APPENDIX G
FIGURES

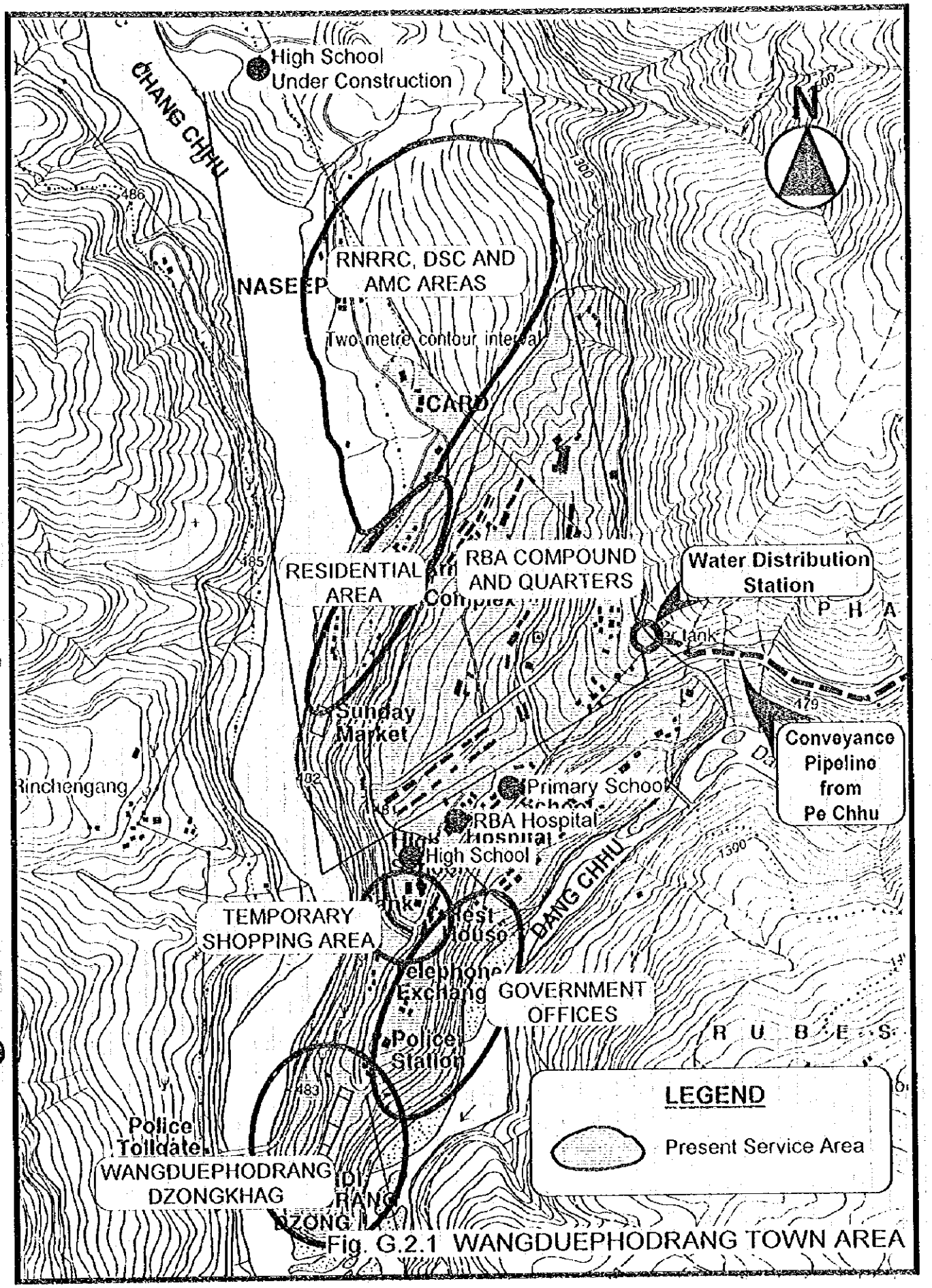


Fig. G.2.1 WANGDUEPHODRANG TOWN AREA

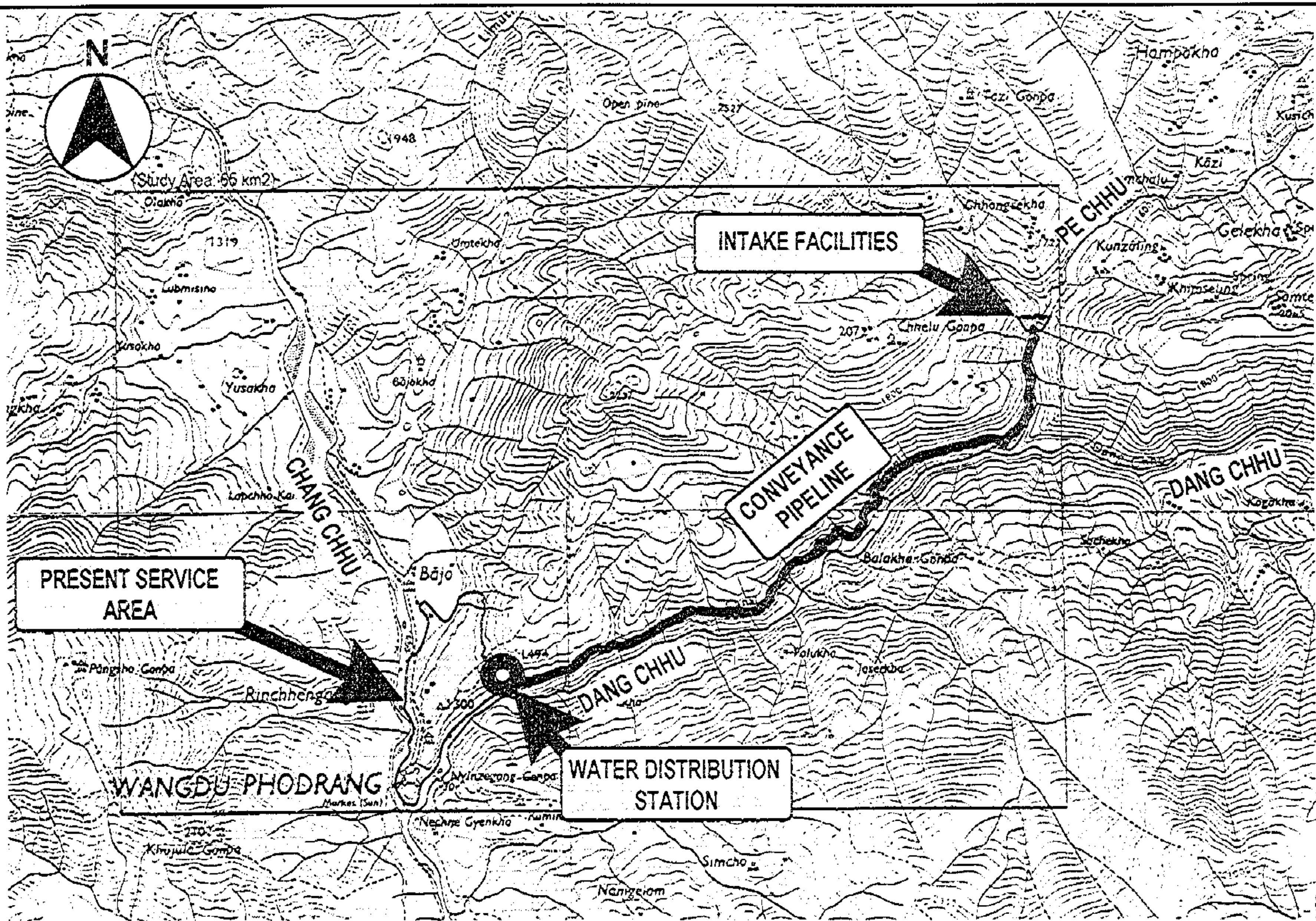


Fig. G.2.2 EXISTING URBAN WATER SUPPLY SYSTEM FOR WANGDUEPHODRANG TOWN AREA

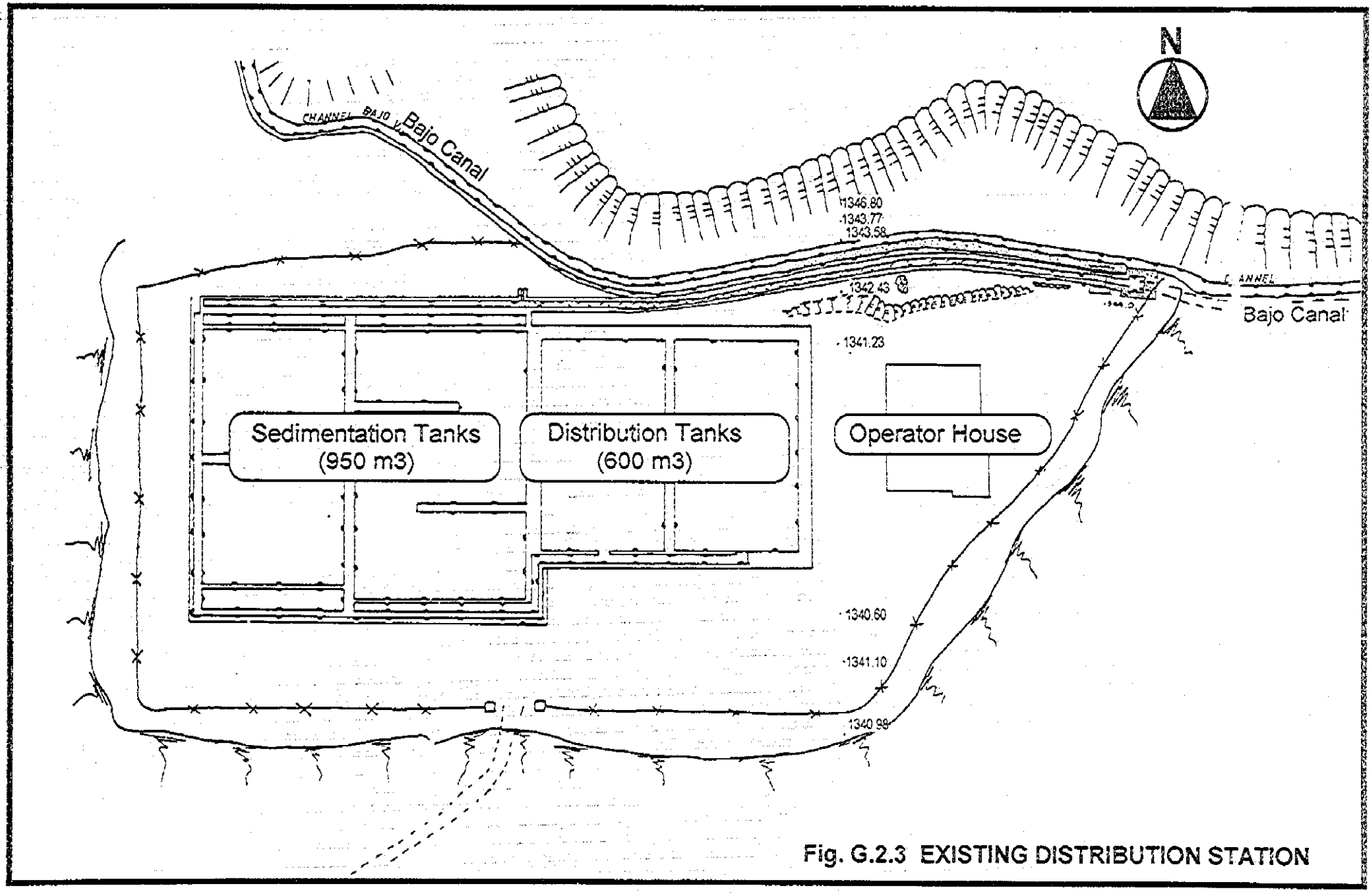


Fig. G.2.3 EXISTING DISTRIBUTION STATION

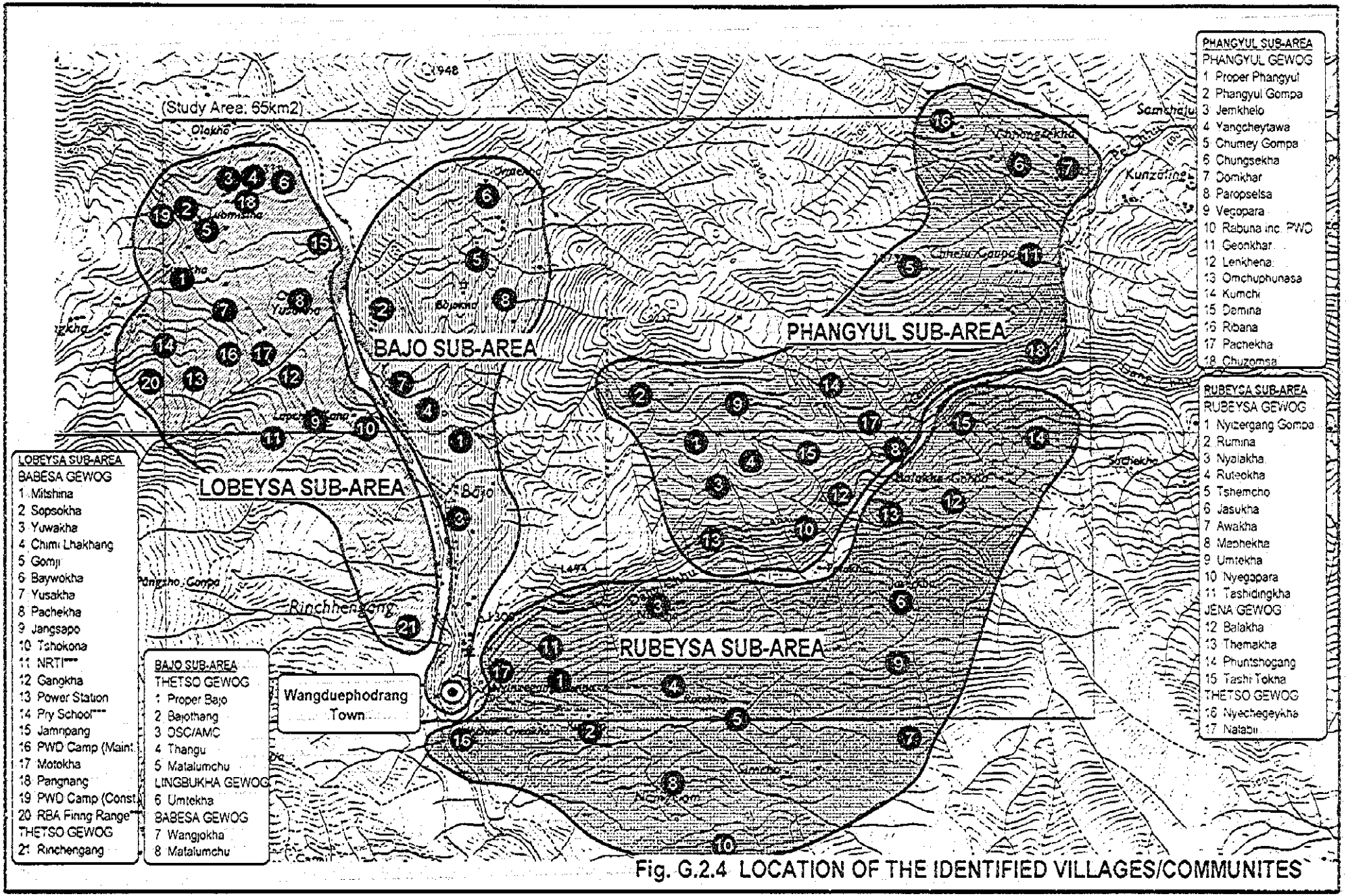


Fig. G.2.4 LOCATION OF THE IDENTIFIED VILLAGES/COMMUNITES

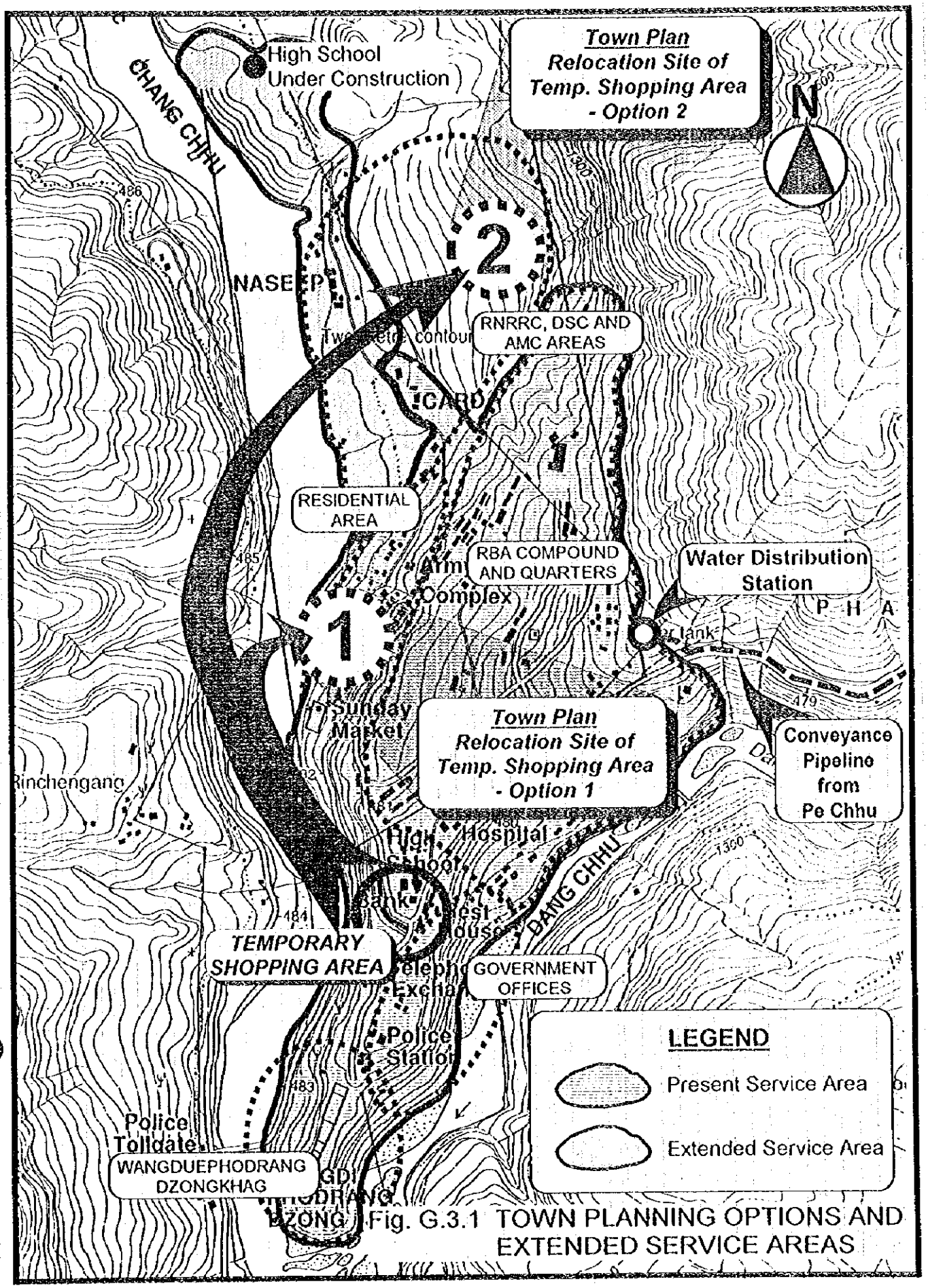


Fig. G.3.1 TOWN PLANNING OPTIONS AND EXTENDED SERVICE AREAS

Categories	1995	2002	2007
1. Present Service Area			
Resident	6,035	6,932	7,654
Growth Rate (%)		(2.00)	(2.00)
Dayvisitors (38%)	2,293	2,634	2,908
Sub-total	8,328	9,567	10,562
2. Extended Service Area			
Resident	0	47	202
Dayvisitors	0	233	448
Sub-total	0	280	650
3. Total Population			
Resident	6,035	6,979	7,856
Dayvisitors	2,293	2,867	3,356
Total	8,328	9,847	11,212

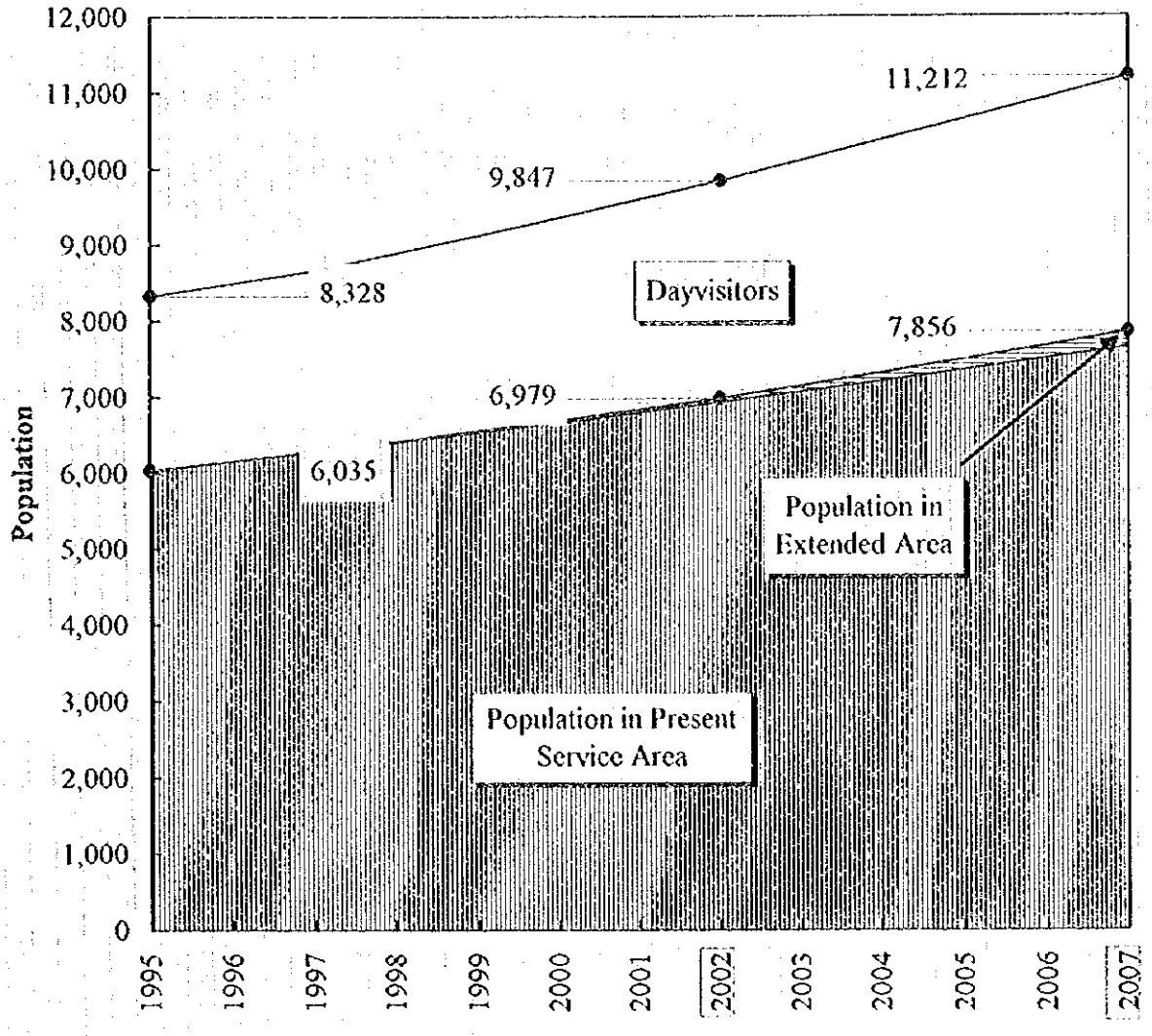


Fig. G.3.2 POPULATION PROJECTION FOR WANGDUEPHODRANG TOWN AREA

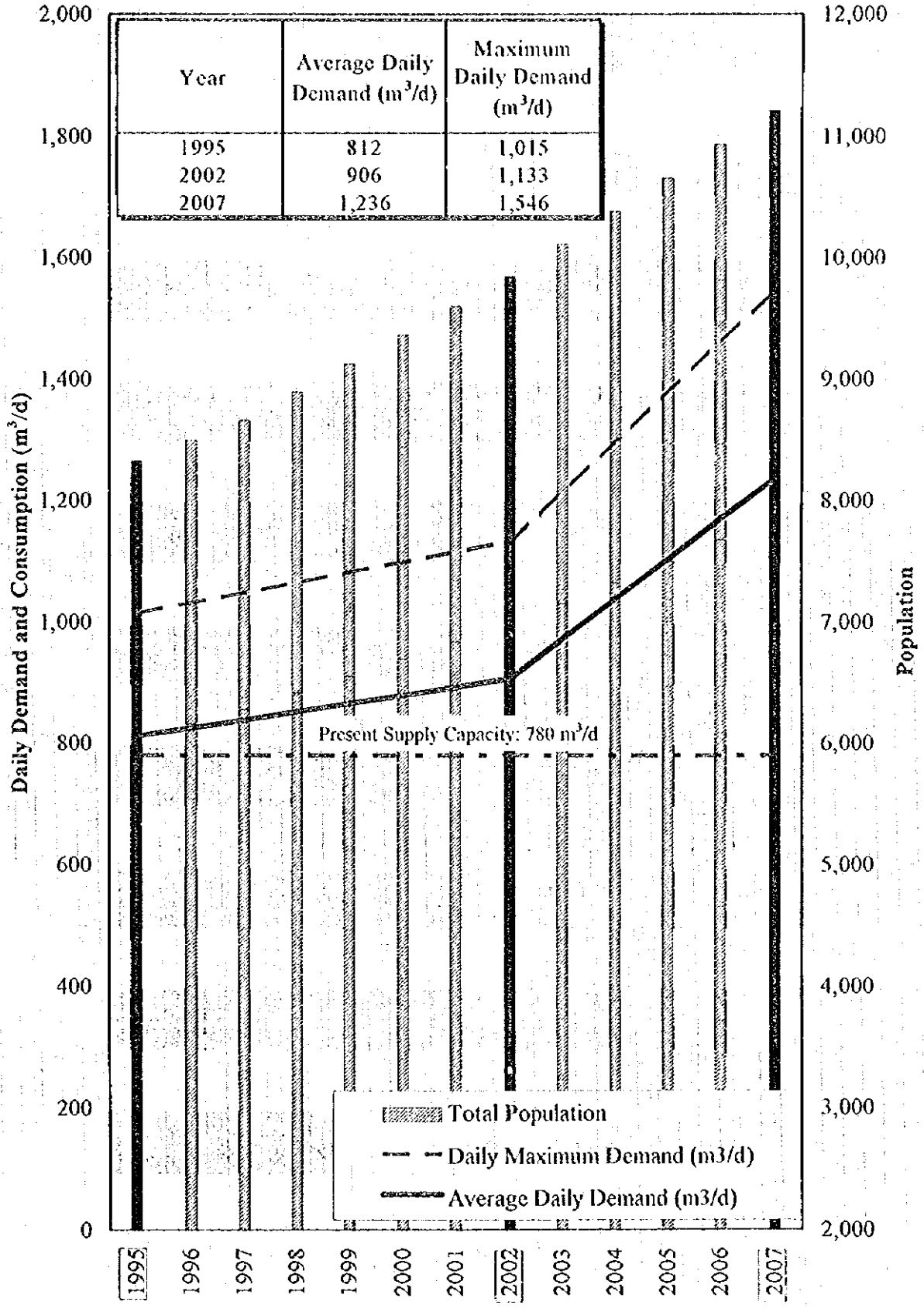


Fig. G.3.3 FUTURE WATER DEMAND AND CONSUMPTION

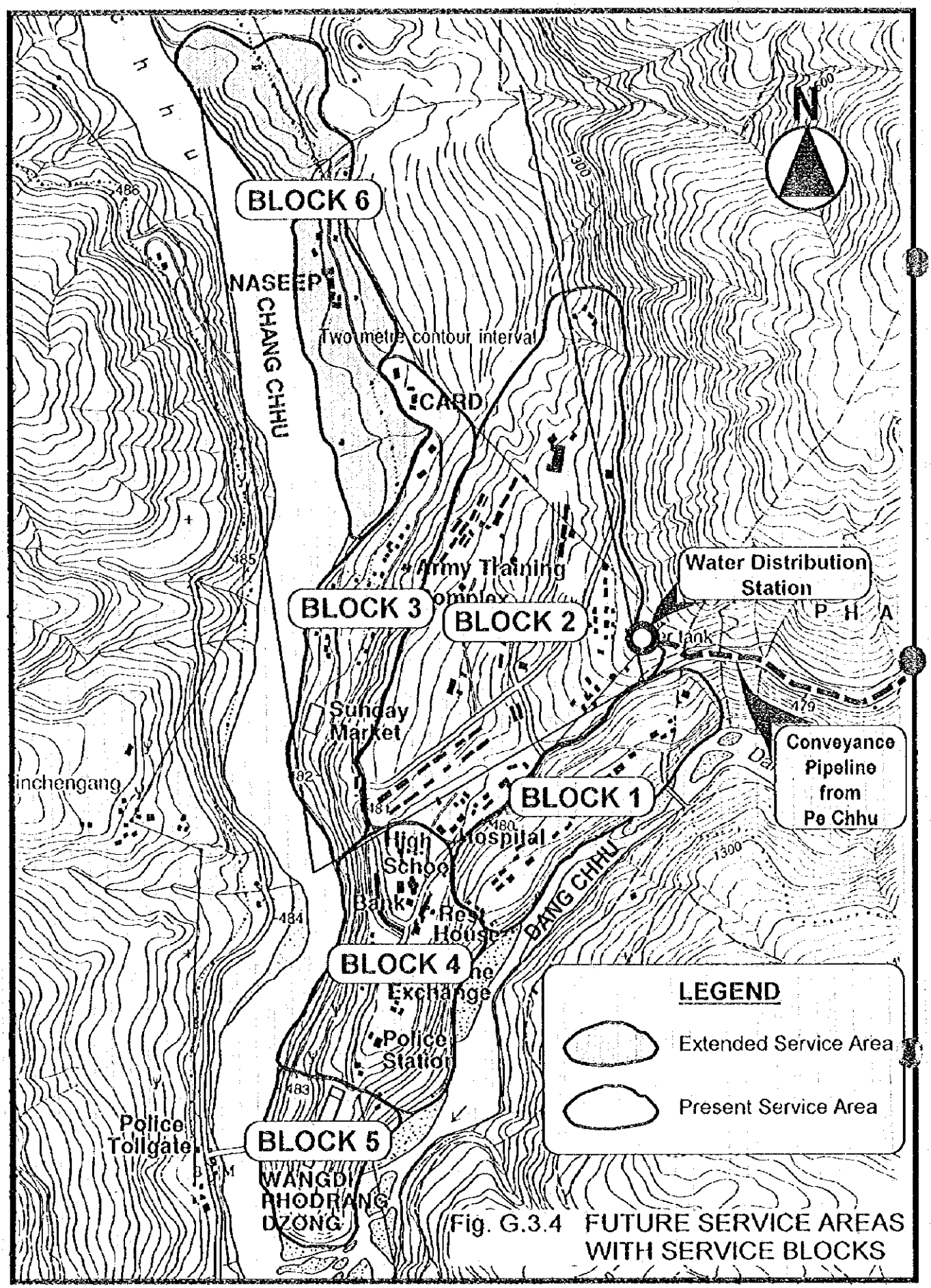


Fig. G.3.4 FUTURE SERVICE AREAS WITH SERVICE BLOCKS

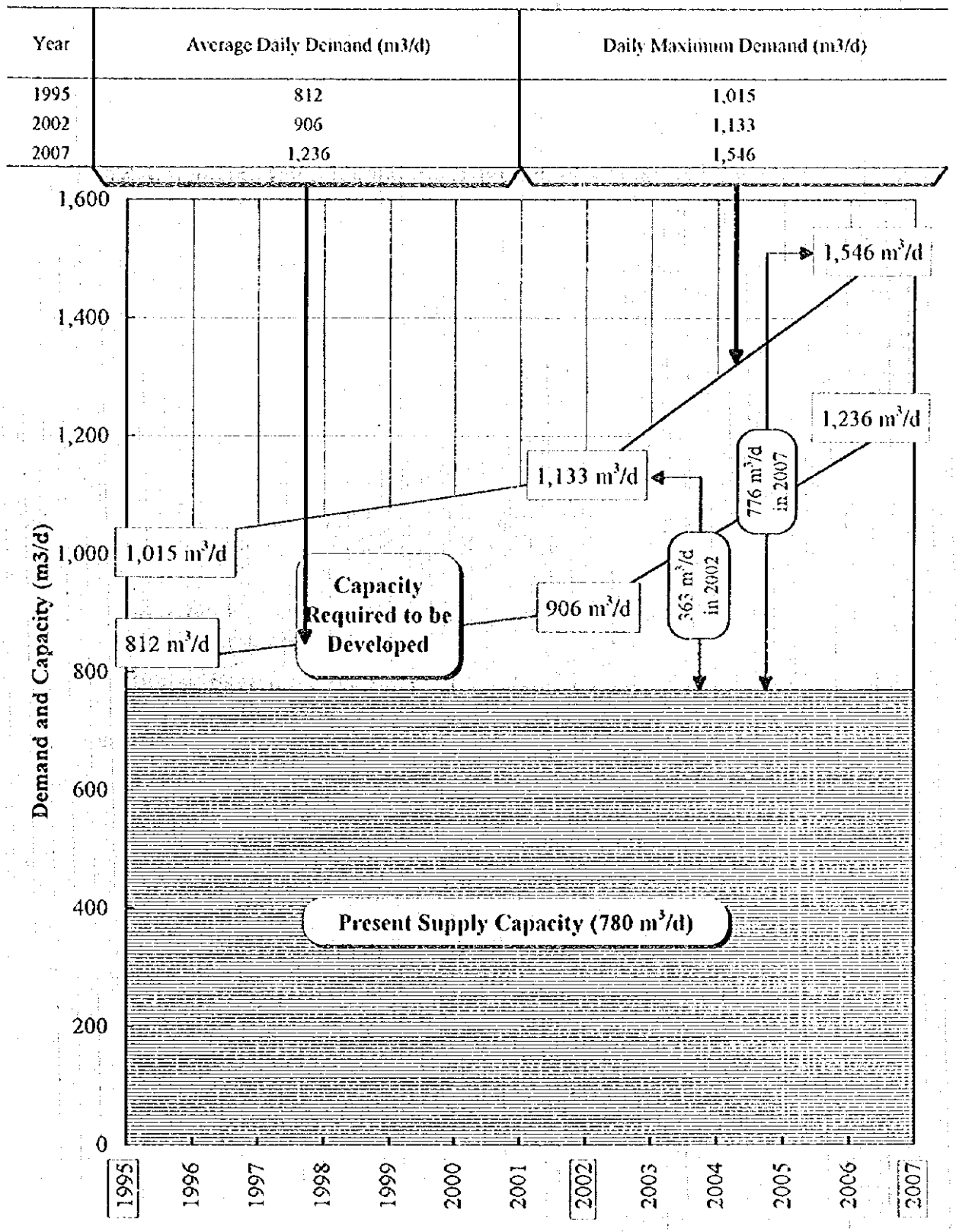


Fig. G.4.1 FUTURE WATER REQUIREMENT

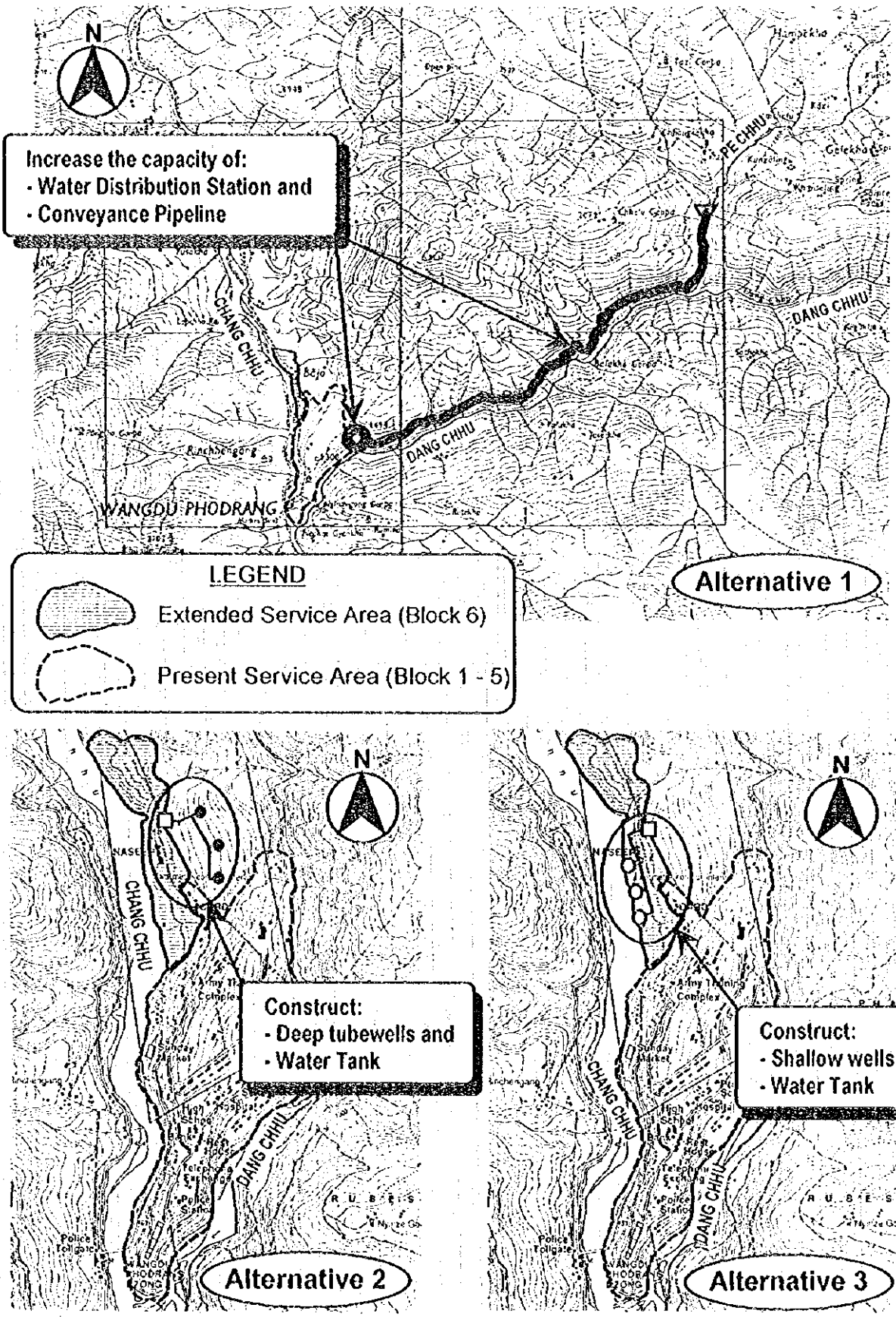


Fig. G.4.2 ALTERNATIVES FOR URBAN WATER SUPPLY SYSTEM

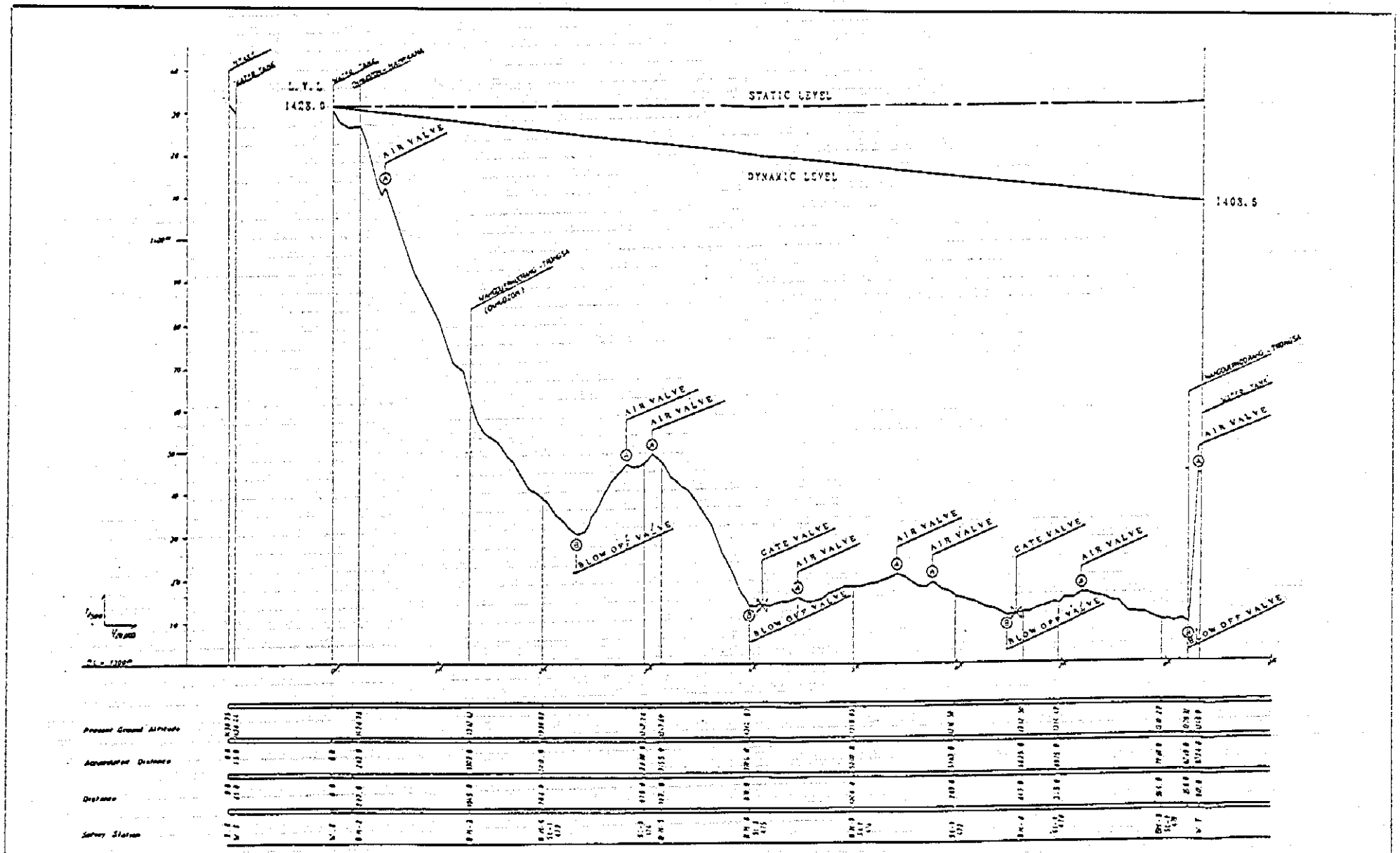


Fig. G.4.3 HYDRAULIC PROFILE OF CONVEYANCE PIPELINE

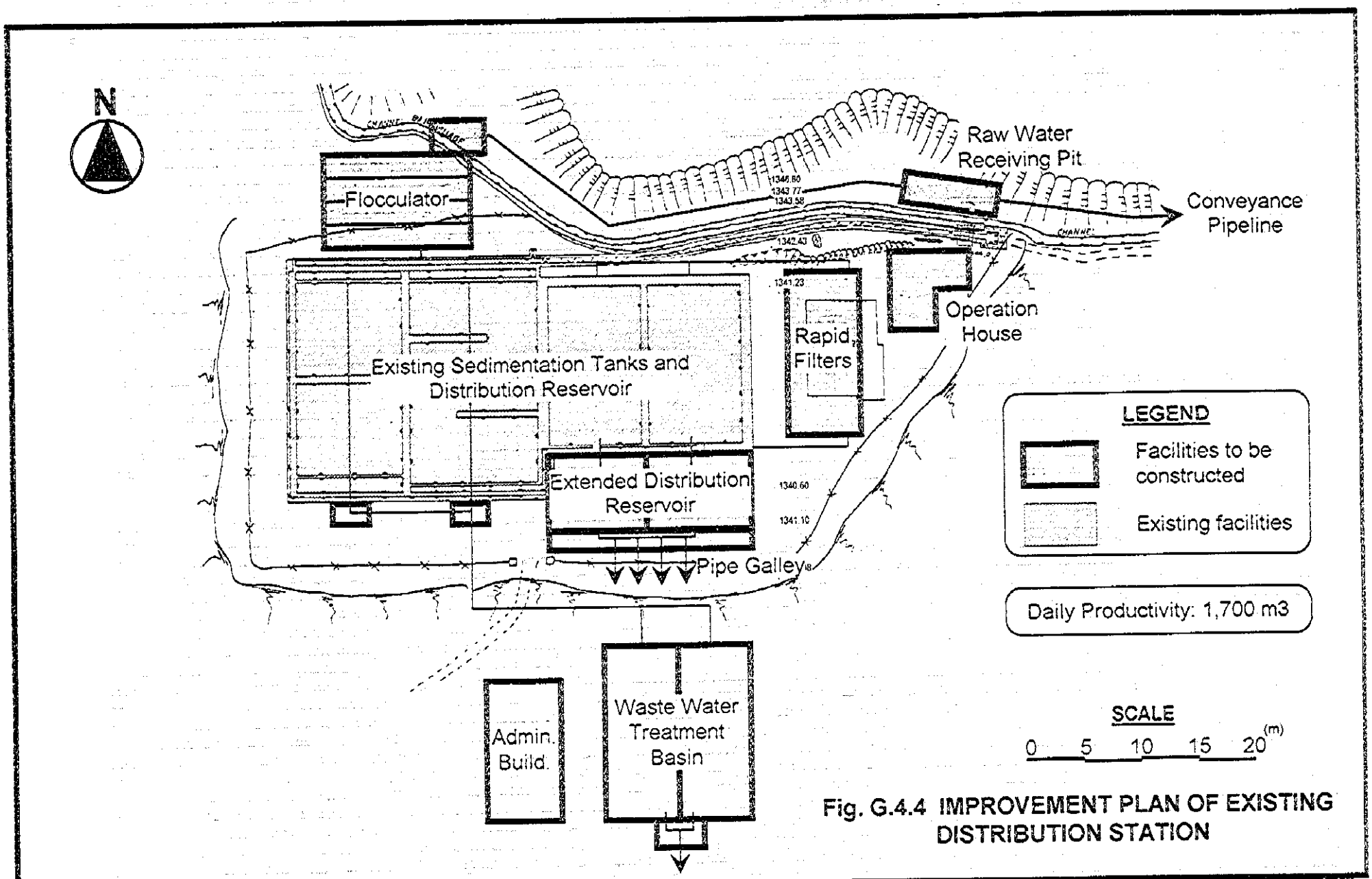


Fig. G.4.4 IMPROVEMENT PLAN OF EXISTING DISTRIBUTION STATION

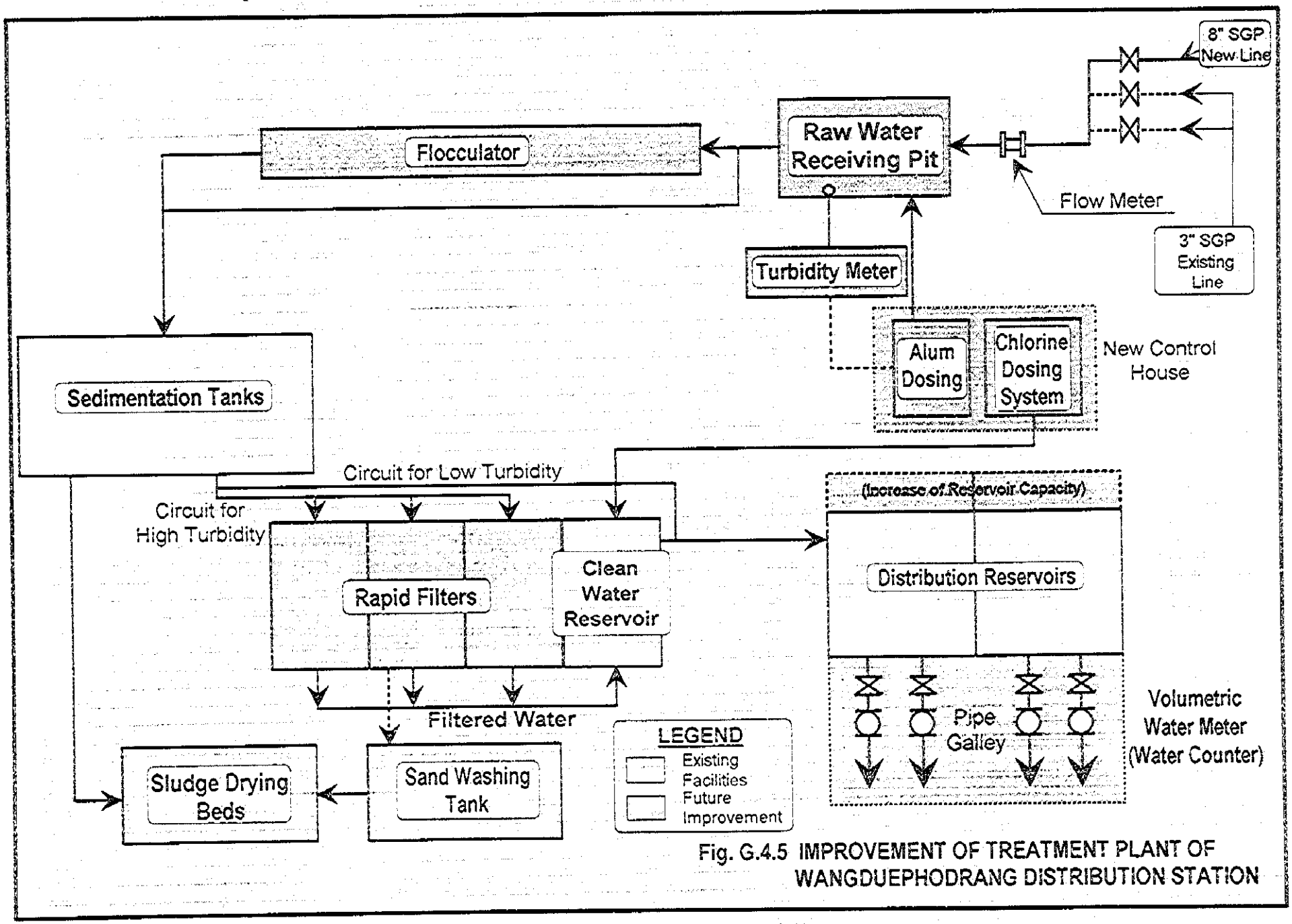


Fig. G.4.5 IMPROVEMENT OF TREATMENT PLANT OF WANGDUEPHODRANG DISTRIBUTION STATION

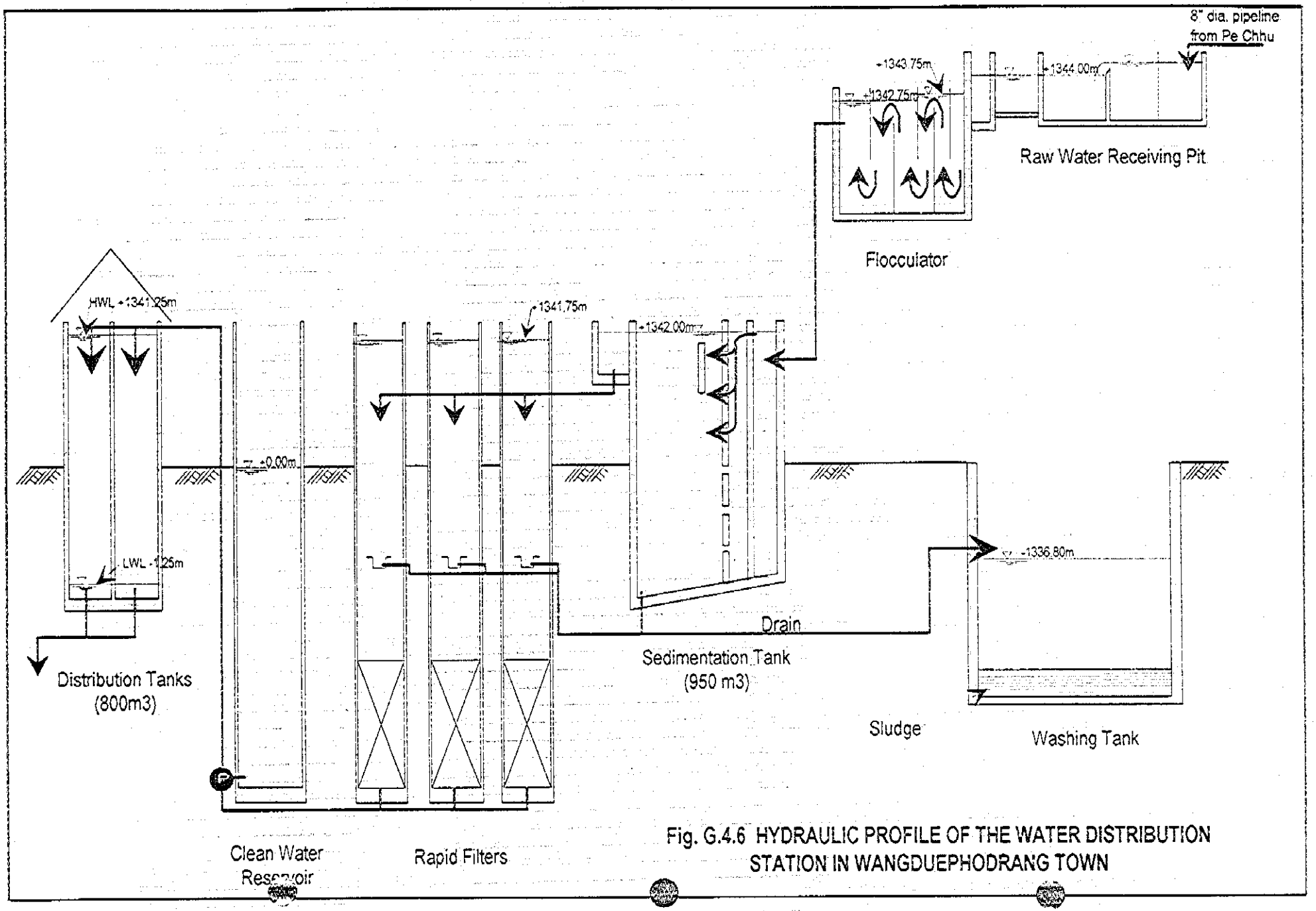


Fig. G.4.6 HYDRAULIC PROFILE OF THE WATER DISTRIBUTION STATION IN WANGDUEPHODRANG TOWN

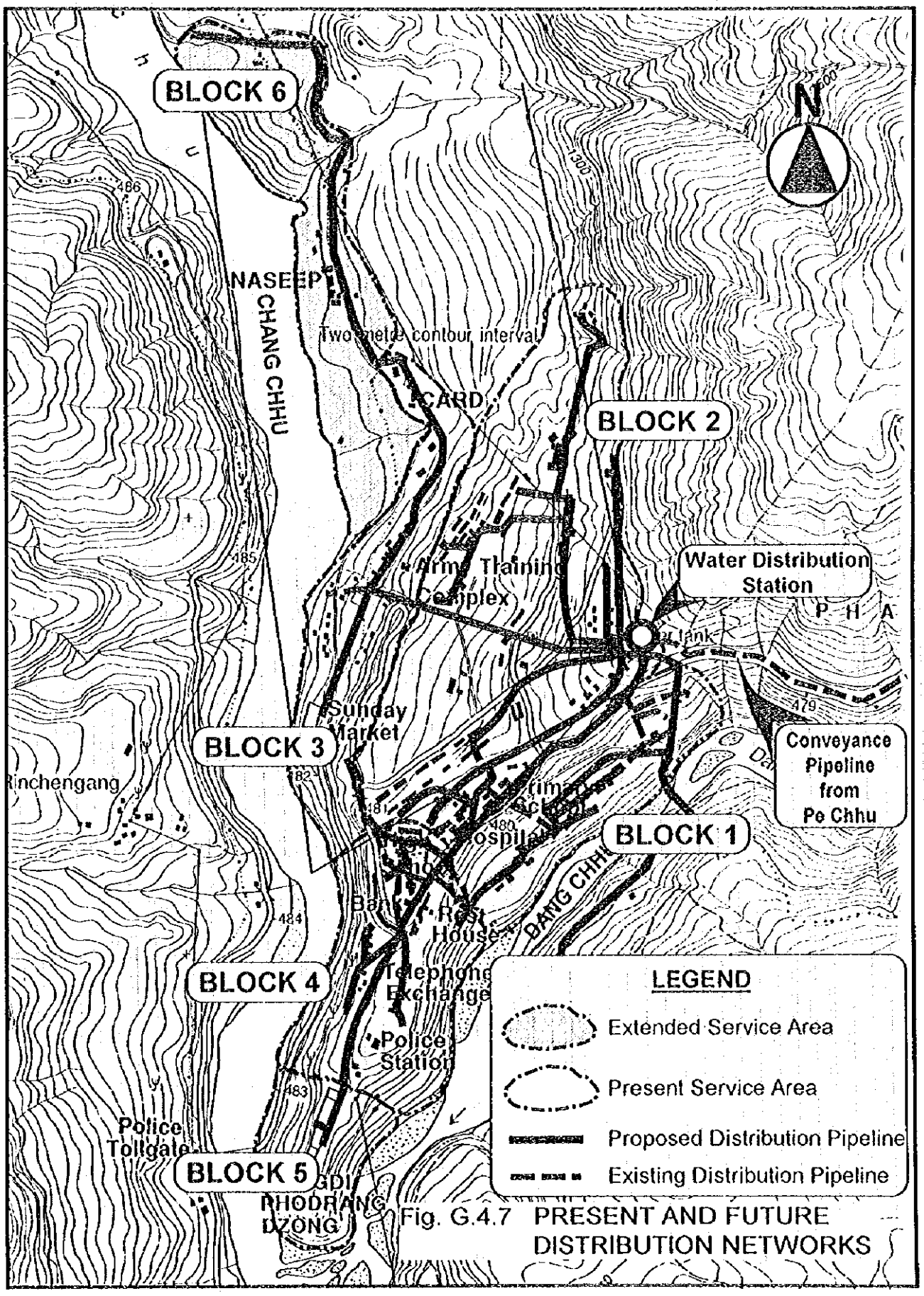


Fig. G.4.7 PRESENT AND FUTURE DISTRIBUTION NETWORKS

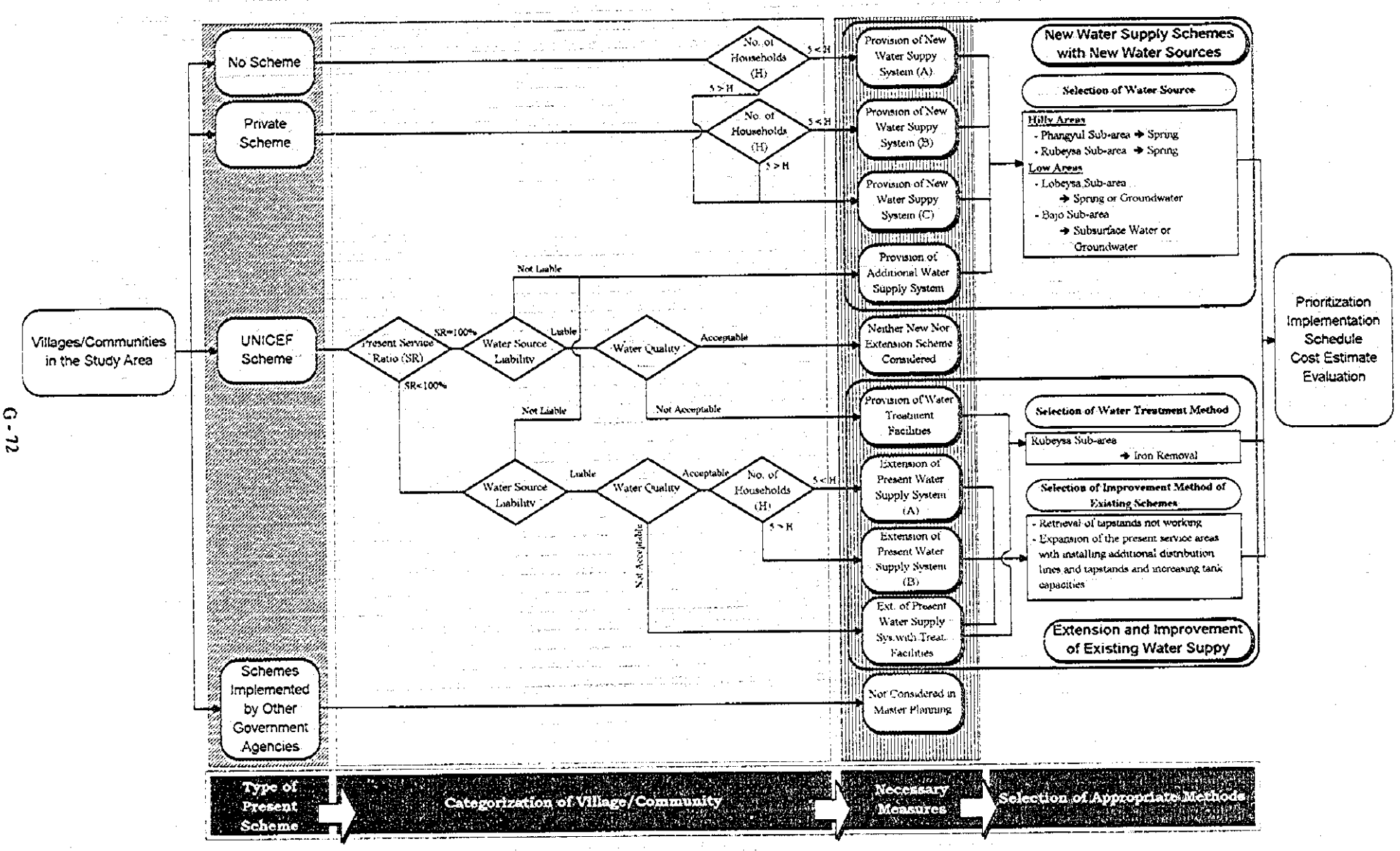
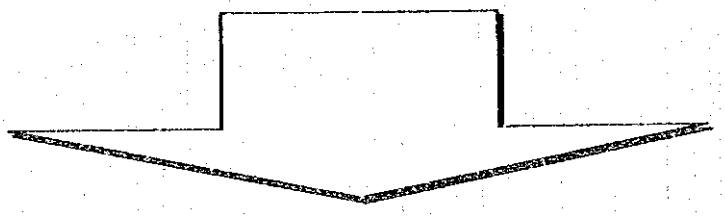


Fig. G.4.8 SCHEMATIC FLOW FOR SELECTING MEASURES TO BE TAKEN

Sub-areas	Available Water Sources: Spring Water	Sub-surface Water	Groundwater	Stream/River Water**	Water Sources Considered in Alternative Study
Lobeysa	◉	●	◉	×	→ Spring Water & Groundwater
Bajo*	●	◉	◉	×	→ Sub-surface Water & Groundwater
Phangyul	◉	×	×	×	→ Spring Water
Rubeysa	◉	×	×	×	→ Spring Water

Note:
*: Spring water source is considered partly in hilly area.
**: Stream and river water is not considered in the study since they may easily be contaminated biologically.



Sub-areas	Item	New Scheme (A)	New Scheme (B)	New Scheme (C)	Additional Scheme	Extension Scheme (A)	Extension Scheme (B)	Extension with Treatment	Water Treatment Scheme
Lobeysa	No. of Village	L-1 2	0	L-2 2	0	0	S-4 1	0	0
	Average Population	25	0	23	0	0	67	0	0
Bajo	No. of Village	B-1 3	0	B-2 1	B-1 1	0	0	0	0
	Average Population	128	0	61	185	0	0	0	0
Phangyul	No. of Village	3	1	7	0	3	0	0	0
	Average Population	S-1 120	49	18	0	S-3 76	0	0	0
Rubeysa	No. of Village	2	0	S-2 2	0	1	S-4 2	0	T-1 1
	Average Population	93	0	21	0	109	27	0	123
Whole Area	Total No. of Village	9	1	12	1	4	3	0	1
	Average Population	131	49	24	185	99	40	0	123

Case S-1:	Spring Development - New (Large)	Case B-1:	Groundwater vs Subsurface Development (Large)
Case S-2:	Spring Development - New (Small)	Case B-2:	Groundwater vs Subsurface Development (Small)
Case S-3:	Spring Development - Extension (Large)	Case L-1:	Spring vs Groundwater Development (Large)
Case S-4:	Spring Development - Extension (Small)	Case L-2:	Spring vs Groundwater Development (Small)
Case T-1:	Water Treatment - Iron Removal		

Fig. G.4.9 CASES SIMPLIFIED FOR EACH CATEGORY

APPENDIX H
IRRIGATION IMPROVEMENT STUDY

THE STUDY
ON
GROUNDWATER DEVELOPMENT
IN
WANGDUEPHODRANG DISTRICT OF BHUTAN

FINAL REPORT

VOLUME III: SUPPORTING REPORT

APPENDIX-II IRRIGATION IMPROVEMENT STUDY

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APPENDIX-H IRRIGATION IMPROVEMENT STUDY

H.1 Summary

H.1.1 Objective of the Study

The main objective of the study is to clarify the present conditions of irrigation system and to suggest the optimum irrigation improvement plan in the Study Area.

RGOB has made efforts to promote agricultural development in conformity with the objectives of the Seventh Five Year Plan (1992-1997). The objectives of the agricultural sector are as follows:

- sustainable development of arable production to enable self sufficiency in food production;
- improvements in the incomes, living and nutrition standards of the rural population;
- sustainable utilization of natural resources.

The Study Area is located within the main valley of the Chang Chhu, Dang Chhu river systems and tributaries and has good potential for agricultural production, because of its climatic conditions, especially for rice-based cropping system.

In addition to the natural conditions, farmers in the lower part of valleys (Lobeysa and Bajo Sub-area) can easily obtain farm inputs and have access to markets (Wangduephodrang town and Thimphu town). Technical information and services also can be obtained through RNRRC, NASEPP and AMC located in the Bajo Sub-area. Farmers therefore have good opportunity to carry out a higher level of farming practices compared to other areas.

As mentioned above, agriculture in the Study Area is relatively developed compared to other areas of Bhutan with regards to productivity and technology adopted. However, the following constraints should be overcome in order to increase agricultural production and the living standard of farmers. The major constraints of agricultural development in the Study Area are as follows.

In the Study Area, most of the cultivable lands have already been developed to the maximum extent, and therefore, it is necessary to consider the improvement of land productivity, workability, and economic efficiency in order to improve the agriculture production.

On the other hand, it is possible to apply rice double cropping in certain portions of the irrigated land of the Study Area without any change in the present conditions of the existing agricultural infrastructure. However, rice double cropping is applied only in less than two (2) % of the area at present, and the production of rice has been decreasing since 1990. It is considered that this phenomenon is caused not only by the technical factor but also by the socio-economical factor.

This means that it is difficult to develop the agricultural sector in the Area with carrying out only irrigation improvement project and some of additional plan like

improvement of agricultural supporting system must be required with consideration of the objectives for agricultural development.

Therefore, in this Appendix, the agricultural indicator in the area is also clarified based on the date collected through the Field Works for the purpose of groping for necessary countermeasure in addition to irrigation improvement plan.

H.1.2 Summary of Field Work

(1) Collection of information

Following data and information were collected.

- Land use data by Gewogs
- Agricultural production and cropping area by Gewogs
- Trading statistics data
- Farm gate price of agricultural production (up to 1992)
- Marketing price of agricultural production (1992 ~ 1994)
- Construction cost ratio (August, 1995)
- Irrigation facilities design manual (1994)

(2) Inventory works on the irrigation canal

Following inventory works on the main irrigation schemes in the Sub-areas was carried out.

- Profile and longitudinal survey for seven schemes (scale 1/500 sketch work)
- Discharge capacity
- Off take and command area
- Cropping pattern
- Water management system

(3) Field survey

Over roll field survey of the 10 of main irrigation schemes concerned in the Sub-areas was carried out and physical conditions and problems were found out. Those were confirmed through the hearing investigation from farmers and irrigation officers.

(4) Preliminary Statistical Analysis for Agricultural Sector

Based on the land use data of the Land Use Planning Project in MOA and the statistical data of Center Statistics Organization (CSO) in MOP, preliminary statistical analysis for agricultural sector was carried out for finding out the present conditions of agricultural aspect in the Bhutan. Similar analysis was also carried out for the Sub-areas based on the land use data by Gewogs.

(5) Evaluation of Traditional Water Management System

Based on the result of the inventory works and field survey, traditional water management system of each main irrigation scheme was evaluated.

H.1.3 Summary of Case Study Result

There are 22 irrigation schemes in and around the Study Area and 10 irrigation schemes among them are supplying the irrigation water for the Sub-Study Area as shown in Fig. H.1.1. Considering the conditions of topography and water resources, two (2) irrigation schemes were selected for the case study to find out the optimum irrigation improvement plan. The results of the case study are summarized as shown below;

- For low flat area

  The highest benefit/cost ratio can be obtained by applying 40% of double paddy cropping through the improvement of water management system and canal capacity.

- For high hilly area

  The highest benefit/cost ratio can be obtained by applying 10% of crop diversification from paddy through improvement of water management system.

H.1.4 Summary of Basic Irrigation Improvement Plan

According to the objectives of the agricultural development in the Seventh Five Year Plan, following basic concepts were considered for irrigation improvement plan based on the results of the case study;

- Basic concepts

  ① Improvement of effective irrigation water use
  ② Improvement of effective land use

As it is necessary to consider the proper implementation plan for the prevention of any social conflict caused by the rapid development, the improvement plan should be studied for short term and long term. From the result of mutual discussions between MOA and the study team, following target years are settled based on the physical year of the Five Year National Development Plans in the Bhutan.

- 2002 year for short term improvement plan
- 2007 year for long term improvement plan

Considering the conditions of water resources, farmers economy and food self sufficiency in Bhutan, following strategies were suggested based on the results of the Case Study.

- Proposed Strategy

① For low flat area
- ❶ Short term
  Supplying sufficient irrigation water
  Applying double paddy cropping for 40% of present paddy field
- ❷ Long term
  Supplying sufficient irrigation water
  Applying double paddy cropping for 100% of present paddy field

② For high hilly area
- ❶ Short term
  Establishment of new water management system
  Applying crop diversification for 10% of present paddy field
- ❷ Long term
  Improvement of water management system
  Research on optimum crop for the diversification

Based on theses basic concepts and strategies, the irrigation improvement projects for 10 schemes were planned by applying the following counter measures:

- For Lobeysa and Bajo Sub-Study Area
  - ❶ Short term
    a. Rehabilitation of present irrigation canals (3 schemes, totally 30 km) with enforcement of the protection works at the hazard area for supplying sufficient irrigation water
    b. Establishment of new water management system for effective use of the irrigation water
    c. Applying the double paddy cropping for 40% of present paddy field for effective use of the agricultural land
  - ❷ Long term
    a. Applying double paddy cropping for 100% of present paddy field for increase of the paddy production. (as the maximum water requirement is more or less 5% less than that for the short term plan, the same facilities as for short term can be applied)

- For Rubeysa and Phangyul Sub-Study Area
  - ❶ Short term
    a. Establishment of new water management system with new construction of offtake facilities for effective use of irrigation water
    b. Applying 10% of diversification for present paddy field considering the effective land use
  - ❷ Long term
    a. Research of the optimum crop for the diversification considering the improvement of agricultural activities

The proposed irrigation improvement projects are summarized as shown below;

Summary of Irrigation Improvement Project

Category of land	Low Flat Area			
Sub-Area	Lobeysa		Bajo	Total
Name of Canal	Upper Lobeysa	Lower Lobeysa	Bajo	
Code	C1	C2	C9	
Canal Length (km)	7.1	8.1	15.0	30.2
Command Area (ha)	61	300	143	504
Number of Benefited Households	117	123	52	292
Number of Offtake Facilities	32	52	35	119
Proposed Counter Measures	Rehabilitation of Irrigation Canal with Enforcement of Protection Works Establishment of New Water Management System Applying Double Paddy Cropping (40% for short term, 100% for long term)			
Total Construction Cost (1000Nu.)	1,152	3,027	5,016	9,195
Required O M Cost (1000Nu./year)	21	32	48	102
Estimated Net B C Ratio	2.25	2.21	2.80	-

Category of land	High Hilly Area			
Sub-Area	Pangyul		Rubeysa	
Name of Canal	Phangyul	Genukha	Nalakha	Rutekha
Code	C10	C15	C18	C19
Canal Length (km)	16.0	3.5	3.9	2.2
Command Area (ha)	91	15	29	40
No. of Benefited Households	42	23	60	44
Number of Offtake Facilities	32	12	20	28
Proposed Counter Measures	New Construction of Offtake Facilities Establishment of New Water Management System Applying Diversification for 10% of Paddy Field			
Total Construction Cost (1000Nu.)	286	47	119	207
Required O M Cost (1000Nu./year)	58	12	15	10
Estimated Net B C Ratio	1.95	1.53	1.57	1.88
Sub-Area	Rubeysa			Total
Name of Canal	Maphekha	Naykoyuwa	Rumina	
Code	C20	C21	C22	
Canal Length (km)	2.2	1.7	1.1	30.6
Command Area (ha)	27	24	28	254
No. of Benefited Households	44	18	35	266
Number of Offtake Facilities	25	20	16	153
Proposed Counter Measures	New Construction of Offtake Facilities Establishment of New Water Management System Applying Diversification for 10% of Paddy Field			
Total Construction Cost (1000Nu.)	148	119	95	1,021
Required O M Cost (1000Nu./year)	9	7	5	115
Estimated Net B C Ratio	1.59	1.74	1.91	-
Research Project for the Diversification				
Required Project Cost (1000Nu./year)	487			

H.1.5 Summary of Alternative Study

The alternatives as shown in Fig. H.5.1 were considered for the irrigation improvement in the Sub-study area. In the Case Study, most of the alternatives were analyzed except for the following case.

- Supplying sufficient water using the river pump or shallow well system instead of canal improvement.

This counter measure can be applied only for low flat area and the improvement of water management system and applying 40% double paddy cropping should be required for achieving same project benefit as that of irrigation canal improvement.

Applying the same condition for the design, the comparison of system cost including O/M cost between the shallow well and river pump systems was studied. The results are summarized as shown below and the river pump system was proposed for the alternative study.

Summary of Comparison of the Water Supply System

(unit:1000Nu.)

Type of Systems	Shallow Well	River Pump	Remarks
Civil Works	355	220	
Pump Facilities	807	807	for 20 years
O M Cost	502	502	for 20 years
Total	1,665	1,530	

For the low flat area, the total project cost for 1 year including O/M cost of river pump system was compared with that of irrigation canal improvement. The result is summarized as shown below and the canal improvement was proposed for irrigation improvement plan.

Summary of Comparison of Net Project Cost

(unit : 1000Nu /year)

Name of Canal	Code	With River Pump System	With Canal Improvement
Upper Lobeysa	C1	530	35
Lower Lobeysa	C2	213	132
Bajo	C9	216	69

II.1.6 Summary of Project Implementation Plan

Based on the estimated B/C ratio of the projects, the priority was considered for the implementation of the irrigation improvement plan. The inventory and priority of the projects are tabulated as shown below;

Inventory of the Irrigation Improvement Project

Category of Land	Sub-Area	Name of Canal	Code	Command Area (ha)	Construction Cost (1000 Nu.)	O/M Cost for 1 year (1000 Nu.)	Estimated B C Ratio	Priority
Low Flat Area	Lobeysa	Upper Lobeysa	C1	61	1,152	21	2.25	②
		Lower Lobeysa	C2	300	3,027	32	2.21	③
	Bajo	Bajo	C9	143	5,016	48	2.80	①
High Hilly Area	Thangyul	Thangyul	C10	91	286	58	1.95	①
		Gunkha	C15	15	47	12	1.53	⑦
	Rubeysa	Nalakha	C18	29	119	15	1.57	⑥
		Rutekha	C19	40	207	10	1.88	③
		Maphekha	C20	27	148	9	1.59	⑤
		Naykeyuwa	C21	24	119	7	1.71	④
		Rumina	C22	28	95	5	1.91	②

Based on the priority of the project, the implementation schedule of the irrigation improvement plan was proposed as shown below considering the target year and total construction cost.

Proposed Implementation Schedule

Category of Land	Sub-Area	Name of Canal	Code	Priority	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1	②											
		Lower Lobeysa	C2	③											
	Bajo	Bajo	C9	①											
High Hilly Area	Phangyul	Phangyul	C10	①											
		Genikha	C15	⑦											
	Rubeysa	Nalakha	C18	⑥											
		Rutekha	C19	③											
		Maphekha	C20	⑤											
		Naykoyuwa	C21	④											
		Rumina	C22	②											
	Research the Optimum Diversification Crop														

Based on the implementation schedule, the annual disbursement schedule of the project and O/M cost were estimated and summarized as shown below;

Proposed Disbursement Schedule for the Irrigation Improvement Project

(unit : 1000 Nu.)

Category of Land	Sub-Area	Name of Canal	Code	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1				230	922						
		Lower Lobeysa	C2		605	908	1,514							
	Bajo	Bajo	C9	2,257	1,756	1,003								
High Hilly Area	Phangyul	Phangyul	C10	257	29									
		Genikha	C15					47						
	Rubeysa	Nalakha	C18				71	48						
		Rutekha	C19		41	166								
		Maphekha	C20			15	133							
		Naykoyuwa	C21			83	36							
		Rumina	C22		95									
Research on the Optimum Diversification Crop						487	487	487	487	487	487	487	487	487
Annual Total				2,515	2,526	2,662	2,471	1,503	487	487	487	487	487	487

Proposed O/M Cost for the Irrigation Improvement Project

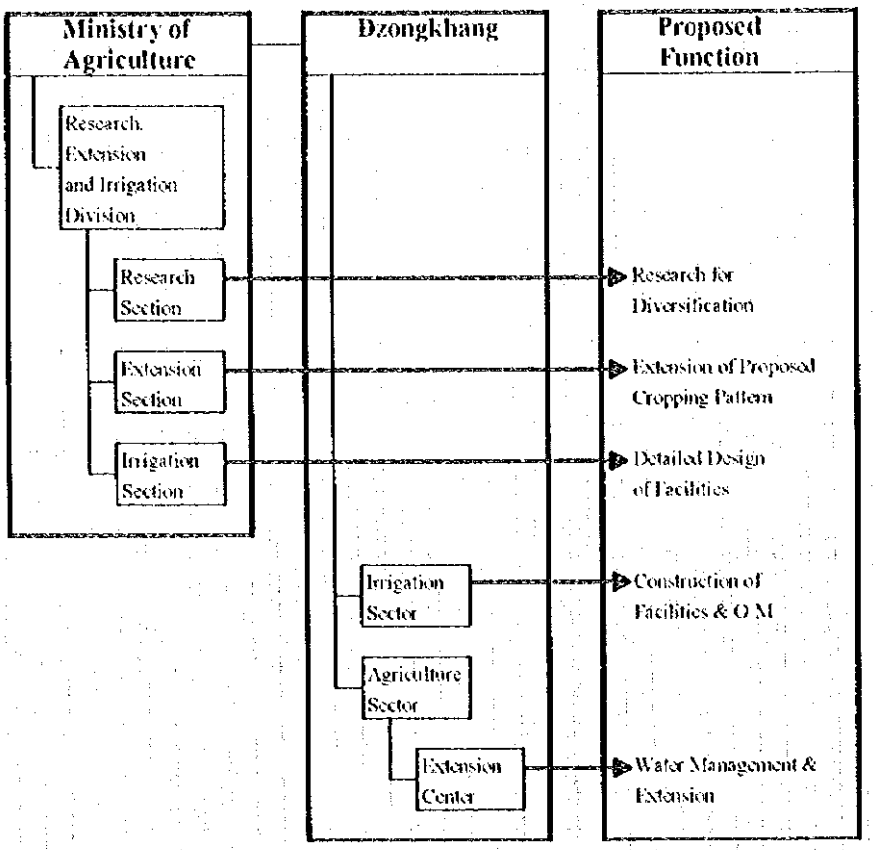
(unit : 1000 Nu.)

Category of Land	Sub-Area	Name of Canal	Code	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1						21	21	21	21	21	21
		Lower Lobeysa	C2					32	32	32	32	32	32	32
	Bajo	Bajo	C9				48	48	48	48	48	48	48	48
High Hilly Area	Phangyul	Phangyul	C10			58	58	58	58	58	58	58	58	58
		Genikha	C15						12	12	12	12	12	12
	Rubeysa	Nalakha	C18						15	15	15	15	15	15
		Rutekha	C19				10	10	10	10	10	10	10	10
		Maphekha	C20					9	9	9	9	9	9	9
		Naykoyuwa	C21					7	7	7	7	7	7	7
		Rumina	C22			5	5	5	5	5	5	5	5	5
Annual Total						62	120	168	216	216	216	216	216	216

Considering the characteristics and annual cost of the project, the project can be implemented by present organizations and it is not necessary to establish any kind of new organization.

The function of present organizations should be proposed as shown below.

Present Organization and Proposed Function for the Project



H.1.7 Summary of Drainage Improvement

At present, there are no systematic drainage canals under irrigation schemes in the Study Area. The damage for crop caused by poor drainage was not found in the Study Area except at some wet land in Phangyul. As for direct runoff drainage from heavy rain, the land sliding is often found in the hazard area and the gully erosion is also found at some of agricultural lands during the rainy season.

The land sliding does not occur in every year. From the result of field investigations and information of Dzongkhang office, it takes 10 ~ 20 days for the renovation of canal after occurrence of the land sliding. Though it depends upon the scale of disaster and season, the crop yield is not expected to be affected so much in an average year. The protection works for enforcement of irrigation canal at the hazard area was proposed in the irrigation improvement plan. However, suggested structures are one of the prevention schemes for the land sliding and further studies should be required for the proper counter measures if perfect prevention of land sliding are considered. For the planning of irrigation improvement, based on the vulnerability index, the selection of the proper canal route will be one of the counter measures for the land sliding.

The gully erosion was observed at the agricultural land where the main drainage tributaries are connected. It can be expected that some portion of agricultural lands has been eroded every year, however, there is no information/data about the amount of loosing land caused by gully erosion. The gully erosion is only occurring at the connecting part of the agricultural land with main tributaries and it was considered that this problem is caused by the direct runoff of rainfall from the agricultural land. The drainage system which is consist of the collecting ditch and outlet works were designed for the prevention of the gully erosion and the construction cost was estimated as shown below;

Summary of Construction Cost for Drainage System

Sub-Area	Total Drainage Area (ha)	Construction Cost (1000Nu)
Lobeysa	300	528
Bajo	118	182
Phangyul	67	186
Rubeysa	138	278
Total	623	1,176

The drainage system for the prevention of gully erosion is supposed to be constructed using only approximately 1.2 million Nu; however, it is necessary to consider decrease of the agricultural production caused by the land clearance for the construction. Therefore, further analysis is required for the consideration of economical feasibility before implementation of the construction.

There is some poor drainage area in the high hilly area caused by the spring water. Some terraced land which is located at the down part by the spring has been not used. At present, the amount of these area is quite a few and this should not be a big problem for the agricultural activities. The installation of small catch drain can be considered for the poor drainage area, but, benefited area is quite a few.

H.1.8 Summary of Recommendations

The following considerations was recommended for the further detailed study and implementation of the irrigation improvement plan.

- To improve and reinforce of basic information and data such as;
  - Meteo-hydrological data
  - Geological and hydrogeological data
  - Farming conditions such as soil, unit yield and production cost
  - Economical conditions such as farm gate price and marketing system
  - Social conditions such as population
  - Other basic information
- To design irrigation facilities based on the site conditions
- To acquire the understanding and cooperation of farmers
- To improve the supporting system

H.2 GENERAL

H.2.1 Present Land Use

(1) Land Use in Bhutan

Based on the land use data from the Land Use Planning Project, the Bhutan can be divided 4 zones as shown in Fig. H.2.1 and the present land use in the Bhutan was estimated as shown below;

Land Use in Bhutan (km2)

Zone	Western Zone	West Central Zone	East Central Zone	Eastern Zone	Total
Forest	6,111 (73.5%)	6,928 (60.5%)	7,165 (89.0%)	8,861 (77.9%)	29,045 (72.5%)
Others	1,041 (12.5%)	3,634 (31.7%)	931 (9.1%)	835 (7.3%)	6,321 (15.8%)
Agriculture	558 (6.7%)	460 (4.0%)	661 (7.4%)	1,410 (12.4%)	3,088 (7.7%)
Pasture	569 (6.8%)	411 (3.6%)	310 (3.5%)	275 (2.4%)	1,565 (3.9%)
Horticulture	32 (0.4%)	16 (0.1%)	9 (0.1%)	1 (0.0%)	58 (0.1%)
Total area	8,311 (100.0%)	11,449 (100.0%)	8,935 (100.0%)	11,382 (100.0%)	40,077 (100.0%)

The area of forest is accounted as approximately 2,904 thousand ha which is equivalent to about 73 % of total area in the Bhutan. The agricultural sector land including horticulture and pasture is accounted as approximately 466 thousand ha (approx. 12 %).

On the other hand, based on the same data, the agricultural land use in Bhutan was estimated as shown below;

Agricultural Land Use in Bhutan (km2)

Zone	Western Zone	West Central Zone	East Central Zone	Eastern Zone	Total
Irrigated Wetland	119 (21.3%)	118 (25.6%)	77 (11.6%)	74 (5.3%)	388 (12.6%)
Dryland Cultivation	198 (35.5%)	131 (28.5%)	178 (26.9%)	470 (33.3%)	977 (31.6%)
Shifting Cultivation	53 (9.6%)	68 (14.7%)	173 (26.2%)	590 (41.8%)	883 (28.6%)
Mixed Cultivation	188 (33.7%)	144 (31.2%)	233 (35.3%)	276 (19.6%)	840 (27.2%)
Total area	558 (100.0%)	460 (100.0%)	661 (100.0%)	1,410 (100.0%)	3,088 (100.0%)

Almost all of the irrigated wetlands are used for paddy and, considering the self sufficiency of the rice production, the paddy cropping in the western and west central zones should be important in the Bhutan. Looking for the land use in the East central and Eastern zones, the portion of shifting cultivation is quite high.

(2) Land Use in the Study Area

The land use in the Study Area was measured using land-use working map from the Land Use Section as shown below;

Land Use in the Study Area (ha)

Category	Study Area		Sub-Area							
			Lobeysa		Bajo		Phangyul		Rubeysa	
1 Forest	4,066	(62.6%)	10	(2.4%)	12	(6.3%)	769	(68.1%)	440	(50.6%)
2 Agriculture										
Wetland Cultivated	1,099	(16.9%)	216	(52.8%)	161	(85.2%)	151	(13.3%)	218	(25.1%)
Dry land Cultivated	0	(0.0%)	0	(0.0%)	0	(0.0%)	8	(0.7%)	70	(8.0%)
Other Agriculture	471	(7.2%)	132	(32.3%)	5	(2.6%)	115	(10.2%)	43	(4.9%)
Sub-Total	1,570	(24.2%)	348	(85.1%)	166	(87.8%)	274	(24.2%)	331	(38.0%)
3 Orchard & Horticulture	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
4 Pasture	253	(3.9%)	35	(8.6%)	0	(0.0%)	87	(7.7%)	80	(9.2%)
5 Settlement	93	(1.4%)	-	-	-	-	-	-	-	-
6 Others	518	(8.0%)	16	(3.9%)	11	(5.8%)	-	-	19	(2.2%)
Total Area	6,500	(100.0%)	409	(100.0%)	189	(100.0%)	1,130	(100.0%)	870	(100.0%)

The land use of the Study Area and sub-areas are illustrated in the Fig. H.2.2, and the following conditions were found out during the Field Work.

- Lobeysa and Bajo Sub-areas

  Most of the areas of the Lobeysa and the Bajo Sub-areas are utilized as agricultural land covering 85.1% and 87.8% of the sub areas respectively. Most of the cultivated areas within agricultural land are utilized as irrigated wetland and are located at the bottom of the valley. The forest area covers only a small area of these sub areas.

- Phangyul and Rubeysa Sub-areas

  Some parts of the Phangyul and the Rubeysa sub-areas are utilized as agricultural land, which occupy 24.2% and 38.08% of the sub areas respectively. Agricultural land in these sub-areas is located in the mountainous area, which has a relatively gentle slope. The forest area covers 68.1% and 50.6% of the sub areas respectively. Coniferous forest is found in the lower parts of these sub-areas, while broadleaf forest is found in the upper parts of the sub-areas.

H.2.2 Present Agricultural Activities in the Study Area

(1) Present Cropping Pattern

Crop season in the Study Area is broadly divided into two (2) seasons; monsoon (rainy) and winter (dry) seasons. The present cropping pattern in the Sub-areas is illustrated in Fig. H.2.3.

The main crop grown in the monsoon season is paddy, followed by winter crop (mainly wheat and mustard). In the upland area which is under rainfed condition, the main crop in the monsoon season is vegetables, but only a few such areas exist. Recently, some irrigation canals have been improved under the Punakha - Wangdue Valley Development Project financed by IFAD and in some areas irrigation becomes possible throughout the year. In these areas, it is possible to start land preparation for paddy even in February during the winter season, and double cropping of paddy is carried out even though such areas are considered small.

Present major cropping patterns in the Study Area are stated below.

Paddy - Wheat
Paddy - Mustard
Paddy - Fallow
Paddy - Vegetables
Vegetables - Wheat

Paddy occupies around 95% of irrigated area during the monsoon season. The planted area of crops in the Sub-areas are summarized as follows:

(unit : ha)

	Lobeysa		Bjjo		Thangsul		Rubeysa		Total
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	
Paddy	285	-	112	-	64	-	131	-	592
Wheat	-	121	-	52	-	29	-	58	260
Mustard	-	33	-	14	-	8	-	16	71
Others	15	15	6	6	3	3	7	7	62
Total	300	169	118	72	67	40	138	81	
	469		190		107		219		985

(2) Present Farming Practice

Most farmers are planting local varieties of paddy. Maap is a local red rice variety and Kaap is local white rice variety. Most people prefer the taste of local red rice (Maap). Usually the farmers prepare the seeds by themselves. In case of the improved varieties of paddy, RGOB is promoting improved varieties (IR64, No.11, IR20913 etc.) and distributing seeds to farmers through the Agriculture Extension Center under Dzongkhang.

1) Paddy Cropping

The land preparation for paddy single cropping is started in the beginning of the monsoon season which is generally in the middle of May, and the land preparation is carried out from the upper part of area where water is supplied from existing canals. Depending on the amount of canal water discharge, it takes one or one and half months for the land preparation of all paddy area. The transplanting is started after land preparation from the upper part to lower part, resulting in a difference of about one to one and half months in the cropping period between upper and lower parts. Usually, surplus water of upper terrace is effectively reused in the next lower terrace.

2) Winter Crop

As a result of interview survey, it was found out that the winter crop such as wheat (variety: Bajoka, Sonalika, Local) mustard and vegetables are planted after rice harvesting which is generally in the middle of October. The winter crop is also irrigated depending on the weather conditions, and the amount of canal discharge is quite low in that season but is generally enough for seeding.

3) Vegetables in Monsoon Season

The vegetables of the monsoon season are cropped only in the areas with high altitude where irrigation water cannot be obtained from any canal or small stream. These depend on the seasonal rainfall and the seeding is carried out with the first rainfall in April or May. Production also depends on the rainfall condition.

4) Double Cropping of Paddy

Double cropping of paddy is followed in the areas with the improved irrigation canals constructed by the IFAD Project; especially, sufficient irrigation water is available throughout the year. Depending on the climate conditions, land preparation is carried out in the middle of February. The first rice cropping is harvested in July and the second rice cropping is started soon after.

According to the data obtained during the survey, the area under paddy double cropping has increased from 1987 in the Punakha - Wangdue Valley, but double cropped area has declined from 1992.

The reason for this is reported that double cropping is possible only where there is sufficient man power. Accordingly double cropping has been well adopted for farmers with small land holdings. Hence farmers with bigger land holdings can produce sufficient rice for their own consumption by single cropping of rice.

5) Agricultural Equipment

Various agricultural tools, instruments and implements are also used to improve the farming works.

Due to road accessibility and more favorable topography, power tillers are used for land preparation in the Lobeysa and Bajo Sub-areas. In contrast, cattle plowing is common in the Phangyul and Rubeysa Sub-areas. Power tillers with trailer are used for transportation of agricultural inputs (green manure, chemical fertilizer, etc.) and outputs.

6) Livestock

Cattle perform the most important role for farmers as draft animals and for milk production in the Study Area. Most farm households have several horses, pigs and poultry. There are a certain number of cattle which do not produce viable amounts of milk and instead are used for the production of manure.

Cattle are classified into three (3) categories; local cattle, cross bred cattle and methane cattle. The most prevailing is considered to be local cattle. RGOB is promoting breed improvement, fodder and pasture development, etc., to increase output of livestock products. Rice straw is used for livestock feed in the feed-scarce winter season and wheat straw is used for livestock bedding.

(3) Crop Yield and Production

The Gewog-wise data on planted areas, yields and production of paddy, wheat and mustard in the Study Area were obtained from the Agriculture Sections of the Wangduephodrang Dzongkhang and RNRRC. The yield and production of the four (4) Gewogs; Thetso, Rubeysa and Phangyul Gewogs in Wangduephodrang Dzongkhang, Babesa Gewog in Thimphu Dzongkhang and the whole of the Wangduephodrang Dzongkhang are estimated below.

Gewog	Paddy			Wheat			Mustard		
	Area(ha)	Prod(t)	Yield(t/ha)	Area(ha)	Prod(t)	Yield(t/ha)	Area(ha)	Prod(t)	Yield(t/ha)
Bajisa	93	248	2.67	16	21	1.31	5	5	1.00
Phangyul	400	1265	3.16	34	50	1.47	10	8	0.80
Thedtsho	400	1267	3.17	15	22	1.47	6	5	0.83
Rubeysa	630	1992	3.16	44	66	1.50	14	12	0.86

Based on these data of crop yield and production, production of each sub-area was estimated as follows:

Sub-Area	Paddy			Wheat			Mustard		
	Area(ha)	Yield(t/ha)	Product(t)	Area(ha)	Yield(t/ha)	Product(t)	Area(ha)	Yield(t/ha)	Product(t)
Lobeysa	285	2.67	760	121	1.31	159	33	1.00	33
Bajo	112	3.16	354	52	1.47	76	14	0.86	11
Phangyul	64	3.17	203	29	1.47	43	8	0.83	7
Rubeysa	131	3.16	414	58	1.50	87	16	0.86	14
Total	592	-	1,731	260	-	365	71	-	65

Paddy production was estimated as 1,731 tons in the above 4 sub-areas and average yield was estimated as 2.90 tons.

Total production of wheat is 365 tons and yield is 1.40 ton/ha in the same 4 sub-areas. In the case of mustard, production is 65 tons and yield is 0.91 ton/ha.

The vegetables grown in the Study Area are chili, tomato, onion, radish, cabbage, cauliflower, beans, etc. These vegetables are cultivated in small fields or kitchen gardens near farm houses.

H.2.3 Present Conditions of Irrigation System

(1) Existing Irrigation System

Most of the existing irrigation canals were constructed by the farmers themselves a long time ago, and, therefore, the year of construction of such canals is not known. The original canals which were constructed by farmers themselves years ago. Those are of gravity-flow type intake made of stone masonry and of earth canals carrying water by gravity. As presented in Table H.2.1, there are 22 irrigation canals in and around the Study Area, and the total length is measured as over 100 km and total command area is approximately 1,250 ha. The location of these canals is shown in Fig. H.1.1. All of the irrigation canals have their source in the tributaries or small streams flowing into the Chang Chhu and the Dang Chhu, but not in such major rivers themselves. Most of these canals are unlined.

Since 1981, the Small Farms Development and Irrigation Rehabilitation Project (SFDIRP:IFAD-Phase 1) have been undertaken by RGOB with assistance by IFAD and 37 irrigation canals in the Punakha-Wangdue Valley have been renovated. The total command area is reported to be about 3,400 ha. From July 1989, the Punakha-Wangdue Valley Development Project (PWVDP:IFAD-Phase 3) was started as a follow up of the above SFDIRP. One of the objectives of the PWVDP is to improve agricultural production through rehabilitation of the existing irrigation canals. The PWVDP going on at present is scheduled to be completed in June 1996. Under PWVDP, stone masonry canals are constructed partially, mainly for the upper portions of canals where land sliding often occurs.

As described above, some of these canals constructed by local farmers years ago have been rehabilitated, improved and reconstructed under IFAD finance, and by the Dzongkhangs of Wangduephodrang and Thimphu. The participation by IFAD which is considered to provide the most extensive assistance in recent years is indicated in Table H.2.1.

- Lobeysa Sub-area

  The Sub-area is irrigated by Lobeysa Lower and Upper irrigation canals, and the length of these canals are measured to be about eight (8) and seven (7) km, respectively. Irrigated area from these canals is about 330 ha. The water source of these canals is the Tabe Rongchhu flowing into the Chang Chhu.

  Intakes of these canals are the natural flow type, without water control facilities such as gates, etc. Also, spillways exist on these canals to drain surplus water to Tabe Rongchhu.

  The canals run along valley slope of the Tabe Rongchhu with an approximate 3 km length from the intake sites to the command area of Lobeysa Sub-area. Soil erosion occurs often due to rainfall and drain runoff from Thimphu-Wangdue road on the valley slope resulting in damage to the irrigation canals. The Upper Lobeysa canal is currently under renovation under the IFAD project.

- Bajo Sub-area

  Bajo canal which is also under assistance by IFAD is one of the longest canals in the Study Area, and its length and command area are 15.0 km and 143 ha (including RNRRC area), respectively. The irrigation canal was constructed to provide irrigation water to cultivated areas of the Bajo Sub-area as well as to provide domestic water to Wangduephodrang town. The water source of this canal is the Pe Chhu, one of the tributaries of the Dang Chhu. Parallel lines of pipeline have been constructed along the existing road from the Pe Chhu intake site to the drinking water station of the Wangduephodrang town to convey water more effectively.

  Bajo canal runs on the mountain slope for an approximate 9 km distance from the Pe Chhu intake site to the drinking water station near Wangduephodrang

town. Along this segment of canal, spill over of irrigation water has occurred due to poor water management.

The irrigation water of this Sub-area is provided mainly from the Bajo canal, but during the dry season when the conveyed water is not enough to irrigate this area, surplus water of the Limti Chhu has been commonly utilized for irrigating this Sub-area. However, during the transplanting season, almost all discharge of the Limti Chhu is diverted to paddy fields at the upper part of the river.

- Phangyul Sub-area

The Phangyul Sub-area extends along the south-eastern side of the mountain ridge running along the Pe Chhu and the Dang Chhu toward Wangduephodrang town. Most of the cultivated lands are developed on the steep slopes of the area forming rice terraces. The most important irrigation canal of this Sub-area is the Phangyul canal which has its water source at Lachu, a tributary of the Komathang Chhu. The length of the Phangyul canal running along the contour line over 2,000 m southwestward is about 16 km. Although a large amount of water is diverted at its intake, the water is not conveyed properly to the canal end point located near Wangduephodrang town, because of seepage from the canal and excessive discharge taken from the canal at its upstream portion. The Gemkha canal is also located in this Sub-area, but its command area is measured as a small 15 ha only. Water source of this canal is the Uship, a tributary of Komathang Chhu.

- Rubeysa Sub-area

The Sub-area extends along the Taka Rongchhu and the left side of the Mochuna. There are five (5) irrigation canals running through the Sub-area. The water sources of these canals are the Take Rongchhu and Mochuna flowing from the southeastern mountain area. The Sub-area suffers from serious irrigation water shortage especially in the downstream portion of Taka Rongchhu. One of the reasons of water shortage is seepage from the canal at its upstream portion. Most of the canals are unlined, and permeability of soil is high.

(2) Water Management, Operation and Maintenance and Water rights

Generally, water management activities are done by beneficiary farmers. Farmers appoint one or two water guards for inspection of the main canal and intake. Water management for secondary to on-farm canals is done by each farmer or jointly by several farmers related to the operation of the respective canals. From the main canal, small secondary canals (sometimes gullies or natural water courses) run down the slope to the field level. Usually farmers have to divert the irrigation water to the field which is located on the highest terrace, from where water flows to the subsequent lower terraces.

Water is distributed to farmer fields in rotation, and the irrigation interval differs from canal to canal depending on location of field, water availability and farmer's water right. For example, each household in a village receives water on a fixed day at a fixed time, regardless of the area, number and location of the land he owns.

Mostly, canal cleaning is done once a year before transplantation period of paddy by farmers. Each household dispatches a person for this canal maintenance work. In the case of repair work for damaged canals, farmers jointly work to carry materials such as stone, sand, log flumes, etc. Results of survey of water management and O/M situation of several canals in the Study Area are described in Table H.2.2.

Recently, the MOA launched the National Irrigation Policy (NIP) for a sustainable approach to irrigation development through the effective participation of the water users. Under this policy, project beneficiaries associate themselves in an organization which is formally constituted as a Water Users Association (WUA). A WUA can be officially established at any time but always begins before implementation of the government-assisted project. The NIP was approved officially in August 1992. According to procedure of NIP in PWVDP, several WUAs were formed before the commencement of rehabilitation works of irrigation canals. There are more than 30 WUAs in the Punakha - Wangdue Valley area.

(3) Irrigation Water Requirements

Some information on water requirement is available at RNRRC but the cropping conditions of cultivated land in the Study Area are quite different from that of RNRRC. Therefore, the water requirements were estimated in the manner employed in the FAO Irrigation & Drainage Paper No.24 (1977) as described below:

1) Potential Evapotranspiration, Land Preparation Requirement, Percolation Losses and Water Layer Requirement

Based on the records up to 1992, the potential evapotranspiration (ETo) for the Wangdue Valley has been estimated in the IFAD Project report (1993) using the Penman method. The calculation was reviewed carefully and the result was found to be quite reasonable, and it is considered that if such ETo is recalculated in the same manner using the records up to 1993 the difference of the result would be not more than five (5) %. Therefore, this ETo was applied for the estimation of water requirements in the Study Area.

The land preparation, percolation loss and water layer requirements were also estimated in the IFAD Project (1993). From the result of the field investigations, it was found that these estimated values were more or less reasonable. Therefore, these values were also applied for the estimation.

2) Crop Coefficient (kc)

Based on the results of field investigation, the crop coefficients were calculated in the manner presented in FAO Irrigation and Drainage Paper No.24 considering the data and information collected in RNRRC and the IFAD Project.

3) Rainfall and Effective Rainfall

Using the result of the rainfall analysis (Appendix-E), the rainfall pattern in the Study Area was estimated as shown in Table H.2.3. According to the FAO Irrigation and Drainage Paper No.24, the USDA criteria was applied for the estimation of the effective rainfall. The estimated effective rainfall is tabulated in Table H.2.3.

4) Effective Reuse of Irrigation Water

Irrigation water at the upper part of fields is reused at the lower part to some extent in the case of paddy cultivation. The following effective reuse coefficients were assumed from the result of field investigations.

Rubeysa and Phangyul Area 20 %
Bajo and Lobeysa Area 15 %

5) Irrigation Efficiency

In the calculation, the values of field efficiency and canal efficiency used in the IFAD Project report were adopted for the proposed cropping pattern. Considering the water leakage from the canals and inadequate water management, a smaller value of 0.24 to 0.36 is applied for canal efficiency for the calculation of present water demand.

Present Condition	Field Efficiency	Conveyance Efficiency	Total Efficiency
Paddy	0.9	0.4	0.36
Upland Crop	0.6	0.4	0.24

6) Unit Water Requirement and Diversion Water Requirement

Based on the above assumptions, the unit water requirement was estimated for each cropping pattern as shown in Table H.2.4. Considering the present cropping area, the diversion water requirements for each sub-area were estimated as shown in Table H.2.5 and the result are summarized as below;

Maximum Water requirement (May)

(unit: l/s)

Returen Period	Bajo	Lobeysa	Rubeysa	Phangyul
1/2	946	370	190	385
1/5	965	378	195	395
1/10	972	381	197	400
1/20	977	383	199	403
1/5 (Exceedance)	910	356	183	371
1/10 (Exceedance)	887	347	179	362
1/20 (Exceedance)	864	338	175	354

(4) Problems of Existing Irrigation Scheme

1) Estimation of Water Balance for 10 Irrigation Schemes

For the consideration of irrigation improvement plan, 10 irrigation schemes in the Sub-area were selected and inventory work was carried out and cropping area of the command area for the 10 schemes are shown below;

Present Cropping Area of 10 Schemes (ha)

Canal Code	Name of Canal	Cropping Pattern					Total
		CP1	CP2	CP3	CP4	CP5	
C1	Upper Lobeysa	21	6	0	31	3	61
C2	Lower Lobeysa	105	30	0	150	15	300
C9	Bajo	50	15	0	72	7	143
C10	Phangyul	31	10	0	46	4	91
C15	Gemkha	5	2	0	8	1	15
C18	Nalakha	10	3	0	15	1	29
C19	Rutekha	14	4	0	20	2	40
C20	Maphekha	9	3	0	14	1	27
C21	Naykoyuwa	8	2	0	12	1	24
C22	Rumina	10	3	0	14	1	28

The result of inventory work is summarized as shown in Table H.2.6. As 2 schemes in Lobeysa and 4 schemes in Rubeysa are using the water from same river, 6 groups can be formed for these 10 schemes.

Based on the result of hydrological study, the river discharge at each intake site were roughly estimated as shown in Table H.2.7. The water requirement for each canal was estimated based on the water requirement for the Sub-Area and the result of inventory work. Using these results, the water balance at each intake site was calculated as shown in Table H.2.8.

From this Table, it is expected that the water shortage occurs at 3 groups (6 irrigation scheme) in May which is transporting season for paddy and one of the most important period of rice planting. This means that the paddy can not be planted for all paddy field in most year and, according to hearing investigation, almost half of their paddy field can not be planted in usual year. Furthermore, in group C (Phangyul canal), water shortage occurs from January

to March and, considering the cropping period, the production of winter crop at this area might be reduced in this case.

On the other hand, the water sufficiency in May is shown in Table H.2.9 with a consideration of water requirement and the canal capacity. In this Table, the canal capacity was estimated considering design dimensions and actual condition of the canal. It was expected that the capacity of each canal is not sufficient as about 7 % ~ 16 % of the maximum water requirement in May.

Considering the result of field investigation, 40 % ~ 60 % of influence from water shortage is applied for estimation of cropping rate. As a result, 86 % of average cropping rate for total command area was roughly estimated and there is a basic constrain in 6 of 10 schemes for irrigation water source. This cropping rate may vary depending on the available rainfall in each year and not always shows the actual condition. However, this can be used as some kind of indicator for the consideration of irrigation condition.

2) Evaluation of Present Water Management System

The preliminary evaluation of present operation system was analyzed using following manner:

a. Selection of Major Offtake

The major off take was selected considering the topographic conditions, their command area and present management system. For example, there are 27 offtake in the Phangyul canal (C10) and 12 offtake points were selected as shown in Table H.2.10 for smooth calculation. The command area of the offtake not selected was included in the command area of the offtake at the upper part.

b. Estimation of Water Requirement at the Selected Offtake

Based on the water requirement calculated for the Sub-Area, the water requirement at the selected offtake point was estimated considering the estimated cropping pattern of their command area. The sample is shown in Table H.2.10.

c. Estimation of Canal Discharge for 1 Day Use at Offtake

Considering the present operation system and water right as shown in Table H.2.2, the available canal discharge for 1 day use was estimated at selected offtake point. For example, in the Phangyul canal as shown in Table H.2.10, the certain amount of irrigation water can be taken at 3 offtakes in the upper part, and therefore, the amount of available water at those 3 offtake was assumed as same amount as the water requirement. For the other offtakes, the amount of available water was assumed reducing the water for 3 offtakes from the available water at intake site. In present conditions, there are 21 offtakes with 24 hours use for 21 days rotation and

this means 1/21 amount of canal discharge may be available for 1 day use at each offtake. Based on the calculation, this value is equivalent as 1/9 amount of canal discharge as shown in Table H.2.10.

d. Calculation of Water Balance at Offtake

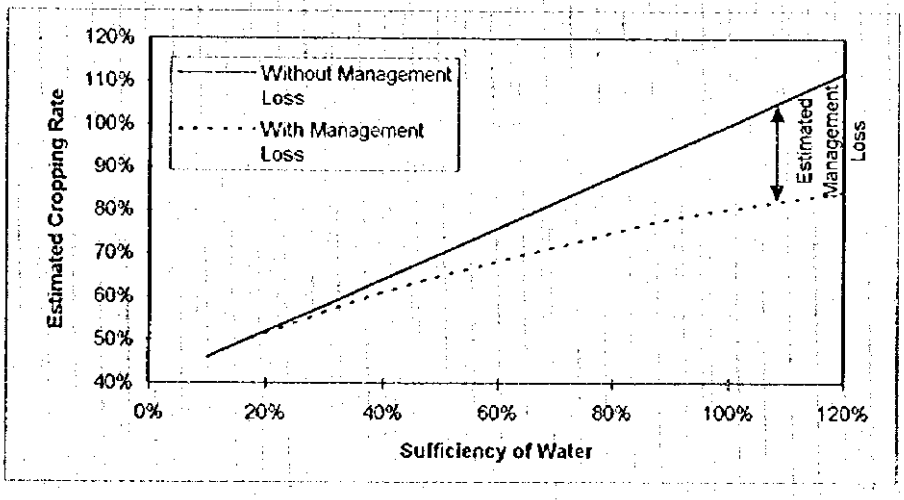
Based on the water requirement and available canal discharge for 1 day use, the water balance was calculated at each offtake point. In case this value becomes a positive value, it means that some over irrigation may occur at that offtake point. Depending on the amount of available water at intake site, the water balance may vary as shown in Table H.2.10.

e. Estimation of Cropping Rate in Each Command Area

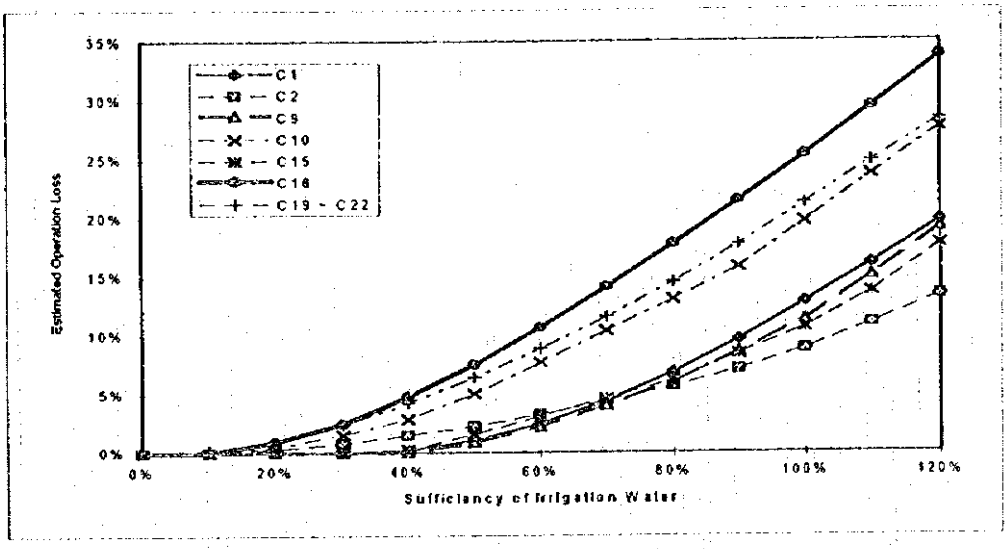
Applying 40 % ~ 60 % of influence from water shortage, the cropping rate in the command area of each offtake was estimated. The planting area was also estimated, and, based on the total command area and estimated planting area, the total cropping rate with operation loss was estimated.

f. Estimation of Water Management Loss

The sufficiency of irrigation water can be calculated based on the total water requirement and the amount of available irrigation water at intake site. Based on the sufficiency of irrigation water, the total cropping rate without operation loss can be estimated. The difference between the cropping rate without and with the operation loss may indicate the degree of operation loss. For example, as shown in Table H.2.10, around 20 % of operation loss was expected when the water sufficiency is 100 %. In case of applying around 30 % of water sufficiency, about 1.5 % of operation loss was expected. This tendency is shown below;



Using the same manner as mentioned above, the irrigation loss at 10 schemes was estimated as shown below;



Around 10 % ~ 25 % (14 % for total area) of water management loss was expected even if 100 % of irrigation water was applied. In the present condition, as there is a constrain of irrigation water coursed from water source or canal capacity as shown in Table H.2.9, around 1 % ~ 23 % (7 % for total area) of water management loss was expected. The results are summarized in Table H.2.11.

H.3 Case Study

H.3.1 Objective of Case Study

Considering the effective use of the agricultural land and limited water resources, the following counter measures were proposed for irrigation improvement plan.

- Improvement of water management system (Case A)
- Improvement of irrigation capacity (Case B)
- Improvement of water sources (Case C)
- Crop diversification (Case D)
- Expansion of double paddy cropping (Case E)
- Combination of counter measures above mentioned

Based on the topographic conditions, the Study Area can be roughly categorized into 2 zones, one is high hilly area and the other is low flat area. The constraints for irrigation improvement are quite different among each Sub-Study Area and the optimum counter measures should also be different depending on the constraints of the Sub-Study Area.

For finding out of the optimum counter measure, 2 irrigation schemes were selected from the 10 irrigation schemes as shown in Fig H.1.1 and the cost and benefit of each counter measure was estimated as case study. The flow of the case study is shown in Fig. H.3.1 and the study case was summarized as shown in Table H.3.1.

H.3.2 Conditions of Case Study

(1) Water Requirement

Based on the calculation manner mentioned in H.2.2, the water requirement was calculated for each 10 schemes. In case of the consideration for improvement of irrigation canal capacities, following irrigation efficiency was applied based on the IFAD project.

Present Condition	Field Efficiency	Conveyance Efficiency	Total Efficiency
Paddy	0.9	0.72	0.648
Upland Crop	0.6	0.72	0.432

In the case study, the water requirement was recalculated when the improvement of canal capacities or changing of the cropping area were considered. (See Data Book

(2) Influence of the Insufficiency of the Irrigation Water

From the results of the field investigation, following influence coefficient of the irrigation water insufficiency was estimated.

- For planting area 50% of insufficiency for low flat area
  40% of insufficiency for high hilly area
- For cropping yield 13 % of insufficiency

Considering these coefficients, the reduction of yield was estimated for each Case.

(3) Conditions of Benefit

Based on the farm gate price and production cost in 1992, the net production value was estimated as shown below;

Estimated Net Production Value (Nu./ha)

	Paddy	Double Paddy		Wheat	Mustard	Vegetable	Vegetable
	(Summer)	First	Second	(Winter)	(Winter)	(Winter)	(Summer)
Unit Yield (t/ha)	3.20	2.56	2.56	1.80	0.67	1.50	1.50
Farm Gate Price (Nu./t at 1992)	3,960	3,960	3,960	4,400	7,499	7,430	7,430
Farm Gate Price (Nu./t at 1995)	5,029	5,029	5,029	5,588	9,524	9,436	9,436
Gross Production Value (Nu./ha)	16,093	12,875	12,875	10,058	6,381	14,154	14,154
Production Cost (Nu./t)	8,047	8,626	8,626	3,219	1,021	8,634	8,634
Net Production Value	8,047	4,249	4,249	6,840	5,360	5,520	5,520

In the estimation, 27% of inflation from 1992 was considered. The difference between the total net production value with and without the improvement plan should be the benefit of the improvement plan.

(4) Conditions of Cost Estimation

The Conditions of cost estimation are summarized as shown below;

- Base year and month : July, 1995
- Exchange rate : US 1 $ = 30.85 Nu.

The basic information for cost estimation for the Case Study is shown in Table H.3.2.

H.3.3 Present Condition (Case O)

Based on the present conditions and applying the influence coefficient above mentioned, the production ratio of present condition was estimated as shown below, and average production rate was estimated considering the probability.

Estimated Production Ratio with Present Condition (Case O)

	Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
Return Period	Summer Crop	Winter Crop	Summer Crop	Winter Crop
1/2	77%	100%	38%	51%
1/5	75%	100%	37%	49%
1/10	75%	100%	37%	49%
1/20	74%	100%	36%	48%
1/5 (Exceedance)	79%	100%	38%	53%
1/10 (Exceedance)	81%	100%	39%	54%
1/20 (Exceedance)	82%	100%	39%	55%
Average	77%	100%	38%	51%

Based on the cropping area, the net production value of present condition was estimated as shown below;

Estimated Net Production Value (Case O 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
1,320		421	

H.3.4 Water Management Improvement (Case A)

(1) Method of Water Management Improvement

In the present condition, generally there is no offtake facilities and the water management is done one time for 24 hours. The interval of water management is decided based on the number of offtake facilities. Hence, irrigation water is distributed with no consideration of the scale of command area and over irrigation

is done at some offtake site. Considering these conditions, the following water management improvement plan was suggested.

- The water management should be done one time for 12 hours
- The distribution time should be decided based on the scale of command area
- For the smooth water management, it is necessary to construct the offtake facilities.

An example of the effects of water management plan is shown in Table H.3.3 and these effects were calculated and considered for 12 months.

(2) Estimated Production Ratio and Net Production Value

The estimated production ratio and the net production value are summarized as shown below;

Estimated Production Ratio with Water Management Improvement (Case A)

	Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
Return Period	Summer Crop	Winter Crop	Summer Crop	Winter Crop
1/2	87%	100%	42%	71%
1/5	85%	100%	41%	69%
1/10	85%	100%	41%	68%
1/20	84%	100%	41%	68%
1/5 (Exceedance)	89%	100%	43%	74%
1/10 (Exceedance)	91%	100%	44%	77%
1/20 (Exceedance)	92%	100%	44%	80%
Average	87%	100%	42%	71%

Estimated Net Production Value (Case A 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
1,454		508	

(3) Cost Estimation for Water Management Improvement

For a smooth water management, it is necessary to construct offtake facilities. The design conditions of offtake facilities for Case A was determined based on the present irrigation capacities as shown Table H.2.9. The preliminary design of offtake facilities is shown in Data Book (V) and the necessary cost including O/M cost for one year of Case A was also estimated. The result is summarized as shown below;

Estimated Net Cost for One Year (Case A 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
63		52	

H.3.5 Improvement of Canal Capacities (Case B)

(1) Recalculation of Water Requirement

For the improvement of canal capacities, the rehabilitation of canals and enforcement of protection works were considered. As irrigation efficiency was different from the present condition, the water requirement of each canal was recalculated for same cropping pattern as Case O and the maximum water requirement is summarized below;

Maximum Water Requirement for Case B (l/s)

Code	C1	C2	C9	C10	C15
Name of Canal	U. Lobeysa	L. Lobeysa	Bajo	Phangyul	Genikha
Command Area (ha)	61	300	143	91	15
1/2	106.4	523.1	252.6	142.0	24.5
1/5	108.6	533.9	257.6	145.6	25.2
1/10	109.5	538.0	259.5	147.3	25.5
1/20	110.1	541.0	260.9	148.6	25.7
1/5 (Exceedance)	102.4	503.4	243.1	136.8	23.6
1/10 (Exceedance)	99.9	490.9	236.9	133.5	23.0
1/20 (Exceedance)	97.3	477.9	230.6	130.6	22.5
Code	C18	C19	C20	C21	C22
Name of Canal	Nalakha	Rutekha	Maphekha	Naykoyuwa	Rumina
Command Area (ha)	29	40	27	24	28
1/2	46.2	62.8	42.9	36.3	44.5
1/5	47.3	64.3	43.9	37.2	45.6
1/10	47.8	65.1	44.4	37.6	46.1
1/20	48.2	65.6	44.8	37.9	46.5
1/5 (Exceedance)	44.5	60.5	41.4	35.0	42.9
1/10 (Exceedance)	43.5	59.0	40.4	34.2	41.9
1/20 (Exceedance)	42.5	57.6	39.4	33.4	40.9

(2) Estimated Production Ratio and Net Production Value

Using the same manner as Case O and recalculated water requirement, the production ratio and net production value were estimated as shown below;

Estimated Production Ratio with Canal Capacity Improvement (Case B)

	Code	Name of Canal	Code	Name of Canal
	Canal C9	Bajo	Canal C10	Phangyul
Return Period	Summer Crop	Winter Crop	Summer Crop	Winter Crop
1/2	87%	100%	50%	76%
1/5	86%	100%	49%	75%
1/10	85%	100%	49%	74%
1/20	85%	100%	49%	74%
1/5 (Exceedance)	89%	100%	52%	78%
1/10 (Exceedance)	89%	100%	52%	80%
1/20 (Exceedance)	90%	100%	52%	81%
Average	87%	100%	51%	76%

Estimated Net Production Value (Case B 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
1,454		587	

(3) Cost Estimation for Improvement of Canal Capacities

Based on the maximum water requirement for 5 years return period, the design discharge was determined and each irrigation scheme was designed preliminarily (see Data Book V). The enforcement of protection works were considered for stabilization of irrigation water supply. For the roughly cost estimation of protection works, the type of protection works was considered considering the Vulnerability index of each canal. The cost estimation is shown in Data Book V and the result of net cost including O/M cost for one year is summarized below;

Estimated Net Cost for One Year (Case B 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
60		171	

H.3.6 Improvement of Water Resources (Case C)

(1) Improvement Plan

Considering the river discharge at the Bay Chhu, there is sufficient river discharge for Bajo canal. Therefore, the improvement of water resources plan was studied only for Phangyul canal. The detailed improvement plan is shown in the Data Book V and summarized below;

- Proposed water source : Small stream of Pe Chhu
- Catchment area at intake site : 2.2 km^2 (Elevation 2,550m)
- The design discharge : 0.066 m^3/s
- Intake works : 1 unit
- Length of driving canal : 3.5 km

(2) Estimated Production Ratio and Net Production Value

Applying this improvement plan, it can be expected that --% of available irrigation water will be increased and based on this irrigation water, the production ratio and net production value for Case C was estimated, as follows;

Estimated Production Ratio with Water Resources Improvement (Case C)

	Code Canal C10	Name of Canal Phangyul
Return Period	Summer Crop	Winter Crop
1/2	46%	69%
1/5	45%	68%
1/10	45%	67%
1/20	44%	67%
1/5 (Exceedance)	47%	71%
1/10 (Exceedance)	48%	73%
1/20 (Exceedance)	48%	74%
Average	46%	69%

Estimated Net Production Value (Case C 1000 Nu.)

Code Canal C10	Name of Canal Phangyul
531	

(3) Cost Estimation for Improvement of Water Resources

The preliminary design of structures was shown in Data Book V and the cost of water resources improvement for one year including the additional O/M cost was estimated as shown below;

Estimated Net Cost for One Year (Case C 1000 Nu.)

Code Canal C10	Name of Canal Phangyul
164	

II.3.7 Applying Diversification (Case D)

(1) Diversification Plan

In the present condition, approximately 10 ~ 20% of paddy field has not been planted because of insufficiency of irrigation water and effective rainfall. For effective use of agricultural land and limited irrigation water, the crop diversification from the paddy was considered. However, the portion of unused paddy field is varied depending upon the effective rainfall in a year and the highest net production value is expected from the paddy cropping. Therefore, it is necessary to find out the optimum portion of diversification with a consideration of probability and net benefit. For this purpose, the following case of diversification was studied.

- Case D-1 : 5% diversification
- Case D-2 : 10% diversification
- Case D-3 : 15% diversification
- Case D-4 : 20% diversification

(2) Estimated Production Ratio and Net Production Value

As the cropping pattern should be changed for diversification, the water requirement was recalculated as shown in the Data Book V and, based on the these water requirements, the production ratio and net production value for each case were estimated. The results are summarized below;

Average Production Ratio with Diversification (Case D)

Case	Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
	Summer Crop	Winter Crop	Summer Crop	Winter Crop
D-1 (5%)	78.94%	100.00%	38.51%	51.01%
D-2 (10%)	80.87%	100.00%	39.41%	51.01%
D-3 (15%)	82.90%	100.00%	40.39%	51.01%
D-4 (20%)	85.01%	100.00%	41.48%	51.01%

Estimated Net Production Value (Case D 1000 Nu)

Case	Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
D-1 (5%)	1,391		424	
D-2 (10%)	1,357		420	
D-3 (15%)	1,271		394	
D-4 (20%)	1,241		385	

(3) Cost Estimation for Diversification

Only for diversification, it is not necessary to construct any structure but the extension of tectonics of diversification should be required. In the present condition, there is one extension technician in each Gewog but it is necessary to consider the training for the new agricultural tectonics for them. Therefore, the additional extension cost for the net cost of the diversification was estimated including the necessary equipment as shown in the Data Book V and the result was summarized below;

Estimated Net Cost for One Year (Case D 1000 Nu.)

Code Canal C9	Name of Canal Bajo	Code Canal C10	Name of Canal Phangyul
22		20	

H.3.8 Applying Double Paddy Cropping (Case E)

(1) General Idea of Double Paddy Cropping

In the present condition, the double paddy cropping is applied at less than 1% of paddy field in the study area. Considering the water balance at intake site, it is possible to apply the double paddy cropping at almost of all paddy fields in the low flat area. For increasing the total production of rice, it is better to apply the double paddy cropping as much as possible, however, the following constrains must be considered for expansion of double cropping.

- There are problems such as lack of seasonable labors for the period of paddy planting season.
- Considering the meteorological conditions in the Study Area, the same unit yield of paddy can not be expected as that of usual period.
- Production cost of double cropping is higher than that of present cropping pattern.
- The high net production value is not expected from the double cropping comparing with the increase of work load.

Therefore, it is necessary to study the optimum portion of double paddy cropping with a consideration of farmers financial condition and effective land use. For this purpose, the following case of double cropping was studied.

- Case E-1 : 20 % double paddy Cropping
- Case E-2 : 40 % double paddy Cropping
- Case E-3 : 60 % double paddy Cropping
- Case E-4 : 100 % double paddy Cropping

(2) Estimated Production Ratio and Net Production Value

As the cropping pattern should be changed for double paddy cropping, the water requirement was recalculated as shown in the Data Book V and, based on the these water requirements, the production ratio and net production value for each case were estimated. The results are summarized below;

Estimated Production Ratio with Applying Double Paddy Cropping (Case E : 1000 Nu.

Code			Name of Canal		
Canal C9			Bajo		
Case	Summer Crop	Winter Crop	First Paddy	Second Paddy	Winter Crop
Case E-1 (20%)	82%	100%	92%	100%	100%
Case E-2 (40%)	87%	100%	95%	100%	100%
Case E-3 (60%)	92%	98%	95%	100%	100%
Case E-4 (100%)	98%	93%	91%	99%	100%

Estimated Net Production Value (Case E : 1000 Nu.)

Case	Code	Name of Canal
	Canal C9	Bajo
Case E-1 (20%)	1,408	
Case E-2 (40%)	1,458	
Case E-3 (60%)	1,476	
Case E-4 (100%)	1,396	

(3) Cost Estimation for Double Paddy Cropping

Only for double paddy cropping, it is not necessary to construct any structure but the extension of tectonics of double paddy cropping should be required. In the present condition, there is one extension technician in each Gewog but it is necessary to consider the training for the new agricultural tectonics for them.

Therefore, the additional extension cost for the net cost of the double paddy cropping was estimated including the necessary equipment as shown in the Data Book V and the result was summarized below;

Estimated Net Cost for One Year (Case E : 1000 Nu.)

Case	Code	Name of Canal
	Canal C9	Bajo
Case E-1 (20%)	33	
Case E-2 (40%)	55	
Case E-3 (60%)	66	
Case E-4 (100%)	77	

II.3.9 Combined Counter Measures Case

Using the same procedure shown below as the above mentioned, the combination of each counter measure case was studied.

- Recalculation of water requirement
- Estimation of production ratio and net production value
- Preliminary design of necessary structure and estimation of net cost for one year

The procedure and calculation of each item is shown in the Data Book V and the result is summarized in Table II.3.4 and Fig. II.3.2.

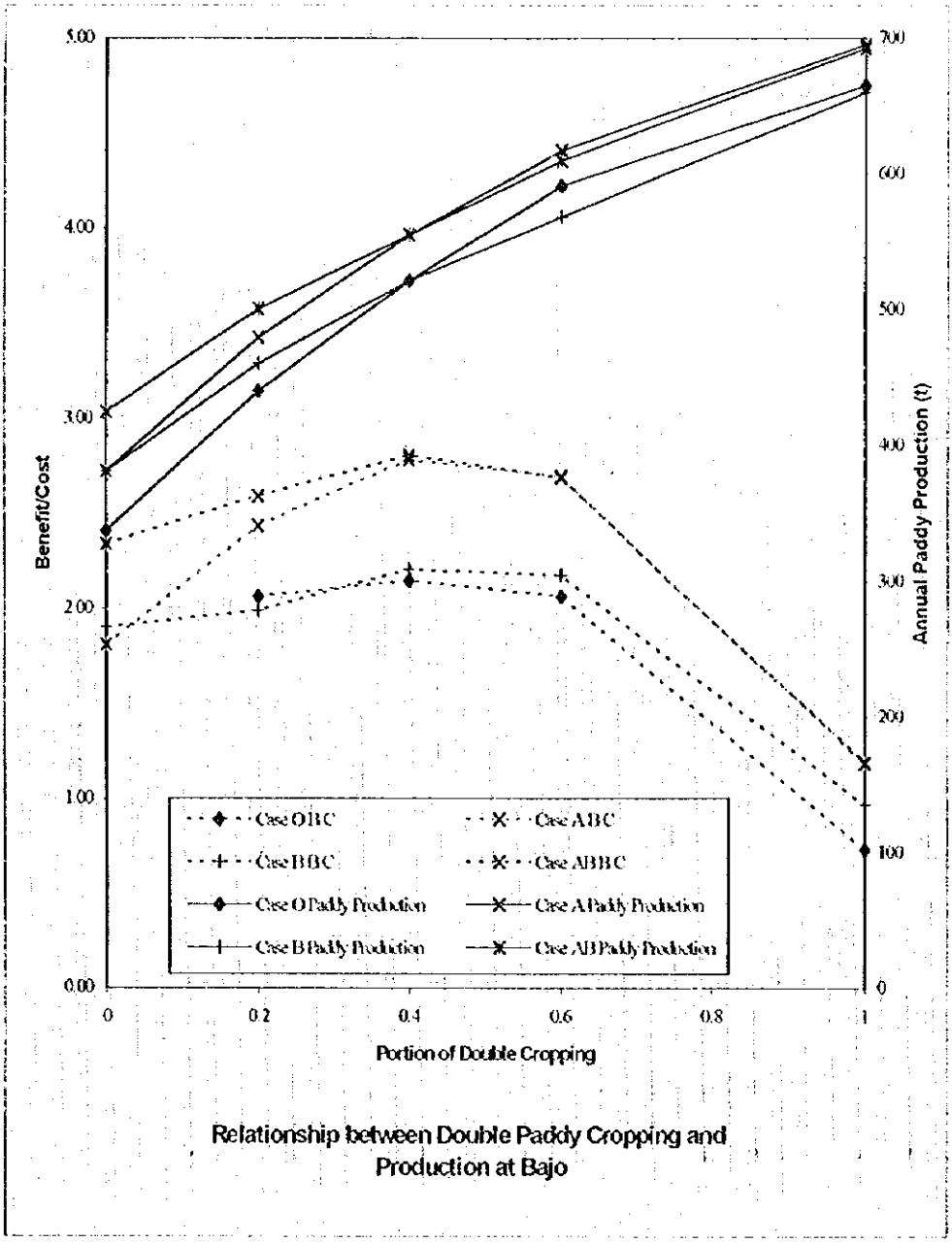
II.3.10 The Result of Case Study

From the result of case study, the following basic strategy can be suggested for irrigation improvement plan.

- For low flat area (Lobeysa and Bajo area)

  With no consideration of applying the double paddy cropping, the highest benefit/cost ratio can be obtained applying the Case AB (combination of water management and canal capacities improvement) and the improvement of canal facilities and establishment of new water management system should be proposed. for improvement of irrigation plan in the low flat area.

  With consideration of applying the double paddy cropping, it is technically possible to apply the double cropping to all the present paddy fields. However, applying 40% of the double paddy cropping with Case AB shows the highest B/C ratio, and, this means that it is necessary to consider the proposed portion of double cropping based on the development concept in the area. The relation between the B/C ratio, production and the portion of the double cropping is shown below;



Relationship between Double Paddy Cropping and Production at Bajo

- For high hilly area (Phangyul and Rubeysa area)

The highest B/C ratio can be obtained in the Case AD-2 (combination of water management improvement and applying 10% of the diversification) and improvement of water management system with 10% of diversification should be proposed. As there is no sufficient irrigation water at intake site in these area, the high B/C ratio cannot be expected applying the improvement of canal capacities. Considering the effective use of the agricultural land and limited irrigation water, it is better to consider applying the diversification. In this study, Chili was considered for diversification instead of paddy, and it is necessary to research the optimum crop for the diversification in future.

H.4 Basic Improvement Plan for 10 Irrigation Schemes

H.4.1 Basic Concepts and Proposed Strategies for Improvement Plan of 10 Irrigation Schemes

Considering present condition of agricultural activities in the Study area and based on the result of the Case Study, the following basic concepts should be considered for the agricultural development.

- Improvement of the effective irrigation water use
- Improvement of the effective land use

As it is necessary to consider the proper implementation plan for the prevention of any social conflict coursed by the rapid development, the improvement plan should be studied for short term and long term. From the result of mutual discussions between MOA and the study team, following target years is settled based on the physical year of the Five Year National Development Plans in the Bhutan.

- 2002 year for short term improvement plan
- 2007 year for long term improvement plan

Furthermore, since there are a lot of differences in the conditions such as meteorological, topographical and other between the low flat area (Lobeysa and Bajo) and high hilly area (Phangyul and Rubeysa), the strategy of irrigation improvement plan should be different for both areas.

(1) Proposed Strategy for the Low Flat Area

Considering the food self sufficiency in the Bhutan, it is necessary to produce paddy as much as possible. However, the financial conditions of farmers should also be considered. Consequently, following strategies were proposed based on the result of the Case Study.

- Short term
  Supplying sufficient irrigation water
  Applying double paddy cropping for 40% of present paddy field

- Long term
  Supplying sufficient irrigation water
  Applying double paddy cropping for 100% of present paddy field

(2) Proposed strategy for the High Hilly Area

Considering the hydrological condition in the high hilly area, it is impossible to plant the paddy for all paddy fields in the area. In the present condition, 30 ~ 40% of paddy field has not been used in an average year and it is necessary to consider the diversification for effective land use. Consequently, the following strategies were proposed based on the result of the Case Study.

- Short term
  Establishment of new water management system
  Applying the diversification for 10% of present paddy field

- Long term
  Improvement of water management system
  Research the optimum crop diversification

H.4.2 Irrigation Improvement Plan for Low Flat Area

According to the basic concept and strategies, the irrigation improvement plan was studied for the Upper Lobeysa (C1), Lower Lobeysa (C2) and Bajo (C9) Canals supplying irrigation water to the agricultural land in the low flat area.

(1) For Short Term

1) Conditions of Improvement Plan

For supplying the sufficient irrigation water, the rehabilitation of irrigation canals and improvement of water management were considered. For the stabilization of the irrigation water supply, the enforcement of protection works was also considered based on the vulnerability index of the canals. Applying the double paddy cropping for 40% of present paddy field considering the highest B/C ratio. The design conditions are summarized below;

Summary of Design Conditions

Name of Canal	Code	Canal Length (km)	Command Area (ha)	Design Discharge (l/s)	Number of Offtakes	Average Vulnerability Index
Upper Lobeysa	C1	7.1	61	88	32	39.8
Lower Lobeysa	C2	8.1	300	434	52	39.9
Bajo	C9	15	143	210	35	46.8

2) Project Cost

Based on these design conditions, the necessary structures were designed preliminarily as shown in the Data Book. The project cost including O/M cost was also roughly estimated and the results are summarized as shown below;

Summary of Project Cost for Upper Lobesa, Lower Lobeysa and Bajo Canal

(unit:1000Nu.)

Name of Canal Code	Upper Lobeysa C1	Lower Lobeysa C2	Bajo C9	Remark
Canal Rehabilitation Weks	772	2,428	2,190	
Protection Works	379	600	2,825	
Total Construction Cost	1,152	3,027	5,016	
Canal O M Cost	23	61	100	for 20 years
O M Cost for Water Management	354	524	750	for 20 years
Additional O M Cost for Double Cropping	51	58	109	for 20 years
Total Project Cost	1,580	3,670	5,975	
(for 1year)	(79)	(183)	(299)	

3) Net Project Cost and Benefit

Based on the result of the Case study, the net project cost and benefit were estimated and the result is summarized as shown below;

Net Benefit and Net Project Cost

(Unit:1000Nu.)

Name of Canal / Code	Upper Lobeysa C1	Lower Lobeysa C2	Bajo C9	Remarks
Present Net Production Value	570	2,898	1,340	
Net Production Value with Project	649	3,190	1,532	
Net Benefit	79	292	193	
Total Project Cost	79	183	299	for 1 year
Average Present O/M Cost	44	51	230	for 1 year
Net Project Cost	35	132	69	for 1 year
(B/C Ratio)	(2.25)	(2.21)	(2.80)	

(2) For Long Term

1) Conditions of Improvement Plan

The same conditions of improvement plan as that for short term were considered except applying the double paddy cropping for 100% of present paddy field for the increase of paddy production with a consideration of improvement of food self sufficiency in the Bhutan. The maximum water requirement for 100% double paddy cropping is less than that of 40%. Therefore, the irrigation canal facilities for the short term can be applied.

Maximum Water Requirement and Paddy Production

	Name of Canal / Code	Upper Lobeysa C1	Lower Lobeysa C2	Bajo C9
Present Condition	Max. Water Requirement (l/s)	196 (May)	961 (May)	464 (May)
	Estimated Paddy Production (t)	164	807	338
40% Double Cropping	Max. Water Requirement (l/s)	88 (May)	434 (May)	210 (May)
	Estimated Paddy Production (t)	235	1,157	555
100% Double Cropping	Max. Water Requirement (l/s)	86 (Apr.)	425 (Apr.)	205 (Apr.)
	Estimated Paddy Production (t)	293	1,441	692

2) Project Cost

As the design discharge is almost same as that of short term, the project cost was also almost same as that for short term.

3) Project Cost and Benefit

Using the same manner as for the short term, the project cost and benefit with the project were estimated and the results are summarized as shown below;

Net Benefit and Net Project Cost

Name of Canal Code	Upper Lobeysa C1	Lower Lobeysa C2	Bajo C9
Present Net Production Value	570	2,898	1,340
Net Production Value with Project	602	2,962	1,422
Net Benefit	**32**	**64**	**82**
Net Project Cost	**35**	**132**	**69**
(B/C Ratio)	(0.93)	(0.49)	(1.19)

II.4.3 Irrigation Improvement Plan for High Hilly Area

According to the basic concept and strategies, the irrigation improvement plan was studied for following irrigation schemes in the high hilly area.

- Phangyul Canal (C9, Phangyul sub-area)
- Gemkha Canal (C15, Phangyul sub-area)
- Nalakha Canal (C18, Rubeysa sub-area)
- Rutekha Canal (C19, Rubeysa sub-area)
- Mapekha Canal (C20, Rubeysa sub-area)
- Naykoyuwa Canal (C21, Rubeysa sub-area)
- Rumina Canal (C22, Rubeysa sub-area)

(1) For Short Term

1) Conditions of Improvement Plan

For establishment of the new water management system, it is necessary to construct the offtake facilities for easy water management. As there is not enough available irrigation water for present cropping pattern at intake sites of these canals, it is also necessary to consider the diversification from the paddy for the improvement of effective land use. In the present conditions, 10 ~ 30% of paddy field is not used in the average year. Therefore, 10% of diversification was considered based on the result of the Case Study. The design conditions are summarized below;

Summary of Design Conditions

Name of Canal	Code	Canal Length (km)	Command Area (ha)	Design Discharge (l/s)	Number of Offtakes	Average Vulnerability Index
Phangyul	C10	16	91	240	32	41.3
Gemkha	C15	3.5	15	42	12	44.5
Nalakha	C18	3.9	29	78	20	44.5
Rutekha	C19	2.2	40	106	28	36.2
Mapkekha	C20	2.2	27	73	25	36.2
Naykoyuwa	C21	1.7	24	61	20	30.8
Rumina	C22	1.1	28	75	16	36.6

2) Project Cost

Based on these design conditions, the necessary structures were designed preliminarily as shown in the Data Book V. The roughly project cost including O/M cost was also estimated and the results are summarized as shown below;

Summary of Project Cost

(unit:1000Nu.)

Name of Canal Code Number of Offtake	Phangyul C10 32	Gemkha C15 12	Nalakha C18 20	Rutekha C19 28	Remark
Offtake Construction Works	286	47	119	207	
O M Cost for Water Management	748	161	192	136	for 20 years
O M Cost for Diversification	403	88	98	55	for 20 years
Total Project Cost	1,437	295	409	399	for 20 years
(for 1 year)	(72)	(15)	(20)	(20)	

Name of Canal Code Number of Offtake	Maphekha C20 25	Naykoyuwa C21 20	Rumina C22 16		Remark
Offtake Construction Works	148	119	95		
O M Cost for Water Management	125	97	67		for 20 years
O M Cost for Diversification	55	43	28		for 20 years
Total Project Cost	329	259	189		for 20 years
(for 1 year)	(16)	(13)	(9)		

3) Net Project Cost and Benefit

Based on the result of the Case study, the net project cost and benefit were estimated and the result is summarized as shown below;

Net Benefit and Net Project Cost

(unit:1000Nu.)

Name of Canal Code	Phangyul C10	Gemkha C15	Nalakha C18	Rutekha C19	Remark
Present Net Production Value	421	108	184	225	
Net Production Value with Project	562	131	216	263	
Net Benefit	141	23	31	38	
Net Project Cost	72	15	20	20	for 1 year
(B C Ratio)	(1.95)	(1.53)	(1.57)	(1.88)	

Name of Canal Code	Maphekha C20	Naykoyuwa C21	Rumina C22		Remark
Present Net Production Value	152	135	158		
Net Production Value with Project	177	158	175		
Net Benefit	25	23	17		
Net Project Cost	16	13	9		for 1 year
(B C Ratio)	(1.59)	(1.74)	(1.91)		

(2) For Long Term

1) Conditions of Improvement Plan

From the result of the Case study, it is not feasible to improve the water source for irrigation considering the hydrological condition in the high hilly area. Therefore, it is necessary to improve the water management system for the effective irrigation water use and to research the optimum diversification crops for the effective land use.

For the improvement of the water management system, the monitoring and analysis for the water management should be proposed after completion of project for short term.

For the research of the optimum diversification crops, it is necessary to carry out further investigations such as soil survey, marketing study and etc. As it can be considered that the existing organizations such as RNRRC in Bajo will able to study those investigations, it is not necessary to construct any kind of facilities for this purpose.

2) Project Cost

The monitoring and analysis cost of the water management is already included in the O/M cost for water management of short term.

The project cost for research was roughly estimated and is summiarized as shown below;

Project Cost for Research

(unit:1000Nu./year)

Description	Amount	Remark
Officers and Labor	226	
Necessary Equipment	102	for 1 year
Other Expens	160	
Total	487	

3) Project Benefit

It is impossible to count this kind of project benefit but the result of research should be available for the consideration of further agricultural improvement plan and these information will make a great contribution to rural development in future.

II.5 Alternative Study of Irrigation Improvement for Sub-Study Area

II.5.1 Study Conditions of Alternatives

For the irrigation improvement in the Sub-study area, alternatives as shown in Fig. II.5.1 were considered. In the Case Study, most of the alternatives were analyzed except the following case.

- Supplying sufficient water using the river pump or shallow well system instead of canal improvement.

This counter measure can be applied only for low flat area and the improvement of water management system and applying 40% double paddy cropping should be required for achieving the same project benefit as that of irrigation canal improvement. Considering the supplying the irrigation water supplementarily, the design conditions for these system are shown in the Data Book V and summarized below;