAL STUDY

4.1 Hydrogeology of the Project Area

Bhaktapur area lies in the easterly central part of Kathmandu Valley and is composed of very thick clay at the top section of the deposit and low permeable coarse unconsolidated sediments at the bottom section of the deposit. Groundwater in the deeper depth of project area is almost non-rechargeable and very old in age. Groundwater recharge of Bhaktapur region is controlled by the widespread very thick black clay which prevents easy access to the deep aquifers. The hydrogeological study indicates that the middle reach of Manohara river flood plain is suitable for shallow groundwater development as well as for medium scale deep groundwater development.

4.2 Hydrogeological Analysis

Hydrogeological analysis of Bhaktapur area was done on the basis of existing information and actual field survey. To evaluate and analyze the groundwater condition, the Bhaktapur region was divided into five study areas and were categorized as per their groundwater potentiality. The study areas were as follows:

a) Bode - Nilbarahi - Gamphedi (Changu Narayan)
b) Sallaghari - Duwakot
c) Bhaktapur - Jhaukel - Pikhel
d) Bhaktapur - Bansbari - Mahadev Khola
e) Katunje and its surroundings

Among the above study areas of Bhaktapur for deep groundwater development, the most potential area available is north of Bode to the foothill of Changu Narayan on the banks of Manohara River. Other areas of study falls in low to poor groundwater potential and are not along the Manohara river suitable for the development for water supply to Bhaktapur project.

The identified potential area from the analysis is along the left flood plain of Manohara river. The aerial extension of the area is 5.5 km from Manohara bridge towards north east to the foothill of Changu Narayan. The area is suitable for development of both shallow groundwater and deep groundwater as a source of water supply.

Manohara is a widespread perennial river which has around 65 sq.km. of catchment area. This river has flat gradient and the channel is widespread and it has shifted its channel position several times in the past along the flood plain area. With monsoon rains this river has overflown its banks several times and in response coarse sand and gravel have been deposited on the banks due to its reduced energy in the flat terrain. The Manohara flood plain consists of river deposits, talus deposits and top soil. Coarse to very coarse saturated materials are available all over the flood plain of Manohara river. The materials are coarser towards the north and finer towards the south.

Source : Urban Water Supply and Sanitation Project Design of Rehabilitation and Extention of Bhaktapur Water Supply System Design Report, 1997. I D 4

4.3 Classification of Sub-Surface Water

From the field survey and as well as from hydrogeological study it is found that the shallow aquifer along the river flood plain of Manohara has a high potential as it is continuously recharged from both surface river flow and sub-surface flow as well as from rainfall in the whole catchment area.

Similarly the hydrogeological condition for deep groundwater extraction is also suitable in Manohara flood plain as the granular sediments are as thick as 60 meter and known as main aquifers. The area is suitable for medium scale groundwater development by deep tubewells. The recharge of deep aquifer in the four other study areas of Bhaktapur region is controlled by thick widespread black clay preventing the easy access of water to the aquifer for recharge. Groundwater level depletion of deep aquifer is continuous in Bhaktapur area due to limited infiltration and recharge condition.

Sub-surface water has been classified as:

a) Shallow Sub-surface Water
b) Deep Sub-surface Water

4.4 Shallow Sub-surface Water

Eight 10 meter deep shallow investigation holes were drilled along the left flood plain of Manohara river to verify the existence of shallow groundwater aquifer. The thickness of coarse sediments are not equally distributed.

Eight large diameter dugwells of around 6 meter is proposed at the investigation location no. 2, 4, 5, 6, 7, 8 and two more at locations 400 m apart downstream of DW_8.

4.4.1 Location

The tentative location of shallow sub-surface water source for the construction of dugwells are shown in the map in Annex I. The topography survey of those points and their elevations are shown in the lithological log of proposed dugwell sites. The suitable location for dugwell construction is along the flood plain of Manohara river north of Bode towards north east to the foothill of Changu Narayan (Annex II).

4.4.2 Yield Assessment

a) A pumping test was performed on the existing NWSC dugwell of 1.38 m diameter and depth 3 m located at Bode on the flood plain on Manohara to get an idea of the probable yield and to determine the value of specific yield (C) of the well on December 24, 1996. The well was tested at three different discharge rates of 12.9 lit/sec, 14.66 lit/sec and 22.5 lit/sec. The depression head for different discharge rates are shown in Table 4.1. The test details and plotting are attached in the Annex III. Static water level was 0.60 m below the ground level during the pumping test.

Table 4.1 : Depression Head Vs Discharge in Test Wells

Discharge (Q) in liters/sec	Depression Head (H) in meters
12.90	0.97
14.66	1.25
22.50	2.16

b) A second continuous pumping test was performed in the same dugwell of NWSC at Bode at the discharge rate of 14.25 lit/sec on 10 June 1997. Pumping was continued for the period of more than 8 hours. Water level stabilized in short duration of pumping and it could attain its original level within few hours of pump shut off. The test details are attached in the Annex III.

c) The drainable water from the shallow aquifer in storage can be calculated as follows:

Area of Interest	-	12.5 km^2
Saturated Thickness	-	4.0 m
Specific Yield of the Aquifer (Theoretical)	-	15%

So drainable water in storage $= 12.5 \times 4 \times 0.15$
$= 7.5$ MCM

d) A recuperation test was performed to calculate the value of specific yield of the aquifer in the Manohara river flood plain. The details are attached in Annex III.

If the water level inside the dugwell rises from S_1 to S_2 in time t, then from Darcy's law.

$Q = KiA$ Where,
- Q = discharge
- i = hydraulic gradient
- A = area of cross section

or $Q = CAS$ Where,
- C = specific yield
- S = drawdown at any time t

We have the relation for specific yield as follows :

$$C = \frac{2.30}{t} \log_{10} \frac{S_1}{S_2}$$

The specific yield for different discharge rate was calculated and the average C value works out to 3 which corresponds to very coarse gravel (refer Annex III.).

Hence, conservatively, the value of 2 is adopted for the specific yield.

4.4.3 Design Criteria of Dugwell

While designing the dugwell several parameters has to be assessed:

- Aquifer materials
- Specific yield
- Available depression head
- Well diameter
- Critical velocity
- Well construction process
- Well development procedure
- Well discharge capacity
- Drainable water in storage
- Well depth
- Strength of the wall of the well
- Well spacing

The bottom of the dugwell should always rest on gravel or sand bed. The dugwell spacing are kept at a minimum 400 m apart to avoid long term interference and also for better recharge and more seepage area. For the soil to remain stable water from dugwells must be withdrawn only at a velocity smaller than the critical velocity of 7.5 cm/min. A factor of safety of 2 for critical velocity is adopted for the safe dugwell design.

4.4.4 Typical Design of Dugwell

For the design of dugwell, eight investigation drill holes at the proposed locations were drilled each to the depth of 10 meters. The lithology is dominated by sand and gravel.

We have,

Q = CAH Where, Q (Discharge) = 82.8 m^3/hr (i.e. 2 mld)
H (Maximum depression head) = 2 meters
C (Specific yield) = 2
A = Area of cross section

Now,

$$A = \frac{Q}{CH} = \frac{82.8}{4} = 20.7\ m^2$$

For the design consideration of dugwell the critical velocity should not be greater than 7.5 cm/min. For safe side design a safety factor of 2 is recommended which implies that the actual velocity should not be greater than 3.75 cm/min. But here the actual velocity V= Q/A = 6.66 cm/min is greater than the actual safe value of 3.75 cm/min.

Now for the required discharge of 2 mld with 3.75 cm/min velocity the required cross section area of the well will be :

$$A = \frac{Q}{V} = \frac{0.023 \times 60 \times 100}{3.75} = 36.8 \text{ m}^2$$

The diameter of dugwell comes out to be :

$$D = 6.9 \text{ m} \quad \text{which is rather a large diameter.}$$

So to decrease the diameter of the well the entry of water is also considered through the sides of the well. The lithology of the drilled hole in the proposed dugwell fields suggests that the maximum perforation in length should be provided at the bottom 2 meters of the dugwell with 20 percent open surface area.

This implies :

$$36.8 = \frac{\pi D^2}{4} + \pi D\,(2 \times 0.2)$$

Which gives a diameter of about 6 meter.

Now with 6 meter diameter dugwell, the actual depression head created will be :

$$H = \frac{Q}{CA} = 1.16 \text{ m} < 2\text{m (Max. Depression Head)}$$

Hence, the design is safe.

Therefore, a dugwell is of 6 meter diameter is proposed.

The tentative depth, diameter and anticipated discharge from the proposed dugwells at different investigation locations are shown in Table 4.2.

Table 4.2 : Tentative Depth, Diameter & Anticipated Discharge of the Proposed Dugwells

Location	Elevation	Proposed Depth (m)	Proposed Diameter (m)	Anticipated Discharge (mld)
DW_2	1321.28	6.0	6.0	2.0
DW_4	1319.29	7.0	6.0	2.0
DW_5	1315.91	7.0	6.0	2.0
DW_6	1313.90	6.0	6.0	2.0
DW_7	1309.97	5.0	6.0	2.0
DW_8	1306.28	7.0	6.0	2.0

Location DW_1 & DW_3 are not taken in consideration due to their thin aquifer thickness which will restrict the available depression head resulting in low discharge.

The dugwell spacing are kept 400 m apart as per design criteria. Two more dugwells are proposed as replacement of DW_1 & DW_3 further downstream at Manohara river flood plain at 400 m apart downwards of DW_8.

The lithological log of all the 8 drillholes at proposed dugwell locations are shown in Annex II.

The typical dugwell design is shown in Annex IV. The proposed dugwell is 6 m in diameter and the depth ranges from 5 to 7 meters. The design discharge from each well is 2.0 mld of water.

The proposed dugwells are of permanent cast in-situ R.C.C. in the flood plain of Manohara river because shallow sub-surface water remains always favorable in this area.

Well bottom rests on sand or gravel layer. Well curb diameter will be somewhat larger than the actual diameter of the dugwell. Bottom 2 meter portion of dugwell should be perforated and water entry to the well is provided by means of several P.V.C. small diameter pipes. The annular space between the well curb and wall of dugwell should be fully gravel packed and also the bottom of the well to the maximum thickness of 30 cm. should be gravel packed to avoid sand entry inside the dugwell.

4.5 Deep Sub-Surface Water

Manohara river has a widespread river course with around 65 sq.km catchment area. Area northeast of Bode towards the foothill of Changu Narayan has a good potential for deep groundwater development. This area falls in the northern groundwater region of Kathmandu valley. The existing six wells of Manohara wellfield and five wells of Bhaktapur wellfield also falls in this region. The permeability and transmissibility of the aquifer in this region is comparatively higher than the other areas of Bhaktapur. Geologically, the domination in lithology is mostly by coarse grained materials and aquifer source rocks are weathered auger gniesses, banded gniesses and schist. So properly constructed wells with periodic monitoring and timely repair and maintenance can yield considerable quantity of water from the above area for the water supply to Bhaktapur. This area has a good potential for deep groundwater development.

4.5.1 Location

The potential area lies on the left flood plain of Manohara river. The area suitable for deep groundwater development is shown in the map in Annex V. In order to meet the demand of the year 2010, the existing tubewell at BH_4 is proposed to be rehabilitated. The elevation of the location of the well is shown in the map in Annex VI.

4.5.2 Yield Assessment

Field visits were made to all the sites of Manohara and Bhaktapur wellfields.

Both the Manohara and Bode wells discharged 4 mld of water at the time of construction in 1984/85.

Now the yield of all the wells are decreased tremendously from the original 4 mld.

The yield of the Bode and Manohara wells last in four Finincial Years as per record are shown in Table 4.3.

Table 4.3 : Yield of Bode & Manohara Wells

Year	Bode (Bhaktapur) Wells Yield in MLD					Manohara (Kathmandu) Wells Yield in MLD			
	BH_1	BH_2	BH_3	BH_4	Solar	MH_2	MH_5	MH_6	MH_7
1992/93	0.94	1.17	1.03	0.82	-	1.30	2.05	0.99	1.56
1993/94	0.55	1.00	0.92	0.74	-	0.79	1.99	1.05	1.42
1994/95	0.30	0.86	0.90	0.72	-	0.90	1.90	0.86	1.38
1995/96	0.56	0.93	1.14	0.55	0.30	-	1.52	0.86	1.41

Bode tubewells are pumped for 24 hours a day for water supply which creates flow of water in the aquifer in one direction only. Daily starting and stopping of the pump allows drawdown and recovery which provides movement of water in more than one direction thereby achieving a gentle flushing or development action. The proposed start/stop operation will give better performance of aquifer. Sooner or later all the tubewells get encrusted and corroded and require redevelopment, chemical treatment and timely maintenance. Otherwise the structure will fail completely.

Periodic monitoring, timely repair maintenance and rehabilitation works on Bode wells are not performed. The casing and screen of BH_4 and BH_3 are disconnected due to mechanical failure so they need replacement. BH_3 is replaced by a new one and BH_4 also requires the same. The decrease of discharge and deterioration of tubewell is not only due to poor performance of aquifer but it is also due to poor electro mechanical components, improper pump installation and lack of monitoring.

Properly constructed wells in the flood plain of Manohara area can each yield 1.5 mld of water if appropriate pumps are installed and timely maintenance and periodic monitoring is provided.

4.5.3 Design Criteria of Deep Tubewell

Following parameters will be considered while designing the tubewell :

- Aquifer materials
- Grain size distribution
- Well diameter
- Entrance velocity
- Screen length
- Well development procedure
- Water quality and quantity
- Strength of well construction materials

Diameter of casing and screen are calculated as follows :

$$D = \sqrt{\frac{4Q}{3.14V}}$$

Where, Q = Discharge in cm^3/sec
V = Upward velocity of water assumed to be 150 cm/sec
D = Diameter in cm

Minimum screen length can be calculated as follows :

$$S_L = \frac{Q}{3.14\, DV_eO_P\,(1-Cr)}$$

Where, S_L = minimum screen length in cm
D = diameter in cm
V = entrance velocity
= 3 cm/sec (assumed)
O_P = open area = 15% (assumed)
Cr = clogging ratio = 0.8 (assumed)

4.5.4 Design of Deep Tubewell

We have,

The discharge, Q = 1.5 mld = 17361 cm^3/sec
Upward velocity, V = 150 cm/sec

$$\text{From } D = \sqrt{\frac{4Q}{3.14V}}$$

The diameter is 12.14 cm, say 15 cm
Now using 15 cm diameter the minimum length of the screen can be calculated as follows:

$$S_L = \frac{Q}{\pi DV_eO_p\,(1-Cr)} = \frac{17361}{17 \times 15 \times 3 \times 0.15\,(1-0.8)} = 4094 \text{ cm} \simeq 41 \text{ m}$$

However, the designer should consider various existing factor. It is recommended that a screen length greater than this value should be provided wherever possible to keep the entrance velocity lower than 3 cm/sec in order to ensure a longer life of the tubewell.

The design on theoretical basis should, of course, be considered but it should also be considered that the groundwater condition of one area differs widely in aquifer materials, grain size distribution, permeability, transmissibility, intercalation of permeable and impermeable materials, recharge condition etc.

The recharge condition of groundwater for whole Kathmandu valley is poor due to the presence of widespread thick black clay layer which prevents easy access to aquifer.

The existing Manohara tubewells are installed with 250 mm diameter screen and length more than 90 meters. Bode wells also have 250 mm screen diameter of lengths more than 70 meters. Even with these long section of screens, the wells yield only 0.56 to 1.52 mld of water at the moment.

Practical experience has shown that for the longer life of the tubewell longer section of screens are necessary. Higher entrance velocity results in higher frictional loss through the screen openings and thereby results in more incrustation and corrosion. In the Manohara wellfield the screenable aquifers are a maximum of 60 meters, so the designer should utilize all the possible aquifers encountered within the specified depth of 250 meter for the longer life and better performance of the tubewell.

From the study of various case histories of existing wells it is recommended that the diameter of screen and casing pipes for 20 lit/sec discharge rate is 20-25 cm.

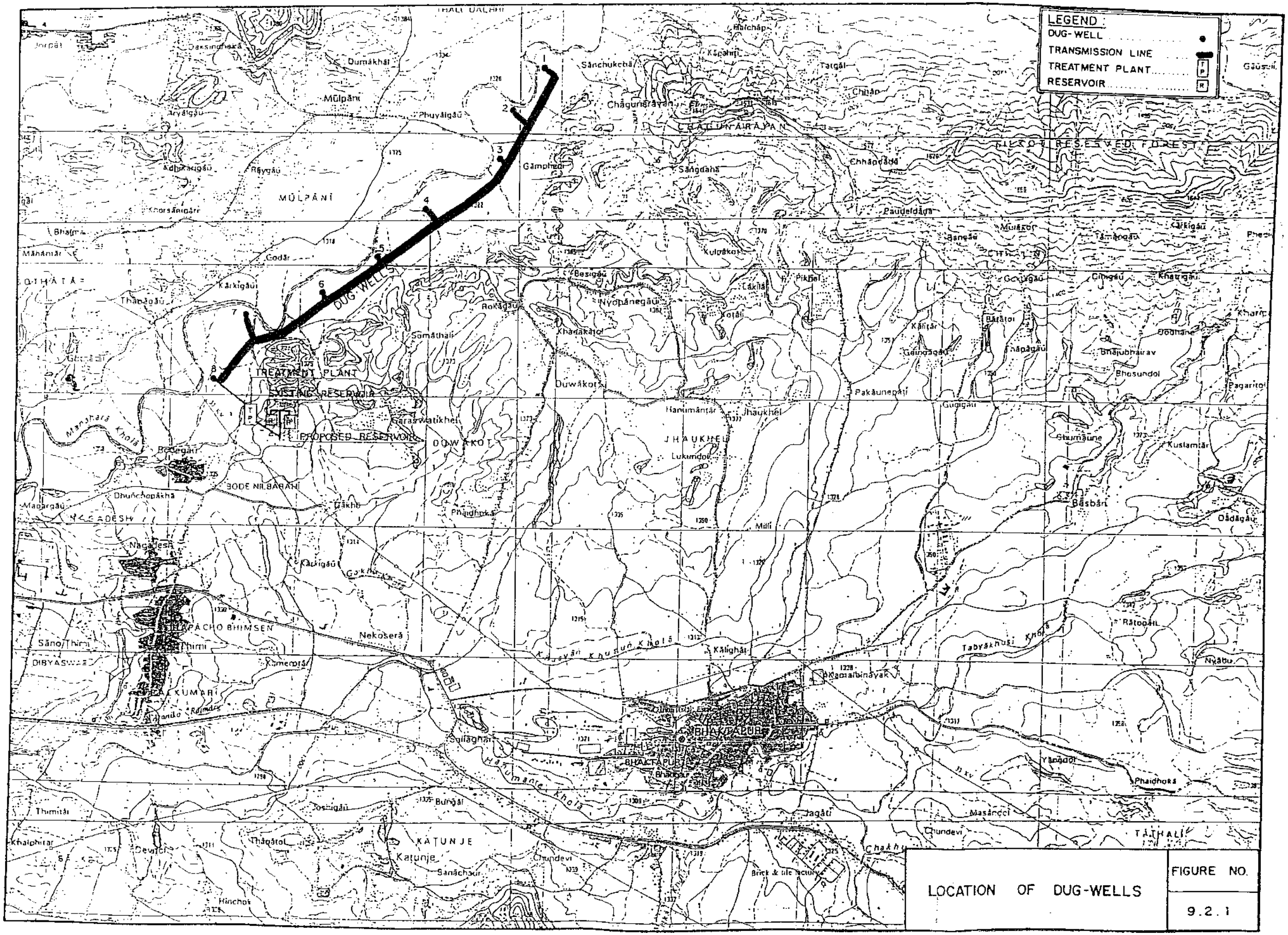
Instead, the following dimensions have been proposed for wells with 20 lit/sec discharge rates:

Housing casing 300 mm diameter	-	60 m
Casing pipes 250 mm diameter	-	130 m
Screen pipes 250 mm diameter	-	60 m

This implies the entrance velocity :

$$V_e = \frac{17361}{60 \times 100 \times \pi \times 25 \times 0.15\,(1-0.8)} = 1.23 \text{ cm/sec} \quad \underline{\text{Ok}}$$

The typical design of deep tubewell is shown in Annex VIII.



LOCATION OF DUG-WELLS

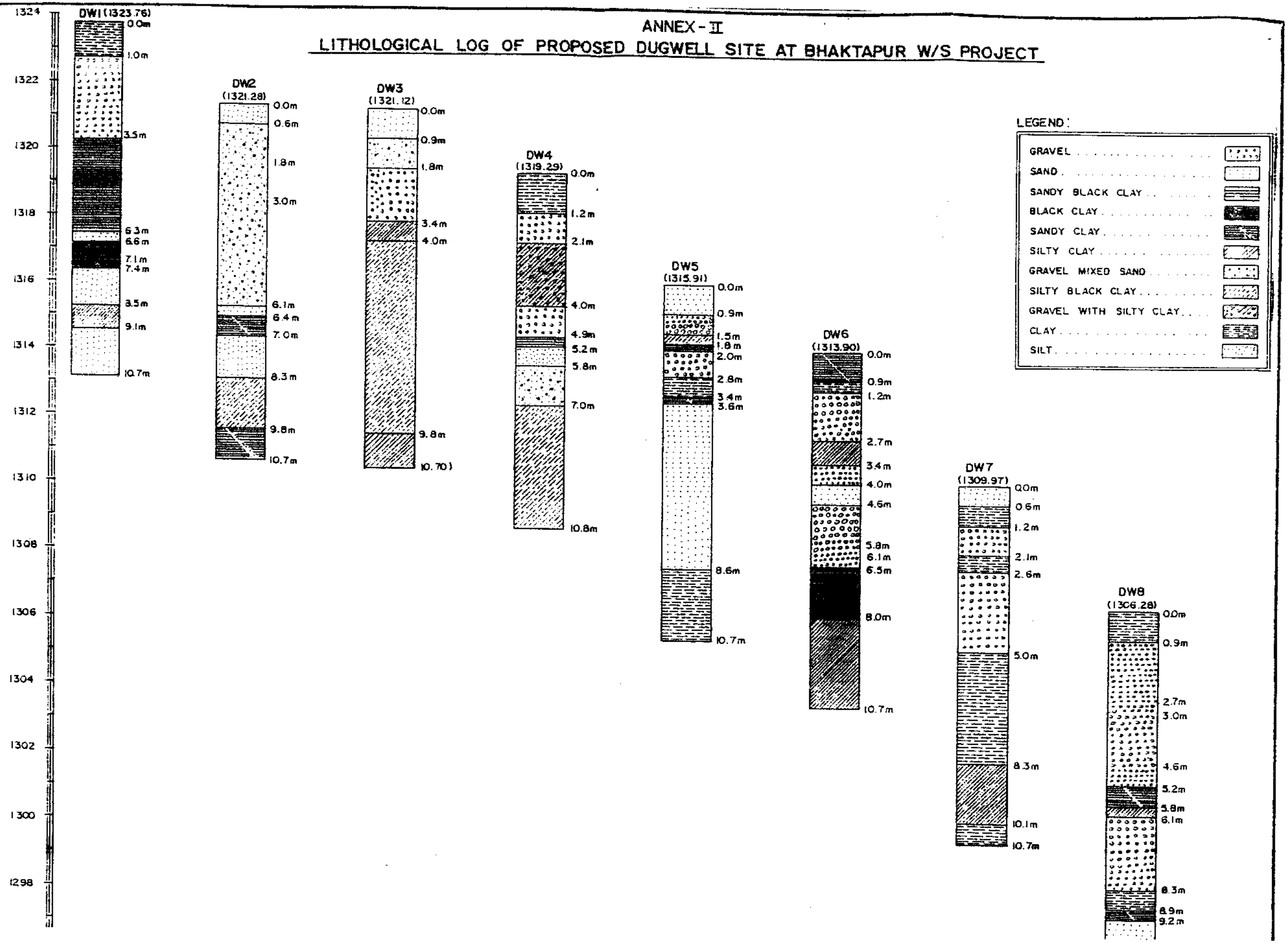
FIGURE NO. 9.2.1

ANNEX II

LITHOLOGICAL LOG OF PROPOSED DUGWELL SITE AT BHAKTAPUR W/S PROJECT

ANNEX - II

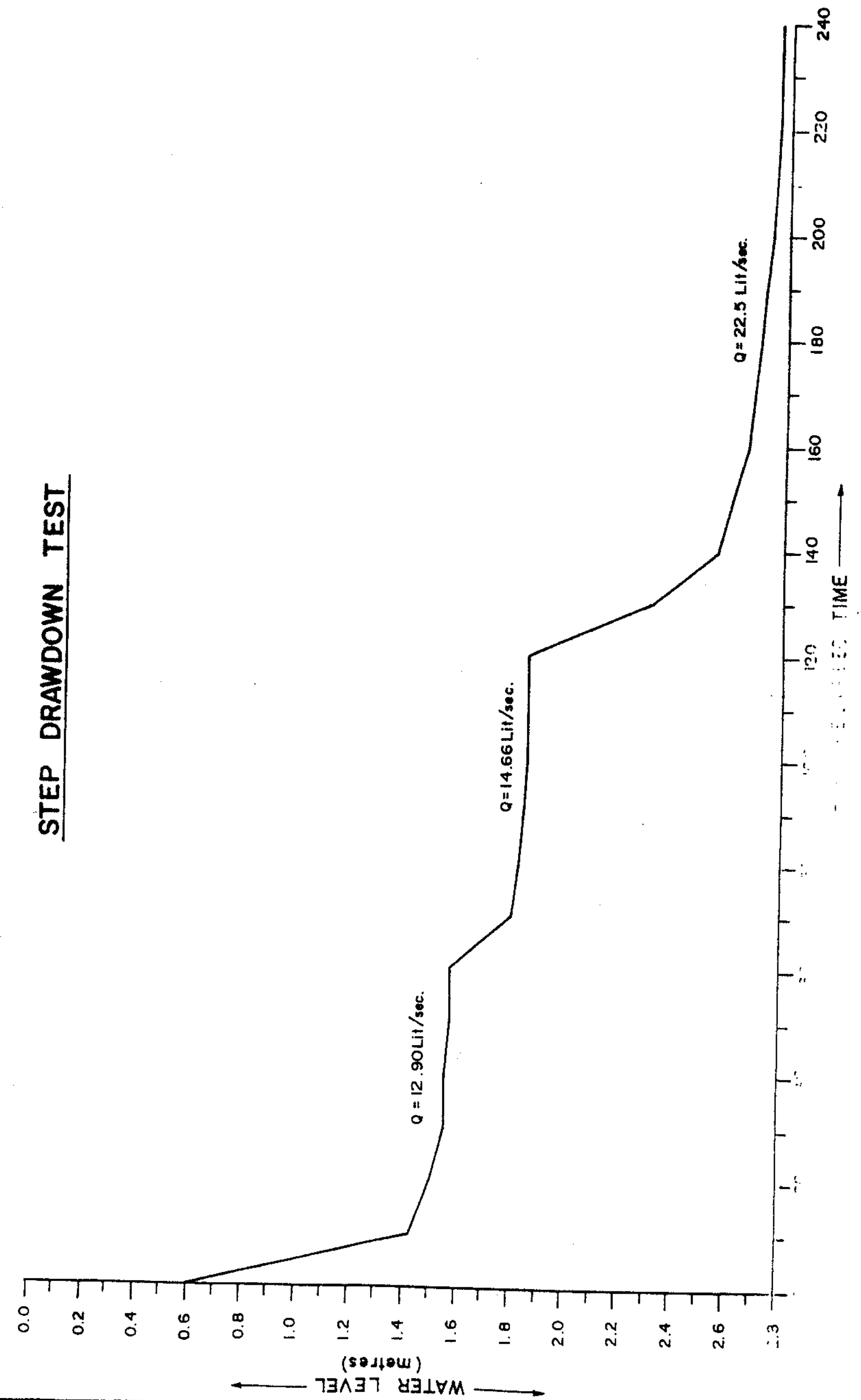
LITHOLOGICAL LOG OF PROPOSED DUGWELL SITE AT BHAKTAPUR W/S PROJECT



ANNEX III

STEP DRAWDOWN TEST & CONTINUOUS PUMPING TEST

ANNEX-III


STEP DRAWDOWN TEST
Q = 12.90 Lit/sec.
Q = 14.66 Lit/sec.
Q = 22.5 Lit/sec.
WATER LEVEL
(metres)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
TIME
140
160
180
200
220
240

Step Drawdown Test

	Elapsed Time	Water Level	Discharge Rate lit/sec.	Remarks
I Step	0	0.60	12.90	
	10	1.42		
	20	1.50		
	30	1.55		
	40	1.55		
	50	1.57		
	60	1.57		
II Step	70	1.80	14.66	
	80	1.82		
	90	1.84		
	100	1.85		
	110	1.85		
	120	1.85		
III Step	130	2.31	22.50	
	140	2.55		
	150	2.60		
	160	2.66		
	170	2.68		
	180	2.70		
	190	2.72		
	200	2.74		
	210	2.75		
	220	2.76		
	230	2.76		
	240	2.76		

Recuperation Test (Recovery)

Time	Elapsed Time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec.	Remarks
	0	1.57	0.00	12.90	From ground level (SWL) = 0.60m
	1	1.22	0.35		
	2	1.00	0.57		
	3	0.89	0.68		
	4	0.83	0.74		
	5	0.79	0.78		
	6	0.76	0.81		
	7	0.75	0.82		
	8	0.74	0.83		
	9	0.73	0.84		
	10	0.70	0.87		
	15	0.66	0.91		
	20	0.65	0.92		
	25	0.65	0.92		
	30	0.64	0.93		
	60	0.64	0.93		

Specific Yield

$$C = \frac{2.303}{t} \log_{10} \frac{S_1}{S_2}$$

where, $S_1 = 0.97$, $S_2 = 0.04$ and $t = 1$ hr.

Therefore, C = 3.18

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<u>Drawdown Test</u>

Time	Elapsed Time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec.	Remarks
	0	0.60	0.00	12.90	SWL = 0.6m
	1	1.03	0.43		
	2	1.21	0.61		
	3	1.30	0.70		
	4	1.38	0.78		
	5	1.38	0.78		
	6	1.40	0.80		
	7	1.40	0.80		
	8	1.40	0.80		
	9	1.40	0.80		
	10	1.42	0.82		
	11	1.44	0.84		
	15	1.45	0.85		
	20	1.50	0.90		
	25	1.54	0.94		
	30	1.55	0.95		
	35	1.55	0.95		
	40	1.55	0.95		
	60	1.57	0.97		
	70	1.57	0.97		

<u>Recuperation Test (Recovery)</u>

Time	Elapsed Time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec.	Remarks
	0	1.89	0.00	14.66	From ground level (SWL) = 0.60m
	1	1.38	0.47		
	2	1.14	0.71		
	3	0.99	0.86		
	4	0.92	0.93		
	5	0.87	0.98		
	6	0.83	1.02		
	7	0.81	1.04		
	8	0.79	1.06		
	9	0.77	1.08		
	10	0.76	1.09		
	15	0.71	1.14		
	20	0.69	1.16		
	25	0.67	1.18		
	30	0.65	1.20		
	45	0.61	1.24		
	60	0.58	1.25		

<u>Specific Yield</u>

$$C = \frac{2.303}{t} \log_{10} \frac{S_1}{S_2}$$

where, $S_1 = 1.29$, $S_2 = 0.04$ and $t = 1$ hr.

Therefore, C = 3.47

Drawdown Test

Time	Elapsed Time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec.	Remarks
11.53	0	0.50	0.00	14.66	
	2	1.08	0.58		
	3	1.36	0.86		
	4	1.48	0.98		
	5	1.55	1.05		
	6	1.61	1.11		
	7	1.63	1.13		
	8	1.66	1.16		
	9	1.68	1.18		
	10	1.71	1.21		
	15	1.77	1.27		
	20	1.78	1.28		
	25	1.74	1.24		
	30	1.75	1.25		
	35	1.76	1.26		
	45	1.78	1.28		
	60	1.80	1.30		
	90	1.82	1.32		
	120	1.84	1.34		
	220	1.85	1.35		

Recuperation Test (Recovery)

Time	Elapsed Time Min.	Water Level (m)	Recovery Rate (m)	Discharge Rate lit/sec.	Remarks
	0	2.75	0.00	22.50	From ground level (SWL) = 0.60m
	1	2.08	0.67		
	2	1.59	1.16		
	3	1.33	1.42		
	4	1.17	1.58		
	5	1.08	1.67		
	6	1.02	1.73		
	7	0.97	1.78		
	8	0.94	1.81		
	9	0.91	1.84		
	10	0.89	1.86		
	15	0.82	1.93		
	20	0.77	1.98		
	25	0.74	2.01		
	35	0.69	2.06		
	45	0.66	2.09		
	60	0.65	2.10		

Specific Yield

$$C = \frac{2.303}{t} \log_{10} \frac{S_1}{S_2}$$

where, $S_1 = 2.15$, $S_2 = 0.05$ and $t = 1$ hr.

Therefore, C = 3.76

Drawdown Test

Time	Elapsed Time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec.	Remarks
1.03	0	0.64	0.00	22.50	
	1	1.24	0.60		
	2	1.74	1.10		
	3	2.00	1.46		
	4	2.16	1.52		
	5	2.27	1.63		
	6	2.34	1.70		
	7	2.38	1.74		
	8	2.37	1.73		
	9	2.35	1.71		
	10	2.31	1.67		
	11	2.36	1.72		
	12	2.40	1.76		
	13	2.45	1.81		
	14	2.44	1.80		
	15	2.46	1.82		
	20	2.55	1.91		
	25	2.58	1.94		
	30	2.60	1.96		
	35	2.66	2.02		
	40	2.66	2.02		
	45	2.66	2.02		
	60	2.70	2.06		
	90	2.72	2.08		
	120	2.74	2.10		

Recuperation Test (Recovery)

Time	Elapsed Time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec.	Remarks
17.15	0	2.53	0.00	14.25 (1.23 mld)	SWL = 0.75 m below the existing ground level
17.20	5	1.19	1.34		
17.25	10	1.06	1.47		
17.30	15	1.02	1.51		
17.40	25	0.94	1.59		
17.50	35	0.89	1.64		
18.15	60	0.81	1.72		
18.50	95	0.79	1.74		

Specific Yield

$$C = \frac{2.303}{t} \log_{10} \frac{S_1}{S_2}$$

where, $S_1 = 2.53 - 0.75 = 1.78$ m, $S_2 = 2.53 - 1.72 - 0.75 = 0.06$ and $t = 1$ hr.

Therefore, $C = 3.39$

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Drawdown Test

Time	Elapsed Time Min.	Water Level (m)	Drawdown (m)	Discharge Rate lit/sec.	Remarks
8.50	0	0.75	0.00	14.25 (1.23 mld)	SWL = 0.75 m below the existing ground level
9.00	10	2.51	1.76		
10.00	70	2.61	1.86		
10.30	100	2.61	1.86		
10.40	110	2.64	1.89		
10.55	125	2.63	1.88		
11.20	150	2.60	1.85		
11.50	180	2.55	1.80		
12.15	205	2.55	1.80		
12.45	235	2.55	1.80		
13.15	265	2.53	1.78		
13.45	295	2.53	1.78		
14.15	325	2.53	1.78		
14.45	355	2.53	1.78		
15.15	385	2.53	1.78		
15.45	415	2.53	1.78		
16.15	445	2.53	1.78		
16.45	475	2.53	1.78		
17.15	505	2.53	1.78		