CHAPTER 2 WATER DEMAND AND POTENTIAL

2.1 Future Socio-Economic Framework

2.1.1 Development Plan in Indonesia and Bali

(1) National Development Program

"*Program Pembangunan Nasional (PROPENAS)*" is the five-year development plan of the Central Government that was formed in August 2000 based on the Guidelines of the Government Policy named "*Garis-Garis Besar Haluan Negara* (GBHN)".

From the economic point of view, PROPENAS aims to achieve broad-based economic growth oriented by market on the basis of Indonesia's comparative advantages by focusing on globalization and decentralization. For infrastructure, PROPENAS put the priority on rehabilitation and betterment of existing infrastructure to fulfill the economic and urgent social needs that support production and export activities and expanding employment and business opportunities.

(2) Development Program of Bali Province

"*Program Pembangunan Daerah (PROPEDA) 2001-2005*" is drawn up as the provincial five-year development plan to support national development policy of PROPENAS. The strategy of Bali Provincial Government aims economic recovery in short term and economic stability in medium term. To achieve those aims, the Bali Provincial Government sets out the policy and development programs especially on the leading sectors of Bali Province such as tourism, small & medium industry, and agriculture.

(3) New National and Provincial Planning System

The Law No.25, 2004 provides establishment of new National and Provincial Planning System; therefore above PROPENAS and PROPEDA end the role, and the following planning system described in Table-II-2.1 will supersede them.

Table-II-2.1 New National and Provincial Planning System

Government	Name of the Plan	Duration
Central	Rencana Pembangunam Jangka Panjang (RPJP)	National Long-term Development Plan: 20 years
	Rencana Pembangunam Jangka Menengah (RPJM)	National Medium-term Development Plan: 5 years
	Rencana Kerja Pemerintah (RKP)	National Annual Development Plan: 1 year
Regional	Satuan Kerja Perangkat Daerah (RENSTRA-SKPD)	Regional Medium-term Development Plan: 5 years
	Rencana Kerja Pemerintah Daerah (RKPD)	Regional Annual Development Plan: 1 year

Source: National System of Development Planning, Law No.25, 2004

2.1.2 Spatial Plan of Bali Province

The Bali Provincial Government made up "Spatial Plan of Bali Province" in 1996, which was revised as "Revised Spatial Plan of Bali Province 2003 – 2010" for super-ordinate plan of PROPEDA. The Revised Spatial Plan aims the broad revision of transportation network, irrigation system, river water system, and economic development of sectors such as agriculture, manufacturing industry and tourism. The socio-economic targets of the Revised Spatial Plan are summarized as follows.

(1) Population

The Revised Spatial Plan envisages the future population in Bali Province on the basis of three scenarios as shown inTable-II-2.2.

Table-II-2.2 Population

Scenario	Population Growth	Projected Population of Year 2010
1. High Growth Scenario	1.26% (same rate as during 1990 - 2000)	3,567,000
2. Medium Growth Scenario	1.18%	3,539,000
3. Low Growth Scenario	1.05%	3,493,000

Source: Revised Spatial Plan of Bali Province 2003 – 2010

(2) Economic Growth

The Revised Spatial Plan, taking into consideration the growing demand of domestic consumption and export, views that the economic growth of Table-II-2.3could be achieved

Table-II-2.3 Economic Growth

Sector	2003-2005	2006-2010
All Sector	3.73 %	6.63 %
Manufacturing	5.49 %	8.44 %
Transportation & Communications	5.82 %	8.03 %

Source: Revised Spatial Plan of Bali Province 2003 – 2010

(3) Manufacturing Industry

The Revised Spatial Plan focuses development of middle and large processing industries related to agriculture products. To achieve this, the Revised Spatial Plan proposes the necessity for development of industrial zone especially at the area of Celukan Bawang in Buleleng and Pengambengan in Jembrana.

(4) Tourism

The Revised Spatial Plan proposes the following nine areas to be developed more intensively in order to attract and increase number of tourists.

1) Kailibukbuk in Buleleng
2) Batuampar in Buleleng
3) Candikesuma in Jembrana
4) Nusa Penida in Klungkung
5) Candidasa in Karangasem
6) Ujung in Karangasem
7) Tulamben in Karangasem
8) Soka in Tabanan
9) Perancak in Jembrana

2.1.3 Socio-economic Framework

In formulating the socio-economic framework, the basic data and information of the Revised Spatial Plan were mostly referred to with careful study and discussion with Bali Provincial Government.

(1) Population

The population projection is framed by applying two steps that are: Trend Projection and Development Projection.

<Trend Projection>

- Until 2010, the middle scenario 1.18% of the Revised Spatial Plan is considered to be more realistic according to the information from Bali Provincial Government.
- From 2011, the low scenario 1.05% of the Spatial Revised Plan is applied.

<Development Projection>

According to the suggestion of the Revised Spatial Plan for the industrial development at Celukan Bawang in Buleleng, inter-regency migration of workers is taken into consideration by assuming as follows:

- A half of food/beverage and textile industries in Badung and Denpasar are assumed to be shifted to Celukan Bawang in Buleleng during the period of years 2010-2025.
- Accordingly, employees of the industries and their families are assumed to move to Buleleng. A half of employees are assumed singles, and household size is set at 4 persons.

Thus, the population of the development projection is applied as presented in Table-II-2.4

Table-II-2.4 Population Projection

Unit: 1000 persons

Regency/City	Census	Trend Projection			Development Projection
	2000	2004	2010	2025	2025
Jembrana	232	237	244	263	263
Tabanan	376	386	400	436	436
Badung	346	378	425	547	540
Gianyar	393	416	451	541	541
Klungkung	155	157	159	164	164
Bangli	194	200	210	235	235
Karangasem	361	366	375	396	396
Buleleng	558	563	571	591	613
Denpasar	532	601	704	966	951
Total	3,147	3,304	3,539	4,139	4,139

Note: The actual growth rate of 1990 – 2000 was reflected in projection of the respective Kabupaten.
Source: Study Team

(2) Economic Growth of Manufacturing Industry Sector

The Revised Spatial Plan envisages the industry sector economic growth as follows: 1) 5.49% for years 2003 – 2005, and 2) 8.44% for years 2006 – 2010. However, the growth rate is reviewed and projected by Study Team as shown in Table-II-2.5.

<Year 2004 – 2005>

The growth rate of 5.5% that is envisaged by the Revised Spatial Plan is applied through consideration of previous years' potential economic growth of manufacturing industry sector of Bali Province.

<Year 2006 -2025>

The growth rate of 7% is applied, which is the average rate between 5.5% and 8.4% envisaged by the Revised Spatial Plan, through consideration of the potential area size and current condition of the infrastructure of Celukan Bawang in Buleleng where is proposed as industrial promotion area by the Revised Spatial Plan.

Table-II-2.5 Projected Growth Rate of Manufacturing Industry Sector

Actual	Projected	
2002/2003	2004-2005	2006-2025
2.6 %	5.5 %	7 %

Source: Study Team

(3) Output of Manufacturing Industry

Industrial output is used for industrial water demand projection. The output until the target year 2025 is projected as presented in Table-II-2.6 by applying the above economic growth rate to manufacturing industry sector.

Table-II-2.6 Projection of Industrial Output

Unit: billion Rp.

Kabupaten	Actual	Trend Projection			Development Projection
	2003	2004	2010	2025	2025
Jembrana	297	313	463	1,270	1,270
Tabanan	137	144	213	585	585
Badung	293	309	458	1,256	715
Gianyar	155	164	242	664	664
Klungkung	22	23	34	93	93
Bangli	5	5	7	20	20
Karangasem	62	66	97	267	267
Buleleng	10	10	15	42	1,559
Denpasar	538	568	838	2,302	1,326
Total	1,519	1,602	2,367	6,499	6,499

Source: Study Team

(4) Necessary Number of Hotel Rooms

Water demand for tourism is to be projected based on necessary number of hotel rooms that is estimated by assuming the number of tourist, number of guest at hotel, number of guest at room, and length of stay at hotel. Thus, necessary number of hotel rooms until 2025 is estimated as shown in Table-II-2.7.

Table-II-2.7 Projected Necessary Hotel Rooms

Classification of Hotel	2004	2010	2025
Classified hotel	9,300	12,200	24,100
Non-classified hotel and other accommodations	5,400	7,100	14,000
Total	14,700	19,300	38,100

Source: Study Team

<Assumptions for Projection>

The following sumptions are applied to project the necessary number of hotel rooms.

- Number of Tourists direct to Bali

  Year 2004: 1,458,000
  Year 2010: 1,900,000
  Year 2025: 3,690,000

- Number of Hotel Guest

  Foreigners
  Classified hotel: 87% of foreign direct visitors
  Non-classified hotel and other accommodations: 49% of foreign direct visitors
  Indonesian
  Statistic data of hotel guest (BPS of Bali Province) by applying average growth rate of GDP/capita (3%) of the years 2000-2003

- Number of Guests

  2.1 persons at one room

- Length of Stay

Class of Hotel	Foreigners	Indonesian
Classified hotel:	4.3 days	3.7 days
Non-classified hotel and other accommodations:	4.2 days	2.0 days

2.2 Water Demand Projection for Domestic and Non-domestic Water

Water demand of domestic water and non-domestic water (commercial/public/institutional water, manufacturing industry water and tourism water) was projected based on the conditions as shown in Table-II-2.8 and Table-II-2.9.

2.2.1 Domestic Water Demand

(1) Public Water Supply

The future unit consumption rate of domestic water use through public water supply system should be decided considering the change of life style (such as improvement of sewerage system, wide motorizations, spread of electric equipment use, etc.). Unit consumption rate of each PDAM service area is decided based on the current rate and future life style of users. However, the rates for Denpasar and Badung (PTTB service areas) are set as 220 lit/head/day and 210 lit/head/day respectively, minimizing the increase (10 lit/head/day for 20 years) of the rate through campaigns for save water.

(2) Non-public Water Supply

Regarding the domestic water obtained by non-public water supply system, unit rates are decided based on the questionnaire survey for 9 regencies/city conducted by the Study Team. The current unit consumption rate is 60 lit/head/day. This rate will be constant in future.

Table-II-2.8 Base Data for Domestic Water Demand Projection

<table>
<tr><th rowspan="3">Water Supply Enterprises</th><th colspan="9">Public Supply</th><th>Non-Public W. Supply</th></tr>
<tr><th colspan="3">Unit Consumption (liter/person/day)</th><th colspan="3">Service Coverage Ratio (%)</th><th colspan="3">Unaccounted Water Rate (%)</th><th>Consump. (ltr/p/day)</th></tr>
<tr><th>2004</th><th>2010</th><th>2025</th><th>2004</th><th>2010</th><th>2025</th><th>2004</th><th>2010</th><th>2025</th><th>2004</th></tr>
<tr><td>Denpasar</td><td>210</td><td>220</td><td>220</td><td>45</td><td>55</td><td>70</td><td rowspan="10">25</td><td rowspan="10">20</td><td rowspan="10">20</td><td rowspan="10">60</td></tr>
<tr><td>Badung</td><td>170</td><td>180</td><td>210</td><td>35</td><td>45</td><td>70</td></tr>
<tr><td>PT.TB</td><td>200</td><td>210</td><td>210</td><td>65</td><td>70</td><td>80</td></tr>
<tr><td>Gianyar</td><td>130</td><td>140</td><td>160</td><td>45</td><td>55</td><td>70</td></tr>
<tr><td>Jembrana</td><td rowspan="6">110</td><td rowspan="6">120</td><td rowspan="6">150</td><td>30</td><td>35</td><td>50</td></tr>
<tr><td>Tabanan</td><td>40</td><td>50</td><td>70</td></tr>
<tr><td>Klungkung</td><td>50</td><td>55</td><td>70</td></tr>
<tr><td>Bangli</td><td rowspan="3">20</td><td rowspan="3">30</td><td rowspan="3">50</td></tr>
<tr><td>Karangasem</td></tr>
<tr><td>Buleleng</td></tr>
</table>

Source: JICA Study Team

2.2.2 Non-domestic Water Demand

<Commercial/Public/Institutional Water>

Bali Water Supply Master Plan conducted by SMEC International PTY LTD in 2000 estimated commercial/public/institutional water consumption by applying the ratio of 20% to domestic water consumption. Similarly, the same ratio was set up in this study as shown in Table-II-2.9 referring the present consumption of this category of each water supply enterprise.

Service coverage ratio is assumed to be 100 % considering the place where this category actually locates and difficulty in obtaining non-public supply there.

<Manufacturing Industry Water>

The survey on major industry of Bali Province such as food/beverage, textile and wood industries was conducted by the Study Team. According to the data collected, the unit water consumption of manufacturing industry was estimated at 10 m^3/day/annual output of billion Rp. as shown in Table-II-2.9. Manufacturing industry output is projected in Chapter 2.1.3 and presented in Appendix-4.2.

Actually, there are many manufacturing industries that take water from wells, river water, etc. Accordingly, service coverage ratio for this category is supposed to be low. In this study, the ratio is estimated currently at 20 % and 40 % in 2025.

<Tourism Water>

The survey on hotels of Bali Province was conducted by the Study Team. According to the data collected, the unit water consumption of star hotel and non-star hotels was estimated respectively at $3.3m^3$/room/day and $1.5m^3$/room/day as shown in Table-II-2.9. In fact, there are many hotels that utilize well water. So, current service coverage ratio of this category is not high, which is estimated at around 20 %. It is expected that number of tourist to Bali Island will continuously increase. However, most luxurious hotels that utilize well water are located near the sea. The well near the sea is limited to use because it may bring about contamination of sea water into the well. In order to cope with incidental increasing tourism water demand, most of hotels supposedly use more public water in future. Thus, service coverage ratio was assumed 70 % in 2025.

Table-II-2.9 Base Data for Non-domestic Water Demand Projection

Category	Water Consumption		Service Coverage Ratio (%)		
	Entity	Unit Rate	2004	2010	2025
Commercial/Public/Institutional	PT.TB	30% of Domestic Water	100	100	100
	PDAM Denpasar and Tabanan	20% of Domestic Water			
	Other 7 PDAMs	10% of Domestic Water			
Industrial	Manufacturing	10 m^3/output in billion Rp.	20	25	40
Tourism	Star hotel	3.3 m^3/room/day	20	40	70
	Non-star hotel	1.5 m^3/room/day	100	100	100
Unaccounted Water	Same as rate of domestic water (%)		25	20	20

Source: JICA Study Team

2.2.3 Water Supply Requirement of Bali Province

By applying all factors mentioned above (1) and (2), overall water supply requirement of Bali Province is projected and summarized in Table-II-2.10.

Table-II-2.10 Water Supply Requirement by Regency of Bali Province

(Unit: lit/s)

Regency//City Year	Public Water Supply			Non-Public Water Supply			Total		
	Domestic	Non-Domestic	Total	Domestic	Non-Domestic	Total	Domestic	Non-Domestic	Total
Jembrana									
- 2005	125	26	152	113	31	144	239	57	296
- 2010	148	35	184	109	40	149	258	75	333
- 2025	285	109	395	91	88	179	376	197	573
Tabanan									
- 2005	276	69	345	156	19	174	432	88	519
- 2010	347	89	436	138	23	160	485	112	597
- 2025	663	195	858	90	45	135	753	240	993
Badun (Total)									
- 2005	470	248	718	145	251	396	615	499	1,114
- 2010	625	378	1,003	138	257	396	763	635	1,398
- 2025	1,189	1,000	2,189	264	99	363	1,288	1,264	2,552
Badung-PDAM									
- 2005	237	37	273	118	29	147	355	66	421
- 2010	343	55	398	111	35	146	454	90	544
- 2025	721	130	851	74	38	111	794	167	962
Badung-PTTB									
- 2005	233	211	444	27	222	249	260	433	693
- 2010	281	323	604	27	223	250	309	545	854
- 2025	468	870	1,338	25	226	252	494	1,096	1,590
Gianyar									
- 2005	397	64	461	155	23	178	552	87	639
- 2010	503	83	586	140	28	168	643	111	754
- 2025	876	182	1,058	112	53	164	988	235	1,223
Kulungkung									
- 2005	136	15	151	53	3	56	189	18	207

Regency//City Year	Public Water Supply			Non-Public Water Supply			Total		
	Domestic	Non-Domestic	Total	Domestic	Non-Domestic	Total	Domestic	Non-Domestic	Total
- 2010	151	18	169	49	4	53	201	21	222
- 2025	249	33	282	34	7	41	282	40	323
Bangli									
- 2005	74	10	83	110	0	110	183	10	193
- 2010	109	14	123	101	1	102	211	14	225
- 2025	255	31	287	81	1	82	336	33	369
Karangasem									
- 2005	136	30	166	198	10	208	334	39	374
- 2010	195	41	236	181	11	192	376	52	428
- 2025	430	97	526	136	21	158	566	118	684
Blereng									
- 2005	211	34	245	304	6	309	515	39	554
- 2010	297	46	344	275	6	281	573	52	625
- 2025	665	194	859	211	113	324	876	306	1,182
Denpasar									
- 2005	929	251	1,180	227	99	326	1,157	350	1,507
- 2010	1,232	345	1,577	218	115	333	1,450	460	1,910
- 2025	2,119	686	2,805	197	134	330	2,316	820	3,136
Bali - Total									
- 2005	2,754	747	3,501	1,460	441	1,901	4,215	1,188	5,402
- 2010	3,608	1,048	4,657	1,350	485	1,834	4,958	1,533	6,491
- 2025	6,731	2,527	9,259	1,050	726	1,776	7,782	3,253	11,035
SARBAGI									
- 2005	1,796	563	2,359	527	373	900	2,324	936	3,260
- 2010	2,360	806	3,166	496	400	897	2,856	1,206	4,062
- 2025	4,184	1,868	6,052	573	286	857	4,592	2,319	6,911

2.2.4 Sensitivity Analysis on Water Supply Requirement for Metropolitan Area

Sensitivity analysis on water supply requirement previously projected is conducted herein. As material variation factors, population growth, manufacturing industry growth, foreign tourist increase, and domestic water coverage ratio are selected. Scenarios for respective factors are set from both viewpoints of higher and lower scenarios than the projection as shown in Table-II-2.11.

Table-II-2.11 Scenarios for Sensitivity Analysis

Demand Variation Factors	Scenarios		Remarks
1. Population Growth	High 1	1.26%	Spatial Plan of Bali Province
	High 2	1.18%	Spatial Plan of Bali Province
	Low	1.05%	Spatial Plan of Bali Province
2. Manufacturing Ind. Growth	High	8.4%	Spatial Plan of Bali Province from 2006
	Low	5%	30% lower than the projection from 2006
3. Foreign Tourist Increase	High	5%	10% higher than the projection
	Low	4%	10% lower than the projection
4. Coverage Ratio of Domestic Water	90% in 2025		Coverage ratio of WB study

Source: Study Team

The result of water supply requirement based on the above scenarios is presented in Table-II-2.12. It is obvious that the water supply requirement does not change significantly compared with the projection as for variation factors of population, manufacturing and foreign tourist; however, it should be noted that the requirement will soar by 22% in year 2025 if domestic water coverage ratio increases from 70% and 80% of the projection to 90%.

Table-II-2.12 Variation in Water Supply Requirement

Unit: liter per second

Demand V. Factor	Scenario	Badung			Gianyar	Denpasar	Total	Projection =100
		PDAM	PTTB	Total				
Projection		851	1,338	2,189	1,058	2,805	6,052	100
1. Population	High 1	899	1,375	2,274	1,102	2,995	6,371	105
	High 2	874	1,356	2,230	1,080	2,898	6,208	103
	Low	835	1,326	2,161	1,044	2,744	5,949	98
2. Manufacturing	High	857	1,344	2,201	1,070	2,829	6,100	101
	Low	844	1,332	2,176	1,046	2,782	6,004	99
3. Foreign Tourist	High	853	1,395	2,248	1,063	2,820	6,131	101
	Low	848	1,282	2,130	1,054	2,791	5,975	99
4. Coverage Ratio	90%	1,077	1,418	2,495	1,334	3,532	7,361	122

Source: Study Team

2.2.5 Water Demand Projection in Lowest Case for Metropolitan Area

The Master Plan proposed the water demand projection of 6,052 lit/sec (522,890 m^3/day) in 2025 for the metropolitan area. To compare this projection, the lowest water demand projection considering the increasing rates of population, manufacturing and tourism are examined as below.

(1) Conditions of Lowest Projection

The conditions of lowest water demand projection for population, manufacturing, tourism are as follows:

- Population: 1.05% (Minimum Value of Spatial Plan)
  The current Bali Spatial Plan sets three annual population growth scenarios:
  (1) High Growth Scenario = 1.26%
  (2) Medium Growth Scenario = 1.18%
  (3) Low Growth Scenario = 1.05%

- Manufacturing: 3.5% (Half Growth Rate of Master Plan)
  The Water Master Plan sets 7.0% of annual manufacturing growth rate in Bali.

- Tourism: 2.1% (Average Growth Rate from 1999 to2004 excluding 2003)
  The Water Master Plan sets 4.5% of annual tourism growth rate in Bali.

(2) Lowest Projection for Metropolitan Area

The lowest water demand projections in the year of 2025 are calculated as shown in Table-II-2.13. The total lowest water demand is 5,571 lit/sec. This value is 92% of the projection (6,052 lit/sec) in the Master Plan. The difference between two projections is 481 lit/s.

Table-II-2.13 Projection of Lowest Water Demand in 2025 for Metropolitan Area

Unit: lit/sec

Demand	Senario	Badung PDAM	Badung PTTB	Gianyar PDAM	Denpasar PDAM	Total	Remarks
Domestic	Projection in M/P	721	468	876	2,119	4,185	◆ Current Water Supply Capacity (CWSC) = 2,623 lit/sec ◆ Balance between Projection in M/P and CWSC = 3,429 lit/sec ◆ Balance between Lowest Projection and CWSC = 2,948 lit/sec
	Lowest Projection	707	459	863	2,068	4,098	
Commercial & Public	Projection in M/P	72	141	88	424	724	
	Lowest Projection	71	138	86	414	708	
Industry	Projection in M/P	23	19	38	77	156	
	Lowest Projection	12	10	20	40	81	
Tourism	Projection in M/P	35	710	56	186	987	
	Lowest Projection	24	492	39	128	683	
Total	Projection in M/P	851	1,338	1,058	2,805	6,052	
	Lowest Projection	813	1,099	1,008	2,650	5,571	

2.3 Water Demand Projection for Agricultural Water

In general, agricultural waters to be evaluated for water resources development are irrigation, water consumption by livestock and inland fish culture. However, inland fishery including both catching and culture is negligibly small (2 % of provincial fish production). Besides, water for livestock relies on small ponds/shallow wells at small scale. Therefore, irrigation water that dominates agriculture water in Bali is examined to estimate the water demand.

2.3.1 Projection of Future Agriculture

To estimate water demand until the target year, 2025, it is necessary to project future agriculture in Bali. Based on two important agriculture plans and analysis of agriculture trend in the past, the projection and assumptions of future agriculture in Bali were made.

(1) Spatial Plan

"Revision of Regional Spatial Plan of Bali Province, 2003-2010, Provincial Regional Development Agency: BAPPEDA (herein after referred as the spatial plan)" aims to optimize the utilization of potential agriculture lands, specifying the planning policy for the wetland and dry land as described below.

<u>Wetland</u>

- Maximum utilization of paddy field with irrigation facilities, particularly Tabanan, Badung, Gianyar, Jembrana and Buleleng regencies, where paddy cultivation is intensively conducted.
- Intensification of cultivation, such as improvement of productivity
- Protection of paddy fields from change in landuse, such as residential areas, in accordance with Minister Decree of Home Affairs No. 410-1851 dated on June 15, 1994, stipulating that wetlands/technical irrigation areas shall not be changed to other functions.

<u>Dry Land</u>

- Extension of cropping, such as palawija and horticulture, to the potentially arable land
- Application of palawija cultivation in the paddy field during the dry period
- Promotion of short growing period horticulture with high economic value
- Designation of palawija cultivation to each regency
- Maize, soybean and peanut in Bangli, Karangasem and Buleleng regencies
- Cassava, sweet potatoes and potatoes in other regencies except Denpasar

(2) RENSTRA

"Strategy Plan on Food Crops Agriculture in Bali Province, 2004-2008 (herein after referred as RENSTRA" was formulated by Food Crops Agriculture Service of Bali Province (DINAS Pertanian Tanaman Pangan Propinsi Bali) in accordance with the spatial plan. RENSTRA is a short term plan, while the spatial plan is a regional long-term plan. RENSTRA specifies the policy and target to mitigate issues associated with agriculture.

Issues

- Small land tenure: 55 % of the total farm households have less than 0.5 ha of agriculture land.
- Decrease in paddy area: Paddy area in Bali has been decreasing at the rate of 1.01 % (approximately 870 ha) in average during 1997-2003.
- Lack of irrigation water during the dry season
- Lack of labors (mostly from outside Bali), particularly during the harvesting time
- Limited financial capability
- Organism disease
- Price fluctuation (very low price during the harvesting time)
- Lack of agribusiness

Policy

- Intensification of farming, such as improvement of crop productivity and quality, rehabilitation of irrigation facilities, market oriented crop culture, diversification of crops, increase in farmers income
- Development of high quality food crop commodities

Target

- To mitigate the decreasing ratio of paddy field at 0.45 % during 2004-2008
- To improve paddy production (dry unhusked rice) from 5.509 ton/ha in 2004 to 5.550 ton/ha in 2008
- To improve the annual production of palawija at several % depending on crops
- To promote high yield, quality and market competitive varieties of horticulture
- To develop horticulture agro-business
- To improve production of horticulture

(3) Future Agriculture

Based on the two plans and past trend analysis regarding agriculture, the followings are most likely pictures of future agriculture in Bali.

- The area of paddy field (wetland paddy) tends to decrease. In the last 7 years (1997 ~ 2003), 1.01 % of paddy field in Bali Province were annually changed to other uses. This reduction is mainly due to urbanization stimulated by development of tourism. Although the spatial plan and RENSTRA aims to protect the paddy field from landuse change, it is not realistic to achieve this goal immediately because of expansion of tourism sector. It will probably take some period to settle the paddy area decrease.
- Productivity of wetland paddy in Bali (5.5 ton/ha) is already high compared to the national average (4.2 ton/ha). Ideal production of paddy rice is 8 ton/ha; however, to reach the ideal takes a long time with sophisticated farming and irrigation management. Thus, an improvement of paddy productivity is considered to continue gradually.
- New irrigation scheme will be limited at small scale with mainly groundwater development because almost all irrigable land has been already utilized as wetland paddy field.
- Crop diversification will progress and selection of crop culture will be market oriented. Since the paddy culture will be maintained as staple food, palawija will be subject to change into horticulture/fruit culture. However, palawija is also important as non-rice food crop, at least certain area of palawija to satisfy demands will be maintained.
- Potential arable dry land will be utilized for palawija/horticulture/fruit culture.

2.3.2 Parameters for Irrigation Water Demand

Irrigation water for wetland paddy is a function of crop water requirement (ETcrop), effective rainfall (70%R80), irrigation efficiency (E), percolation (P) and farming conditions, such as land preparation (LP) and water layer replacement (WLR). Besides, cropping calendar and crop intensities affect the irrigation water. The definition and determination of each factor are discussed in the following section and an image of irrigation water is show in Figure-II-2.1.

Irrigation Water Requirement (Wetland Paddy) = (ETcrop + P + LP + WLR – 70%R80)/E

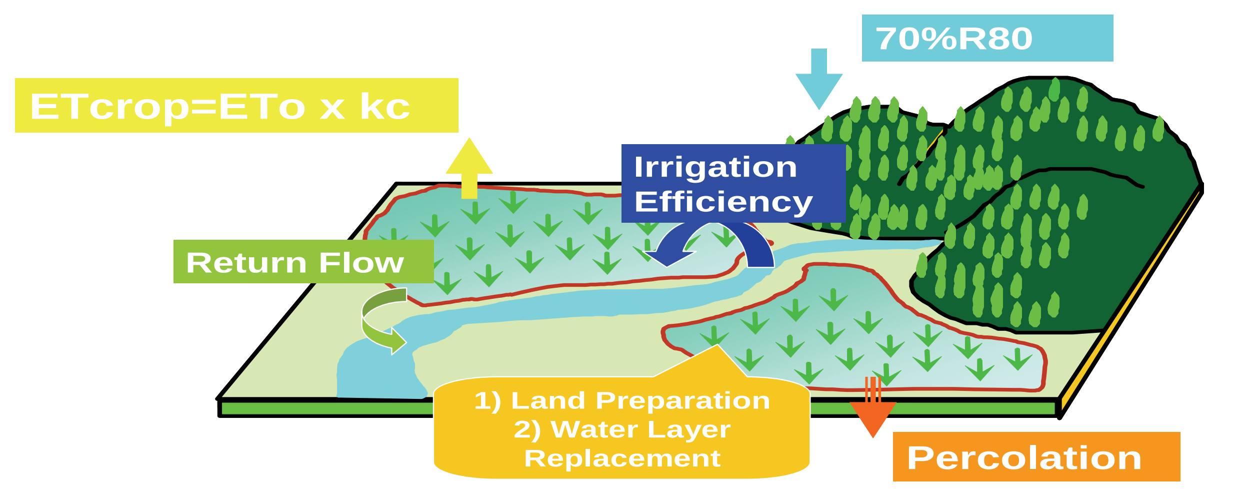


Figure-II-2.1 Conceptual Image of Irrigation Water

(1) ETcrop

Crop water requirement (ETcrop) is evapotranspiration of a disease-free crop grown in optimum conditions of soil fertility, water and production potential under given environment. It is a function of reference crop evapotranspiration (ETo: formerly defined as potential evapotranspiration) and crop coefficient (kc). Penman-Monteith equation was adopted to calculate ETo, while kc was obtained from "FAO Irrigation and Drainage Paper 24".

6 meteorological stations out of 13 stations (4 BMG stations and 9 stations belonged to Public Works Service of Bali Province) were selected considering the data availability and spatial variation of climate factors. ETo calculation requires a set of monthly data, consisting of maximum and minimum temperature, relative humidity, surface wind speed and sunshine hours. As shown in Figure-II-2.2, ETo in Bali ranges within 3 mm/day to 5 mm/day.

Crop coefficient depends on growing stage of crops. Therefore, the kc for paddy culture was adopted with the following conditions and assumptions.

- An application of irrigation to palawija/vegetables is very limited. Thus, irrigation is considered for paddy only.
- Length of paddy growing season is 110 days after land preparation, adopting the most typical length in Bali.
- kc for paddy culture in the humid Asia ranges from 1.10 (crop development) to 0.95 (maturity).
- Starting month of land preparation depends on regency and series of cropping pattern.

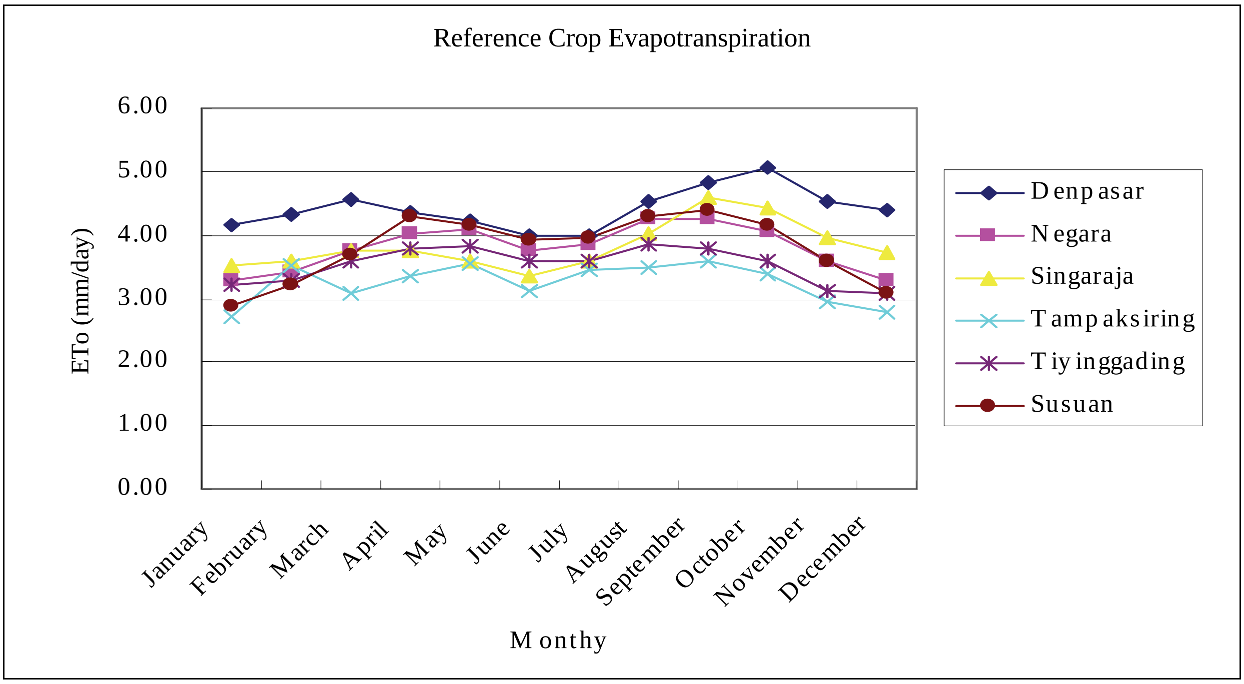


Figure-II-2.2 Reference Crop Evapotranspiration

(2) Effective Rainfall

Effective rainfall (70%R80) is rainfall stored in the root zone and effective to the crop growth. Considering annual variation of rainfall, 80 % probability rainfall (R80) was adopted as dependable rainfall, and successively 70 % of the dependable rainfall is assumed as the effective rainfall. Effective rainfall (70%R80) is 70 % of dependable rainfall and the estimate result is summarized in Table-II-2.14. Some amount of rainfall (0.3 mm/day – 1.5 mm/day depending on month and location) is available for crop growth even during the dry season contributing to increase in crop intensities of paddy culture.

Table-II-2.14 Effective Rainfall

(Unit: mm/day)

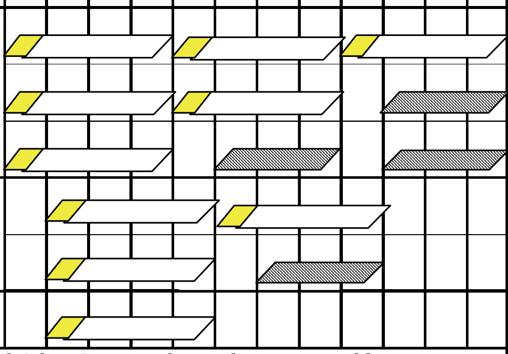
REGENCY	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
JEMBRANA	437	4.20	3.58	2.53	1.28	0.63	0.07	0.14	0.14	0.42	0.78	3.03	3.32
TABANAN	440h	5.58	5.70	4.56	1.45	0.25	0.28	0.70	0.05	0.16	0.99	2.38	3.61
BADUNG	440a	5.24	4.78	3.43	1.56	0.75	0.44	0.59	0.29	0.26	0.43	2.46	3.91
DENPASAR	445	7.34	6.05	1.29	0.79	0.07	0.00	0.25	0.00	0.00	0.09	0.72	1.81
GIANYAR	440c	7.50	6.38	3.92	1.33	0.86	0.84	1.20	0.27	0.61	1.11	3.90	4.00
BANGLI	441d	7.29	5.20	5.49	1.63	1.29	0.26	0.75	0.29	0.61	1.47	3.92	4.13
KLUNGKUNG	444f	5.01	4.05	3.09	0.96	0.81	0.30	0.45	0.34	0.05	0.52	2.78	3.03
KARANGASEM	442d	6.03	5.40	3.27	1.42	0.50	0.28	0.72	0.38	0.40	0.43	1.68	3.25
BULELENG	438e	4.81	5.55	2.91	1.00	0.05	0.00	0.00	0.00	0.00	0.00	0.37	2.42

(3) Cropping Pattern and Calendar

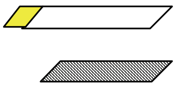
Cropping pattern and cropping calendar in regency were identified based on “Statistics of Food Crops Agriculture in 2003 (Food Crops Agriculture Service of Bali Province)” and “Report on Cropping Pattern in Paddy Fields in 2003 from 8 regencies and Denpasar”. Since paddy culture dominates irrigation in Bali in terms of area and amount of water consumed, 13 cropping pattern surveyed by regency were integrated into 6 cropping patterns associated with paddy and 1 pattern for other crop cultures/fallow as show in Table-II-2.15.

Table-II-2.15 is assumed as typical and present cropping pattern and calendar in Bali and was used for projection of irrigation water demand.

Table-II-2.15 Cropping Pattern and Calendar



Cropping Pttern	Cropping Calendar 1	2	3	4	5	6	7	8	9	10	11	12	Planting Area (%) Jem	Tab	Bad	Gia	Klu	Ban	Kar	Bul	Den
3 Crops													1.7	27.7	46.5	30.4	8.4	39.6	4.3	29.0	8.6
													11.2	7.3	38.9	7.4	43.2	36.7	33.3	38.6	27.4
													8.8	0.9	0.4	2.1	33.0	7.1	46.2	9.4	17.8
2 Crops													17.3	54.5	9.8	47.1	2.2	12.6	4.3	8.9	15.3
													35.7	2.6	0.9	2.4	6.8	4.0	5.6	13.6	16.5
1 Crop													20.2	5.0	2.0	6.8	6.4	-	3.2	0.2	4.2
Fallow and Other Crops, such as palawija, vegetables; sometime 2 cropping/year													5.1	2.0	1.5	3.8	-	-	3.1	0.3	10.2
									Total (%)				95	98	99	96	100	100	97	100	90
									Starting Month				Nov	Nov*	Nov	Nov	Nov	Nov	Dec	Dec	Nov



: paddy (30 days for land preparation & 80 days from transplanting to harvesting)

: palawija/vegetable (90 days)

Note: *: 2 crops and 1 crop also start in November.
Jem: Jembrana, Tab: Tabanan, Bad: Badung, Gia: Gianyar, Klu: Klungkung, Ban: Bangli, Kar: Karangasem,
Bul: Buleleng, Den: Denpasar
Source: "Statistics of Food Crops Agriculture in 2003 (Food Crops Agriculture Service of Bali Province)" for Calendar
"Report on Cropping Pattern in Paddy Fields in 2003 from 8 regencies and Denpasar" for Pattern

(4) Other Parameters for Paddy Irrigation

Other parameters required for the estimate of irrigation water demand were set, considering local factors obtained from review of previous studies in Bali, information from agencies concerned and so on. Parameters are summarized below.

Irrigation Efficiency

Irrigation efficiency is to take account for losses of water during conveyance, distribution of field canal and field application. In general, irrigation efficiency for paddy with a good system (facilities and management) varies from 40 – 60 % and that of primitive system is less than 40 %. Since 86 % of the potential irrigation area are equipped with either technical or semi-technical irrigation system as a result of rehabilitation works and 14 % of the potential irrigation area is still considered as primitive system, the overall irrigation efficiencies adopted in this Study is 0.5.

Percolation/Seepage Loss

Since the wetland paddy requires maintaining some water depth in the paddy field, there are always percolation losses into soil profiles. Percolation losses vary depending on soil properties, groundwater table, farming method and so on. For the planning and design, percolation losses normally adopted ranges from 1 mm/day for the clayey soil to 5 mm/day for the sandy soil. Considering the present conditions, percolation losses are assumed as 2 mm/day.

Land Preparation and Water Layer Replacement

Before transplanting paddy seedlings, the large amount of water is required for land preparation, while a water layer is replaced normally twice per one crop season. Based on information from agencies concerned, particularly Food Crops Agriculture Service of Bali Province, an amount of water required for land preparation and water layer replacement is assumed as follows.

- Land preparation requires 200 mm of water and takes 30 days.
- Water layer replacement is conducted one month and two month later after transplanting. Each time, an amount of water necessary is 50 mm and it takes 15 days.

(5) Conditions and Assumptions

The following conditions and assumptions were made to estimate the irrigation water demand.

Target Crops for Irrigation

As discussed in the previous sections, the paddy culture currently dominates irrigation in Bali. Since almost all irrigable land has been already cultivated for wetland paddy, the further irrigation development targets rehabilitation works to improve the irrigation efficiency in the paddy field, and new irrigation schemes for fruit culture/horticulture with a very limited scale in terms of area and volume of water. The dominance of paddy culture in Bali irrigation will not vary by the year of 2025. Therefore, the Study, considers only paddy culture for the present and future irrigation water demand.

Unit of Demand Projection

A project design is a series of studies at different level from wide rage to specific goals/sites. Since the Study is at a master plan level to examine conditions, issues and countermeasures for the whole Bali Province, an effective and efficient way of the study is to deal with subjects by approximation and average over some certain area.

The complexity of irrigation system in Bali has led lots of unknown factors, such as area and location of irrigation schemes, water conveyance and distribution system, volume of return flow and so on. Therefore, factors associated with irrigation were identified and examined by regency and irrigation water demand projection was also conducted by regency as the minimum unit.

Projection of Future Paddy Area

One of the important policies stipulated in the spatial plan and RENSTRA is to protect the paddy field from change in function. Through the discussion with government agencies concerned, particularly Public Works Service of Bali Province and Food Crops Agriculture Service of Bali Province, and analysis of factors affecting decline tendency of paddy area, the following rates of decrease are considered reasonable and adopted in this Study.

Period	Provincial Average of Decreasing Rates
2003 – 2005:	transition period from 1.01 % to 0.45 % (RENSTRA target)
2005 – 2015:	decreasing rate of 0.45 %
2015 – 2025:	decreasing rate of 0.23 % (half of RENSTRA target)

New Irrigation Development

Almost all arable land for paddy is already cultivated intensively in Bali. Based on the present conditions and the agriculture development plans (the spatial plan and RENSTRA), it is assumed that there is no significant extension of new irrigation project due to the following reasons. Thus, the present situation that dominant crop of Bali irrigation is wetland paddy will not change.

- ◆ Considering the availability of water, surface water development for irrigation requires a storage facility, such as dams. If the storage facility targets only irrigation, it will not be feasible in terms of cost vs. benefit. Therefore, if the surface water development is applied to intensification of irrigation schemes, it will have multiple functions.
- ◆ There are some new irrigation schemes for fruit culture and horticulture by groundwater development but its scale is very small. These schemes will be promoted but their scale will be negligibly small in terms of area and water consumption.

Cropping Pattern and Calendar

With the following reasons, the present cropping pattern and calendar in the paddy fields are assumed not to alter significantly and can be applied to the future projection of irrigation water demand.

- ◆ Paddy/palawija culture will be maintained in accordance with the provincial policy of self sufficiency of food crops. Therefore, the market oriented crop diversification will mainly happen in the dry land.
- ◆ Since the double cropping of paddy followed by palawija/fallow is ideal considering maintaining soil fertility and disease control, the triple cropping of paddy will not extend from the present area.

2.3.3 Irrigation Water Demand

(1) Irrigation Demand per Unit Area

Table-II-2.16 summarizes the irrigation water requirement (intake volume) per unit area estimated and those figures are assumed to reflect the present consumption of irrigation water. High crop intensities of paddy and low effective rainfall during the dry season induce high irrigation water demand in May and September.

Table-II-2.16 Irrigation Water Requirement per Unit Area

(Unit: liter/sec/ha)

REGENCY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
JEMBRANA	0.660	0.722	0.557	0.405	0.511	0.456	0.226	0.031	0.031	0.018	0.174	0.734
TABANAN	0.345	0.146	0.426	1.278	1.552	0.976	0.373	0.490	0.484	0.257	0.917	0.753
BADUNG	0.647	0.421	0.678	1.405	1.632	1.125	0.743	0.855	0.920	0.608	0.802	0.915
GIANYAR	0.000	0.175	0.411	1.082	1.295	1.002	0.775	0.500	0.484	0.262	0.240	0.585
KLUNGKUNG	0.370	0.430	0.473	0.780	0.829	0.552	0.140	0.137	0.145	0.084	0.729	0.863
BANGLI	0.000	0.278	0.305	1.136	1.270	0.969	0.648	0.649	0.630	0.308	0.498	0.607
KARANGASEM	0.204	0.386	0.528	0.565	0.707	0.734	0.466	0.112	0.077	0.077	0.033	0.631
BULELENG	0.565	0.445	0.655	1.078	1.293	1.283	0.933	0.546	0.556	0.563	0.329	0.728
DENPASAR	0.144	0.304	0.801	0.811	0.956	0.720	0.303	0.164	0.176	0.119	0.721	1.178

(2) Present and Future Irrigation Water Demand

Present and future irrigation water demand is a multiplication of the irrigation water requirement per unit area by the area of paddy field. Since climate factors, farming factors and water management factors are assumed not to vary, the irrigation water requirement per unit area estimated for the year of 2003 is applicable to the future irrigation water demand. Thus, the change in paddy area is only a factor affecting the future irrigation water demand.

Table-II-2.17 summarizes the irrigation water demand by regency. A decline in irrigation water is due to the area decrease of paddy field. The provincial irrigation water demand will decrease from 1,625 million m^3 in 2003 to 1,485 million m^3 in 2025. Since the decreasing rates of regency vary depending on local conditions, such as decreasing rates in paddy area, crop intensities of paddy, and so on, the residual water of regency (difference between water demands in 2003 and in 2025) ranges from 0 to 46 million m^3.

Table-II-2.17 Irrigation Water Demand by Regency

(Unit: million $m^{3)}$

REGENCY	Year						Difference
	2003	2005	2010	2015	2020	2025	2025-2003
JEMBRANA	82.97	78.99	74.23	70.60	68.47	66.37	16.60
TABANAN	476.69	468.59	458.58	450.46	445.55	440.83	35.86
BADUNG	292.61	281.68	268.70	258.29	252.36	246.41	46.20
GIANYAR	268.07	265.80	263.02	260.72	259.38	258.03	10.04
KLUNGKUNG	57.03	56.51	55.81	55.22	54.94	54.59	2.44
BANGLI	55.43	55.43	55.43	55.43	55.43	55.43	0.00
KARANGASEM	83.50	82.42	81.23	80.13	79.51	78.82	4.68
BULELENG	260.23	257.03	253.12	249.95	248.04	246.18	14.05
DENPASAR	48.10	45.79	43.03	40.93	39.65	38.39	9.71
TOTAL	1,624.63	1,592.24	1,553.15	1,521.73	1,503.33	1,485.05	139.58

Source: Estimate of JICA Study Team

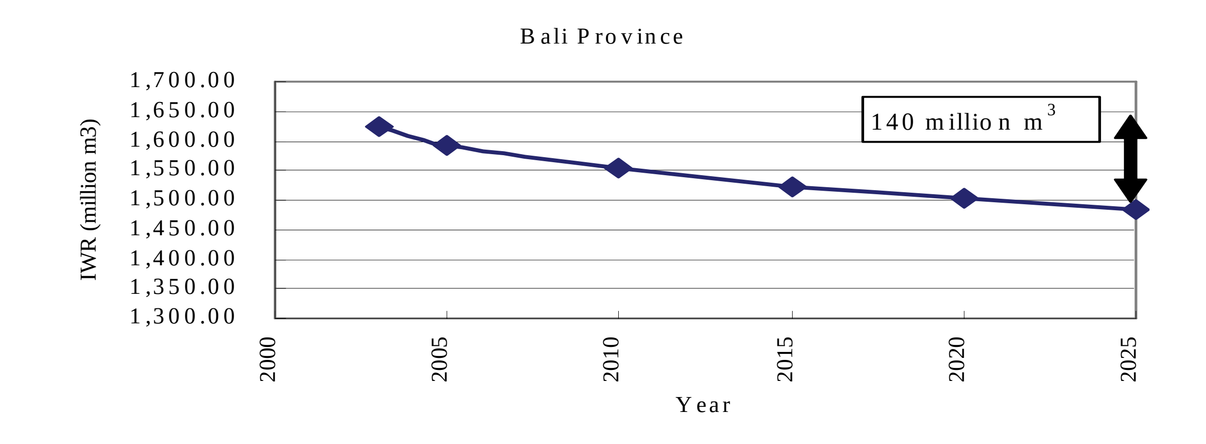


Figure-II-2.3 Decrease in Irrigation Water Demand

2.4 Water Potential

2.4.1 River Water

It is essential to estimate the naturalized flow at the selected key stream flow gauging stations (SGSs) in order to work out the surface water potential for the whole Bali Province. On the other hand, the long-term runoff data at the 14 candidate SGSs, which are estimated in the Phase II stage, are the ones observed at each of the candidate SGSs and do not include the irrigation water consumed in an upstream area of each SGS, although the irrigation areas are unexceptionally located upstream of each of the candidate SGSs.

To estimate the naturalized streamflow at each of the candidate SGSs, the total river abstraction water consumed in upstream irrigation areas of SGS needs to be added to the runoff observed thereat.

(1) Irrigated Area Upstream of Candidate Stream Gauging Stations (SGSs)

To estimate the river abstraction water lost in the upstream irrigation areas with accuracy, the detailed irrigation data such as intake water, dimensions and alignment of exiting irrigation canals, cropping patters, cropping intensities, etc. are required. In order to estimate the water volumes lost in the upstream irrigation areas of each candidate SGS, in the Phase II stage, the existing irrigation areas located upstream of the 14 candidate SGSs were investigated through site reconnaissance including data/information collection from the regional PU office.

Based on the site reconnaissance and data/information from the PU regional office, the data on existing irrigation area located upstream of each of the candidate SGSs are summarized in Table-II-2.18.

Table-II-2.18 Total Irrigation Area Located Upstream of Candidate SGSs

ID	Name of Candidate SGSs	Regency	Catchment Area(km2)	Irrigated Area (ha)
07-021-00-003	TK,Ayung Buangga	Badung	217.00	768
07-024-00-02	TK.Sungi	Tabanan	35.00	421
07-028-00-01	TK.Balian	Tabanan	152.20	1,027
07-027-00-01	TK.Yeh Otan	Jembrana	38.42	2,639
07-031-00-03	TK.Yeh Satang	Jembraba	25.19	252
07-033-00-01	TK.Biluk Poh	Jembrana	67.47	651
07-034-00-01	TK.Jogading	Jembrana	38.26	798
07-034-00-03	TK.Daya Timur	Jembrana	29.09	972
07-007-00-02	TK.Sabah	Buleleng	52.54	1,167
07-007-00-05	TK.Mendaum	Buleleng	11.53	1,183
07-008-00-03	TK.Buleleng	Buleleng	12.69	423
07-009-00-01	TK.Daya Sawan	Buleleng	77.39	823
07-014-00-01	TK.Nyuling	Karangasem	30.12	121
07-020-00-01	TK.Petanu	Gianyar	55.33	3,184

(2) Estimate of Irrigation Water Lost in the Upstream Irrigation Areas of SGSs

To estimate the naturalized flow in each of the candidate SGSs, the irrigation water lost in the upstream irrigation areas thereof is preliminarily estimated based on the available data. Some amount of the river water diverted at the upstream intake weir site for irrigation is lost due to evapotranspiration/percolation in fields and leakage from canals until it returns the rivers and some amount might be transferred to the other river basin.

In Bali Island, however, available data on irrigation water loss ratios are very limited. The return flow ratios were estimated only for the Ayung River Basin in the course of feasibility study on Ayung hydropower development project (1989, JICA). The previous JICA study estimated the return flow for each irrigation area of the Ayung River Basin by dividing the basin into two (2) zones, namely the upstream and downstream areas of Ayung River Buanga SGS.

Based on the data used for the previous JICA study, the ratio of irrigation water loss to net irrigation water requirement in the upstream irrigation area is estimated to be 88% on the average. In this Study, a ratio of 80% is adopted as the ratio of irrigation water loss to the net irrigation water requirement, taking into account the conservative side estimate of the naturalized flow as well as the uncertainty associated with the estimate of the irrigation water loss ratio. The ratio of 80% to net irrigation water requirement is equivalent to the ratio of 40% to irrigation water requirement on the condition of irrigation efficiency of 50% assumed in this Study.

The total irrigation water requirement is calculated by multiplying the irrigation water requirement per unit area by the upstream irrigation area. The monthly water loss for each of the candidate SGSs is calculated multiplying 40 % to total irrigation water requirement.

(3) Estimate of Naturalized Flow at Candidate SGSs

The long-term naturalized flow is estimated by adding the water lost in irrigation areas located upstream of the SGS to the observed discharges at SGS as represented by the following equation:

$$Q_n = Q_o + Q_{I-loss} \tag{2.1}$$

Where, Q_n : Naturalized mean daily discharge at SGS (m^3/sec)
Q_o : Observed mean daily discharges at SGS (m^3/sec)
$Q_{I\text{-}loss}$: Water lost in irrigation areas located upstream of SGS (m^3/sec)

(4) Selection of the SGSs to be used in the Study

The streamflow conditions at each of the 14 candidate SGSs are assessed based on the estimated naturalized flow and information obtained through site reconnaissance and from the concerned staff of the PU Bali Office. Based on the following examination, the SGSs for estimating other basin runoff and for estimating the runoff in their own catchment are selected, and the estimated naturalized discharges at those SGSs are summarized in Table-II-2.17.

Table-II-2.19 Estimated Mean Monthly Discharge (Naturalized Flow)

Stream Gauging Station (SGS)	Catchment Area (km^2)	Mean Monthly Discharge(m3/sec) averaged between 1994 and 2003												Annual Mean Discharge (m^3/sec)	Annual Mean Runoff Depth (mm)
		Jan	Feb	Mar	Apr	Mey	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
R. Ayung Buangga	217.00	10.22	10.67	11.15	10.63	9.69	9.13	8.57	8.57	8.44	8.61	9.04	9.01	9.48	1,377
R. Sungi	35.00	0.97	1.17	1.24	1.13	0.98	0.75	0.53	0.44	0.43	0.55	0.88	0.83	0.82	743
R. Balian	152.20	15.49	17.12	16.64	14.90	10.83	8.41	7.51	6.32	6.23	9.39	14.57	12.19	11.63	2,410
R. Yeh Otan	38.42	1.47	1.90	1.75	1.90	1.08	0.88	0.73	0.44	0.65	1.13	2.00	1.62	1.30	1,064
R. Yeh Satang	25.19	1.00	1.18	1.39	1.07	0.53	0.55	0.48	0.35	0.48	0.79	1.33	1.13	0.86	1,071
R. Biluk Poh	67.47	5.68	5.74	6.83	3.41	0.99	0.72	0.38	0.38	0.53	0.70	0.89	3.98	2.52	1,178
R. Jogading	38.26	2.11	1.96	2.57	2.37	0.81	0.93	0.74	0.41	0.47	1.33	2.84	2.01	1.55	1,274
R. Daya Timur	29.09	3.03	2.73	2.69	2.60	1.37	0.86	0.55	0.29	0.31	1.16	1.41	1.57	1.55	1,678
R. Sabah	52.54	3.39	4.09	3.41	3.58	2.72	2.10	2.02	1.80	1.62	1.96	2.15	2.51	2.61	1,568
R. Mendaum	11.53	0.99	1.01	0.86	0.89	0.61	0.50	0.46	0.33	0.34	0.37	0.42	0.50	0.61	1,657
R. Buleleng	12.69	0.70	1.12	1.34	1.20	0.82	0.63	0.51	0.46	0.42	0.42	0.53	0.69	0.74	1,830
R. Daya Sawan	77.39	3.52	5.36	4.86	3.31	2.08	1.72	1.46	1.26	1.13	1.20	1.53	1.96	2.45	998
R. Nyuling	30.12	0.81	0.88	0.61	0.53	0.39	0.35	0.34	0.34	0.36	0.39	0.37	0.41	0.48	506
R. Petanu	55.33	3.03	3.54	3.38	3.37	2.83	2.47	2.21	2.02	1.91	2.13	2.43	2.31	2.63	1,501

(5) Estimate of Runoff in Bali

For the ungauged basins which are not covered by the SGSs mentioned inTable-II-2.20, the runoff data at the fourteen (14) key SGSs are transposed to runoff of the ungauged basins in proportion to their catchment area and basin average rainfall as expressed below:

$$Q = \left(A / A_0\right) \cdot \left(R / R_0\right) \cdot Q_0 \qquad (2.2)$$

Where, Q : Mean runoff of ungauged basin (m^3/sec)
Q_0 : Mean runoff at key SGS (m^3/sec)
A : Catchment area of ungauged basin (km^2)
A_0 : Catchment area at a key SGS (km^2)
R : Basin average rainfall for ungauged basin (mm/year)
R_0 : Basin average rainfall for a basin of key SGS (mm/year)

Prior to the transposition of the runoff data at the key SGSs to the ungauged basins, the area to be covered by each key SGS is examined from the geological and hydrological aspects. Then, the runoff data at each key SGSs are transposed to each of the ungauged basins. For each of major ungauged basins, the long-term mean runoff for the period from 1992 to 2003 is estimated by applying the aforesaid procedures.

Based on the annual average runoff in each of the major river basins, the surface water potentials of the rivers are estimated by Sub-basin, and are listed in Appendix and summarized in Table-II-2.20. As shown in Table-II-2.20 the total surface water potential in the Study Area is derived to be 6,195mil.m^3/year(196.5m^3/sec) or 1,104mm/year. The runoff ratio against average rainfall for the whole Bali Province is derived to be about 55 %.

Table-II-2.20 Estimated Total Surface Water Potentials in Bali Island

No.	Sub-Basin Code No.	Catchment Area (km2)	Basin Average Rainfall (mm/year)	Annual Runoff of All the River Basins		
				Total		Runoff Depth(mm)
				(mil. m^3)	(m^3/sec)	
1	03.01.01	555.64	2,078	718.5	22.78	1,293
2	03.01.02	601.75	2,450	917.4	29.09	1,525
3	03.01.03	288.34	2,582	501.7	15.91	1,740
4	03.01.04	392.37	2,360	406.5	12.89	1,036
5	03.01.05	158.92	2,112	198.7	6.30	1,250
6	03.01.06	228.44	1,978	278.2	8.82	1,218
7	03.01.07	243.52	1,583	237.2	7.52	974
8	03.01.08	367.22	1,365	328.8	10.43	895
9	03.01.09	222.39	2,096	305.8	9.70	1,375
10	03.01.10	114.24	1,704	169.5	5.38	1,484
11	03.01.11	243.48	2,005	383.1	12.15	1,574
12	03.01.12	311.65	1,792	255.7	8.11	820
13	03.01.13	357.14	1,798	164.6	5.22	461
14	03.01.14	295.38	1,911	144.7	4.59	490
15	03.01.15	272.53	1,629	276.2	8.76	1,013
16	03.01.16	342.08	2,237	476.0	15.09	1,392
17	03.01.17	257.78	2,337	374.9	11.89	1,454
18	03.01.18	48.84	2,700	0.0	0.00	0
19	03.01.19	102.19	1,809	0.0	0.00	0
20	03.01.20	208.87	1,079	57.8	1.83	277
Total/Average		5,612.77	2,003	6,195.2	196.4	1,104

2.4.2 Lake Water

There exist four (4) closed lakes in Bali Island. These are Tamblingan Lake, Buyan Lake, Beratan Lake and Batur Lake in the western to eastern direction. These four (4) caldera lakes have no outlet to the rivers except having the spillway at Beratan Lake. It is said that water of these caldera lakes infiltrates and pours out into the neighboring river basins as springs. It is sure that springs with abundant water pour out into the Telagawaja River. Besides, it is said that abundant streamflow of the Ayung River and Penarukan River are partially yielded by groundwater from some of the four (4) closed caldera lakes. The main features of the four closed lakes are shown in Table-II-2.21.

Table-II-2.21 Main Features of the Four (4) Closed Lakes

Name of Closed Lake (Caldera Lake)	Catchment Area (km^2)	Lake Area (km^2)	Elevation of Lake Surface * (EL.m)
Batur Lake	102.2	16.6	1,221
Beratan Lake	13.2	3.8	1,238
Buyan Lake	24.3	4.8	1,250
Tamblingan Lake	11.3	1.4	1,221
Total	151.0	26.6	-

Note: *; The lake surface levels are read on 1 to 25,000 scale topographic maps.

According to the water level records observed at the water level gauging stations on lakes, the actual lake surface water levels varied in the past as shown in Table-II.2.2. Although the Buyan Lake shows large yearly variations, it appears that the surface levels of these lakes usually vary in a small range of 1 to 2 m.

Table-II-2.22 Yearly Maximum Variation of Lake Surface Water Level

Year	Batur Lake (m)			Beratan lake (m)			Buyan Lake (m)			Tamblingan Lake (m)		
	Max.	Min.	Diff.	Max.	Min.	Diff.	Max.	Min.	Diff.	Max.	Min.	Diff.
1996	3.32	1.50	1.82	2.70	0.81	1.89	5.97	2.24	3.73	5.26	3.95	1.31
1997	3.32	1.50	1.82	-	-	-	7.00	4.40	2.60	6.00	4.03	1.97
1998	-	-	-	2.40	0.73	1.67	5.61	4.61	1.00	4.39	3.93	0.46
1999	3.00	2.19	0.81	2.17	1.02	1.15	6.08	3.87	2.21	-	-	-
2000	4.01	2.68	1.33	2.21	1.11	1.10	6.70	4.84	1.86	5.19	2.68	2.51
2001	3.97	3.06	0.91	2.02	1.06	0.96	8.51	2.73	5.78	6.70	5.66	1.04
2002	3.49	1.84	1.65	-	-	-	6.69	4.22	2.47	6.00	4.00	2.00
2003	3.61	2.32	1.29	1.14	0.15	0.99	-	-	-	5.78	4.06	1.72
Mean	3.53	2.16	1.38	2.11	0.81	1.29	6.65	3.84	2.81	5.62	4.04	1.57

The groundwater infiltrated from each of the four (4) closed lakes into the neighboring basins was preliminarily calculated by the following equation:

$$Q_{out} = (CA \cdot R - A_l \cdot E_0 - R_{loss} - A_0 \cdot E_v) / 1000 \qquad (2.3)$$

Where, Q_{out} : Groundwater infiltrated into neighboring basins (mm/year)
CA : Catchment area of caldera lake (km^2)
R : Rainfall
A_l : Lake area (km^2)
E_0 : Evaporation from caldera lake (mm/year)
R_{loss} : Rainfall loss in the land area (mm/year)
A_0 : Land area in a catchment of lake (km^2) (= $CA - A_1$)
E_v : Evapotranspiration in land area (mm/year)

Since surface levels of the four (4) closed lakes are situated at higher elevation of 1,220 to 1,250 m, the evaporation depths from the lake surface are estimated to be less as compared with those at the lower altitudes. Besides, it is generally accepted that the actual evaporation from the lake surface is 70% of the measured Pan-A evaporation depth. The evaporation rate from each of the four (4) lakes is simply assumed to be 3 mm/day, since any data at such higher altitudes are not available. Thus, the evaporation rate of 3 mm/day and assumed rainfall loss of 700 mm in the land area are adopted with reference to the values estimated for basins of high altitudes in Indonesia in the past. With these values, the annual infiltration amounts in the four (4) closed lakes are calculated as shown in Table-II-2.23. It is preliminarily estimated that the lake water of **6.7 m^3/sec or 211.0 mm/year** contributes to the augmentation of base flow in the neighboring basins.

Table-II-2.23 Preliminarily Estimate of Infiltration from Caldera Lake

No.	Lake Name	Average Rainfall (mm/year)	Rainfall Volume (10^6 m^3/year)	Rainfall Loss (10^6 m^3/year)	Infiltration Amount	
					(mm/year)	(m^3/sec)
1.	Danau Batur	1,809	184.9	78.1	106.8	3.4
2.	Danau Beratan	2,741	36.2	10.7	25.4	0.8
3.	Danau Buyan	2,994	72.8	18.9	53.8	1.7
4.	Danau Tamblingan	2,958	33.4	8.5	25.0	0.8
Total		-	327.2	116.2	**211.0**	**6.7**

2.4.3 Groundwater Potential

(1) Groundwater Flow and Recharge

Groundwater flow (Q) through an aquifer is calculated by the following equation:

$$Q = kHWI \qquad (2.4)$$

where *k*: hydraulic conductivity
H: saturated thickness of the aquifer
Transmissivity (*T*) may be substituted for *kH*, if it (*T*) is available as a result of pumping tests.
W: the width of the aquifer through which groundwater flow occurs
I: the hydraulic gradient

The estimated flow can be considered to approximately be a recharge to the aquifer. This approach was used by the previous studies that constructed boreholes and conducted the pumping tests, which were Bali Groundwater (1977), Southern Bali Groundwater Investigation (1985), and North Bali Groundwater Irrigation and Water Supply Project (1995). Bali Groundwater (1977) has calculated the groundwater flow of the 7 zones out of the 8 zones selected for the study. The 7 zones (Zone II – VIII) are shown in Figure-II-2.4 Southern Bali Groundwater Investigation (1985) has calculated the flow of the southern zones from the eastern part of Tabanan to the western part of Karangasem shown in the S.B Zone 1-35. North Bali Groundwater Irrigation Project (1995) constructed more than 30 production wells in the area of zone VI in Bali Groundwater (1977). Based on the results of the pumping tests conducted by the project, they calculated the flow of each divided narrow zone in the Zone VI.

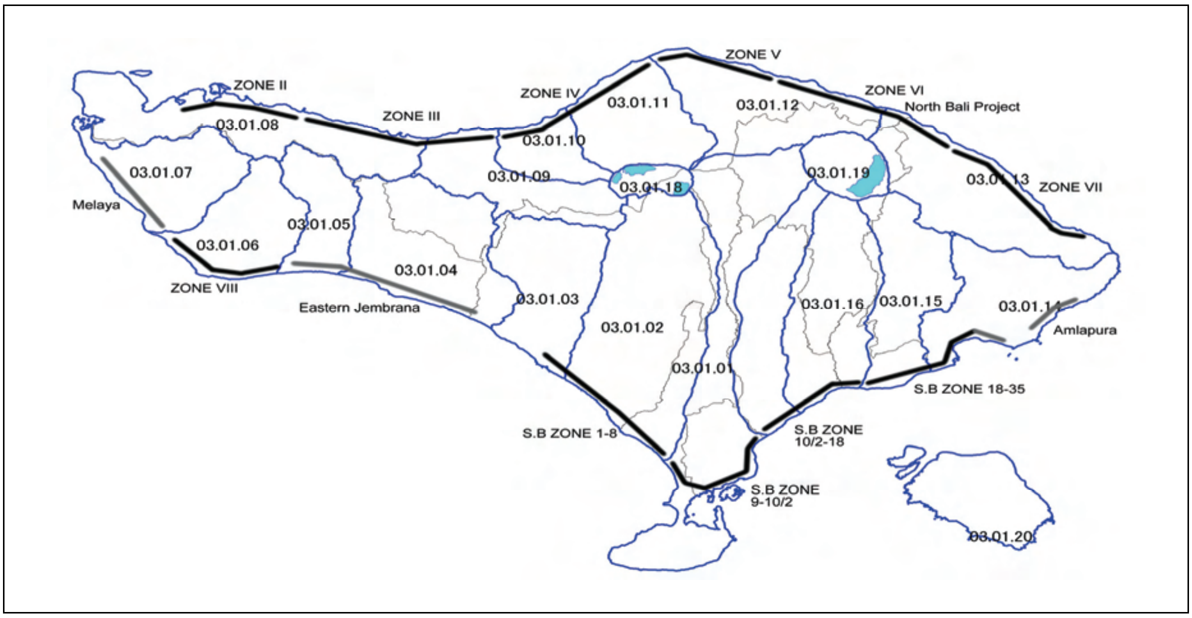


Figure-II-2.4 Zones for Groundwater Flow Estimation

As shown in Figure-II-2.4, the zones of which the groundwater flow estimated covers almost entire Bali except some local areas, which are the plains of Melaya(03.01.07 in figure), the coastal plains of the eastern part of Jembrana(03.01.04), and the area around Amlapura(03.01.14).

Groundwater flow is roughly calculated for these areas based on assumed values of transmissivity estimated by the values of specific capacity. After reviewed the previous results, all of the estimated results were summarized in Table-II-2.23.

Another approach to estimate groundwater recharge is a water budget study or water balance analysis based on meteorological-hydrological data. To compare the groundwater flow with the total volume of precipitation in the main river basins contributing for the evaluated zones, the percentage of flow was calculated. The result is also shown in Table-II-2.24.

Table-II-2.24 Calculated Groundwater Recharge

		Bali Groundwater (1977)							
Zone		Zone II	Zone III	Zone IV	Zone V	Zone VI		Zone VII	Zone VIII
Area Name		West Gerokgak	East G. to Sheririt	Shingaraja	Kubutanbahan	East Bulelen to Tianyar	North Bali Project (1995)	Tianyar to Amed	Negara
W	m	18000	24000	27000	5000	28000	29000	20000	22000
H	m		50	50					50
k	m/day		18	18					14
T	m2/day	200	900	900	450	880	(665)	880	700
I		0.018	0.007	0.007	0.01	0.006		0.006	0.005
Grounwater flow	m3/day	**64,800**	**151,200**	**170,100**	**22,500**	**147,840**	**81,816**	**105,600**	**77,000**
	m3/year	**23,652,000**	**55,188,000**	**62,086,500**	**8,212,500**	**53,961,600**	**29,862,749**	**38,544,000**	**28,105,000**
	MCM/y	**179.0**						**66.1**	**Jembrana**
Kabupaten		**Bleleng**						**Karangasem**	
Flow/Rainfall	%	14.2%	8.7%	9.1%	3.0%	11.0%	6.1%	9.0%	3.7%
Rainfall	m3/year	166,530,000	632,659,440	682,842,360	277,760,000	491,722,000		427,924,000	765,232,960
	mm	1365	1365 2096	1704 2005	1792	1792 1798		1798	2237
Area	km2	122	122 222.39	114.24 243.48	155	155 119		238	342.08
Sub-basin Name		a part of 03.01.08	part of 03.01.08 03.01.09	03.01.10 03.01.11	a part of 03.01.12	a part of 03.01.02 a part of 03.01.03		a part of 03.01.13	03.01.06
		Southern Bali Groundwater Investigation (1985)				JICA estimation			
Zone		Zone 1-8	Zone 9-10/2	Zone 10/2-18	Zone 19-35				
Area Name		Eastern Tabanan - Badung West	Denpasar	Giyanar-Klungkun west	Klungkun East-Manggis	Melaya	Eastern Jembrana (Mendoy, Pekutatan)	Amlapura	
W	m	30750	9500	37400	16800	12000	23000	6000	
H	m								
k	m/day								
T	m2/day	181	3000	300	51	2000	500	200	
I		0.0132	0.0092	0.0383	0.0461	0.005	0.01	0.03	**Total**
Grounwater flow	m3/day	**73,468**	**262,200**	**429,726**	**39,498**	**120,000**	**115,000**	**36,000**	**1,748,908**
	m3/year	**26,815,784**	**95,703,000**	**156,849,990**	**14,416,945**	**43,800,000**	**41,975,000**	**13,140,000**	**638,351,468**
	MCM/y	**26.8**	**95.7**	**156.8**		**113.9**			**638.4**
Kabupaten		**Tabanan**	**Badung/ Denpasar**	**Gianyar/Bangli/Klungkun,**	**Karangasem**	**Jembrana**		**Karangasem**	
		(Reviced calcluration by JICA)							
Flow/Rainfall	%	1.2%	8.3%	11.5%	2.4%	11.4%	3.3%	4.2%	**6.2%**
Rainfall	m3/year	2,218,781,380	1,154,619,920	1,367,664,820	612,119,370	385,492,160	1,261,632,240	310,862,370	**10,264,121,020**
	mm	2450 2582	2078	2237 2337	1911 1629	1583	2360 - 2112	1911	
Area	km2	601.75 288.34	555.64	342.08 257.78	88 272.53	243.52	392.37 158.92	162.67	
Sub-basin Name		03.01.02 03.01.03	03.01.01	03.01.16 03.01.17	part of 03.01.14 03.01.15	03.01.07	03.01.04 03.01.05	a part of 03.01.14	

Groundwater potential analysis derives the results of 6.2 % of annual rainfall in whole Bali or 639 Mm^3 per year. In addition to the above, IUIDP-Bali Project (1989) adopted a different type of technique for the groundwater estimation. A "recharge coefficient" was determined for each geological formation using the base flows of 11 rivers. The volume of recharge to each regency was calculated with the recharge coefficient of the formation covered the regencies and the rainfall to the area. The IUIDP Project recommended that 10% of the calculated recharge must be the exploitable limit, because some of the infiltrated water flow into streams and discharge as springs and then the rest is pumped from wells. Table-II-2.25 shows the revised result of IUIDP method with the latest data by JICA Study Team**.**

Table-II-2.25 Groundwater Recharge estimated by IUIDP approach

Kabupaten	Area (km^2)	Rainfall (mm)	Recharge Coefficient	Recharge		Groundwater Exploitation Limit (10% of recharge)	
				(mm)	(mil./year)	(lit./s)	(mil./year)
Jembrana	858.26	1,970	0.21	413.7	355.1	1126	35.5
Tabanan	855.4	2,549	0.36	917.6	784.9	2489	78.5
Badung	398.29	2,078	0.41	852.0	339.3	1076	33.9
Denpasar	125.36	1,790	0.41	733.9	92.0	292	9.2
Gianyar	367.96	2,323	0.46	1,068.6	393.2	1247	39.3
Klungkung	106.77	1,763	0.3	528.9	56.5	179	5.6
Bangli	531.3	2,092	0.44	920.5	489.1	1551	48.9
Karangasem	846.32	1,810	0.43	778.3	658.7	2089	65.9
Buleleng	1333.59	1,834	0.27	495.2	660.4	2094	66.0
Nusa Penida	209.61	1,079	0.4	431.6	90.5	287	9.0
Total/Average	5632.86	2,003	-	-	3,919.6	12,429	**392.0**

Source: Revised by JICA

(2) Groundwater Use

<Deep Wells>

Groundwater resources have been exploited by deep wells for the purposes of irrigation, drinking water supply and other commercial use such as industries and hotels. The present condition of the groundwater use was summarized in Table-II-2.26.

Table-II-2.26 Present Groundwater Use

Regency/City	Pumping Rate from Tube Wells						Total
	Irrigation		PDAM		Others		
	(lit./sec)	(mil./year)	(lit./sec)	(mil./year)	(m^3/day)	(mil./year)	(mil./year)
Jembrana	357	11.3	139	4.4	7338	2.7	18.3
Tabanan	10	0.3	5	0.2	7257	2.7	3.1
Badung (*	31	1.0	236	7.4	24107	8.8	17.2
Denpasar	0	0.0	350	11.0	25647	9.4	20.4
Gianyar	0	0.0	359.5	11.3	7120	2.6	13.9
Klungkung	0	0.0	5	0.2	2469	0.9	1.1
Bangli	0	0.0	0	0.0	764	0.3	0.3
Karangasem	113	3.6	69	2.2	2112	0.8	6.5
Buleleng	305	9.6	81.5	2.6	2035	0.7	12.9
Nusa Penida	0	0.0	5	0.2	-	-	0.2
Total	816	25.7	1,250	39.4	78,849	28.8	**93.9**

Note: *: Badung includes PT.TB.

<Dug Wells>

There are numerous dug wells used for domestic purpose. The amount was calculated based on per capita consumption of 60 - 80 liter/day and the ratio of people using dug wells. These values were shown in Table-II-2.27.

Table-II-2.27 Extracted Amount of Dug Wells

Regency/City	Estimated Groundwater Use from Dug Wells		Regency/City	Estimated Groundwater Use from Dug Wells	
	(m^3/day)	(mil./year)		(m^3/day)	(mil./year)
Jembrana	6,047	2.2	Klungkung	131	0.1
Tabanan	3,142	1.1	Bangli	424	0.2
Badung	12,335	4.5	Karangasem	882	0.3
Denpasar	6,082	2.2	Buleleng	11,181	4.1
Gianyar	1,520	0.6	Nusa Penida	201	0.1
			Total	**42,003**	**15.3**

<Springs>

Springs also have been widely used for irrigation, drinking water supply by PDAM and others. The inventory survey conducted by JICA Study Team revealed the utilized amount of water from springs, which is summarized in Table-II-2.28.

Table-II-2.28 Utilized Volume of Springs

Regency/City	Yield		Abstracted Volume				
			Irrigation	PDAM	Others	Total	
	(lit./sec)	(mil./year)	(lit./sec)	(lit./sec)	(lit./sec)	(lit./sec)	(mil./year)
Jembrana	118.9	3.7	3.0	0.0	0.2	3.2	0.1
Tabanan	4148.6	130.8	832.5	1022.0	7.5	1862.0	58.7
Badung	1335.2	42.1	406.8	15.0	55.6	477.4	15.1
Denpasar	-	0.0	-	-	-	0.0	0.0
Gianyar	3051.9	96.2	80.0	393.0	1339.0	1812.0	57.1
Klungkung	263.1	8.3	0.0	78.8	56.6	135.4	4.3
Bangli	3393.4	107.0	517.0	131.3	43.4	691.7	21.8
Karangasem	9955.9	314.0	2357.7	183.2	1992.1	4533.0	143.0
Buleleng	6172.6	194.7	147.2	408.1	2378.8	2934.1	92.5
Nusa Penida	524.9	16.6	0.0	20.0	0.0	20.0	0.6
Total	28,964.5	913.4	4,344.2	2,251.4	5,873.2	**12,468.8**	**393.2**

(3) Groundwater Development Potential

Groundwater development potential is considered to be the total groundwater flow from which the pumped volume of deep wells is deducted. The calculation of groundwater flow analysis does not count subsurface flows affected by dug wells and springs. First, the potential of exploitable groundwater by deep wells are estimated, and then the further development potential of dug wells and springs are described.

<Deep Wells>

For the estimation of deep wells groundwater potential, two kinds of approaches are executed shown in below.

Groundwater Flow Approach

Groundwater development potential from deep wells can be estimated by the balance of the total groundwater flow and the discharge from wells at the present. Based on the results explained in the previous sections, Table-II-2.29 was provided to show the potential.

Table-II-2.29 Groundwater Development Potential

Unit: MIL./year

Regency/City	Groundwater Flow	Discharge from Wells	Portion of Discharge from Wells	Potential
	A	B	B/A	A –B
Jembrana	113.9	18.3	16.1%	95.6
Tabanan	26.8	3.1	11.7%	23.7
Badung	95.7	17.2	39.3%	58.1
Denpasar		20.4		
Gianyar	156.8	13.9	9.7%	141.5
Klungkung		1.1		
Bangli		0.3		
Karangasem	66.1	6.5	9.8%	59.6
Buleleng	179.0	12.9	7.2%	166.1
Nusa Penida		0.2		(0.2)
Total	638.3	93.9	14.7%	544.4

Generally the volumes of water pumped from wells are around **15 % of the groundwater flow,** as shown in the above table. In Badung and Denpasar, however, almost 40 % of the total flow has been already exploited.

Recharge Coefficient Approach (IUIDP method)

Based on another approach conducted by IUIDP project, another evaluation of the development potential was done. IUIDP project proposed the values equivalent to **10% of the estimated recharge** as the groundwater potential. The modified approach shown in Table-II-2.30 calculated the further development potential, which is calculated by deducting present exploited discharge from 10% of estimated recharge.

Table-II-2.30 Groundwater Potential by IUIDP Approach

Regency/City	Recharge(a) (estimated with recharge coefficient)		Present Exploited Discharge(b)			Potential	
			Deep Wells	Dug Wells	Springs	Recharge – Exploited Discharge(a)-(b)	Future Exploitation Limit (10%)
	(mm)	(mil./year)	(mil./year)			(mil./year)	
Jembrana	413.7	355.1	18.3	2.2	0.1	334.5	33.5
Tabanan	917.6	784.9	3.1	1.1	58.7	722	72.2
Badung	852	339.3	17.2	4.5	15.1	302.5	30.3
Denpasar	733.9	92	20.4	2.2	0	69.4	6.9
Gianyar	1,068.6	393.2	13.9	0.6	57.1	321.6	32.2
Klungkung	528.9	56.5	1.1	0.1	4.3	51	5.1
Bangli	920.5	489.1	0.3	0.2	21.8	466.8	46.7
Karangasem	778.3	658.7	6.5	0.3	143	508.9	50.9
Buleleng	495.2	660.4	12.9	4.1	92.5	550.9	55.1
Nusa Penida	431.6	90.5	0.2	-	0.6	89.7	9.0
Total	7,140.3	3,919.7	93.9	15.3	393.2	3,417.3	341.7

<Dug Wells>

Many dug wells have already been constructed in the locations where subsurface water may be extracted. Although the subsurface water is easy and cheap to use, excessive extraction certainly causes some problems such as the decline of the water table and the quality. The results of pumping tests of dug wells conducted by Bali Groundwater (1977) indicated that the potential of dug wells is suited to a very small-scale development. The potential of subsurface water is practically limited.

<Springs>

The balance of spring can be calculated simply by deducting the utilized amount from the yield, which is shown in Table-II-2.31.

Table-II-2.31 Yield and Abstracted Volume of Springs

Unit: MIL./year

Regency/City	Yield	Abstracted Volume	Balance
	A	B	A – B
Jembrana	3.7	0.1	3.6
Tabanan	130.8	58.7	72.1
Badung	42.1	15.1	27.0
Denpasar	0.0	0.0	0.0
Gianyar	96.2	57.1	39.1
Klungkung	8.3	4.3	4.0
Bangli	107.0	21.8	85.2
Karangasem	314.0	143.0	171.0
Buleleng	194.7	92.5	102.2
Nusa Penida	16.6	0.6	16.0
Total	913.4	393.2	**520.2**

2.4.4 Hydrological Water Balance

(1) Hydrological Water Surplus/Deficit

<Annual Variation>

Based on the hydrological analysis, monthly average rainfall and monthly average potential evapotranspiration were estimated for the whole Bali Province, and are shown in Table-II-2.32 and Gambar-II-2.5. According to them, the annual variation of hydrological water surplus/deficit is understood as follows.

Table-II-2.32 Monthly Average Rainfall and Potential Evapotranspiration

Month	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Rainfall	360	347	257	172	68	55	42	23	40	140	220	278	2,003
Potential Evapotranspiration	101	98	115	117	120	108	115	126	127	127	109	104	1,367
Surplus	259	249	142	55	-52	-53	-73	-103	-87	13	111	174	636

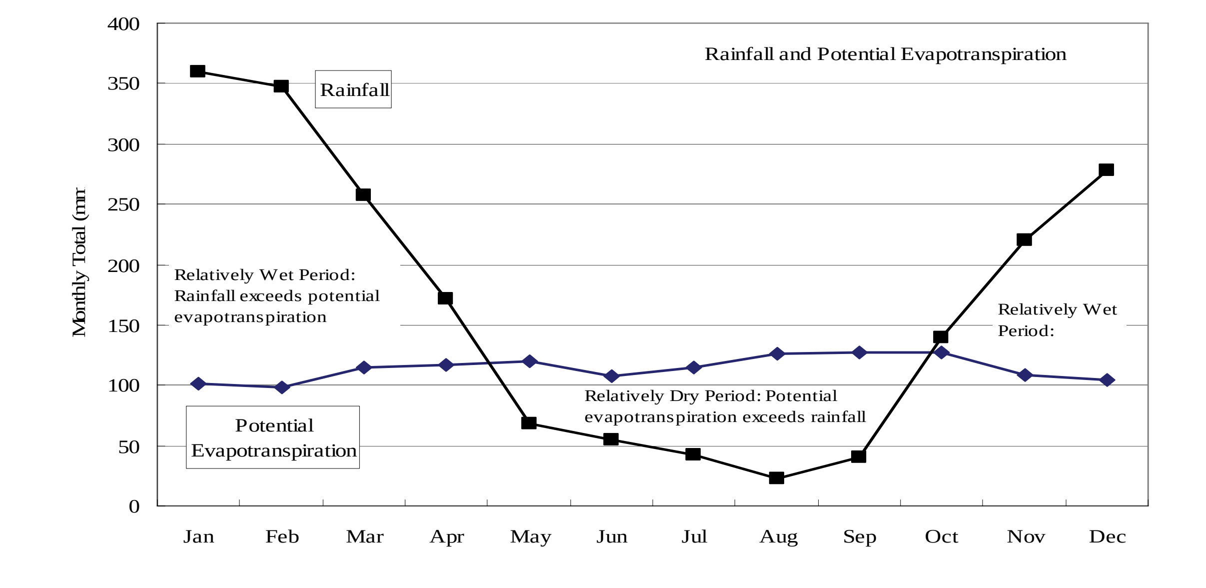


Figure-II-2.5 Hypothetical Patterns of Rainfall and Potential Evapotranspiration

The months from May to September are of hydrological deficit showing relatively dry period. Meanwhile, the months from October to April are of hydrological surplus showing relatively wet period.

<Regional Variation>

According to the rainfall and potential evapotranspiration, regional variation of hydrological water surplus/deficit is tabulated in Table-II-2.33, and the distribution of the surplus is shown in Gambar-II-2.6. Nusa Penida(S.B 03.01.20 in figures) and West Buleleng(03.01.08) are of the most hydrological water deficit, and the second deficit areas are in central(03.01.10) and east Buleleng(03.01.12), west Jembrana(03.01.07) and Karangasem(03.01.15). West Tabanan(03.01.03) and Bedugul Highland(03.01.18) shows the richest water surplus. As for the whole Bali Province, hydrological water surplus shows 636 mm under the annual rainfall of 2,003 mm.

Table-II-2.33 Regional Variation of Rainfall and Potential Evapotranspiration

Sub-basin Name	Area (km^2)	Annual Rainfall (mm)	Annual Potential Evapotranspiration (mm)	Rate	Surplus (mm)
03.01.01	555.64	2,078	1,184	57%	894
03.01.02	601.75	2,450	1,289	53%	1,161
03.01.03	288.34	2,582	1,289	50%	**1,293**
03.01.04	392.37	2,360	1,389	59%	971
03.01.05	158.92	2,112	1,389	66%	723
03.01.06	228.44	1,978	1,389	70%	589
03.01.07	243.52	1,583	1,389	88%	**194**
03.01.08	367.22	1,365	1,397	102%	**-32**
03.01.09	222.39	2,096	1,397	67%	699
03.01.10	114.24	1,704	1,397	82%	**307**
03.01.11	243.48	2,005	1,397	70%	608
03.01.12	311.65	1,792	1,397	78%	**395**
03.01.13	357.14	1,798	1,387	77%	411
03.01.14	295.38	1,911	1,387	73%	524
03.01.15	272.53	1,629	1,387	85%	242
03.01.16	342.08	2,237	1,184	53%	1,053
03.01.17	257.78	2,337	1,184	51%	1,153
03.01.18	48.84	2,700	1,110	41%	**1,590**
03.01.19	102.19	1,809	1,110	61%	699
03.01.20	208.87	1,079	1,387	129%	**-308**
Bali Province	5,612.77	2,003	1,367	68%	**636**

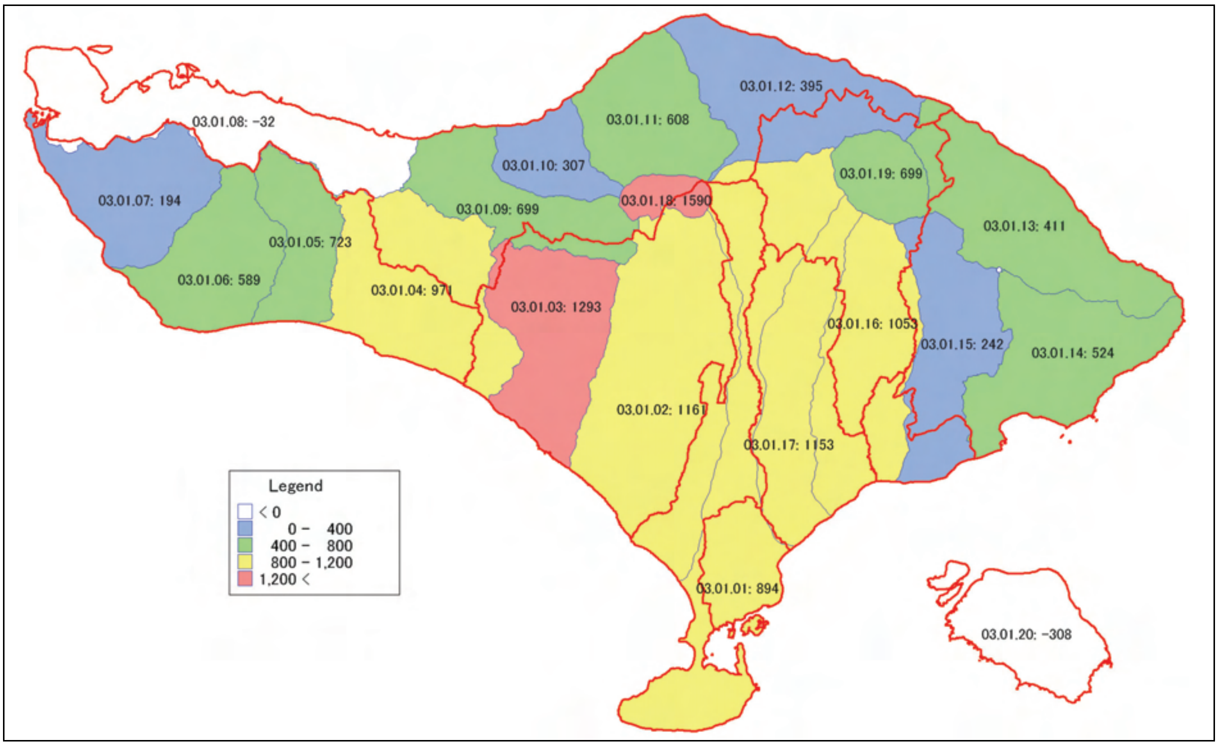


Figure-II-2.6 Regional Variation of Hydrological Water Surplus

(2) Hydrological Water Balance in Bali Province

In order to examine the reliability of surface water and groundwater resources potential, brief assessment of hydrological water balance has been made. Hydrological water balance is basically explained by the equation of "[Basin Storage] = [Inflow] – [Outflow]", and using the elements of hydrological cycle, it can be expressed as the following equation:

$$\Delta S = P - [Et + R + G] \qquad (2.5)$$

Where, *P*: Rainfall
Et: Evapotranspiration
R: River runoff
G: Groundwater recharge
Δ*S*: Change of basin water storage

Regarding change of basin storage as zero for long term hydrological balance, annual hydrological balance in Bali Province were preliminary assessed herein. Taking into consideration of land and water use condition in Bali, the above hydrological elements are explained as follows:

(a) Rainfall (*P*):

Annual rainfall in Bali is estimated 2,003 mm or 11,242 mil.m^3(356.5m^3/sec) as the a verage of 1992 – 2003

(b) River runoff (*R*):

The naturalized river flow in Bali can be expressed as follows:

[Naturalized flow] =

[Measured flow] + [Lost and consumed volume by paddy fields] (2.6)

As it is assumed in the Study that 40% of irrigation water requirement might be lost, the lost and consumed volume by paddy fields can be estimated 520 Mm^3 or 5 % of annual rainfall. Hence, river runoff is estimated 6,195 mil.m^3(196.4m^3/sec)or 1,104 mm as naturalized flow.

(c) Groundwater recharge (*G*):

Groundwater flow (G) consists of groundwater outflow to the sea (*Gout-to-sea*) and groundwater abstraction (*Ga*). Groundwater potential analysis derives the results of *Gout-to-sea* as 6.2 % of annual rainfall in whole Bali. Thus total volume of groundwater outflow to the sea is estimated 697 mil.m^3 per year(22.1m^3/sec). For *Ga* is estimated 94 mil.m^3(3.0m^3/sec). Hence, total groundwater recharge could be estimated 791 mil.m^3(25.1m^3/sec) or equivalent to 7 % of annual rainfall.

(d) Evapotranspiration (*Et*):

It is calculated by the remaining balance of rainfall(a) and river runoff(b)/groundwater recharge(c) because of difficulty of its actual figure. But it might be said that the range of actual evapotranspiration could be within 50 % to 70 % of potential evapotranspiration (1,367 mm), and could be within 680 mm to 960 mm.

The above assessment results are summarized in Table-II-2.34 as the naturalized flow case and the measured flow case.

Table-II-2.34 Hydrological Water Balance in Bali Province/Island

Assessment Case	Elements of Hydrological Cycle	Height (mm)	Volume (mil.m^3)	Discharge(m^3/s)	Percentage
-	Annual rainfall	2,003	11,242	356.5	100 %
Naturalized flow case	Groundwater flow	141	791	25.1	7 %
	River runoff	1,104	6,195	196.4	55 %
	Evapotranspiration	758	4,256	135.0	38 %

Note: Basin Area of Bali Province: 5,612.77km^2

2.5 Water Balance between Demand and Potential

2.5.1 Methodology of Water Balance Analysis

The purpose of the water balance analysis between demand and potential is to indicate a quantitative range of surpluses or deficits between the water demand for irrigation and water supply as main water users and the water potential (available water) on a region-by-region basis.

Surface water resources (runoff) potential, i.e. the largest water source, is evaluated by sub river basin, while water demand such as irrigation and water supply is evaluated by regency/city. The balance analysis is carried out based on the administrative divisions as the following zone:

- Jembrana Regency
- Tabanan Regency
- Badung Regency
- Gianyar Regency
- Klungkung Regency except Nusa Penida Islands
- Bangli Regency
- Karangasem Regency
- Buleleng Regency
- Denpasar City
- Nusa Penida District

There are many cases where regency boundaries do not coincide with basin boundaries, and they are treated in the following simple way:

- Each segment area of the river basins included in the above zones is obtained using the GIS database.
- Runoff potential of the above segment area is estimated according to a basin area ratio of the segment area to whole basin area.
- Runoff potential of the zone is calculated summing up runoff potentials of each segment area included in the zone.

The administrative boundaries and sub-basin boundaries can be referred to the Study Area Map shown at the first page of this report.

The basic equation of the water balance is described as follows:

$$WB = (SWP + GWP) - (WSD + IWD) \quad (2.7)$$

Where,
- WB: Water balance
- SWP: Surface water potential
- GWP: Groundwater potential
- WSD: Water supply demand including domestic and non-domestic water
- IWD: Irrigation water demand

2.5.2 Water Resources Potential and Demand Projection

Water potential and demand are compared by annual potential and annual water demand in this water balance study, and are derived and expressed as follows:

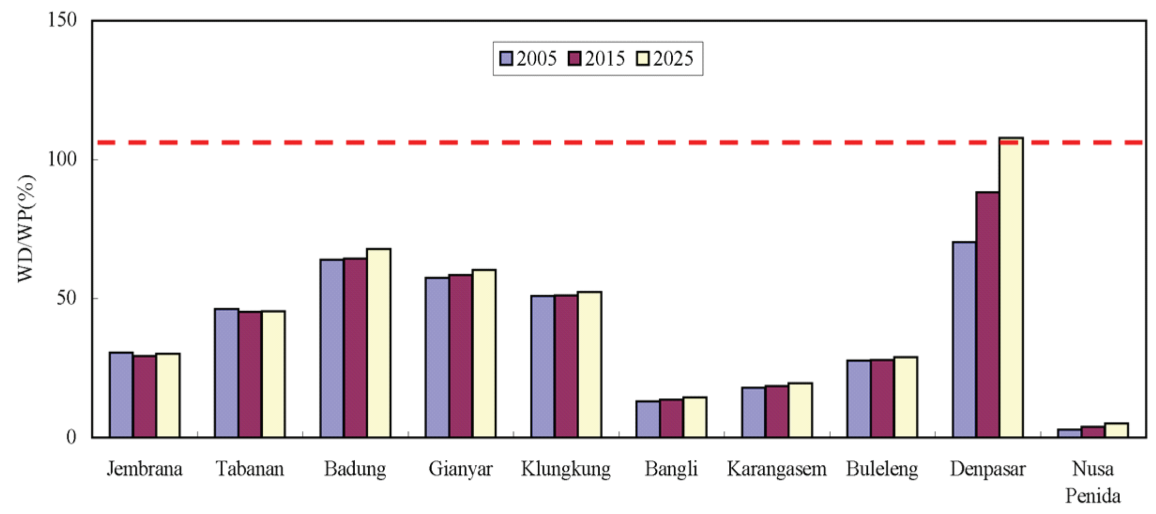
- Surface water potential was discussed in subsection 2.4.1 was counted as surface water potential in the water balance study, and was accumulated into each sub river basin respectively.
- Groundwater potential was discussed in subsection 2.4.3. Although groundwater might include water of deep wells, springs and dug wells, 10 % of annual groundwater recharge into aquifers is referred as groundwater potential, because spring water and dug well water is intermediate flow water and could be regarded as surface water at last. Hence annual groundwater potential is derived from Table-II-2.23.
- Demand projection of domestic/non-domestic water and irrigation water is discussed in section 2.2.

The annual surface water runoff is the average figure through a year, and most runoff is concentrated in the rainy season. Then, 95 % river discharge is introduced herein as available river water. According to the low flow analysis, 95 % discharge is approximately equivalent to about 25 % of annual mean discharge ranging from 15 % to 38 %, and this ratio is applied to estimate 95 % discharge from annual discharge.

Based on the balance between water resources potential and water demand, surplus and deficit of water balance are shown in Table-II-2.35 and drawn in Gambar-II-2.7.

Table-II-2.35 Balance between Water Resources Potential and Water Demand

Regency	Water Resources Potential		Water Demand						Water Balance			WD/WP(%)		
	Surface Water	Ground water	Water Supply			Irrigation Water								
			2005	2015	2025	2005	2015	2025	2005	2015	2025	2005	2015	2025
Water Resources Potential and Water Demand in Year at Mean discharge (Unit: million m3/year) *Note: Surface Water Potential: All the river basins*														
Jembrana	946.6	35.5	9.3	13.0	18.1	61.9	55.3	52.0	910.9	913.8	912.0	7.3	7.0	7.1
Tabanan	1,312.0	78.5	16.4	23.0	31.3	373.0	358.6	351.0	1,001.1	1,009.0	1,008.3	28.0	27.4	27.5
Badung	548.2	33.9	35.1	56.2	80.5	232.3	213.0	203.2	314.7	312.9	298.5	45.9	46.2	48.7
Gianyar	520.9	39.3	20.2	28.7	38.6	211.6	207.6	205.4	328.5	324.0	316.3	41.4	42.2	43.5
Klungkung	127.6	5.6	4.7	5.8	7.5	43.7	42.7	42.2	84.8	84.7	83.6	36.3	36.4	37.3
Bangli	508.8	48.9	6.1	8.7	11.6	44.1	44.1	44.1	507.5	504.9	502.0	9.0	9.5	10.0
Karangasem	528.2	65.9	11.8	16.2	21.6	63.3	61.5	60.5	519.1	516.5	512.1	12.6	13.1	13.8
Buleleng	1,485.1	66.0	17.5	25.6	37.3	211.3	205.4	202.3	1,322.4	1,320.2	1,311.6	14.7	14.9	15.4
Denpasar	160.2	9.2	47.5	73.1	98.9	37.8	33.8	31.8	84.0	62.5	38.7	50.4	63.1	77.2
Nusa Penida	57.8	9.0	1.4	1.8	2.4	0.0	0.0	0.0	65.4	65.0	64.4	2.0	2.7	3.6
Total	6,195.4	391.8	169.9	252.1	347.7	1,278.9	1,221.8	1,192.3	5,138.4	5,113.3	5,047.3	22.0	22.4	23.4
Water Resources Potential and Water Demand in Year at 95% discharge (Unit: lit./sec) *Note: Surface Water Potential: All the river basins*														
Jembrana	6,238	1,126	296	413	573	1,962	1,753	1,649	5,106	5,198	5,142	30.7	29.4	30.2
Tabanan	24,223	2,489	519	729	993	11,829	11,370	11,129	14,364	14,613	14,590	46.2	45.3	45.4
Badung	12,160	1,075	1,114	1,783	2,552	7,365	6,754	6,442	4,756	4,698	4,240	64.1	64.5	68.0
Gianyar	11,554	1,246	639	910	1,223	6,709	6,581	6,512	5,452	5,309	5,065	57.4	58.5	60.4
Klungkung	2,830	178	148	185	237	1,386	1,354	1,337	1,474	1,469	1,434	51.0	51.2	52.3
Bangli	10,667	1,551	193	276	369	1,398	1,398	1,398	10,627	10,544	10,451	13.0	13.7	14.5
Karangasem	11,186	2,090	374	513	684	2,006	1,949	1,917	10,896	10,814	10,674	17.9	18.5	19.6
Buleleng	24,085	2,093	554	811	1,182	6,699	6,512	6,414	18,925	18,855	18,582	27.7	28.0	29.0
Denpasar	3,552	292	1,507	2,318	3,136	1,199	1,072	1,008	1,138	454	-300	70.4	88.2	107.8
Nusa Penida	1,177	285	43	57	76	0	0	0	1,420	1,406	1,387	2.9	3.9	5.2
Total	107,674	12,424	5,387	7,995	11,025	40,553	38,743	37,806	74,158	73,360	71,266	38.3	38.9	40.7



Note:
WD = WSD + IWD, WP = SWP + GWP
Where, SWP:Surface water potential as Naturalized 95% discharge
GWP:Groundwater potential as Recharg(estimated with recharge coefficient)
WSD:Water supply demand including domestic and non-domestic water
IWD:Irrigation water demand

Figure-II-2.7 Water Demand Proportion for Water Resources Potential (%)

2.5.3 Water Balance Analysis

According to the balance between water resources potential and water demand in Bali Province shown in Table-II-2.35, the following water balance could be found in the present and future in Bali:

- Looking at annual water balance between potential and demand in year at mean discharge, water potential in Bali could be considered to be more than enough in total; especially surface water potential seems to be very large.
- Picking up the balance at Denpasar City in case of "at 95% discharge", however, potential and demand becomes almost balancing in 2015 and becomes short in 2025 of the target year.
- Water demand in 2025 of Badung, Gianyar, Tabanan and Klungkung Regency also show the large portion with varies 52% to 68% for water resources in case of "at 95% Discharge".
- On the other hand, water demand of Jembrana, Karangasem and Bangli show the little portion with less than about 30% for the water resources and it will continue until 2025.

CHAPTER 3 BASIC CONCEPT OF MASTER PLAN

3.1 Goal and Objective of Master Plan

According to “Concept of Regional Policy for Water Resources of Bali Province in June 2003” by *Dinas PU* of Bali Province, the vision that will be achieved by the development of water resources in Bali is as follows.

> ***Water Resources is a component that forms identity of culture and development power of Bali People based on the philosophy of “Tri Hita Karana”.***

And to realize this vision, the some missions are explained as follows:

- Improvement of Water Use: To improve water resources utilization by paying attention to the various economic sectors and SUBACK
- Food Production: To increase food production for achieving food self-sufficiency
- Eco-System: To relieve and improve quality of echo-system especially for river basin area as an effort for sustainable water resources conservation
- Bali Culture: To maintain identity of Bali Culture which is quite supported by the agricultural culture value system through water supply

Daily life in SUBACK societies is based on the philosophy of the “*Tri Hita Karana*” (See Figure-II-3.1. Three Happiness Causes that are regarded as the causes for achieving the happiness), with the three harmonious relationships among:

- Human beings and God as the creator of the world,
- Human beings and the environment, and
- Human beings themselves.

The rules of the “*Tri Hita Karana*” permeate SUBACK members, providing a strong interconnection between the material and spiritual aspects of daily activities.

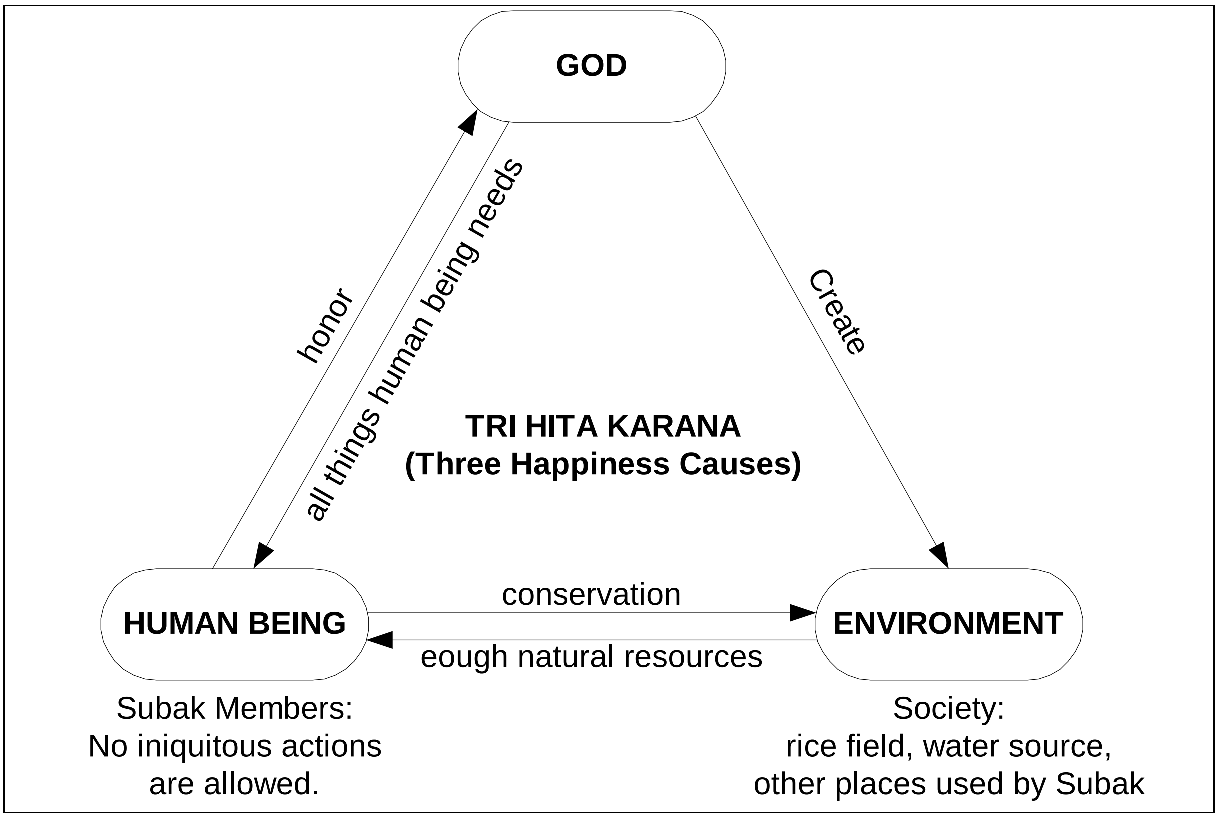


Figure-II-3.1 Principle of “*Tri Hita Karana*” (Three Happiness Causes)

3.2 Components of Master Plan

The Water Master Plan targeting the year of 2025 covers the following components or sub-sectors:

- Water Resources Development for:
  - ✓ Public Water Supply
  - ✓ Irrigation Water
- Flood Control
- Water Resources Management for:
  - ✓ Institutional Development for Water Resources Management
  - ✓ Water Quality Improvement
  - ✓ River Basin Conservation

3.3 Planning Policy

(1) New Water Law

In March 2004, the new Water Resources Law was enforced and its philosophy could be summarized as below:

- **Principles**
  Water resources are managed based on the principles of conservation, balance, public benefit, integration and harmony, justice, independence as well as transparency and accountability.

- **Optimal Prosperity of People**
  Water resources are managed comprehensively, integratedly and environmentally friendly with a view of realizing sustainable benefits of water resources for the optimal prosperity of people.

- **Functions**
  Water resources have social, environmental, and economic functions that are harmoniously implemented and realized.

- **Everyone's Right**
  The state guarantees everyone's right to obtain water for the daily minimum basic need for fulfilling their healthy, clean and productive life

- **Communal Rights of Local Traditional Communities**
  The control over water resources is implemented by the central government and/or regional governments by recognizing continuously communal rights of local traditional communities and similar rights, so long as they are not contradictory to national interests and legislative regulations..

(2) General Strategy for Water Master Plan of Bali Province

Under the philosophy of the New Water Resources Law, The general strategy for the Water Master Plan of Bali Province is set up below.

- **Basement of Water Master Plan**
  Keeping the New Water Resources Law, and respecting Bali-peculiar spiritual culture, the Master Plan for Water resources Development and Management in Bali Province should be formulated as to meet an international standard.

- **Basic Concept**
  Water resources development and management should be based on the concept of "one island (basin), one plan, and one management".

- **Respect of SUBACK**
  Bali has been historically having its own traditional, cultural and religious commitment, which is embodied in SUBACK. SUBACK should be respected in water resources development and management.

- **Community Participation**
  In formulating the Master Plan, efforts for community participation should be made through stakeholders' meetings.

- **Water Development & Allocation**
  To seek water sources, water users have to find water sources first at their regency and their river basin and second at other regency or other river basin. According to the water balance between future demand and water potential, Denpasar and Badung have no more water potential within the areas. Thus, conveyance of water developed in other river basins or other regencies is inevitable.

3.4 General Strategies for Master Plan

3.4.1 Strategies for Water Resources Development

(1) Raw Water Development

<Options of Water Sources and Development Policies>

The options of water sources to be develop in Bali are as follows: (Refer to Table-II-3.1)

Table-II-3.1 Characteristics of Water Resources to Develop in Bali

Sources / Items	Direct Intake from River Water	Development by Reservoir	Spring	Groundwater
Development Scale	Small→Medium	Medium→Large	Small→Medium	Small→Medium
Merit	✓ To be developed by small scale facilities such as intake	✓ To be developed in relatively large scale volume by storing flood water in reservoir	✓ Simple water treatment due to good water quality ✓ As springs are located in high altitude, gravity distribution system is applicable	✓ Simple water treatment due to good water quality ✓ To be developed near users
Demerit	✓ As river water is well utilized, large scale intake is hard.	✓ Construction of dam and reservoir may gives large scale environmental impacts.	✓ Usable spring is relatively small scale	✓ Development over capacity of 100lit/s is not applicable due to small scale yield per well (10lit/s).
Remarks	✓ Agreement between new users (or developer) and current users with water right is essential. ✓ Water source should be safe against drought.	✓ Agreement between new users (or developer) and current users with water right is essential. ✓ Water source should be safe against drought.	✓ Agreement between new users (or developer) and current users with water right is essential. ✓ Water source should be safe against drought.	✓ Low potential areas, well development may cause water table dropdown in shallow wells and seawater intrusion.

- The options of water sources are river water, spring water, groundwater and natural lake water. But due to religious reason the use of lake water is prohibited except for the use of the peoples around the lake. The lake water is not a target of water source to develop.
- Although the river water is used mostly for irrigation, it will be promising water source to develop after confirmation of it's surplus potential.
- The methods to develop river water are 1) Direct Intake from River Flow, and 2) Storage of Flood Water in Reservoir. The former is suitable for small and medium scale projects and the latter is suitable for large scale projects.
- Due to the hydrologic and hydro-geologic characteristics of the volcanic island of Bali, there are many perennial springs. Many of these springs are used in Bali. Springs not to be used will be the target to develop, but will be relatively small or medium scale. As the water quality of

spring is good enough for drinking water, springs will be promising water sources to develop in small or medium scale.

- Regarding the development of river flows and springs, developers (or new users) shall get agreement from the downstream users (existing water right holder, especially from irrigation users or SUBAK).
- Groundwater is used widely by deep wells and shallow wells. Deep wells are used for public water supply, industry, hotels etc. Shallow wells are used for domestic use. Water supply coverage by public water supply system in Denpasar and Badung areas is now around 50% because the shallow wells are prevailing in these areas.
- As the water quality of deep wells is relatively good, deep wells will be the water sources of public water supply system. However, the scale of deep well development will be restricted. Large scale development of groundwater is not applicable due to economic reason and capacity of potential. In case of small capacity of groundwater potential, groundwater development will lower the groundwater table and cause dry-up of well, intrusion of seawater and so on.

<Surface Water Development>

Surface water is the largest water source in Bali. Effective use of surface water is key point to mitigate water shortage in Bali. The strategies for surface water development are set as follows:

- **Abstraction of River Water**
  Direct water abstraction of river should not be planned without understanding necessary compensation to the downstream by the detailed observation of naturalized river flows and the amount of the existing intake water.

- **Development by Reservoir**
  Surface water development should be made mainly by reservoir development such as a small-scale pond, estuary reservoir, and large-scale reservoir. Once reservoir development is planned, effects to society and environment have to be minimized, and the consensus to agree to the development has to be obtained from stakeholders such as SUBACK and local peoples. Especially, compensation water amount to the downstream is an important issue to make progress of a large-scale reservoir development in the mid/upstream, and to reach the consensus among stakeholders.

- **Lake Water**
  Water in the four natural lakes in Bali, Lake BATUR, Lake BRATAN, Lake BUYON and Lake TAMBLINGAN, is not utilized for a certain scale of water resources development except for small-scale personal use by surrounding residents.

- **Safety against Drought**
  Some margin of safety against drought should be introduced to avoid unstable uses of irrigation water and domestic and non-domestic water. In the Master Plan, raw water development is planned so as to secure water even in the drought once in five years for irrigation, and once in ten years for water supply.

- **Clear Explanation to All Users**
  Relating to the above issues of compensation water to the downstream, observation of river water/flow and intake water amounts for irrigation and water supply should be strengthened to clearly explain the present situations and future conditions after reservoir development. Moreover, it would certainly contribute to solve water conflicts between SUBACKs and the other users such as PDAM, by means of knowing whether river has still remaining water potential to be abstracted by new users and developers.

<Groundwater Development>

Groundwater is access-friendly water resources that could be easily developed near necessary areas with economical cost. Strategies for groundwater development are set as follows:

- **Exploitable Groundwater Volume**
  The most important point for sustainable groundwater development is to extract groundwater less than natural recharge. Exploitable groundwater should be less than 10 % of natural groundwater recharge for sustainable use.

- **Development Area**
  A further groundwater development should be essentially prevented in seaside areas where the groundwater has been already over exploited, and should be carefully planned also in other seaside areas even not yet started to be developed. The location of groundwater production wells should be selected to avoid seawater intrusion and over-pumping operation.

- **Monitoring**
  Monitoring of groundwater level and groundwater quality is essential for appropriate aquifer management.

- **Subsurface Dam for Groundwater Development**
  Detailed examination is necessary to plan a subsurface dam not only from technical but also economical viewpoints, because development of deep wells might be economical and practical in many cases in the vicinity under the same hydrogeological condition.

- **Dug Wells**
  As dug wells have only small water potential and the water use is usually limited to the individual, a development planning of dug wells is not discussed in the Master Plan.

- **Springs**
  Springs are very economical water resources and the development of them should be positively progressed. Nevertheless, new spring use or further intake should be carefully planned so as not to affect the downstream water use, because spring water use upstream may cause decrease of river flow resulting in water shortage in the downstream. In case that spring water use is found to affect the downstream water use, spring water development is not recommended.

- **Development in Nusa Penida**
  In Nusa Penida, spring water use could be reasonable and practical, because no other water sources including surface water and groundwater by deep wells are expected.

(2) Improvement of Water Supply Capacities

All the PDAMs will be faced with severe water shortage in the near future. Thus, to meet the future water demand it is required to develop new water sources and to construct the additional water supply facilities such as water transmission pipeline, reservoir, water treatment plant, pipeline for the distribution networks and pumping station for booster. The strategies for developing water sources and construction of water supply facilities are set as follows:

<Requirement for Water Sources>

The following conditions of water sources should be taken into account to select water sources for domestic and non-domestic water supply system:

- **User's Territory and User's Basin**
  When each water supply company seeks new water sources to meet new water demand, he has to find them first in his territory (Regency) and his river basin. Other territory and other basin are the second option.

- **Location of Water Sources**
  Water sources at upstream or higher elevation are preferable for applying a gravity water distribution system. And the nearest location to water consumption areas is better to convey water.

- **<u>Water Quality of Water Sources</u>**
  Water quality should meet the water quality standards in Indonesia for domestic and non-domestic water supply.
- **<u>Number of Water Sources</u>**
  From the economical viewpoint, some limited water sources are better than many water sources because of reducing operation and maintenance cost.

<Minimum Water Cost>

To develop new capacity for water supply, water cost per cubic meter shall be minimizes considering 1) Development Cost for Water Sources and 2) Operation and Maintenance Cost.

<Staged Implementation>

To implement the improvement of water supply capacity, a step-by-step construction to meet time-to-time water demand is preferable.

<Maintenance of Facilities>

PDAMs in Bali were established in 1970's and more than 30 years have already passed since starting operation. Water pipes, pumps, motors and related facilities become older and are necessary to be improved and replaced, to keep them in good operation and maintenance, and to reduce water leakage from pipes. The average unaccounted water rate at present in Bali is 23 %, which is still low level. To keep this rate in low level is equivalent to water saving and new water sources development. Moreover, proper replacement of pumps and motors saves their running costs.

(3) Strategies for Irrigation Water Development

Paddy fields are expected decreasing not only in whole Bali but also in all regencies/city except Bangli. Thus, there will be the residual irrigation water as long as farming method and crop intensities etc. are same as the present conditions. Since SUBACK as irrigation water users has customary water right, it has been using the said residual water for raising crop intensity or other extension within the irrigation sector, although there might be some places where irrigation water is too much because of urbanization.

Under the above circumstance in Bali, the following strategy for irrigation water development is raised in the Master Plan:

<Purpose of Irrigation>

Irrigation water should be developed for the following three purposes;

- To increase crop intensity to 300 %
- To stabilize irrigation agriculture even at the time of drought
- To improve cropping patterns as the ideal pattern of "paddy/paddy/palawija", unless other patterns are preferred/suitable for specific areas

The above irrigation water development should be planned and implemented on demands of irrigation water necessity, poverty alleviation and rural development, because irrigable lands have already developed and a large scale new irrigation project is unlikely expected.

<Residual Water Resulting from Decrease in Paddy Fields>

Residual water resulting from decrease in paddy fields should be used in general for the purposes of the above three purposes within irrigation sector. In the area such as "SARBAGITAKUNG" that has already been of high crop intensity however, possibility to use the residual water to other purposes such as drinking water should be sought out by obtaining consensus among SUBACK and other stakeholders.

<Rehabilitation of Irrigation Facilities>

Rehabilitation works of irrigation facilities should progress to improve irrigation efficiency, and should be regarded as one of irrigation water development. It can be save irrigation water, and improve crop intensities, crop productivity and irrigation water management.

<New Irrigation Areas>

Areas necessary to develop irrigation water should be determined based on necessity of the above three purposes as well as requirement of poverty alleviation and rural development.

<Water Sources of Irrigation>

Water resources for irrigation water are mainly developed with surface water by means of reservoirs such as a small reservoir off a river and a large reservoir in rivers.

<Priority Area of Irrigation Water Development>

Even though the priority area of irrigation water development should be determined based on the various requirements such as necessities, potential and suitability, present crop intensity might help the decision making of priority areas.

3.4.2 Strategies for Flood Control

(1) Purpose

The purposes of flood control are:

- ◆ To cope with river flooding and landside water inundation,
- ◆ To mitigate flood damages by structural and non-structural measures, and
- ◆ To improve river environment condition through the implementation of flood control measures.

(2) Countermeasures

To achieve the purposes mentioned above, the following structural and non-structural countermeasures are to be applied on the basis of the policy of “*STAY HARMONY WITH WATER*”:

- ◆ **Structural Measures: Direct Measures to River Course**
  - ✓ River course improvement by dikes, revetment, excavation, consolidation etc.
  - ✓ Flood peak discharge regulation by reservoir, retarding basin, diversion channel etc.
- ◆ **Non-structural Measures: Indirect Measures to River Course**
  - ✓ Flood forecast and evacuation system
  - ✓ To minimize the increased discharge by urban development based on the policy “Zero Delta Q Policy”
  - ✓ To enhance (or maintain) the flood control function of current basin through conservation of forest and/or reforestation, and conservation of firm lands such as rice fields

(3) Design Scale

The design scale of 10 to 30 years is adopted for the flood control plan depending on river basin areas and urbanized conditions, referring to the following consideration:

“Flood Control Manual Volume II”, which was prepared in the middle of 1990’s by a CIDA aid project, provides a summary of return period criteria which have been used in the design of various flood control projects in Indonesia. In an area of urban/industrial development, the design flood return period varies 10 to 25 years in the short term, and 25 to 50 years in the long term. Also in this manual, recommended minimum design flood standard are presented in

Table-II-3.2. For new projects, minimum design flood return periods of more than 10 years in the initial phase and more than 25 years in the final phase are recommended.

Table-II-3.2 Recommended Minimum Return Period of Design Flood

Flood System	Project Type(for River Flood Control Project) and Total Population (for Drainage System)	Initial Phase	Final Phase
River System	Emergency Project	5-year	10-Year
	New Project	10	25
	Updating Project for rural and/or urban with P < 2,000,000	25	50
	Updating Project for urban with P > 2,000,000	25	100
Primary Drainage System (Catchment area> 500 ha)	Rural	2-year	5-year
	Urban P < 500,000	5	10
	Urban 500,000 < P < 2,000,000	5	15
	Urban P > 2,000,000	10	25

Notes:

1) Higher design flood standard should be applied if an economic analysis indicates that it is desirable or if flooding is a significant risk to human life.
2) P = Total Urban Population
3) Emergency Projects are developed without preliminary engineering and economic feasibility studies at sites where flooding is excessive and flooding problems present a significant risk to human life.
4) New Project include flood control projects where no previous flood projects have been developed or where Emergency Projects have been developed.
5) Updating Projects include rehabilitation projects and improvements to exiting project. Most River Basin Development Projects are considered to be updating projects.
6) Initial Phase is recommended for immediate use.
7) Final Phase is recommended for use in upgrading existing facility when the necessary funds become available.

(4) Target Areas

The target area to be protected against flood should cover the whole Bali Province, referring to “Bali Flood Mapping” as shown in Table-II-3.3. In the Master Plan, however, priority is put on urban areas such as Denpasar and Kuta areas, Singaraja and Negara.

Table-II-3.3 Bali Flood Mapping

Zone	District/City	River Name	Problem/Issues	Countermeasures
East Bali	Karangasem Klungkung	Karobelahan, Daya, Nusu, Sakta, Batuniti, Kates, Kerkuk, Janga, Buhu, Unda (Telagawaja,Yeh Sah, Langon, Barak), Jinah, Lombang	✓ Annual rainfall: 2,200 - 3,000 mm ✓ Influenced by erupted material of Mt. Agung ✓ Erosion is relatively active in the upstream, and causes sedimentation in the downstream.	✓ Check dam, ✓ Sand Pocket, ✓ Groundsill, ✓ Revetment, ✓ Normalization, ✓ Dike
	Gianyar Bangli	Melangit, Sungasang, Pakerisan, Petanu, Oos, Buhu		
Central Bali	Buleleng	Canging, Banyumala, Buleleng	✓ Annual rainfall: 2,000 - 2,800 mm ✓ ”Bottle necks” ✓ Sedimentation ✓ Some rivers are influenced by tide.	✓ Revetment, ✓ Normalization, ✓ Dike ✓ Upstream Lands Conservation
	Badung Denpasar	Badung, Mati, Teba		
	Tabanan	Yeh Ho, Balian, Bakung		
West Bali	Buleleng	Banyupoh, Grokgak, Tinga-Tinga, Sumaga, Gemgem, Saba, Medaum	✓ Annual rainfall: 1,400 - 2,200 mm ✓ Erosion is relatively active in the upstream, and causes sedimentation and river meandering in downstream. ✓ Some rivers are influenced by tide.	✓ Revetment, ✓ Normalization, ✓ Dike ✓ Shortcut
	Jembrana	Sumbul, Bilukpoh, Sowan (Tukad Jogading, Tukad Pergung, Tukad daya Timur)		

Source: Pekerjaan Pembuatan Peta Banjir di Propinsi Bali, Proyek Pengelolaan Sumber Air dan Pengendalian Banjir Bali, 1996

3.4.3 Strategies for Water Resources Management

<Options for the Institutional Framework>

The options for the new institutional framework for water resources management are presented below. Basically, there are two choices:

- Option I: Continue with the existing arrangement,
- Option II: Introduce the Balai PSDA structure in order to have better focus on technical implementation.

If Option II is pursued, then the question is what would be the reasonable demarcation of the technical responsibilities between the province and the regencies/city? Four variations can be considered in response to this question.

- Variation A is to stick to the principle of regional autonomy, i.e. the province is responsible for cross-regency/city rivers and for overall coordination and guidance.
- Variation B is to expand the coverage of the provincial responsibility to include strategically important areas in view of water demands, potential conflicts, and other key factors.
- Variation C is to have the entire technical responsibility for Bali under the provincial responsibility. The areas of technical responsibility will correspond to the areas for which a coordination body will be responsible.
- Variation D is in line with the discussion currently taking place in the Ministry of Public Works, that is, whether to determine Bali as a nationally strategic basin and have it directly under the central government.

<More Structured Mechanisms of Water Allocation>

Four measures shown below for facilitating the resolution of issues facing SUBAK*s* and for structuring water allocation may be considered:

- Government "One Stop Shop" for Subaks
- Water Allocation Plan
- Public Consultation for Licensing
- Measuring Customary Water Use

<Institutional Strengthening Measures>

An action plan with a timetable will have to be prepared. For the implementation of the action plan, task forces may be established comprising concerned officials and staff members within the Dinas PU and linking up with other relevant bodies as necessary to work on specific subjects. The Implementation can be gradual and incremental so as not to cause disturbances in the regular work schedule, but must be time-bound. The key aspects of the action plan will be as follows:

- Rules, Procedures, Responsibilities
- Water Resources Information System
- Organizational Performance

CHAPTER 4 WATER RESOURCES DEVELOPMENT PLAN

4.1 Water Supply Plan

4.1.1 Current Issues of Water Supply

Most of PDAMs apply a metered system of billing rate, and have kept the water tariff at the same rate for a long time. It causes budget constraint every year in most PDAMs except PDAM Buleleng and PT.TB. The PDAMs with budget constraints are under troubles of loan repayment and keeping the water supply facilities a good condition to serve drinking water to users.

Water sources of PDAM Buleleng are located mostly in high elevation, and the gravity system can be adopted for the water supply system. Hence they could reduce their operation and maintenance cost, and have been keeping good financial condition for a long time unlike in another PDAMs. PT.TB has also been keeping their facilities in good operation as same in PDAM Buleleng, because the main water users of PT.TB is star hotels in Nusa Dua, which occupy 40 % of all water users of PT.TB, and because PT.TB charges to star hotels a higher billing rate than that of other PDAMs. Therefore, PDAMs with budget deficit need to introduce an appropriate water tariff system as soon as possible, in order to recover a good financial condition and to keep the existing water supply facilities in good maintenance. Considering the above conditions, the issues on PDAM of domestic and non-dometic water supply bodies are summarized bellow:

- PDAMs in Bali were established in 1970's and more than 30 years have already passed since starting operation. After 30 years, water pipes, pumps, motors and related facilities become older and are necessary to be improved and replaced, to keep them in good operation and maintenance, and to reduce water leakage from pipes. The average unaccounted water rate at present in Bali is 23 %, which is still low level. To keep this rate in low level is equivalent to water saving and new water sources development. Moreover, proper replacement of pumps and motors saves their running costs.
- There are two water treatment plants, of which water intakes are located at the downstream of Badung and Ayung rivers. Water quality at these intake points is bad because of high pollution of biological quality, bacterial quality and toxicity. Sophisticated treatment system is required to remove the harmful substances for drinking water, and also a water quality monitoring system is necessary to check the water quality conditions. Presently no water quality monitoring system exists at these water intakes, but it is necessary to monitor the surface water quality to efficiently produce clean drinking water.
- As gravity system is very economical for a water supply system, new water sources should be developed at the higher elevation or at the upstream side if possible. However, it is not recommended that the locations of the water sources are far from the water consuming areas, even if it is located in higher or upstream place.
- Tap water quality is not observed by each PDAM at present. Regular monitoring of tap water quality is also important to keep drinking water safe and clean as same as the intake water quality monitoring.

4.1.2 Water Demand and Potential by Regency

Table-II-4.1 shows the water demand and potential by regency. This table reveals the following facts:

- For Denpasar, there is no remained potential in the area of city territory to meet the increased future water demand. There is a deficit between demand and potential.
- For Badung and Gianyar, there is some remained potential in the both areas to meet the increased future water demand. But careful examination is necessary to develop new water sources.
- For other regencies, still there is a lot of water potential to meet the increased future water demand.
- For Denpasar Metropolitan area (including Denpasar, Badung and Gianyar), integrated public water supply system is recommendable due to large amount of demand, cross related economic zone and limitation of water resources potential.
- For other regency, as there is a lot of water potential to meet the increased future water demand, each PDAM should supply water to meet demand by developing the promising water sources according to demand.

Table-II-4.1 Water Demand and Water Potential by Regency

Items	DEN	BAD	GIA	TAB	KUL	JEM	BUL	BAN	KAR	Total
Water Potential	3,887	13,260	12,745	26,557	4,577	7,370	26,130	12,073	13,263	119,862
- Surface Water	3,552	12,160	11,554	24,223	4,008	6,238	24,085	10,668	11,186	107,674
- Groundwater	335	1,100	1,191	2,334	569	1,132	2,045	1,405	2,077	12,188
Current Water Use	2,953	10,045	9,037	15,418	1,999	2,810	8,679	2,037	2,986	55,964
- Irrigation	1,447	8,905	8,398	14,899	1,792	2,514	8,125	1,755	2,612	50,447
- Public W/Supply	1,180	744	461	345	151	152	245	89	166	3,533
- Non-Public W/Supply	326	396	178	174	56	144	309	193	208	1,984
Future Demand (PWS)	2,805	2,189	1,112	858	282	395	859	287	526	9,313
Current Capacity (PWS)	1,115	965	562	544	235	139	394	120	224	4,298
- River	800	650	0	81	130	0	0	0	73	1,734
- Spring	0	79	214	458	95	0	312	120	82	1,360
- Well	315	236	348	5	10	139	82	0	69	1,204
Deficit (PWS)	1,690	1,224	550	314	47	256	465	167	302	5,015
Remaining Potential	1,260	3,611	3,886	11,313	1,496	4,699	17,760	1,405	10,485	55,915
Required Capacity Rate	*134 %*	*34 %*	*14 %*	*3 %*	*3 %*	5%	3%	2%	3%	*9%*

- PWS: Public Water SUpply
- DEN: Denpasar, BAD: Badung, GIA: Gianyar, TAB: Tabanan, KUL: Kulungkung, JEM: Jembrena, BUL: Bulereng, BAN: Bangli, KAR: Karangasem
- Surface Water Potential: Drought Discharge (95% flow)
- Required Capacity Rate: Percentage of required capacity (to be developed) against remained potential. Small value shows that the there's much potential to be developed, large value shows that there's little potential to be developed in the area. Values exceeding the rate of 100% show that there's deficit in the area.

4.1.3 Water Sources for Future Water Supply

Table-II-4.2 shows the percentage of the current water sources for public water supply system by regency/city.

Table-II-4.2 Water Sources by Regencies

Regencies	River	Spring	Well	Explanation
Junbrana	-	-	100%	All the water sources are deep wells
Tabanan	15%	84%	1%	Main water sources are springs
Badung	67%	8%	25%	3 water sources are used. Main sources are rivers
Gianyar	-	38%	62%	Springs and wells are water sources. Wells are used more.
Kulungkung	55%	40%	5%	Main sources are rivers and springs
Bangli	-	100%	-	All the water sources are springs.
Karangasem	33%	37%	30%	3 water sources are used evenly.
Buleleng	-	79%	21%	Springs and wells are water sources. Springs are used more.
Denpasar	72%	-	28%	Rivers and wells are water sources. Rivers are used more.
Total	40%	32%	28%	3 water sources are used. Large scale water sources are rivers.

Considering these situations and the plans examined by each regency/city, the Study Team proposed the following future water sources for the integrated system and each regency/city:

- Integrated Public Water Supply System for Denpasar Metropolitan Area: To meet a large amount of demand, development of river flow is inevitable. Promising rivers are Ayung, Penet, Petanu Rivers and so on in the territory, and Unda River outside of the territory. Development of other sources (spring and deep well) is necessary. Deep well development in Denpasar is not recommendable due to the problem of sea water intrusions.
- Tabanan: Hoo River development is undertaken through Teragatunjung Dam. Spring development is recommendable. Klungkung: Future water source is spring for both territories in Bali Island and Nusa Penida. In Nusa Penida, springs have enough capacity. Although distributed users are remote from springs, piped distribution system is recommendable.
- Jembrana: To meet current demand, development of deep wells is necessary. Benel Dam planed by local government will supply domestic water for future demand.
- Buleleng: Future water sources are springs and deep wells.
- Bangli: Future water source is springs. Water distribution to new users in remote areas is carefully examined.
- Karangasem: Future water sources are springs and deep wells. Water distribution to new users in remote areas is carefully examined.

4.1.4 Water Supply Plan for Southern Bali Area

As the southern Bali area (one city and 4 regencies: Denpasar, Badung, Gianyar, Tabanan and Kulungkung: SARBAGITAKU) has concluded the agreement on the cooperation of water supply in the area, the water supply plan for the southern Bali area is examined and prepared.

(1) Current Water Supply Capacity and Demand

The southern Bali area is divided into 2 areas, namely 1) Denpasar & Surrounding Area (SARBAGI) and 2) Other Area (TAKU). Refer to Table-II-4.3 Denpasar & Surrounding Area has a large amount of water demand and a small amount of remaining water potential in the area. Other Area has a small amount of water demand and a large amount of remaining water potential. According to this classification, the water supply capacity and water demand for the southern Bali area are shown in Table-II-4.3.

Table-II-4.3 Water Supply Capacity and Water Demand in Southern Bali Area

Area	Water Supply Company	Items	2005	2010	2015	2020	2025
(A) Denpasar & Surrounding Area (SARBAGI)	(1) Denpasar PDAM	Demand (lit/s)	1,180	1,577	1,986	2,396	2,805
		Capacity (lit/s)	1,115				
		Balance (lit/s)	-65	-462	-871	-1,281	-1,690
	(2) Badung PDAM	Demand (lit/s)	273	399	549	700	851
		Capacity (lit/s)	296				
		Balance (lit/s)	23	-108	-253	-404	-555
	(3) Badung PTTB	Demand (lit/s)	444	604	849	1,094	1,338
		Capacity (lit/s)	650				
		Balance (lit/s)	206	46	-199	-444	-688
	(4) Gianyar PDAM	Demand (lit/s)	461	586	744	901	1,058
		Capacity (lit/s)	562				
		Balance (lit/s)	101	-24	-182	-339	-496
	Total [1+2+3+4]	Demand (lit/s)	2,358	3,166	4,128	5,091	6,052
		Capacity (lit/s)	2,623				
		Balance (lit/s)	265	-548	-1,505	-2,468	-3,429
(B) Other Area (TAKU)	(5) Tabanan PDAM	Demand (lit/s)	345	436	577	718	858
		Capacity (lit/s)	544				
		Balance (lit/s)	201	108	-33	-174	-314
	(6) Kulungkung PDAM	Demand (lit/s)	151	169	206	245	282
		Capacity (lit/s)	235				
		Balance (lit/s)	84	66	29	-10	-47
	Total [5+6]	Demand (lit/s)	496	605	783	963	1,140
		Capacity (lit/s)	775				
		Balance (lit/s)	279	170	-8	-188	-365
Total (A+B)	Total [1+2+3;+4+5+6]	Demand (lit/s)	2,854	3,771	4,911	6,054	7,192
		Capacity (lit/s)	3,398				
		Balance (lit/s)	544	-373	-1,513	-2,656	3,794

(2) Alternative Water Sources

<Surface Water>

According to the article to provide water use of the new water low -2004 (Chapter 4 Article 26(5)), water resources utilization shall be based on the relatedness of rainwater, surface water and groundwater by prioritizing the utilization of surface water. This is why the surface water potential is rather easy to be known in place, at time and in volume, and also countermeasures against the impacts to natural and social environments form development are rather easy to establish.

Surface water development has two methods: 1) direct intake from river and 2) storage rainy season discharge at reservoir. In both cases, it is necessary to arrange water right with downstream users. The water supply agreement of SARBAGITAKU areas give the priority to surface water development at the river mouth to avoid conflict with existing water users. The alternative plans of surface water development for SARBAGITAKU area are shown in Table-II-4.4.

Table-II-4.4 Alternative Plans of Surface Water Development for SARBAGITAKU Area

River	Catchment Area	Development Method	Development Scale	Explanation
Ayung	301.92 km^2	Storage	1,800 lit/s	✓ Storage method can develop a large volume of water ✓ In the case that the intake points are upstream or midstream reaches, it is necessary to arrange the water right with existing users.
		Direct Intake	200 lit/s	
Penut	190.36 km^2	Direct Intake	300 lit/s	
Empas	107.08 km^2	Direct Intake	200 lit/s	
Hoo	170.61 km^2	Direct Intake	300 lit/s	
Balian	154.74 km^2	Direct Intake	900 lit/s	
Oos	119.95 km^2	Direct Intake	100 lit/s	
Petanu	96.89 km^2	Direct Intake	300 lit/s	
Sangsang	84.12 km^2	Direct Intake	100 lit/s	
Unda	232.19 km^2	Direct Intake	500 lit/s	

<Spring and Groundwater>

Spring water and Groundwater are access-friendly water resources with relatively good water quality and could be easily developed near the consumer area. However, development volumes of spring and groundwater are limited and not suitable for large scale development. Regarding spring water development, O&M cost is less expensive than that of groundwater development. However, it is necessary to arrange water right with downstream users. Regarding groundwater development, it is necessary to use groundwater within sustainable potential. Refer to Table-II-4.5.

Table-II-4.5 Spring/Groundwater Use and Potential (SARBAGITAKU Area)

Items / Regency	Spring (lit/s)			Groundwater (lit/s)		
	Potential	Current Use	Remaining	Potential	Current Use	Remaining
Tabanan	4,149	1,862	2,287	2,489	99	2,390
Badung	1,335	478	857	1,075	546	529
Denpasar	0	0	0	292	647	-355
Gianyar	3,052	1,812	1,240	1,246	442	804
Kulungkung	263	135	128	181	34	147
Penida	525	20	505	288	5	284
Total	9,324	4,306	5,018	5,571	1,773	3,799

<Water Source Options by Consumed Scale>

According to the consumed water volume, SARBAGITAKU area divided into two groups of area: 1) Large-Scale Consumed Area and 2) Medium & Small Scale Consumed Area. Refer to Table-II-4.6.

Large-Scale Consumed Areas: To meet a large amount of water demand, the development of river water is inevitable. As options of river water development, Ayung, Penet and Putanu rivers are promising in the area. Out of the area, Balian, Hoo, Empas, Oos, Sangsang and Unda rivers are possible to develop.

Medium & Small Scale Consumed Areas: For these areas, development of spring and deep well are suitable. To distribute water by gravity, development points will be the upstream points from the consumed areas.

Table-II-4.6 Water Source Options for Water Supply (SARBAGITAKU Area)

Area	Consumer	Zone	Supplier	Options of Water Source
Denpasar & Surrounding Area (SARBAGI)	Large Scale	Denpasar	DEN-PDAM	Surface Water: Ayung River (Storage, Direct Intake)
		Northern Kuta / Badung	BAD-PDAM	Surface Water: Punet River (Direct Intake)
		Central Kuta / Badung	BAD-PTTB	Surface Water: Putanu and Unda Rivers (Direct Intake)
		Southern Kuta / Badung		
		Southern Part of Gianyar	GIA-PDAM	Surface Water: Putanu and Unda Rivers (Direct Intake) + Groundwater
	Medium Small	Northern Part of Gianyar	GIA-PDAM	Spring + Groundwater
		Northern Part of Badung	BAD-PDAM	Spring + Groundwater
Other Area (TAKU)	Medium Small	Tabanan	TAB-PDAM	Surface Water: Hoo River (Storage and Direct Intake) + Spring + Groundwater
		Kulungkung	KLU-PDAM	Spring

(3) Zero Option for Water Supply Project

The new Water Law, 2004 stipulates that "The state guarantee the right of every person in obtaining drinking water to fulfill a healthy, clean and productive life." If the Bali Provincial Government (or PDAM, water supply company) does not undertake this water supply project, which would systematically address the rapid increase in water demand in the coming 20 years, the following situations are considered to ensue.

<Effects on Human Health>

Water supply projects are an endeavor that is directly related to the health and safety of people, and aims at the enhancement of the health status and living standard of people through the installation and improvement of hygienic water supply facilities. If a water supply project satisfying the demand is not implemented, it is expected that people would seek the use of other contaminated or deteriorated water resources. This would result in deterioration of hygienic condition and increase in waterborne infectious diseases such as diarrhea.

<Effects on Water Supply Services and Local Community>

Water supply projects are obliged to involve periodical renewal and improvement of facilities, as well as expansion of facilities responding to population growth and improvement in the quality of life of people.

If there is no supply of water that can be drunk safely and is delivered stably, people are expected to depend on alternative water resources other than supplied water. In such case, water charges would not be collected as they should, and water supply authorities would be unable to pay the costs of periodical renewal and expansion of facilities. This would represent a significant disadvantage for the local community.

<Water Environmental Impact from the Development of Easily Accessible Water Resources>

The project area contains 60 deep wells that are used as the sources of potable and industrial water. While the total groundwater potential in Badung Regency and Denpasar City is estimated to be 823 lit/sec, the volume of current use has already reached 561 lit/sec (68%). If water supply is not augmented by the implementation of this project, people are expected to accelerate the development of easily accessible groundwater sources including shallow wells and deep wells.

SARBAGI (Bali Provincial Metropolitan Areas) is located in the coastal alluvial plain comprising intercalating Quaternary clay layer. Because of this, groundwater extraction exceeding its potential would lead to extensive groundwater depletion, as well as land subsidence due to consolidation of clay layer. Inflow of saline water is also anticipated, since the electric conductivity of water in a shallow well near the coastline has reached 1,100 μS/cm.

<Impact of Frequent Water Supply Restriction on Daily Living>

If the demand for alternative water resources is not satisfied by the expansion of supply capacity, a situation would result where a drop of water pressure and restriction of water supply take place routinely. In Denpasar City, water supply restriction is enforced every afternoon, and local people are coping with this situation by storing water in tanks and pails. Persistence of such situation would have a social impact on the daily living of the inhabitants.

As explained above, the Zero Option (no implementation of the water supply project) is not a viable alternative, because it would cause adverse effects on people's health, the local community, and the water environment in the vicinities.

(4) Alternatives of Integrated Water Supply System

The current demand of the Denpasar Metropolitan Area through public water supply system is 2,358 lit/s. This demand is estimated to increase to 6,052 lit/s (about 2.6 times of the current demand) in the target year of 2025.The increased volume will be 3,694 lit/s. To meet the increased demand, the Study Team proposes the following new water supply systems for the Metropolitan Area.

- <u>For northern parts of the area (Northern parts of Badung and Gianyar regencies):</u>
  To meet small or medium scale demands in the different areas, springs and deep wells in the territory will be developed to minimize the water conveyance distance from water sources to the service area according to the potential of each area
- <u>For southern parts of the area (Denpasar and Southern parts of Badung and Gianyar regencies):</u>
  To meet large scale demand in the intensive areas, river flows in the territory first and outside the territory secondly will be developed to economize construction cost and to minimize the impacts to natural & social environments. This integrated water supply system is composed of three (3) sub-systems namely Western System, Central System and Eastern System.

The integrated water supply system for Metropolitan Area is examined and alternative plans of each sub-system are shown in Table-II-4.6 and Figure-II-4.1 to Figure-II-4.4.

Table-II-4.7 Alternatives of Integrated Water Supply System for Metropolitan Area

System and Alternatives	Intake Point	Water Treatment Plant	Water Conveyance	Remarks
Western System	Capacity: 300lit/s Service Area: Mainly middle parts of Badung regency Water Source: Penet River located on the boundary between Badung and Tabanan regencies Terminal Point of Main Water Conveyance Line: KEROBOKAN			
W1	Middle reach of Penet river	Kapal	Pump intake and gravity conveyance	Some existing intakes for irrigation and water supply in downstream.
W2	Mouth of Penet river	Mungu	Pump intake and gravity conveyance	No intake in downstream
Central System	Capacity: 1,800lit/s Service Area: Denpasar and southern parts of Badung regency Water Source (1): With dam in Ayung river Water Source (2): Without Dam, a) Surface water, b) Groundwater, c) Surface water + Groundwater Terminal Point of Main Water Conveyance Line: Existing IPA-Ayung			
C1 (With Dam)	Downstream near dam site	Downstream near dam site	Gravity intake and gravity conveyance	Some existing intakes for irrigation and water supply in downstream
C2 (With Dam)	Middle reach of Ayung river	Near existing IPA-Ayung	Pump intake and no conveyance	Some existing intakes for irrigation and water supply in downstream
C3 (Without Dam)	Surface Water	Near existing IPA-Ayung	Pump intake and pump conveyance	Intake points: River mouths of 6 rivers
C4 (Without Dam)	Groundwater	Near existing IPA-Ayung	Well production and pump conveyance	Well: 180 deep wells
C5 (Without Dam)	Surface Water + Groundwater	Near existing IPA-Ayung	Pump intake / well production and pump conveyance	Intake points: River mouths of 5 rivers Well: 90 deep wells
C6 (With Small Dam)	Middle reach of Ayung river	Near existing IPA-Ayung	Well production and pump conveyance	Small size of dam Well: 90 deep wells
Eastern System	Capacity: 800lit/s Service Area: Southern parts of Badung regency and southern parts of Gianyar regency Water Source: Petanu river and Unda river Terminal Point of Main Water Conveyance Line: Existing IPA/Badung Estuary			
E1	Middle reach of Unda river (Telagawaja)	Middle reach of Unda river (Telagawaja)	Gravity intake and gravity conveyance	Some existing intakes for irrigation and water supply in downstream Water Conveyance: Via Ubud
E2	Middle reach of Unda river (Telagawaja)	Middle reach of Unda river (Telagawaja)	Gravity intake and gravity conveyance	Some existing intakes for irrigation and water supply in downstream Water Conveyance: Via Sunrise Road
E3	Mouth of Unda river	Mouth of Unda river	Pump intake and pump conveyance	Water Conveyance: Via Sunrise Road
E4	Mouth of Petanu river + Mouth of Unda river	Mouth of Petanu river + Mouth of Unda river	Pump intake and pump conveyance	Water Conveyance: Via Sunrise Road Stage installation of intake point
E5	River mouth of Petanu river + Middle reach of Unda river	Mouth of Petanu river + Middle reach of Unda river	Combination of (1) Pump intake and pump conveyance + (2) Gravity intake and gravity conveyance	Water Conveyance: Via Sunrise Road Stage installation of intake point

Central System→ With Dam

System	Alternatives	Explanation
Central System	C1	Intake: Downstream of Dam Water Conveyance: To the existing IPA Ayung by Gravity Water Treatment: Beside the existing IPA Ayung
	C2	Intake and Water Treatment: Beside the existing IPA Ayung

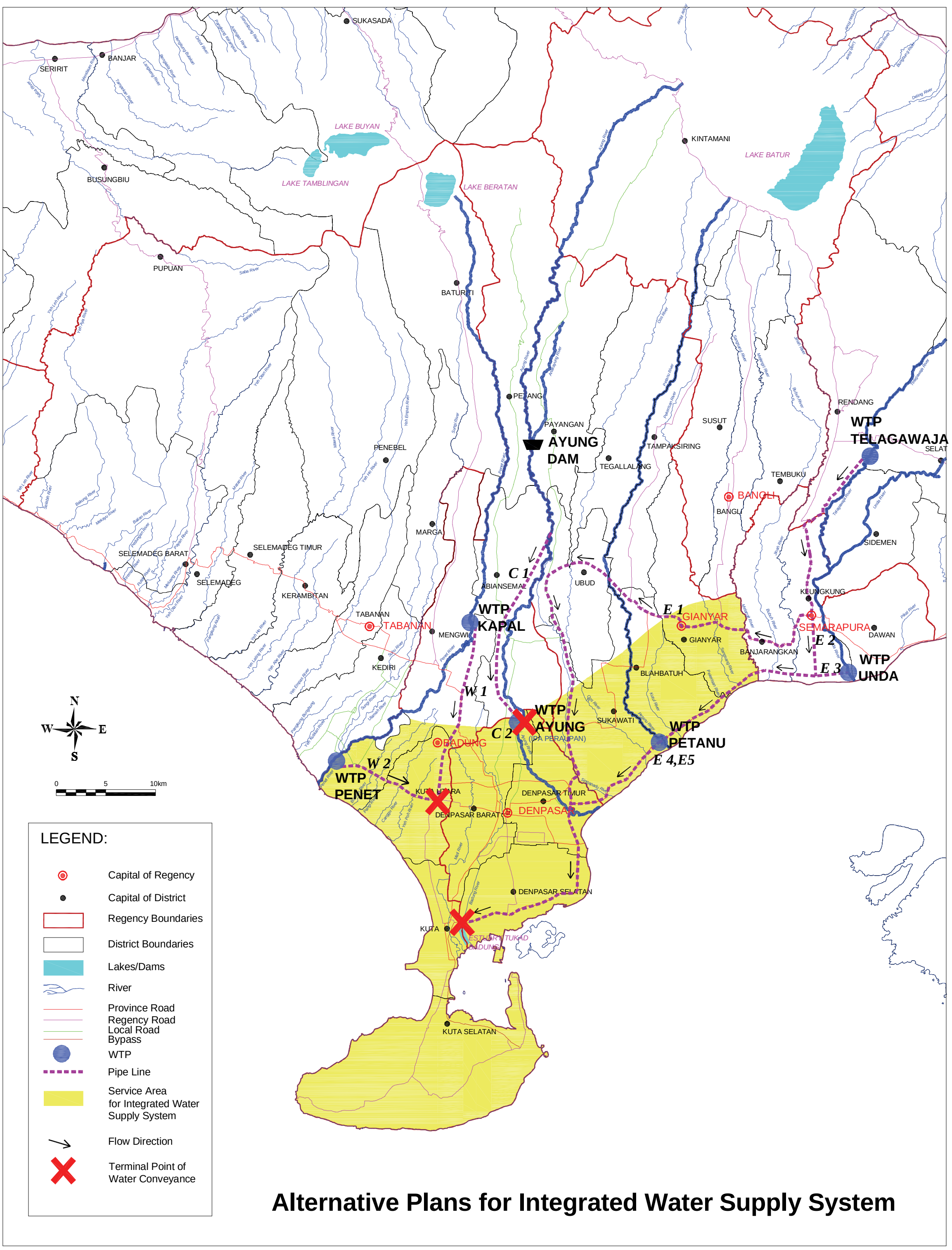


Figure-II-4.1 Alternatives for Water Supply for SARBAGI (With Ayung Dam)

Central System→ Without Dam

System	Alternatives	Explanation
Central System	C3	Water Source: Surface Water at River Mouths, Developmentt River and Volume: Balian R.→ 900lit/s, Hoo R. → 300lit/s, Empas R. → 200lit/s, Ayung R. → 200lit/s, Oos → 100lit/s, Sangsang R. → 100lit/s, Total Volume: 1,800lit/s
	C4	Water Source: Groundwater, Development Area: Tabanan, Total Volume: 1,800lit/s (180 Wells)
	C5	Water Source: Surface Water at River Mouths and Groundwater, <Surface Water> Hoo R. → 300lit/s, Empas R. → 200lit/s, Ayung R. → 200lit/s, Oos → 100lit/s, Sangsang R. → 100lit/s, Volume: 900lit/s, <Groundwater> Volume: 900lit/s (90 Wells)

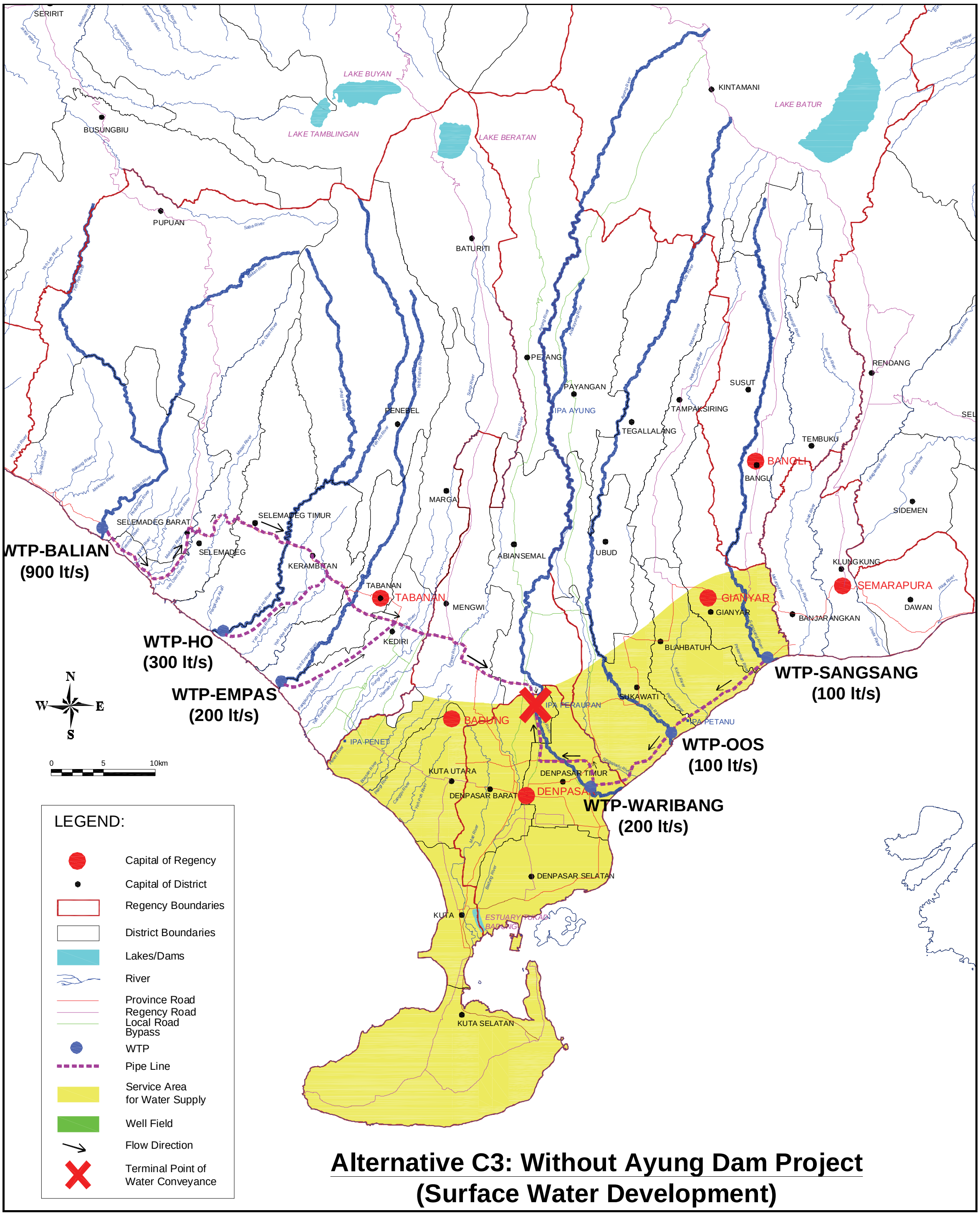


Figure-II-4.2 Alternative Plans without Ayung Dam (Surface Water Development)