CHAPTER 4. ENVIRONMENTAL CONDITIONS AND PRACTICES FOR ENVIRONMENTAL IMPROVEMENT

4.1 DRAINAGE AND SEWERAGE

At present the services of drainage and sewerage systems of the study area are managed by four organizations: Capital Development Authority (CDA), Water and Sanitation Authority (WASA)/Tehsil Municipal Administration (TMA) of Rawalpindi, and Rawalpindi Cantonment Board (RCB), based on their administrative jurisdictions. The drainage system of the Study Area is shown in Fig. 4.1.1, while the sewerage system is shown in Fig. 4.1.2.

4.1.1 Drainage and Sewerage in Islamabad

Islamabad had been developed from Sector 3, located in the East with the governmental offices and foreign embassies. This area is called as Diplomatic Enclave. The urbanized areas had been gradually developed toward West. Presently almost half of the projected urban areas have been developed until around Sectors of 10/11. According to the Urban Master Plan of Islamabad, the ultimate development will reach Sectors of 16. In accordance with the progressive expansion of the urban area in Islamabad, the drainage and sewerage system were designed and set-up from East to West employing the separate system for drainage and sewerage.

1) Drainage System in Islamabad

The drainage system has been installed in the existing urbanized area in CDA step by step, and the present whole built-up areas of Islamabad are in principle served with the drainage system. The Study Team obtained that of Sector I-8 as an example, as shown in Fig. 4.1.3.

According to an officer of CDA, the drainage system of the urbanized area in Islamabad was designed on the rainfall intensity of 75mm/hr, while the actual structural sizes of the existing drainage system were evaluated in the Study to be below the designed scales. However, Islamabad is located on the gradual slope from North to South, and due to the existing drainage system together with the favorable geophysical condition, its storm rainfall could be rather well drained into Lai Nullah. In fact, Islamabad never experienced any serious/disastrous inundation by the storm rainfall flooded except in 2001 flood. The 2001 flood caused the serious river overflow from Tenawali Kas and Saidpur Kas in Sectors I-8 and I-9, but the principal reason of the overflow in 2001 could be attributed to the backwater effect from the mainstream of Lai Nullah to drainage system, but not to shortage of the drainage capacity.

2) Sewerage System in Islamabad

The sewerage system was designed, as the urban development was prepared from East to West in the same way as the above design of the drainage system. Fig. 4.1.4 shows the sewerage system with trunk sewers in Islamabad. They were designed along the rivers to intercept the wastewater generated at households, institutions or others, to convey it to the treatment plant (activated sludge process), located at Sector I-9. The operational condition of the treatment plant is, however, so poor and beside other waster water is discharged without treatment. As a result the water quality of Lai Nullah is heavily polluted at about 100 mg/l of BOD.

The sewerage system in the flat plain may usually need some pumping stations between the generation points and the treatment plant. In Islamabad such pumping stations are, however, not required due to favorable geological conditions of the gradual slope form North to South.

The wastewater generated in the urbanized areas is collected and conveyed to the treatment plant located in Sector of I-9. The Service Department is not monitoring the plant at the regular basis, so the detailed data of water quality (influent and effluent) was not given to the Study Team. It was, however, observed that, due to lack of the treatment capacity and its poor maintenance, most of the collected wastewater is discharged into the Lai Nullah without proper treatment. This may be causing further pollution of the river. According to CDA, the present capacity of treatment plant is only 25% of the total wastewater generated in the area.

At the urbanized areas without direct connections with the sewerage system, on-site systems such as a septic tank are used. This system holds the wastewater from individual house within its premise and discharge into gutter after some kind of treatment. However this system does not work effectively, and discharges almost raw sewage. The French Government decided to provide with a low-interest loan in 2002 for renovation of the existing treatment plant and/or the new treatment plant of CDA. The design capacity of the existing and planned treatment plant is shown in Table R 4.1.1.

Table R 4.1.1 Design Capacity of the Water Treatment Plant of CDA.

Phase	Design capacity		Construction Year	Remark	No. of Served sectors
	MGD	m^3/day			
I	3	13,638	1964-1965	Operational	7
II	3	13,638	1966-1967	Operational	
III	6	27,276	1975-1985	Out of order	10
IV	15	68,190	from 2004	In Planning	9
V	N.A	N.A	N.A	Future Planning	N.A
Total	27	122,742			26

Source: Master Plan of Islamabad (1960)

The existing treatment plants had been completed through Phase I and II from 1964 to 1967. Based on the record of 11^{th} September 2002, the total wastewater flow at the existing treatment plants is estimated at only 1.5 MGD (6,819 m^3/day), which corresponds to only 25% of the total design capacity of 6 MGD (27,276m^3/day).

The quality of influent and treated wastewater at the existing treatment plants has not been analyzed on regular basis since 1995 because of lack of chemicals, according to the persons in charge. Based on the results of the wastewater quality analysis of 30 October 1994, BOD of the influent was 220 mg/l, while that of the effluent was 104 mg/l. This means that the removal rate was only 53%, which is obviously too law for the activated sludge process. The reason is that the aeration time of just 1.5 hours seems to be too short for the expected removal achievement of more than 80%. It is suggested at least to conduct frequent water quality analysis to monitor the existing treatment conditions. The sludge generated at the water treatment plant is dried in the drying bed for sale as fertilizer.

4.1.2 Drainage and Sewerage in Rawalpindi

The Rawalpindi Development Authority (RDA) has commenced the "Urban Water Supply & Sanitation Project Phase 1-Rawalpindi (UWSSP-R)" in 1996 through the budgetary allocation in the Eighth (8th) Five-Year Plan (1993-1998) together with the financial assistance from the Asian Development Bank (ADB). At the early stage of the UWSSP-R, the RDA formulated the Sewerage and Drainage Master Plan to improve the sewerage and drainage system in all the jurisdiction area of WASA. This objective area of the Master Plan covers an area bounded by Shahrah-e-Islamabad and Kahyaban-e-sir roads in the northeast and northwest of the project area (refer to Fig. 4.1.5)

The Master Plan consists of two (2) components of the Sewerage Master Plan and the Drainage Master Plan. The Sewerage Master Plan proposed to check the inflow of sewage from the area of WASA to the Lai Nullah through the following three (3) components of measures. The Master Plan is projected to complete in 2020, and upon the completion, the Lai Nullah would be no longer the outlet of the sewage, and its water quality would be remarkably improved.

(1) Improvement/expansion of the Sewerage Collection Systems, which collects all sewage throughout the aforesaid objective area of the Master Plan to a downstream point of the objective area, (near the point of "Moti Mahar Cinema"),

(2) Construction of the Transfer Sewer, which transfers all collected sewage as described above to the under-mentioned treatment plant about, and

(3) Construction of the Sewage Treatment Plant located at the north bank of Soan River.

As for the Drainage Master Plan, proposed was the following drainage improvement for the area of WASA of RDA, the east side catchment of the Lai Nullah in particular on the premises of the project implementation period of 14 year from 1996 to 2010.

(1) Channel improvement of Lai Nullah as the ultimate destination of the drainage water,

(2) Diversion of the existing primary drains called "Kassi East" and "Kassi West" running the center of the east catchment of the Lai Nullah.

(3) Improvement of secondary and tertiary collection

(4) Transfer strategy options for the primary drains

(5) Construction of pounding and pumping schemes for protection of low lying areas from the rainwater inundation

(6) Clean Drainage Campaign

1) Drainage System in Area of Rawalpindi Water and Sanitation Authority

There are the following three groups of major drains: (a) the drains of 13.2km in length with a top width over 1000 mm, (b) the drains of 5.3 km in length with a top width between 750 mm and 1000 mm and (c) the drains of 52.4 km in length with a top width between 500 mm and 700 mm. The total length of all types of drains is approximately 71.0 km. The drainage system and the typical cross section of drainage channel in Rawalpindi are as shown in Figs. 4.1.5 and 4.1.6, respectively.

Under UWSSP-R Phase I funded by ADB, new drainage system of Satellite Town area was constructed and diverted into Lai Nullah. The Asghar Mall Drain also needs to be constructed to improve the drainage system. The west side of the City area drains directly to Lai Nullah from the boundary of the central catchment, which is approximately close to Saidpur Road/ Circular Road/ Murree Road (South). Whereas the side of the City drains to the tributaries of Lai Nullah both called Kassi Nullah. One runs from Satellite Town and the other from Dhoke Kashmirian and they both outfall to Lai Nullah near RDA offices having come together at or near Nadeem Colony.

In the event of 2001 flood, large areas in Rawalpindi were inundated and some low–laying areas are always subject to inundation. As the detailed information of the design criteria was not available to the Study Team, it would be hard to judge how much the ADB-financed drainage improvement works could cope with the magnitude of the 2001 flood. It is, however, obvious that the present drainage system is far from satisfactory for the purpose.

2) Sewerage System in Area of Rawalpindi Water and Sanitation Authority

Sewerage in the City has been developed since 1953 but more progressively during the last fifteen years following proposals in 1971. Under UWSSP-R Phase I, trunk sewers are being laid to cater for the eastern part of the City and finally discharge into Lai Nullah. A portion of area sewers (lateral sewers) is also to be completed. Besides this land acquisition is being done for Sewage Treatment Plant, which will be executed under Phase-II of the Project. The sewerage system in Rawalpindi is delineated in accordance with the information collected through the Study as shown in Fig. 4.1.7

There are the main gravity sewers of about 11 km in length with more than 300 mm diameter in the City area and 4 km in length in the adjacent Satellite Town. A network of sewers now covers the central city area bounded by Lai Nullah, Ashar, Mall Road and Kassi Nullah, about 30 % of the City area. Sizes of principal sewers range from 225 mm diameter to 1200 mm diameter. The system discharges untreated sewage to Kassi Nullah, which flows into Lai Nullah from the east, just upstream of the confluence of the two Nullahs. The Cantonment is also served by a limited sewerage system. In UWSSP-R Phase-II, the outfall sewers will be designed taking into account the load of Cantonment area for the sewage treatment plant.

Under the Phase-I priority was given to sewer cleaning equipment and basic rehabilitation of the existing sewerage system, mainly by means of repairs to manholes. Provincial allowance is also included in the main sewerage cleaning packages for replacement of damaged sections of sewers as these are identified during the course of the cleaning works.

The scope of the Phase-II sewerage development proposals is to include the following components:

(a) Further rehabilitation of the existing sewerage system at key locations throughout the City. Area. New trunk sewers will be constructed in the following areas:

(i)	Central Sewerage District	: C-1 South East Area
(ii)	West 1 Sewerage District	: W1-1 City Saddar
(iii)	West 2 Sewerage District	: W2-2 South
(iv)	Trunk Sewer serving Satellite Town	: C-2
(v)	North Eastern Sewerage District	: NW-1 and NW-2

(b) New sewerage system in the above areas (excluding Satellite Town, where the adequate sewerage system has been completed)

(c) New house connections in the above areas (except Satellite Town)

4.1.3 Drainage and Sewerage in Rawalpindi Cantonment Area

The Sewerage Master Plan for Rawalpindi Cantonment Board was given to the Study Team. It discusses the present and future (up to year 2030) sewerage production, its collection, transportation, treatment and final disposal. It also discusses the problem in monitoring and maintenance of such services so as to maximize the public health, safety & welfare and to minimize any adverse environmental impact. This Master Plan will help to provide the basis for improvements to the necessary facilities for proper disposal of wastewater in the Cantonment area. Without such improvements, the incidents of water-related diseases and the occurrence of diarrhea, dysentery etc. may be expected to increase.

1) Drainage System in Rawalpindi Cantonment Area

No planned drainage system has been built in the Cantonment area. Surface drainage includes the network of man-made channels within the built-up areas that are intended to convey storm water with the natural channels draining the region within which the Cantonment lies.

The storm wastewater and effluent from households flows in small drains discharging into natural deep rivers. The storm water drains on the North- Eastern side falls into Lai Nullah, which discharges into the Soan River as shown in Fig. 4.1.5. The existing surface drainage system in the Cantonment area deemed to be adequate to drain normal storm water except for floods in Lai Nullah during heavy monsoon rains. In terms of management, however, more adequate maintenance on the facilities would be required

Management of the surface drainage requires knowledge of drainage patterns, a record of drainage assets, control of development to prevent encroachment of buildings into the drainage channels, and a citizenship awareness of their responsibilities regarding use of drainage facilities. Prior to the annual monsoon period (July-August) and campaign of drain cleaning is generally carried out by RCB to overcome the built-up of silt or debris that has accumulated in the drainage channels.

2) Sewerage System in Rawalpindi Cantonment Area

There is no definite plan about the drainage system in the Cantonment area. Rawalpindi Cantonment Board (RCB) puts a high priority on the sewerage system development than the drainage system. RCB completed “Sewerage Master Plan for Rawalpindi Cantonment Board” in February 2002. According to the Master Plan, it is proposed to install sewers and a wastewater treatment plant as shown in Fig. 4.1.7. RCB has a concept to convey wastewater collected in the Western side of the RCB area, to WASA sewers. It is likely that WASA will accept the concept.

RCB has not provided any areas within its jurisdiction with underground piped sewerage system. Where as some residents and army establishments are making use of septic tanks for disposal of wastewater, a major problem in the Cantonment area is addressed to the practice of disposing of untreated wastewater into Lai Nullah and its tributaries. Materials disposed of in this way reduce the self-purification capacity of the rivers and results in ultimate blockage. In addition to the above the presence of uncontrolled wastewater generates various adverse environmental impacts including the following:

(a) Attracts flies and encourages the communication of diseases thus reducing the likely improvement in general health brought about by improved water supplies.

(b) Encourages a poor standard of cleanliness throughout the Cantonment area.

(c) Detracts from the attractiveness of the Cantonment area.

(d) Decrease the aesthetic charm of the Cantonment area

(e) Creates a safety hazard.

(f) Creates a smell nuisance.

According to the Master Plan, the project area comprises the Cantonment area covering about 75.2 km^2, which is bounded by Rawalpindi City on Northeastern side and Islamabad on Northern side. The main two proposed sewerage systems located east and west of the GT Road, each discharging into an independent sewage treatment plant are identified as WTP EAST and WTP WEST. There is a plan to switch the existing septic tank areas to a centralized sewerage system, which will be discharging into an independent plant identified as the Treatment Plant at Chaklala. The sewage flows are summarized in the table below. The flows of ADF and PDF are predicted for three sewerage systems in year 2030.

Table R 4.1.2 Flow Prediction of Water Treatment Plant in Year 2030

Sewerage System	ADF (m^3/day)	PDF (m^3/day)
WTP West	82,944	165,890
WTP East	188,610	377,220
WTP Chaklala	4,086	8,172

Source: Sewerage Master Plan of RCB (Phase-III)(Feb. 2002)
Note: ADF = average daily flow, PDF= peak daily flow

WTP East is the largest among the three systems, and WTP Chaklala is the smallest. For the prediction of the daily flow the three systems are applied with the same PF (Peak Factor) of 2, reflecting the almost the same development stage within the Cantonment area.

The effluent quality is proposed as follows:

(a) BOD : 40 mg / l

(b) Fecal Coli forms : Less than 1000 organisms /100 ml

For this requirements the following treatment process is proposed for WTP WEST and WTP Chaklala on small area: 1) screening, 2) raw sewage pumping, 3) grit chamber, primary settling tank, 5) aeration tank, 6) secondary settlement, 7) sludge pumping, 8) sludge digester, and 9) sludge drying and disposal. On the other hand, the oxidation ditch treatment (followed by maturation lagoon) is considered for the site of WTP East, because wider area is available here and cost saving is possible. This site also offers a greater buffer distance from anaerobic lagoons to the existing planned communities. The cost of the project proposed by the Master Plan is shown in the table below. The project is proposed for implementation in five stages up to year 2018.

Table R 4.1.3 Summary of Cost for Sewerage Development System in RCB

S. No	Component		Amount (Rs million)
1	Sewer Construction	• West • East • Chaklala	159.77 825.31 21.72
2	Treatment Plant Construction	• West • East • Chaklala	247.00 558.00 30.00
3	House Connections (175,000 Nos)		1225.00
4	Land Acquisition	• West (6.5 ha) • East (232 ha) • Chaklala (1.6 ha)	25.60 69.00 8.00
5	Subtotal		3169.40
6	Contingency (5%)		158.47
7	Consultancy (3%)		95.08
8	Total		3422.96

4.1.4 River Water Quality

The river water around the Study Area is generally heavily polluted due to garbage dumping and discharge of untreated wastewater. The pollution level is very high especially in Rawalpindi area, because Lai Nullah and its tributaries are receiving a large volume of polluted wastewater generated in the urbanized area and huge amount of solid waste dumped, which has been deteriorated in the rivers. Those pollutions are accumulated in down streams in Rawalpindi.

In Pakistan it is not common and regulated by law to take water samples in the systematic way to monitor the water quality of the rivers. So, no series of water quality analysis of Lai Nullah and its tributaries was available to the Study Team. A sample of the river water quality around the Study Area was analyzed in April 2000: the sampling points and their water quality data are as shown in Fig. 4.1.8 and Table 4.1.1, respectively. According to the data, the worst water quality was almost as polluted as raw sewage.

4.2 SOLID WASTE MANAGEMENT (SWM)

4.2.1 Law and Organization for SWM

The Study Area is covered by three authorities related to the SWM: CDA (Capital Development Authority), TMA (Tehsil Municipal Authority) and RCB (Rawalpindi Cantonment Board). The SWM service for Islamabad and Rawalpindi areas are described basically in the following laws and regulations:

(1) "The Local Government Act 2001", to describe the roles of Province (Zila Nazim), Tehsil on execution of SWM, and Union on support for execution of SWM.

(2) "The Punjab Local Government Act 2002".

In addition CDA is ruled by "Islamabad Capital Territory Municipal Byelaw 1968". The SWM for RCB is described in "The Cantonment Act, 1924". However, CDA and TMA have no specified law/regulation for SWM. RCB has a special section called as Sanitary Section to collect and dispose of solid waste.

Since the situations concerning the solid wastes have been changing largely in quality and quantity, a long-term strategic policy for SWM is required and upgraded at regular basis. However at present there is no such a long-term plan for these three authorities. They are just involved in the daily collection, transportation and disposal of solid wastes without long-term plan for SWM. They are not aware of how much solid wastes are generated, what kinds of components they are consisted of, and how their characteristics are changing. Due to lack of the collection capacity, they are just collecting some of the generated solid wastes and transporting them to an open dumping site. Only in the jurisdiction area of TMA, some of the solid wastes are transported to the disposal site located near to the airport and covered with soil. It is obvious that the remaining wastes are disposed of in empty lands or into rivers.

4.2.2 Solid Waste Collection Ratio and Served Population

The collection service area of CDA and TMA are limited to the urban centers not covering the remote rural areas, informal administrative villages and communities like " Kachi Abadis" as shown in Fig. 4.2.1. As the results, the collection rations of CDA and TMA are limited to about only 41% and 66%, respectively The non-SWM service areas, therefore, are forced to dispose their own solid waste by themselves causing inappropriate dumping of solid wastes anywhere in and around their communities. As there is no commitment of SWM services by the local government in these areas, the sanitation section officials of CDA and TMA are not almost aware of the present conditions of the service level. The "laissez-faire" policy on SWM has been deteriorating the environment, including the conditions of Lai Nullah and its tributaries. The dumped solid wastes are accumulated in the riverbeds, and the smooth flow is disturbed eventually. In case of a flood, the accumulated wastes may resist the smooth flow of the river and cause the overflow from the bank. Based on the information from three relevant authorities, the total volume of solid waste generated in the jurisdiction area of CDA, TMA and RCB is estimated at 2,150 ton per day, while the volume collected is 1,800 ton per day, which corresponds to only 83% of the generated solid waste as below.

Table R 4.2.1 Solid Waste Collection Ratio and Served Population

Authority	CDA	TMA	RCB	Total
Estimate solid waste generation (t/day)	550	700	900	2,150
Unit generation (kg/c/d)	0.92	0.47	1.00	0.72
Amount of collection (t/day)	500	600	700	1,800
Collection ratio (% , area-wise)	90%	85	78	83
Population (1,000)	600	1,500	900	3,000
Served population (1,000)	250	1,000	900	2,150
Served population ratio (%)	41	66	100	71

Source: JICA Study Team 2002

4.2.3 Functions of Solid West Management (SWM)

"The Local Government Act 2001" describes the functions of SWM to local governments, as follows:

(1) Sweeping（street, road, park, public space）

(2) Door to door collection of waste from residential to commercial areas.

(3) Transportation and disposal of garbage

(4) Removal of dead animals.

(5) Maintenance of public toilet.

(6) Maintenance of six weekly bazaars.

In the line with the concept, the Sanitation Directorate of CDA has started, in 2000, the "New Management Plan" to give additional works beyond the regulated functions including: (1) Sweeping of major/service road in Monday, (2) Cleanliness in one private sector in Tuesday, (3) Cleanliness/inspection of private sector in Wednesday, (4) Collective cleanliness program in Thursday, (5) Cleanliness of marks and public places in Friday and (6) Claening of streets and weekly bazaars in Saturday.

4.2.4 Categorization of Solid Wastes

It is clear that the solid wastes contain a wide variety of wastes: from relatively safe one to highly dangerous one. This is the reflection of the real life, which uses many different kinds of materials. Therefore it is a common practice to define the solid wastes according to the characteristics in many developing or developed countries.

However CDA, TMA and Cantonment at present have no special classification of dangerous solid wastes such as industrial waste, hazardous waste and infectious hospital waste. They are just collecting these wastes together with other usual wastes and dispose of them on the same dumping site. The hospital is responsible for safe disposal of the infectious hospital waste disposal. In spite of the "Medical Waste Guidelines" prepared by Ministry of Health, medical doctors and workers of small clinics and hospitals are reluctant to follow the guideline in their daily works due to financial reasons or lack of facilities. The authorities concerned are not taking any effective measures to stop such unfavorable activities.

As mentioned above, it is essential to understand what kinds of components are contained in the solid waste. In Japan there is a large volume of the database concerning the matter. When the database is available, it becomes quite easy to compare the differences of components of solid waste among the cities, and to assess their historical trends as well as the future forecasting. However in Pakistan, as these kinds of data are not accumulated, it is difficult to conduct simple things in the SWM services. The Study Team had attempted to collect some data for the waste components, and based on them, the components of solid wastes in Pakistan are preliminarily estimated as listed below:

Table R 4.2.2 Component of Solid Waste (TMA)

Component	House	Restaurant	Hotel	Shop	Market	Office	Road sweeping
Paper	5.3	2.6	19.5	16.8	7. 1	48.0	2.6
Kitchen waste	59.3	80.6	43.1	14.1	48.2	15.5	69.7
Plastics	5.2	0.9	6.7	20.0	3.9	3.9	3.5
Textile	3.0	0.0	4.6	4.0	16.2	3.9	4.4
Wood, grass	9.7	0.0	0.3	26.9	22.4	1.1	5.8
Rubber, leather	0.2	0.0	0.0	0.1	0.0	7.1	0.1
Metal	0.7	0.7	0.1	0.5	0.1	1.4	0.3
Glass, stone, bones	7.7	15.2	25.6	0.4	2.1	12.0	3.8
Earth & sand	8.2	0.0	0.0	17.2	0.0	7.1	9.8
Others	0.7	0.0	0.1	0.0	0.0	0.0	0.0
Combustible Waste (%)	83.4	84.1	74.3	81.9	97.8	79.5	86.1
Incombustible Waste (%)	16.6	15.9	25.7	18.1	2.2	20.5	13.9
Density (kg/l)	0.3 1	0.07	0.24	0.10	0.21	0.03	0.27

Source: Solid waste management improvement study in Rawalpindi 1995(JICA)

4.2.5 Collection, Transportation and Disposal System

A sanitary worker collects bags of solid wastes at doors of the houses (door to door collection system) and transports them to the primary collection place (such as containers or concrete bins). CDA, TMA or RCB then collect and transport the solid wastes from the primary collection place to the final disposal site. The owners of markets, factories and offices are, however, obligated to transport their generating wastes directly to the disposal site. A handcart (20 to 25 kg) is used for collection of the bags of the wastes from houses, and a handcart and/or a mechanical road sweeper are for transportation of the solid wastes on the roads to the primary collection place. A garbage trolley (500 kg), a skip, a skip lifter, collector truck, and tractor trolleys are further used for transportation of the bulky solid wastes accumulated at the primary collection place to disposal site.

4.2.6 Recycling by Scavengers

The scavenger is called as the person, who finds and collects valuable materials in the solid waste and sells them. The work itself is simple and anybody including children can scavenge and secure a minimum level of income. Therefore the scavenging is a method with which unskilled people can live in urban areas. They are in a meaning contributing to the recycling and reuse of materials by reducing the solid waste amount. However the working as well as living conditions shall be considered carefully, because they are always facing quite dangerous wastes such as glasses, syringes and infectious wastes. It would be necessary to understand their living conditions from the viewpoint of social welfare and poverty alleviation. In this Study the existing conditions of scavengers are investigated. There are about 200 scavengers in Islamabad, and about half of them work at the dumping site of H-12. There are also some 900 to 1,000 scavengers in Rawalpindi (in the jurisdiction area of TMA not including the area of RCB).

Interview survey to the scavengers was carried out through the Study in both Islamabad and Rawalpindi. According to the results of interview survey, they are collecting wastes of about 25 kg per day. Their income is estimated in the range of Rs 150 to 300 per day, which is a quite low securing only minimum level of living in the urban area. In terms of their contribution to the material recycling, however, the figure of 1.5~2% of the wastes is estimated to be recycled in Islamabad and about 4% in Rawalpindi.

4.2.7 Equipment and Facilities for Collection of Solid Waste

Vehicles are usually used to collect solid wastes from generators. The existing vehicles for collection of SW for the Study Area (CDA, TMA and Cantonment) are listed below:

Table R 4.2.3 Vehicles for Collection of Solid Waste

Authority/Board	Collection Vehicle	Number
CDA (Capital Development Authority)	Refuse compactor	15
	Skip lifter	5
	Bedford vehicle	8
	Tractor trolley	8
TMA (Tehsil Municipal Authority)	Mazda T-3500	16
	Tractor	5
	Container truck	30
	Dumper	4
	Recovery vehicle	1
	Front end loader	1
RCB (Rawalpindi Cantonment Board)	Truck	23
	Tractor blade	2
	Road mechanical sweepers	4
	Pickup truck	5
	Auto loader tractor	5

The facilities required for an effective SWM are the workshop to maintain and repair the machines, parking site, and the dumping site to dispose of solid wastes. In a large service area the transfer station may be required to load solid wastes to larger vehicles by reloading solid wastes in case it is proven to be more economical. Utilities like electricity and water are also important to operate and maintain these facilities.

In the jurisdiction area of CDA, electricity and water are available for the workshop and parking sites at G7/1. At present there is no designed damping site, but a site of about 1 km^2 in Block H-12 is being used as the tentative damping area. For the future a site at Kuri is selected, which is located 22 km from Zero Point (about 25 min). The area is about 100 acres (40 ha).

In Rawalpindi the workshop is located at Mukhsigah State with both electricity and water available. The parking site is located at the Community Center in Satellite Town. The present dumping site is located at Dhoke Gangal (25 Acre, or 10 ha), which is near to Air Force Airport, distanced by 5 to 8 km from the center of the City. Neither electricity nor water is available for the present site. TMA is planning to construct a new dumping site (85 Acres, or 34 ha), which is located about 25 km far from the center of the City. For the new site electricity is planned and water will be supplied from a well.

In Cantonment area the workshop and parking site are located at Gawal Mandi with electricity and water available. The present dumping site (23 acres, or 9 ha) is located along Mistral Road with distance of 10 km from the Cantonment Board Office. There is no plan to construct a new dumping site.

4.2.8 Other Information on Solid Waste Management

Composting and incineration technologies are not introduced in the study area. It is known that the hazardous wastes such as the used medical squirts; hypodermic needles, scalpels, and tweezers are sold in Bazaars of Rawalpindi. In order to improve the present unfavorable solid waste management system, the Government of Japan donated collection vehicles for collection and transportation of the solid wastes to TMA through grant aid program in 1996, and two (2) JOCVs in the field of SWM and one JICA short-term expert of SWM were dispatched to TMA in 2001 and to EPA in 2002, respectively.

Community based SWM Improvement Project in Rawalpindi was also carried out through UNDP fund from 1996 to 2000. This project was called as SWEEP (Solid Waste Management & Environment Enhancement Project). The Project aimed at nurturing community leaders so that the leaders could enlighten the community members on SWM improvement in each district by discussion. The relevant activities posterior to the Project could not be well prevailed, but it was evaluated that the Project gave a certain impact on the concept of “Community Participation to SWM” and “Source Garbage Reduction Method”.

4.3 WATER USE AND WATER RESOURCES

4.3.1 Present Water Supply Capacity in the Study Area

The present water supply in the study area is administrated by the three (3) independent entities; namely, (1) Capital Development Authority (CDA), (2) Water & Sanitation Agency (WASA) under Rawalpindi Development Authority (RDA), and (3) Rawalpindi Cantonment Board (RCB). Islamabad is wholly under jurisdiction of CDA. On the other hand, Rawalpindi is divided into jurisdiction areas of WASA and RCB.

The present water supply capacity for the study area is about 172.8 MGD (785.5 MLD) in total. Out of the total water supply, the service area of CDA (i.e., Islamabad) shares 111.6 MGD (64.6%), while the service areas of WASA and RCB share 27.0 MGD (15.7%) and 34.2 MGD (19.8%), respectively as listed in Table R 4.3.1.

Table R 4.3.1 Water Supply Capacity for the Study Area

Service Area	Water Source	Treatment Plant	Dam Reservoir	Supply Capacity as of '02	
				MGD	MLD
Area of CDA*1	Kurang River	Korang	-	4.0	18.2
		Shadhara	-	1.6	7.3
	Soan River	Simly	Simply	42.0	190.9
	Haro River	Sangjani	Khanpur	16.5	75.0
	Lai Nullah	Said Pur	-	0.8	3.6
		Noor Pur	-	0.7	3.2
	Surface and groundwater	Augmentation		12.0	54.6
	Groundwater	-	-	34.0	154.6
	Sub-total for Area of CDA			111.6	507.3
Area of WASA*2	Kurang	Rawal	Rawal	8.0	36.4
	Haro River	Sangjani	Khanpur	1.0	4.5
	Groundwater	-	-	18.0	81.8
	Sub-total for Area of WASA			27.0	122.7
Area of RCB*3	Kurang	Rawal	Rawal	10.0	45.5
	Haro River	Sangjani	Khanpur	19.7	89.6
	Groundwater	-	-	4.5	20.5
	Sub-total for Area of RCB			34.2	155.5
Total of Study Area	Surface Water			116.3	528.7
	Ground Water			56.5	256.8
	Grand Total			172.8	785.5

Source:
*1: Water Manage Directorate, CDA, 2002
*2: PC-1 for Project Improvement of Water Supply and Sewerage & Drainage System of Rawalpindi City, WASA, RDA, 2002
*3: Sewerage Master Plan for Rawalpindi Cantonment Board (Phase III), 2002

The source of the above water supply capacity is divided into the surface water and groundwater. The groundwater in the study area is abstracted by about 450 tube wells (i.e., 182 wells in the area of CDA, 194 wells in the area of WASA and 74wells in the area of RCB). A particular attention is herein given to the high percentage of the groundwater as the water source, which takes about 33% of the total water supply in the study area: the service area of WASA in particular high percentage of about 67%, as shown in Table R 4.3.2.

Table R 4.3.2 Share of Surface Water and Groundwater as Water Supply Source for the Study Area

Supply Source	Area of CDA		Area of WASA		Area of RCB		Whole Study Area	
	Capacity	Share	Capacity	Share	Capacity	Share	Capacity	Share
	MGD	%	MGD	%	MGD	%	MGD	%
Surface	77.6	69.5	9.0	33.3	29.7	86.8	116.3	67.3
Groundwater	34.0	30.5	18.0	66.7	4.5	13.2	56.5	32.7
Total	111.6	100.0	27.0	100.0	34.2	100.0	172.8	100.0

The surface water supply capacity of 116.3 MGD (528.7 MLD) for the study area is defined as the total capacity of the existing seven (7) treatment plans, which abstract the raw water from the dam reservoirs, or directly from the natural flow discharge of the small tributaries. Among others, the principal surface water sources are Simly Dam on Soan River, Khanpur Dam on Haro River, Rawal Dam on Kurang River, which has a supply capacity of 97.2 MGD (441.9 MLD) or 84% of the total surface water supply capacity as listed Table R 4.3.3.

Table R 4.3.3 Water Supply Capacity from Dam Reservoirs

Dam Reservoir as Surface Water Source	Service Area	Supply Capacity	
		MGD	MLD
Simly	Area of CDA	42.0	190.9
Khanpur	Area of CDA	16.5	75.0
	Area of WASA	1.0	4.5
	Area of RCB	19.7	89.6
	Sub-total	37.2	169.1
Rawal	Area of WASA	8.0	36.4
	Area of RCB	10.0	45.5
	Sub-total	18.0	81.9
Grand Total		97.2	441.9

4.3.2 Present Actual Supply Capacity and Per-capita Consumption

As described above, the present water supply capacity for the study area is 172.8 MGD. On the other hand, the actual daily water supply for sale to customers is limited to 85.9 MGD (390.5 MLD) or 49.7% of the supply capacity as listed in Table R 4.3.4.

Table R 4.3.4 Water Supply Capacity vs. Actual Water Supply for Sale to Customers

Service Area	(1) Supply Capacity		(2) Actual Supply to Customers		(1)/(2)
	MGD	MLD	MGD	MLD	%
Area of CDA	111.6	507.3	55.0*1	250.0	49.3
Area of WASA	27.0	122.7	19.4*2	88.2	71.9
Area of RCB	34.2	155.5	11.5*3	52.3	33.6
Total	172.8	785.5	85.9	390.5	49.7

Source *1: Water Management Directorate, CDA, 2002
*2: Water Supply Distribution System, Design Report, UWSSP-R, MMP, 1998
*3 Results of interview from RCB

The difference between the supply capacity and supply volume for sale could be attributed to several factors such as; (a) unaccounted water including leakage of water and water tapping, and (b) non-operation of the water supply facilities including part-time operation of tube-wells, troubles of supply facilities, and power cut. The present urban population of Islamabad and Rawalpindi is estimated at over 2 million, whereby its average per-capita water consumption is estimated at about 221 liter/person/day based on the aforesaid actual water supply for sale to customers as listed in Table R 4.3.5.

Table R 4.3.5 Gross Per-capita Consumption for Domestic, Public, Commercial and Industrial Use

Item	Unit	Islamabad	Rawalpindi	Whole Study Area
Average Daily Supply	(MLD)	250	161	411
Population	(persons)	621,000*1	1,455,000*2	2,076,000
Service Ratio	(%)	100*1	85*2	90
Served Population	(persons)	621,000	1,236,750	1,857,750
Gross Per-capita Consumption	(lit/person/day)	403	130	221

Source: *1: The Regional Study for Water Resources Development Potential for the Metropolitan Area of Islamabad-Rawalpindi, JICA, 1987.
*2: PC-1 for Project of Improvement of Water Supply and Sewerage & Drainage System of Rawalpindi City, WASA, RDA, July 2002

The above per-capita consumption includes the domestic, public, commercial and industrial use. Accordingly, the net-per capita consumption purely for the domestic use would be far smaller than the estimated value of 221 liter/person/day. According to results of the Study by JICA in 1988, the share of per-capita consumption for the domestic use to the total consumption in 2000 was estimated at 40% for Islamabad and 57% for Rawalpindi. Assuming these rates, the per-capita consumption for the domestic use is estimated as below:

Table R 4.3.6 Per-capita Consumption for Domestic Use

Item	Islamabad	Rawalpindi	Whole Study Area
Gross Per-capita Consumption	403 lit./person/day	130 lit./person/day	221 lit./person/day
Share of Domestic Use	40%	57%	47%
Per-capita Consumption for Domestic Use	161 lit./person/day	74 lit./person/day	103 lit./person/day

Source: *: The Regional Study for Water Resources Development Potential for the Metropolitan Area of Islamabad-Rawalpindi, JICA, 1987.

4.3.3 Forecast of Future Water Demand and Deficit

Islamabad and Rawalpindi have recorded the annual population growth of 5.7% and 3.4%, in the recent ten (10) years, respectively. The population growth of Islamabad is the highest among the major cities in the country, and even the growth rate of Rawalpindi is the ninth highest. Such high urban population growth together with expansion of the government offices and other industrial/commercial entities would bring out the substantial increment of water demand year by year in the future. The future water demand for Islamabad and Rawalpindi was estimated in the previous relevant studies and/or the water supply development plans. According to them, the present water supply capacity for Rawalpindi (i.e., the area of WASA and RCB) falls below the present potential water demand leading to the chronic water shortage as listed in Table R 4.3.7. On the other hand, the supply capacity for Islamabad (i.e., the jurisdiction area of CDA) could apparently meet the future incremental water demand for the time being. Nevertheless, the infrastructures for urban water supply in Islamabad have mostly completed their useful life and a lot of water leakage problems become abundantly visible in the city. Moreover the groundwater level is seriously dropping and causing difficulties in abstracting the water through tube-wells (refer to the following subsection 4.3.2). As the results, the CDA also could hardly secure the reliable water supply.

Table R 4.3.7 Comparison between Average Daily Water Production and Water Demand

Area	Present Supply Capacity		Water Demand (Daily Max.)					
			In 2001		In 2003		In 2010	
	MGD	MLD	MGD	MLD	MGD	MLD	MGD	MLD
Area of CDA[*1]	112	507	102	461	105	478	119	541
Area of WASA[*2]	27	123	50	227	56	255	78	355
Area of RCB[*3]	36	165	44	200	n.a.	n.a.	n.a.	n.a.

*1: The Regional Study for Water Resources Development Potential for the Metropolitan Area
*2: PC-1 for Project of Improvement of Water Supply and Sewerage & Drainage System of Rawalpindi
*3: Sewerage Master Plan for Rawalpindi Cantonment Board (Phase –III)

4.3.4 Degradation of Groundwater as Water Resources

As described in the foregoing subsection 4.3.1, about 30% of the present water supply to the study area relies on the groundwater as the water source, which is abstracted through about 450 tube-wells. Thus, the groundwater is the major water source for the study area. According to the results of interview surveys with CDA, however, the groundwater level has seriously dropped with an annual average rate of about 2m for the recent five (5) year, and the present level has reached 35 to 40 m below the surface ground level. It is also reported by WASA[1] that the groundwater level has dropped from 12m to 45m below ground level during a period of 1982-2001. As the results, the quantity as well as quality of groundwater as the important water source is close to a crisis.

The major reasons of the dropping of the groundwater levels would be attributed to the degradation of recharge capacity, and the excessive abstraction of the groundwater in the study area as enumerated hereinafter:

1) Degradation of Recharge Capacity by Unfavorable Human Activities in Upstream Watershed

The natural forests in the Margalla Hills are regarded as the significant source for recharge of the groundwater in the study area. However, the excessive quarrying works eroded the substantial extent of the forest. Moreover, the inhabitants also make unauthorized use of wood for cooking and heat in the area, and domestic cattle heads overgraze endangering the

[1] "Brief on Water & Sanitation Agency Rawalpindi for Tehsil Nazim/Chairman RDA, dated on August 22, 2002"

natural environment of the forest[2]. These unfavorable activities are likely to aggravate the recharging capacity by the forest in the Margalla Hills.

2) Degradation of Recharge Capacity due to Reduction of Unsealed Infiltration Area in Downstream Watershed

According to the estimates in the previous report[3], about 68% (70 km^2) of the area in Islamabad is remained as the unsealed natural infiltration area in 1981, while the natural infiltration area is being reduced due to the intensive urbanization and going to be reduced to 30% in 2030 due to progress of urbanization. This dynamic reduction of infiltration area is obviously enumerated as one of the principal causes for reduction of recharge capacity of the groundwater.

3) Excessive Exploitation of Groundwater as Water Source

The exploitation of tube-wells has been made with less consideration on the recharge capacity of the groundwater. Any reliable hydraulic investigation on the present states of groundwater has never been made in the study area, and therefore, the appropriate rate of abstraction volume of the groundwater is unknown. Judging from the serious dropping of the groundwater level, however, the current abstraction volume of the groundwater would exceed the allowable limit.

4.3.5 Water Resources and Water Supply Development Project

The on-going and proposed bulk water supply development projects for the study area are such as: (1) Metropolitan Water Supply Project, Phase-1 and 2 (Khanpur-I and II), and (2) the Urban Water Supply & Sanitation Project Rawalpindi, Phase I (UWSSP-R). Through these projects, the study area could increase the present water supply capacity of 172.8 MGD (785.5 MLD) to 265.9 MGD (1,208.8 MLD) in total as listed below:

[2] There exist about 56 quarries and 34 villages in and around the Natural Park with over 26,000 inhabitants.

[3] Refer to “Sustainable Groundwater Exploitation of the Lei-Nullah in 24th WEDC Conference” by Dr. Amir Haider Malic, 1998.

Table R 4.3.8 Present and Future Water Supply Capacity for the Study Area

Year	Supply Capacity (MGD)				Remarks
	Islamabad	Rawalpindi		Total	
	CDA	WASA	RCB		
Present (2002)	111.6 MGD (507.3 MLD)	27.0 MGD (122.7 MLD)	34.2 MGD (155.5 MLD)	172.8 MGD (785.5 MLD)	Refer to Table R 4.3.1
Future (2003)	111.6 MGD (507.3 MLD)	49.6 MGD (225.5 MLD)	53.9 MGD (245.1 MGD)	215.1 MGD (977.9 MLD)	- Increment of 13.6 MGD for WASA and 19.7MGD for RCB by expansion of Khanpur filtration plant under Khanpur-I - Increment of 8MGD for WASA by expansion of Rawal dam filtration plant under UWSSP-1 - Increment of 2MGD for WASA by expansion of tub-well capacity under UWSSP-I
Future (Indefinite)	128.1 MGD (582.3 MLD)	64.2 MGD (291.9 MLD)	73.7 MGD (334.6 MLD)	265.9 MGD (1,208.8 MLD)	Following increment of supply capacity would be made by expansion of Khanpur filtration plant under Khanpur II - Increment of 16.5MGD for CDA - Increment of 14.6MGD for WASA - Increment of 19.7MGD for RCB

The Metropolitan Water Supply Project (Khanpur-I) was proposed to have the daily water supply capacity of 51 MGD from the source of Khanpur dam reservoir to Islamabad and Rawalpindi. Out of the supply capacity, 16.5 MGD was shared to Islamabad, and its treatment plan as well as water distribution system was completed in 2000 with the financial assistance from Overseas Economic Cooperation Fund (OECF), Japan and now under operation.

The remaining 34.5 MGD is shared to Rawalpindi, and its treatment plant/distribution system is going to be completed by 2003 through the Urban Water Supply & Sanitation Project Rawalpindi, Phase I (UWSSP-I) by WASA with financial assistance from ADB.

Succeeding to Khanpur-I, Khanpur-II is now being proposed to expand the water supply capacity for Islamabad and Rawalpindi, although its completion time has not been fixed yet. Upon completion, Islamabad and Rawalpindi would have the supply capacity of 102 MGD. The share of water supply capacity under Khanpur-I and II is as listed in Table R 4.3.9.

Table R 4.3.9 Phased Development of Water Supply Capacity from Khanpur Dam Reservoir

Supply Area	Water Supply Capacity				Remarks
	Phase-1		Phase II		
	(MGD)	(MLD)	(MGD)	(MLD)	
Islamabad	16.5	75.0	33.0	150.0	Phase-I was completed in 1996
Rawalpindi (Area of WASA)	14.8	67.3	29.6	134.6	Phase I is to be completed by 2003
Rawalpindi (Area of RCB)	19.7	89.6	39.4	179.1	Phase I is to be completed by 2003
Total	51.0	231.8	102.0	463.7	

Source: PC-1 for Project of Improvement of Water Supply and Sewerage & Drainage System of Rawalpindi City, WASA, RDA, July 2002

The treatment capacity of the Rawal Lake Filtration Plant is now expanded as a component of the aforesaid UWSSP-I. This project component is scheduled to complete in 2002, and upon completion, the service area of WASA would increase the water supply capacity from Rawal dam reservoir from the present 8 MGD to 15 MGD. Installation of 20 new tube-wells and rehabilitation of 100 existing tube-wells are also being implemented through UWSSP-1. Moreover, WASA further intends to install the new tube-wells year by year with using the WASA’s own fund. Through these installations/rehabilitations of tube-wells, the groundwater supply capacity is projected to increase from 18MGD in 2002 to 22 MGD in 2010.

CHAPTER 5. HYDROLOGICAL AND HYDRAULIC STUDY

5.1 RAINFALL ANALYSES

5.1.1 Rain Gauge Stations

In the Study Area, there exist four (4) rain gauge stations, all of which are all being operated by PMD. They are the Chaklala (Islamabad International Airport), Islamabad (National Agromet Centre), Rawalpindi Agromet Center (RAMC) and Saidpur (Seismological Observatory) Stations.

According to "the Feasibility Report on Flood Control of Lai Nullah in Rawalpindi City, NESPAK – NDC Joint Venture, January 1987", five self-recording rain gauges were installed by CDA in 1960s, but they were very shortly closed after 3.5 to 5 years of operation. The present Islamabad Station used to be called Rawalpindi Station before it was moved from a place near the present RAMC Station to the present location in 1967.

1) Rainfall Observation

Locations and main features of the existing four stations are presented in Fig. 5.1.1 and Table R 5.1.1 respectively. The four (4) stations line up along the eastern boundary of the Lai Nullah Basin with an order of Saidpur, Islamabad, RAMC, and then Chaklala in the north to south direction. The Chaklala and Islamabad Stations have comparatively long operation period of more than 30 years, but the Saidpur and RAMC Stations are so new that they started measurement only 8 and 14 years back respectively.

Table R 5.1.1 Existing Rainfall Stations in Study Area

Station	Location			Year of Establi-shment	Frequency of Measurement	Year of Installation of Self-recorder	Remarks
	Latitude (North)	Longitude (East)	Altitude (m)				
Chaklala	33°37'	73°06'	500	1931	Every 3 hours	(1951)**	Islamabad International Airport
Islamabad	33°41.00'	73°03.87'	520	1967*	Every 3 hours	1999	National Agromet Centre
RAMC	33°38.88'	73°05.13'	500	1989	Three times a day	1989	Rawalpindi Agromet Centre
Saidpur	33°44.56'	73°03.91'	660	1994	Once a day	N/a	Seismological Observatory

Note: * The Islamabad Station (National Agromet Center) moved in 1967 to the present location, Zero Point, Islamabad from Rawalpindi.

** According to the Feasibility Report by NESPAK – NDC Joint Venture, at the Chaklala Station was installed in 1951 a self recording gauge, which no longer exists although it was reportedly operational until 1987 at least.

The frequency of rainfall measurement differs according to the purposes of each station. Rainfall measurement is made every three hours at 0200, 0500, 0800, 1100, 1400, 1700, 2000 and 2300 hours (PST) at the Chaklala and Islamabad Stations, three times a day at 0800, 1400 and 1700 hours at the RAMC Station, and once a day at 0800 hours at Saidpur

Station. A self-recording rain gauge is annexed to two stations, Islamabad and RAMC. In addition, the Chaklala Station also used to have a self-recording gauge between 1951 and 1980s.

2) Data Availability

The Study Team tried to collect short-time rainfall data such as hourly and 3-hourly data recorded during selected heavy rainstorms as well as all available daily rainfall data, visiting PMD Headquarter in Islamabad, Regional Meteorological Center in Lahore and the four stations. etc. Unfortunately the data availability does not correspond to the operation periods of the stations as shown in Tables 5.1.1 and 5.1.2. Considerable parts of precious old data are missing or were already lost, according to PMD officials.

The Chaklala Station is the richest in rainfall data with daily data of 58 years, 3-hourly data of 32 years, and hourly data of 21 years, followed by the Islamabad Station of which daily and 3-hourly data are available since 1983. The RAMC Station has daily rainfall data and self-recorder charts of 13 years since 1989. The new Saidpur Station is the poorest with daily data of 7 years.

Focusing on short-time rainfall data, especially hourly data during heavy rainstorms that are indispensable for analyses of flash floods like the 23 July 2001 Flood, the data availability is too low, mostly due to instrument troubles caused by such rainfall intensities. As seen in Table 5.1.2, hourly data are available only for a few rainstorms among the selected 53 storms since 1970. Due to inadequacy of the hourly rainfall data, the rainfall analyses are alternatively based on the 3-hourly rainfall data as described hereinafter.

5.1.2 Rainfall Characteristics

Using the collected rainfall data, rainfall analyses was made to know general characteristics of the rainfall in the Study Area in terms of duration and distribution in space and time.

1) Duration

First, accumulated rainfall curves of the Chaklala and Islamabad Stations during past major rainstorms were drawn in Fig. 5.1.2, where the accumulated rainfalls were converted in percentages of the total rainfalls. As seen in the figure, the rain duration was generally short. Almost all the rainstorms ended within 12 hours except for that of 27 August 1997, which lasted 24 hours.

2) Distribution in Space

The spacious distribution of storm rainfall in the Study Area was clarified based on the rainfall records of the recent floods on 29 July 1996, 27 August 1997 and 23 July 2001. As shown in Fig. 5.1.3, it is obvious that the three floods show different distribution patterns. The 1997 flood rainfall seems fairly uniform along the eastern basin boundary. The 1996 flood rainfall was biased towards the south. In the 2001 flood, the rainfall of 620.7 mm at Islamabad Station overwhelms those at the other three stations located within a radius of only 8 km. The differences are as big as 300 to 450 mm.

The 3-hourly rainfall data of the Islamabad Station were also plotted against those of the Chaklala Station in the right figure to examine correlation between the two stations. The result shows that no clear correlation is found between them. From the above analyses, it might be concluded that the localization of rainfall is quite significant and the spatial distribution pattern is different from flood to flood.

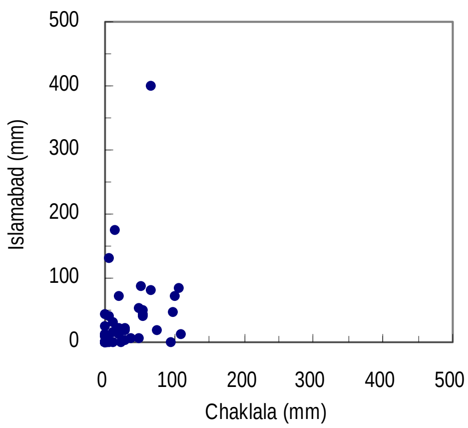

Fig. R 5.1.1 Correlation of 3-hourly Rainfalls

3) Distribution in time

Hyetographs were also drawn for the recent three floods as shown in Fig. 5.1.4 to know rainfall distribution in time. The hydrographs were based on the collected 3-hourly data except for the Chaklala Station of the 1997 flood and the Islamabad Station of the 2001 flood for which hourly data are by chance available. The same scales of graph axes were commonly employed for the three floods to facilitate comparison of the rainfall intensities.

First of all, surprisingly intensive rainfall is found at the Islamabad Station in the 2001 flood. Intensive rainfall over 130mm/hr continued 3 hours between 1000 and 1300 hours on 23 July 2001. The hourly rainfall intensity of 180mm between 1200 and 1300 hours is the recorded maximum in Pakistan according to PMD. Intensity of 90mm/hr was also recorded between 1300 and 1400 hours at the RAMC Station during the same flood.

As for the other floods, the rainfall intensity was quite lower than the exceptional 2001 flood, while the intensive 3-hourly rainfalls of more than 35mm/hr (corresponding to 105mm in three hours) were also observed in the 1996 flood at the Chaklala Station and in the 1997 flood at the Chaklala and RAMC Stations.

5.1.3 Frequency Analysis

As discussed in Subsection 5.1.2, the spatial variation of rainfall is very significant in the Study Area and the spatial distribution pattern also differs from flood to flood. In order to correctly evaluate such rainfall in relation to flood discharges on Lai Nullah, therefore, basin mean rainfalls are more important than point rainfalls observed at each station. In this sense basin mean rainfalls were estimated based on the collected rainfall data, and then a frequency analysis was made to estimate probable basin mean rainfalls for several return periods, as follows:

1) Reference Point

As the first step, Gawal Mandi Bridge that is located in the middle of the habitual flood inundation area between Gunj Mandi and Railways Bridges was defined as a reference point for the estimation of the basin mean rainfalls. In other words, the basin mean rainfalls were estimated not for the whole river basin of 234.8 km^2 but for the catchment area of 199.2 km^2 (85% of the whole basin catchment area) upstream of the bridge, taking it into consideration that flood discharges in the habitual flood inundation area are mostly generated by rainfalls falling in the 199.2 km^2 area.

It is noted that Gawal Mandi Bridge is very meaningful for the present flood warning system of TMA too. As explained in subsection 2.5.2, the water level at this bridge is an indicator for the flood warning issuance. Once the water level rises over the 18 feet level, sirens are to be blown at several warning posts in Rawalpindi.

2) Basin Mean Rainfall

The Thiessen Method was applied to estimate the basin mean rainfalls. Fig. 5.1.5 presents divisions of the Lai Nullah Basin by the Thiessen polygon lines according to the rainfall data availability, and the Thiessen coefficients are summarized below:

Table R 5.1.2 Thiessen Coefficients

Station	Number of Stations of which rainfall data are available			
	4 Stations	3 Stations	2 Stations	1 Station
Saidpur	0.30	N/a	N/a	N/a
Islamabad	0.47	0.77	0.85	N/a
RAMC	0.12	0.13	N/a	N/a
Chaklala	0.11	0.10	0.15	1.00

Using the collected 3-hourly data observed at the stations, 3-hourly basin mean rainfall data were calculated to create a basin mean rainfall database for the selected heavy rainstorms of 32 years from 1970 to 2001.

3) Probable Rainfalls

The annual maximum basin mean rainfalls of four (4) different durations (3, 6, 9, 12-hourly rainfalls) were plotted on the different probability distribution curves including the Gumbel, Log-normal, Pearson Type 3 and Log-Pearson Type 3 (refer to Table 5.1.3 and Fig. 5.1.6). As the results, it is evaluated that the Log-Pearson Type 3 gives good fitting to all the four extreme rainfalls and selected as the optimum distribution. The probable basin mean rainfalls are thus estimated through that the Log-Pearson Type 3 and summarized in Table R 5.1.3, which also shows the actual basin mean rainfalls of the 2001 flood, the probable basin mean daily rainfalls additionally estimated in this Study and the probable daily rainfalls by the on-going ADB Lai Nullah Project so as to facilitate the comparison with the obtained probable rainfalls. As discussed in Section 5.2.3, design hyetographs with different return periods are created from these probable 3, 6, 9 and 12-hourly rainfalls.

Table R 5.1.3 Probable Rainfalls

(mm)

Rainfall	Data Period	Return Period (years)						2001 Flood
		5	10	25	50	100	200	
3-hourly	32 years(1970 – 2001)	105	134	177	216	260	311	239
6-hourly	32 years(1970 – 2001)	128	167	230	287	355	437	349
9-hourly	32 years(1970 – 2001)	146	194	272	346	435	542	401
12-hourly	32 years(1970 – 2001)	151	203	291	376	481	611	444
Daily (This Study)	32 years(1970 – 2001)	152	196	263	324	395	478	411
	42 years(1960 – 2001)	136	175	239	298	371	459	
	58 years(1944 – 2001)	145	186	247	300	361	432	
Daily (ADB)	42 years(1960 – 2001)	136	162	193	215	236	N/a	

*: Annual maximum basin mean daily rainfall data are tabulated in Table 5.1.4 and their probability plotting for three different data periods is given in Fig. 5.1.7.

It is important to evaluate the exceptional flood on 23 July 2001 in terms of return period of rainfall. The 3, 6, 9 and 12-houly rainfalls of the 2001 flood are all slightly smaller than those of the 100-year return period, and the flood could be evaluated at 75 to 90 years of return period.

4) Comparison of Design Rainfall with ADB Project

According to the Design Report of the ADB Project, design rainfalls with duration of 3 hours, which almost corresponds to the concentration time of the La Nullah catchments on the project stretch, were applied to estimate design peak discharges for the river improvement. The design rainfalls were created by converting probable daily rainfalls that were estimated from daily rainfall records of 42 years observed at the Chaklala Station. Since no information of the probable 3-houly design rainfalls is presented in the Design Report, it is virtually difficult to compare them with those of this Study. Instead, the probable daily rainfalls that are luckily presented in the report are compared with the probable basin mean daily rainfalls estimated additionally in this Study by applying the same methodologies as for the 3, 6, 9 and 12-houly rainfalls.

The ADB's daily rainfalls are generally smaller than those of this Study as seen in Table R 5.1.3. The gap is bigger as the return period becomes longer, for example the ADB's 100-year daily rainfall of 236 mm is smaller by 135 mm than this Study's daily value of the same 42 years. This gap is mainly because the ADB estimation was grounded on only the Chaklala Station data that recorded the smallest rainfall among the four stations during the 2001 flood while this Study considers all the four stations to estimate the basin mean rainfalls.

It is also guessed that the ADB design 3-hourly rainfalls are significantly smaller than those of this Study, because they were based on smaller daily rainfalls. In other words, the ADB project might have underestimated the design rainfalls. This rainfall gap seems to further lead to a gap of design discharges between this Study and the ADB project as discussed in subsection 5.2.3.

5.2 HYDROLOGICAL AND HYDRAULIC SIMULATION

Following the above rainfall analyses, hydrological and hydraulic flood simulation analyses are discussed in this section. Objectives of the simulation analyses are as follows:

(1) To clarify the flood inundation mechanism in the Lai Nullah River Basin;

(2) To determine the basic hydrological parameters for designing countermeasures, such as design discharge and design water level; and

(3) To examine effects of conceivable countermeasures.

5.2.1 Software and Model-Set up

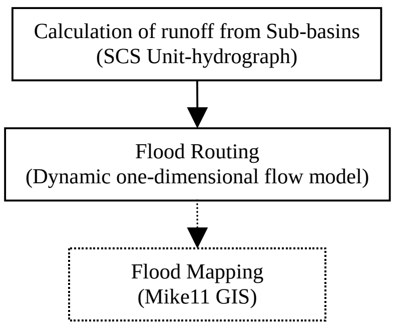

Fig. R 5.2.1 Flow of Flood Simulation

The flood simulation is generally made in two steps, namely calculation of runoff from the sub-basins and flood routing along the rivers. For some special cases, flood inundation maps are additionally generated for the purposes of verification of the established simulation model, estimation of flood damages or just simply generation of flood risk maps. Mike11 software that is an integrated software developed by DHI Water & Environment for river management was used for all the above procedures, selecting appropriate methods for each procedure among a variety of optional methods provided in the software.

A unit-hydrograph method based on the SCS Curve Number that were used often in the previous studies for Lai Nullah was again selected to estimate runoff discharges from the 15 sub-basins presented in Fig. 5.1.1. The estimated runoff discharges were further used as inflow data to the river network for the flood routing as shown in Fig. R 5.2.2.

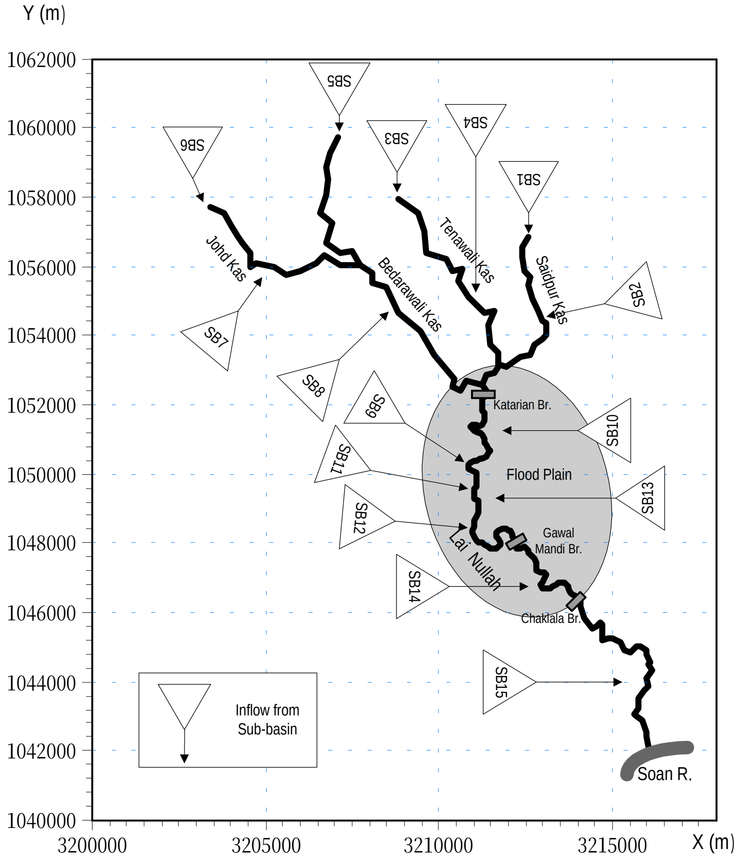

Fig. R 5.2.2 River Network

The main river, Lai Nullah, and four major tributaries, Saidpur Kas, Tenawali Kas, Bedarawali Kas and Johd Kas were considered to build the river network for the flood routing. A dynamic one-dimensional flow model of Mike11 that can simulate hydraulic phenomena more precisely was applied to estimate discharges and water levels in the river network.

The estimated water levels were further exported for the flood map generation to Mike11 GIS, which is an interface module of Mike11 with Arcview GIS software. Flood inundation depths were calculated in Mike11 GIS by interpolating and extrapolating the river water levels over the digital elevation models (DEM) of the flood plain.

1) Runoff Calculation by SCS Unit-hydrograph Method

The US Soil Conservation Service developed a method for computing abstraction from storm rainfall, introducing a concept of the Curve Number. The Curve Number CN is a kind of runoff parameter representing soil, land use and antecedent moisture conditions. The Curve Number is generally defined for normal antecedent moisture conditions (AMC II) and further modified to those for dry conditions (AMC I) or wet conditions (AMC III) according to the antecedent rainfall conditions. Using the Curve Number CN, the depth of excess precipitation P_e is given as follows:

$$P_e = (P - 0.2S)^2/(P + 0.8S) \qquad (5.1)$$

$$S = 25.4 \times (1000/CN - 10) \quad (5.2)$$

where:

P: depth of precipitation.

S: potential maximum retention in mm.

The excess precipitation is converted into runoff discharge by the SCS triangular unit-hydrograph. The lag time t_l is calculated from the catchment characteristics using the standard SCS formula:

$$t_l = (L \times 3.28 \times 10^3)^{0.8} \times (1000/CN - 9)^{0.7}/(1900 \times Y^{0.5}) \quad (5.3)$$

where:

L: hydraulic length of the catchment area in km.

Y: slope.

CN: SCS Curve Number (AMC II).

2) Dynamic One-dimensional Flow Calculation

The dynamic one-dimensional flow calculation module that is based on the 'Saint Venant' equations is a core of Mike11. The equations of continuity and momentum are:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \quad (5.4)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(\alpha \frac{Q^2}{A} \right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0 \quad (5.5)$$

where:

Q: discharge.

A: flow area.

Q: lateral inflow.

h: water level.

C: Chezy resistence coefficient ($C=R^{1/6}/n$).

n : Manning roughness coefficient.

R : hydraulic radius

α : momentum distribution coefficient

The flood routing is made along the river network consisting of the five rivers. Pre-defined water levels at the confluence with Soan River and the estimated runoff discharge from the sub-basin at each of the four upstream ends are given as the boundary data of the river network.

Table R 5.2.1 Rivers in River Network

River	Stretch	Length (km)
Lai Nullah	Kattarian Br. to Soan River	17.5
Saidpur Kas	Zero Point to Tenawali Kas	5.8
Tenawali Kas	Jinnah Avenue to Bedarawali Kas	8.7
Bedarawali Kas	E-9 to Lai Nullah	12.7
Johd Kas	Golra Village to Bedarawali Kas	7.3

3) Flood Mapping

The flood mapping covers some 100 km^2 including the lower Islamabad area (H and I blocks) and the Rawalpindi area as the flood inundation interview survey. A DEM (Digital Elevation Model) is essential for the flood mapping and accuracy of the flood map greatly depends upon that of the DEM. In this Study topographical data obtained from the GPS survey were used to divide the 100 km^2 area into 40,000 square cells of 50 m x 50 m size, each of which was assigned a ground elevation value. Fig. 2.1.2 is the elevation map created from the 50 m DEM.

Mike11 GIS has the function for calculating water levels over each of the DEM cells by interpolating or extrapolating the water levels in the rivers. Finally the water level of each cell is converted to the inundation depth by subtracting the ground elevation.

5.2.2 Reproduction of 2001 Flood and Model Verification

The flood on 23 July 2001 that could provide the richest hydrological data, was selected as the target flood for the model verification, and reproduced to clarify the flood mechanism.

1) Model Calibrations and Model Parameters

The river cross-sectional data was availed from the results of survey by the ADB Project and this JICA Study. The survey by the ADB Project that was carried out immediately after the 2001 flood covers the project stretch between Kattarian and Chaklala Bridges on Lai Nullah. In this Study, the supplementary cross-sectional surveys were conducted between October and November 2002 for lower Lai Nullah downstream of Chaklala Bridge, several tributaries, and Soan and Kurang Rivers. These cross-sectional survey data were incorporated into the river network model.

To express the retarding effects by flood inundation, additional off-stream storage areas, of which area-elevation data were extracted from the generated DEM, were connected to the

Lai Nullah cross sections between Kattarian Bridge and Chaklala Bridge, where inundation was so extensive in the 2001 flood.

The rainfall data observed at the four stations, of which hyetographs are presented in Fig. 5.1.4, were applied for the runoff calculation of the 15 sub-basins. The basin mean rainfalls were firstly estimated for each of the sub-basins based on the Thiessen polygons, and the basin mean rainfalls were input to the SCS unit-hydrograph method.

Trial runs of runoff calculation were made until acceptable accuracy was attained, changing and adjusting model parameters including the SCS Curve Numbers and the Manning's roughness coefficients of the rivers. The SCS Curve Number by land use was finally determined as given in Table R 5.2.2 and those of the 15 sub-basins were estimated as shown in Table 5.2.1 based on the 2001 land use map given in Fig. 3.1.3. The roughness coefficients of all the rivers were determined at 0.035 for the low water channels and at 0.050 for the high water channels.

Table R 5.2.2 SCS Curve Number by Land Use

Land Use	Curve Number CN
Agricultural area	70
Residential area/Densely populated	90
Residential area/Moderately populated	75
Residential area in the Suburbs	70
Forest (Mountain area)	70
Forest (Flat area)	65
Green and grass area	65
Water Body	100

Note: under normal antecedent moisture condition (AMC II)

2) Reproduction Results

Fig. 5.2.1 presents the discharge and water level hydrographs at Kattarian, Gawal Mandi and Chaklala Bridges. As shown in the Fig., the temporal variation of the water level and discharge in the hydrographs is gradual, which could be attributed to the flood retarding effects of the river basin. The peak water level appears around 1400 hours at Kattarian Bridge and around 1800 hours at Gawal Mandi and Chaklala Bridges. The duration of flood Inundation around Gawal Mandi Bridge is estimated at about 10 hours judging from the temporal variation of water level in the hydrograph. These timings and the inundation duration agree with the memories of inhabitants and officials concerned.

Fig. 5.2.2 compares the estimated maximum water levels along Lai Nullah with the elevations of flood marks left at several bridges. It can be said that the estimated water levels match the flood marks very well.

In addition, the flood map is simulated to overview the maximum extent and depth of flood inundation and, it is confirmed that the simulated flood map could well accord with the results of the interview survey as shown in Fig. 5.2.3. As shown in the simulated flood map as well as the results of interview survey in Fig. 5.2.3, the flood inundation expands over low-lying areas along Lai Nullah and the tributaries. The extent of the whole flood inundation area and its corresponding inundation volume were estimated at 9.2 km^2 and 23 million m^3 respectively from the generated flood map.

As discussed above, the reproduction of the 2001 flood is satisfactory enough for the Master Plan Study. In conclusion, the established model is considered acceptable and applicable for estimation of the standard flood discharge described in the following subsection 5.2.3.

5.2.3 Flood Simulation for Future Scenarios

Using the established simulation model, the standard flood discharge was estimated as described hereinafter:

1) Simulation Conditions

The flood simulation is made on the premises of the without-project, which is subject to no flood mitigation effect by any new flood mitigation structure other than the on-going ADB river improvement project. The discharges estimated under this condition are called "standard flood discharge".

a) Rainfall

100-year, 50-year 25-year, 10-year and 5-year design hyetographs with 12 hours of duration were created for the future scenario flood simulation, based on the frequency analysis of 3-hourly, 6-hourly, 9-hourly and 12-hourly rainfalls discussed in Subsection 5.1.3.

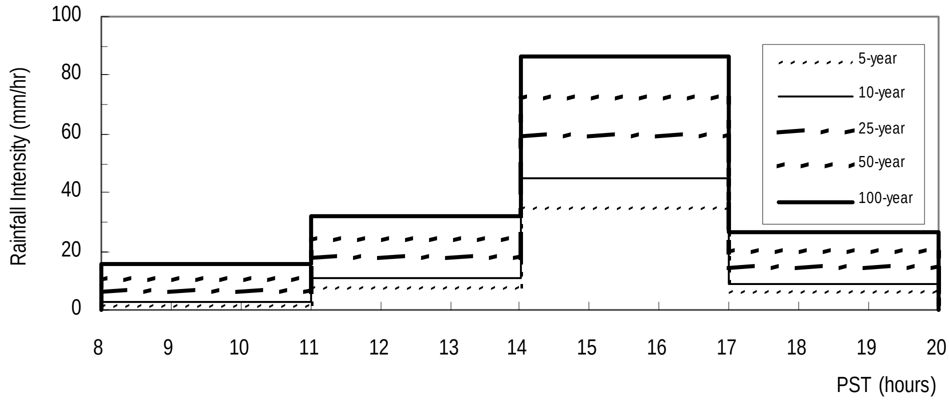

Fig. R 5.2.3 Design Hyetograph

b) Land Use

The 2012 land use condition shown in Fig. 3.1.4 was applied for this calculation. The SCS Curve Numbers of the sub-basins were modified accordingly.

c) Consideration of On-going ADB River Improvement Project

The Lai Nullah improvement project that is now in progress under the financial assistance of ADB is scheduled to complete in early 2003. The Lai Nullah will be widened by 20 to 30 m in the project.

The completion of this on-going river improvement was premised for the flood simulation, and the existing cross sections of Lai Nullah that were used for the reproduction of the 2001 flood were replaced by cross sections designed by the project, of which roughness coefficient were set at 0.030 as designed.

d) Confinement of Flood Discharges in Rivers

The additional off-stream storage areas connected to the cross sections of the simulation model for the 2001 flood were removed to confine all the flood water in the rivers not allowing any spillage because this future scenario simulation aimed to estimate river discharges under no flood inundation.

2) Simulation Results of the Standard Flood Discharge

The aforesaid standard flood discharges under the without-project condition were estimated through a model slightly modified from the simulation model for the 2001 flood. The standard flood discharges thus estimated at the two principal reference points, namely Kattarian Bridge and Gawal Mandi Bridge are compared with the probable discharges estimated from the observed water level as well as those estimated in the ADB Project as shown in Table R 5.2.3.

Table R 5.2.3 Standard Flood Discharge by Return Period

Reference Point	By	Description	5 years	10 years	25 years	50 years	100 years
Kattarian Br.	This Study	Simulated as Standard Flood Discharge	330	620	1,150	1,660	2,270
	ADB project	Estimated by Runoff Analysis	324	425	571	682	784
Gawal Mandi Br.	This Study	Simulated as Standard Flood Discharge	390	720	1,340	1,940	2,640
		Estimated From observed Water levels	490	840	1,500	2,200	3,000
	ADB project	Estimated byRunoff Analysis	563	719	942	1,109	1,264

As listed above, it could be evaluated that the values simulation as the standard flood discharge well accords with the value estimated from the observed water level. As expected in Subsection 5.1.3, however, the considerably big gaps are seen between the values simulated in the Study and estimated in the ADB Projects. These gaps become bigger as the return period is longer. The values simulated for the 100-year return period in the Study are about three times of the values estimated in the ADB project.

3) Increase of Discharge by Urbanization

Land use is also an important factor affecting flood discharges. Urbanization that is generally accompanied by pavement, building and drain installation leads to an increase of flood discharges, as experienced all over the world. It is very important to know the extent of such discharge increase caused by land use change.

In this Study, the basin average Curve Numbers reflected by the land use maps in 2001, 2012 and 2030 were estimated to gradually increase from 72 to 74 as shown in Table 5.2.1. In accordance with the increment of the Curve Numbers, the probable maximum discharge would also increase as listed below:

Table R 5.2.4 Maximum Discharges by Land Use

Reference Point	100-year Discharge (m^3/s)			25-year Discharge (m^3/s)		
	2001	2012	2030	2001	2012	2030
Kattarian Br.	2,200	2,270	2,300	1,110	1,150	1,180
Gawal Mandi Br.	2,551	2,640	2,711	1,260	1,340	1,375

4) Flood Map under Future Land Use

The flood maps were developed for the five (5) cases as shown in Table R 5.2.5. Among the cases, the Case1-2 presents the probable maximum extent and depth of the flood inundation caused by the flood 2001 assuming the flood occurs immediately after the completion of the ADB Project. This flood map will be useful to let inhabitants know what will happen if the awful 2001 flood occurs again.

Cases 2-1, 2-2 and 2-3 presents the maximum extent and depth of the flood inundation caused by the probable flood of 25, 50 and 100-year return period assuming any flood mitigation structures other than the on-going ADB Project is not given to Lai Nullah. These flood maps could be used to estimate flood damages according to the return periods. The generated flood maps and the extents of the flood inundation area are as shown in Fig. 5.2.4, and Table 5.2.2, respectively.

Table R 5.2.5 Summary of Flood Mapping

Case No	Facility Condition	Land Use	Rainfall	Estimated Inundation Area (km2)	Remarks
1-1	Existing Condition	2001	2001 Flood	9.2	Reproduction of 2001 Flood
1-2	After Completetion of ADB Project	2001	2001 Flood	7.2	Flood Risk Map
2-1	After Completetion of ADB Project	2012	100yr Rain	7.6	Without-project Condition
2-2	After Completetion of ADB Project	2012	50yr Rain	4.5	Without-project Condition
2-3	After Completetion of ADB Project	2012	25yr Rain	2.6	Without-project Condition