CHAPTER 2 SOCIOECONOMIC STATUS

2.1 Geographical Features

Munda and its surrounding area in the Swat River basin is located in North-West Frontier Province (NWFP) 37 km north of Peshawar. The Project is located on the Swat River about 5 km upstream of the existing Munda Headworks at Abazai near the town of Shabqadar Deri. The reservoir area of the dam extends upstream to Mohmand and Bajaur Agencies, in Federal Administered Tribal Areas (FATA) and Malakand Agency in Provincial Administered Tribal Areas (PATA). The total length of the water reservoir is about 56 km in the rocky gorge of the Swat River.

The area is formed by barren and rugged hills and basins. Very little vegetation grows, except coarse grass, scrub wood, wild olive and the dwarf palm (*mazri*), which sparsely dot the hills. The Swat River flows through deep gorges, so not much cultivable land is found along its banks. However, various places along the riverbanks are pierced by deep *nullahs* /streams. Patches of alluvial fans are found at such confluences of the basin.

The Warsak Dam left bank canal is the principal source of irrigation area, which commands an area of about 3,306 hectares. Other sources accounting for about 42% of the irrigated area are tube-wells, lift pumps, springs, channels, and small dams. The Palai Dam and Tangi Lift Irrigation schemes bring under their command an area of 1,862 and 715 hectares, respectively.

Presently only 6% of command area is cultivated and the cultivable waste land is about 173,280 hectares. Average farm size is two hectares. Wheat, maize, corn, and sugarcane are the area's major crops.

The reservoir area of Munda Dam falls in Mohmand and Bajaur Agency in FATA which connects with Peshawar District. The Right Bank Command Area falls in the Mohmand Agency whereas the Left Bank Command Area is located in Malakand (PATA). The downstream riparian area is located in Charsadda District.

2.2 Administration Situation

2.2.1 Administration Situation in NWFP and FATA

NWFP became a province in 1901 in the then British India. The province is slightly larger than 100,000 square kilometers with a current population of 17.5 million. Approximately 75% of the area is under the administration of the provincial government including PATA, and the rest is FATA. As shown in the figure below and Figure 2.2.2, there are 21 districts in the province including the key districts of Peshawar and Charsadda close to the Munda Dam site.

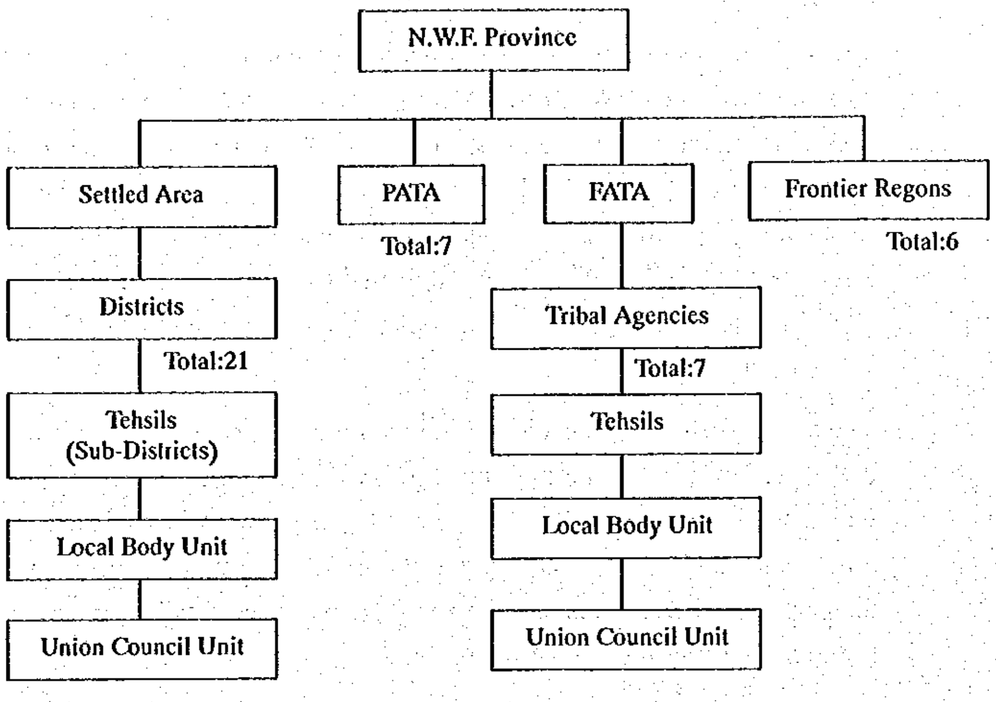

Figure 2.2.1 NWFP Administrative Set-up

Each district is divided into *'Tehsil'* (Subdistrict), which are further divided into local body and union council units. In FATA, the tribal areas are comprised of mountainous territory approximately 650 kilometers long which borders with Baluchistan in the south. The FATA population is estimated to be over 3 million. There are seven agencies and six frontier regions under FATA. The 7 agencies include Mohmand and Bajaur near the Munda Dam site. Agencies are headed by Political Agents appointed by the Prime Minister with the consent of the Chief Minister of NWFP. The six Frontier Regions (FR) are managed by Deputy Commissioners who are responsible to the Commissioner of the Frontier Regions. The FRs are located in Peshawar, Bannu, Lakki, D.I. Khan, Tank and Kohat. The Commissioner is recommended by the Public Service Commission and appointed by the Government of Pakistan. The Commissioner and Deputy Commissioners are civil servants.

2.2.2 Administration Situation in the Command Area

The Command Area (CA) likely to be affected by this Project is spread across three administrative units, namely, Mohmand Agency, Malakand Agency, and one *Tehsil* (Tangi) of District Charsadda as shown in Figure 2.2.3. In Mohmand Agency fall the three *Tehsils* of Yakaghund, Pandialey and Prang Ghaar; in Malakand agency the *Tehsil* is 'Dargai'; and in District Charsadda falls *Tehsil* Tangi. The Command Area comprises five *tehsils*, and has seventy towns, villages or settlements (V/Ss).

The Right CA falls wholly in two of the four *tehsils* (Pandialey & Yakaghund) of the Upper Mohmand Agency and has a total of 32 Villages/Settlements (V/Ss).

There are 38 V/Ss in the Left CA and they are distributed across all the three administrative units: There are 15 V/Ss in the Malakand Agency, *Tehsil* Dargai; 16 in the Upper Mohmand Agency, *Tehsil* Prang Ghaar; and 7 in *Tehsil* Tangi, District Charsadda .

As described earlier, the bulk of the V/Ss fall in Mohmand Agency (48 of 70). Malakand Agency has 16 V/Ss and Tangi has 7.

Administratively, the three units may be distinguishable but on the ground the lines of demarcation are neither clear nor relevant. In this report the Command Area will be dealt with as a whole, despite the fact that it straddles three different administrative entities.

Most of the V/Ss in the CA fall in FATA in the tribal territories and are thus administered accordingly. A picture of the Mohmand Agency administrative system will be given as most of the V/Ss fall in it. The administrative set-up in the V/Ss located in Malakand Agency mirrors that of Mohmand Agency, and those that fall in Tangi *Tehsil* are administered as in the rest of the province and country.

A Political Agent located at Ghalani heads Mohmand Agency. The Agency has two subdivisions, Upper and Lower Mohmand. Upper Mohmand has three *tehsils* and Lower has four. The *tehsil* headquarters are located in Ghalani, Yakaghund, Prang Ghaar, and Lukaro. Except for Lukaro, all *tehsil* headquarters fall in the CA. An Assistant Political Agent heads each sub-division while a Political *Tehsildar* is in charge of each *tehsil*. Sometimes a Political Naib *Tehsildar* may be in charge of a *tehsil*.

2.2.3 Administration Situation in Energy Sector

At the policy level, the Cabinet Committee on Energy (CCE), chaired by the Prime Minister, is responsible for the review and approval of all plans, policies and projects in the energy sector.

Four ministries share the responsibility for the energy sector. The Ministry of Water and Power controls the two vertically integrated power supply utilities, Water and Power Development Authority (WAPDA) in charge for the whole country except the Karachi area and Karachi Electricity Supply Corporation (KESC) in charge for Karachi city and its surrounding area. Their responsibilities include all the power supply activities covering power generation (WAPDA includes hydropower), transmission, and distribution in their concession areas. The Ministry of Petroleum and Natural Resources is responsible for the development and marketing of all hydro-carbon products. The Energy Wing in the Ministry of Planning and Development is in charge of preparing the energy policy and plans of the government. Ministry of Production (MOP) has jurisdiction over the State Petroleum Refining and Petrochemical Corporation and Pakistan Refinery Limited.

There are three organizations responsible for hydropower development and power supply in the NWFP area: (1) Hydro Electric Planning Organization (HEPO), a part of WAPDA, (2) provincial government of NWFP itself, and (3) Sarhad Hydel Development Organization (SHYDO) under the NWFP provincial government handles the Pre-Feasibility Study, Feasibility Study and Detailed Design including preparation of Bidding Documents of hydropower projects. The Provincial Government of NWFP is responsible for rural electrification plan and power supply to the remote FATA area. SHYDO handles small hydropower development. SHYDO also conducts feasibility studies of medium/large run-of-river hydropower projects to be implemented under the IPP program.

In 1997, to introduce a competitive power market in Pakistan, a fully autonomous regulatory authority, the National Electric Power Regulatory Authority (NEPRA) was established for overseeing and controlling power sector activities including power cost studies. NEPRA is also carrying out activities to promote the establishment of competitive and efficient power sector including the private sector participation. The NEPRA has now actively started hearings for tariff increases by WAPDA and KESC.

The ongoing restructuring of WAPDA has involved a corporatization process in which its eight area electricity boards, distribution companies, will be converted into eight public limited companies, its 11 thermal power stations into a number of public limited companies. For this, Pakistan Electric Power Company (PEPCO) has been formed. The transmission system will become a single public limited company. WAPDA will revert to its original role as an organization responsible for the maintenance of existing dams, the building of additional dams on the main rivers and power stations from these dams.

2.2.4 Administration Situation in Irrigation Sector

In irrigation sector reform, the National Drainage Program (NDP) assisted by the World Bank and other international donors will provide a greater role for the private sector and autonomy for public sector agencies. Federal institutions will continue to be responsible for overall assessment, coordination, and the development of inter-provincial water resources and works. The Provincial Irrigation Drainage Authority (PIDA), formed in 1997, is an autonomous provincial water authority responsible for coordinating all planning and development of water resources within the provinces and handles distribution of irrigation water to financially autonomous independent public utilities at the canal command level. A provincial regulatory commission will regulate the Operation and Maintenance charges of the public utilities and adjudicate farmers' disputes.

In NWFP, the North-West Frontier Province Irrigation Drainage Authority (NWFPIDA), has been established by the North-West Frontier Province Irrigation Drainage Act 1997. Though the basic framework of NWFPIDA has been set up, the structure of the organization and process of implementation will be established following the recommendations by the Institutional Reform Consultants assigned in 1999.

2.3 Population

According to the preliminary results of the fifth Population and Housing Census of Pakistan, 1998, the total population is 130.6 million, indicating an average annual growth rate of 2.6% since the last census in 1982. Population in NWFP is 17.5 million, registering an average annual growth rate of 2.8%. Population in FATA area is 3.1 million with a slower growth rate of 2.1%. Eighty-three percent of the population in NWFP reside in rural area compared with 67.5% of the national total.

According to the field survey conducted in 1999, the total number of households in CA is 19,979. Of the total, 78% of the households (15,559) are adobe (*'kutcha'*) constructions, and the remaining 22% (4,420) are brick and mortar. Most of the households are large and joint, some with up to 80 members. The joint family system is the cultural norm in this area and has been traditionally prevalent, as it is economically beneficial. However, over the recent years, changes in socioeconomics have resulted in a substantial level of out-migration.

The total population of CA is 141,530, with 52.6% (74,495) males and 47.4% (67,035) females according to the Survey in 1999. It is likely that the female population have been under-reported. There is a very wide range of population across villages and settlements (V/Ss). There are V/Ss with a total population as low as 80, and on the upper side, the largest V/S has a population of 18,000, with a variety of V/S population sizes in-between.

The entire population is ethnically *Pakhtoo*n and strictly adheres to Sunni Islam. This can be gauged from the very large number of mosques, 389, in the CA. Socially the area is backward and traditional, following the *Pakhtoon* code/s. For example, segregation of women is strictly practiced. Three main tribes, namely, the "Utmankhel", "Tarakzai", and "Burhankhel", with numerous sub and sub-sub tribes, inhabit the Command Area.

The vast majority of households belong to locals. However, there are certain V/Ss with some Afghan refugee presence. There are a total of 1,424 (7%) Afghan refugee households in the CA. Fifty of those are in the Left CA and the remaining 1,374 in the Right CA. The Afghan refugees are located in Mohmand Agency and even within that, the bulk (1,220 households) are concentrated in four V/Ss, of which two are refugee camps. Thus, there are only two V/Ss with a mixture of local and significant refugee populations. However, there are no reports of tension and/or conflicts between the locals and the refugees, qua groups.

2.4 Education and Health

The male literacy rate is 19.37% and the female rate is 10.57% in the CA. The overall literacy rate is low compared to national or provincial averages, while the male literacy rate is about twice that of females. The male literacy rate for the NWFP is 34.1% and female literacy rate for the NWFP is 12.8%. The figures for Pakistan are slightly higher.

The numbers and levels of government schools in the CA are given in the table below:

Government Schools in the Command Area

	PRIMARY		MIDDLE		HIGH	
	F	NF	F	NF	F	NF
Boys	67	2	14	0	8	0
Girls	45	4	8	2	1	0
Total	112	6	22	2	9	0

F= Functional schools NF= Non-functional schools

(Source : Primary Data Collected by the Study Team)

Besides the government run schools there are a total of eight privately run schools; seven functional and one non-functional religious schools or '*madrasaas*'; and one vocational school. There is no NGO-run school in the CA.

Although basic educational facilities exist, the quality is rather poor. Facilities for higher or technical education are non-existent in the CA. However, proximity to cities like Charsadda, Mardan, and Peshawar makes it possible for the children of well-to-do families to obtain such education.

The health facilities in the CA are meager both in terms of infrastructure and personnel. Consequently most people are compelled to travel to Mardan or Peshawar for health services. The sociology and traditions of the area cross-cut with the given realities in such a manner that attention to health, especially of females, is a low priority.

Major health problems in the area are malaria, kidney problems, and cough, colds and fever.

The Basic Health Units (BHUs), doctors and other health facilities in the CA are given below:

Health Facilities in the CA

Health Facilities	Numbers
Infrastructure	
BHUs	10
Family Planning Centers	5
Dispensaries	1
Medicine Shops (Retail)	28
Personnel	
Male Doctors	10
Allied Health Personnel, Male	64
Female Doctors	4
Allied Health Personnel, Female	23 (Including 8 LHVs)

(Source : Primary Data Collected by the Study Team)

Many donor agencies are providing assistance in education, health, and human resource development through the federal government.

2.5 Labor Force and Employment

According to the Labor Force Surveys in 1999, employment is defined as all persons of ten years of age and above who worked at least one hour during the reference period, either "paid employed" or "self-employed." Based on this definition, the unemployment rate is estimated at 6.1% for 1999 in the country. The most recent figure for unemployment in NWFP is not available, but the rural unemployment in Pakistan was 5.7%.

Farming is the main economic activity in the CA. And most of the labor in the CA is unskilled or semi-skilled as the local economy can only absorb such workers. Such workers are all male and work on daily wages. The skilled labor, and the few trained professionals, are, by necessity, forced to migrate to cities and/or to the Middle East. Nevertheless, the migrant workers maintain very close links with the household by remitting or investing a major portion of earnings in the community to which they belong.

Like all rural communities in Pakistan, animal husbandry is an integral part of the economy. Domestic animals are included in almost every household as they contribute in important ways to its running, from providing food to being a source of income.

Given the aridity of the CA, goats and sheep are easy to raise and graze. Most of the grazing is in the communal areas surrounding the V/Ss and young boys take the cattle for grazing during the day. There is no overnight movement to grazing lands. Their meat and milk is consumed at home as well as being sold in the larger settlements and/or neighboring towns and cities. There were roughly about 48,000 goats and 21,500 sheep in the CA in 1999.

There were about 37,000 cows and oxen, and 4,200 water buffaloes in the CA in 1999. Their grazing patterns are similar to those of goats and sheep. Again, as in the case of goats and sheep, this cattle is both a source of food and some income through the sale of milk and mutton.

There also are beasts of burden like donkeys, mules and horses. These animals are used in farming, transportation of goods and people, as well as construction activities. At the time of the survey, the donkeys and mules numbered 3,900 and there were 406 horses. Cattle dung is used as fuel as well as fertilizer.

There are a total of 29 poultry farms in the CA in 1999. The chickens raised in these poultry farms are largely sold in the nearby markets in towns and cities.

There are three veterinary facilities and one (veterinary) dispensary in the CA. The veterinary facilities are located in villages Palai (Nusrat Zai), *Tehsil* Tangi, District Charsadda; Palai Barozai (Paloojor), *Tehsil* Prangghaar, Mohmand Agency; and Gharib Abad, *Tehsil* Dargai, Malakand Agency. The dispensary is in Usmani Khel Garhi, *Tehsil* Dargai, Malakand Agency. Malakand Agency is also the most populated village in the CA.

Soon after its establishment, the Government of NWFP developed the Industries, Commerce, Labor, Mineral Development and Transport Department to promote industry, business, and mineral development in the province. In 1972, the Government development capacity was strengthened by establishing the Directorate of Industries, Commerce, and Mineral Development, the Sarhad Development Authority (SDA), and the Small Industries Development Board (SIDB) to promote large- and small-scale industrialization, trade, and business in the province.

Beginning with only 11 industrial units in 1974, NWFP has nearly 1,500 industrial units employing some 60,000 people as of 1993, of which breakdown is as shown below.

Industrial Projects, Investment & Employment

Period	Units (Number)	Employment (Number)	Investment (million rupees)
Up to 1970	153	22,001	4,041
1971-1975	217	24,366	4,669
1976-1980	360	28,326	5,701
1981-1985	632	35,153	9,962
1986-1990	1,033	42,411	12,332
1991-1993	1,513	59,053	22,129

Source: Sarhad Provincial Conservation Strategy

Industrial units in NWFP in 1993, By Sector

Industry	Units		Employment		Investment	
	Number	%	Number	%	(mil rupees)	%
Food, beverage & Tobacco	392	25.9	14,661	24.8	4,873	22.0
Textile and Leather	384	25.4	20,301	34.4	6,331	28.6
Wood & wood products	72	4.8	1,052	1.8	479.6	2.2
Paper & paper products	37	2.4	2,509	4.2	995.8	4.5
Chemical, petroleum, rubber & plastic products	244	16.1	6,940	11.7	3,894	17.6
Mineral products	198	13.1	5,353	9.1	3,563	16.1
Metal & metal products	164	10.8	7,662	13.0	1,865	8.4
Other manufacturing industries	22	1.5	575	1.0	128	0.6

Source: Sarhad Provincial Conservation Strategy

(1) Government Jobs

As the educational level of the people in the CA is rather low, less than 20% of rate of education, most government employees are in low-paying jobs. However, a few families are highly educated and socially well placed and some of their members have held or are holding important positions in various government departments. Most of those who have government jobs are living away from their hometowns, as the state infrastructure in the CA is too meager to provide jobs.

(2) Mining

Geological studies of the CA started in a small way in the early 70s, and that also in a disguised fashion because of clearance issues of such work in tribal areas. The CA seems quite rich in mineral resources, which are being exploited in small ways by the locals. Mineral potential of the area includes talc, decorative stones, dolomite, chromite, precious stones (emerald), asbestos, soapstone. At present, talc is surface mined in many places and loaded on trucks bound for Peshawar and other cities.

(3) Small Industry

There is a small cottage industry spread over the CA, largely focused on the indigenous mineral resources of the CA.

There are eleven marble and stone cutting, and chip and chip powder production units in the CA. However, the polishing of marble is of low quality.

There are three units that produce heater plates and one unit for producing brake linings for vehicles. For these, locally mined asbestos is used.

Usmani Khel Garhi, in Malakand Agency, which is also the largest town in the CA, has five agro-industrial units: One each of flour and oil and three sugar cane crushing units that produce raw sugar.

(4) Markets & Retail Shops

Most of the V/Ss have general retail shops where daily living goods are available. The number and kinds of shops is a function of the demands in the V/Ss: the larger V/Ss having greater numbers and variety of such shops.

Three V/Ss, all in Malakand Agency, have *'melas'* (open markets) where cattle is bought and sold. The *'mela'* is a traditional trade institution of the rural

Pakhtoon areas. The *'mela'* is a hub of economic activity and takes place at regular intervals, usually on a designated day every week.

Markets for wholesale items are located in the three *tehsil* headquarters, namely, Dargai, Yakaghund, and Tangi. These markets are a source for wholesale purchase of non-perishable items like sugar, cooking oils, etc. For purchase of more sophisticated industrial goods people have to travel to Mardan or Peshawar.

2.6 Economic Profile and Gross Domestic Product

GDP for the fiscal year 1998-99 in Pakistan was US$ 64 billion equivalent, and GDP per capita was US$490 below target due to sanctions and disappointing cotton and wheat yield. GDP grew by 3.1%, lower than the target of 6%. This compared unfavorably to the 4.3% achieved in the previous year. The key agriculture sector grew by just 0.35% compared with a projection of 5.4% and the previous year's growth of 3.8%.

The budget deficit was expected to have fallen to the projected 4.7% of GDP from 5.4% in 1997-98, while the current account deficit was cut in half to US$1.9 billion.

GDP growth is estimated to expand by a rate of 5% in 1999-2000, while agriculture and large scale manufacturing sectors are projected to grow by 4.3%. Inflation is expected to fall to 6%. The trade deficit is projected to be around US$800 million against a deficit of US$1.4 billion in 1998-99.

Economic growth slowdown caused the reduction of the development budget to NWFP in real terms over the years, from a total of Rs.6.1 billion in 1996-97, to Rs.3.9 billion in 1998-99. The reduction in public sector development in relation to GDP is more significant since private sector investment is limited in the NWFP province. Foreign assistance is important to NWFP. During fiscal year 1997-1998, Rs. 2.5 billion of foreign assistance was utilized in development projects which was about Rs. 600 million above the budgeted figure of Rs.1.8 billion.

In the CA, the main sources of income, in descending order, are agriculture, labor (mostly unskilled), remittances of migrant workers, animal husbandry, government jobs, small businesses, mining, and small cottage industry.

Farming is the main economic activity but the arable land resource base is extremely small, roughly about 5-8% of the total land in the CA. Fragmentation of land holdings is widespread and self-cultivation is the dominant mode of farm management. Lack of irrigation is a major hurdle and much of the agricultural activity is subsistence.

In descending order, wheat, maize, barley, sugarcane, and tobacco are the main crops. The cropping patterns are undergoing a slow but definite change towards high value crops.

Vegetables, onions and tomatoes, are harvested quite abundantly in the CA and are an important source of income for the farmers. They are being marketed in the proximal towns and cities.

There are a few fruit orchards, but the fruit crops do not contribute much to the income/s. However, the fruits grown in the CA include dates, oranges/citrus, guava, and mango.

Water for irrigating crops, fruit orchards, and vegetables is being obtained by a variety of methods like tube wells, springs, channels, and lift systems. Most of the irrigation systems have been cobbled together and are maintained by the farmers. These efforts indicate the capacity to work hard under difficult circumstances.

The distribution of land holdings in the CA is given in the following table.

Distribution of Land Holdings by Households in the CA

	No Land	Upto 1 acres	1-5 acres	6-20 acres	Over 20 acres
Number of Households	8,548 (49.3%)	4,963 (28.6%)	2,286 (13.2%)	1,049 (6.0%)	493 (2.8%)

(Source : Primary Data Collected by the Study Team)

As is evident from this table, about 50% of people in the CA do not own any land. Of those who do have land, the largest number (41.8%) have holdings of only up to two hectares (5 acres). In an un-irrigated area such small land holdings can only provide subsistence outputs.

The Project is likely to have a significant positive impact on the agricultural productivity of the CA. However, as the productive value of land increases due to irrigation, conflicts regarding land ownership and use may also rise.

2.7 Infrastructures

Nationally, the total energy supplies from oil, gas, petroleum, coal and electricity in 1998-99 stood at 41.166 million barrels of crude oil (imports: 63%), 551,392 mcf of gas, 12.369 million tons of petroleum products (imports: 61%), 2.9 million tons of coal (imports: 25 percent), and 43,468 GWh of electricity.

The total installed capacity of electricity (hydro and thermal) increased by 5.7% during the first nine months of the 1999-2000 and stood at 19,659 MW, among which IPP accounted 3,771 MW. The number of villages electrified increased to 65,951 during 1998-99 against 64,568 in the previous period.

During 1998-99, the total length of roads in the country was 181,836 km. The road density in Pakistan was 0.23 km. The Islamabad-Lahore Motorway (M-2) was completed and opened for traffic in November 1997. Islamabad-Peshawar Motorway is expected to be completed in December 2000. Pakistan Railways network consists of 8,774 route km and 781 stations. The network of Pakistan International Airlines covers 55 international and 37 domestic stations. Three private air lines operate in the country and provide air travel service to the public. Karachi port, one of the two major ports in the country, handled 17.586 million tons of cargo.

The total installed power capacity in NWFP in 1996 was 3,762 MW, all in hydro, accounting for 29% of the total national installed capacity, reflecting NWFP's importance as a power generation base in Pakistan. In terms of power consumption, NWFP consumed 6,638 GWh of energy, or 17% of the national total. The share of NWFP in power consumption, however, has been increasing in the past ten years, from 14% in 1990 to 17% in 1997.

Per capita electricity consumption of 266 kWh in NWFP for 1998 is lower than the national average at 317 kWh, but per capita consumption in FATA area is much higher than the national average, 567 kWh, reflecting the subsidized rate the region has enjoyed. In 1998, population per telephone was 55 in Pakistan, 95 in NWFP, and 251 in FATA area. Road network density and per capita gas consumption all reflect the lower development level in NWFP.

In the CA, all of the 70 V/Ss are electrified. However, the issue of billing for electricity consumption is a difficult one in tribal areas. Traditionally, consumers would pay a flat rate regardless of the actual consumption. This seems to have resulted in quite a lot of wasteful misuse. And setting up (small) industries which are energy intensive is financially beneficial. Recently the government has been attempting to rationalize electricity billing in tribal areas and the situation is in flux.

Most of the V/Ss in the CA are accessible by roads. However, less than 50% (33 of 70) have metalled ('*pucca*') roads, while just over 50% (36 of 70) have dirt ('*kutcha*'). The primary means of transportation of people and small goods is the pick-up, which is suitable for the rugged, hilly and rough terrain.

There are only two post offices (POs) located in the CA: one each at 'Kharki', Malakand Agency, and 'Bahi Koroona', Mohmand Agency. Because of the scarcity of this service most people have to travel to access a post office. And the average distance of the nearest post office from the V/Ss is 4.5 km.

The CA has a total of twe12 Public Call Offices (PCOs), that are mainly located in the larger V/Ss. Again there is a paucity of PCOs and the average distance of the nearest PCO from the V/Ss is 4.6 km.

Forty-nine percent of households (9,844 out of 19,979) have television sets. Given the backwardness of the area, this is a high proportion and is indicative of the inroads of modernization through the electronic medium. The sociological consequences of exposure to information through TV could be of interest but require separate treatment. The significance of this is illustrated by the fact that only 8 of the 70 V/Ss receive newspapers.

The quality of drinking water provided in the CA is good. However, the water is mostly subterranean and has to be drawn.

The main mode of obtaining potable water is through public wells, which number 3045, including 116 tubewells. There are 4448 electric, and 747 diesel pumps in operation in the CA.

Twenty-one of the V/Ss also have natural springs, which are used as supplemental water sources.

Eleven of the seventy V/Ss (15.7%) have water supply schemes. But the number of households having water supply scheme connections are 5,945 (29.76%).

The drainage system in most of the V/Ss is primitive. There is only one town in the CA, Kharki, in Malakand Agency, with a population of 11,000, that has a cemented drainage system. Fifty-nine V/Ss have mud drains while ten do not have any drainage system at all.

As a result in the streets and alleys of most V/Ss, drainage and sewage water flows and accumulates freely. And these pools of stagnant water create pollution and are as breeding grounds for mosquitoes, flies, etc. The high incidence of malaria in the CA can probably be attributed to the faulty drainage systems.

2.8 Family Income

Rural average household income grew slower than its urban counterpart between 1964 and 1994, and the income of the rural household in 1994 was 58% of its urban counterpart.

In the Munda project region, according to Environmental Survey of Munda Dam Multipurpose Project, during 1997-98, the income per sample household was Rs. 84,652 and per capita Rs. 6,047. Among the total income, the average per farm and per capita in crop production were Rs. 44,639 and Rs. 3,189, respectively. Crop production is the single largest source accounting for 52.7% of the total.

2.9 External Trade Environment in Pakistan

External trade environment remained inhospitable. In July-April 1998-99 Pakistan exported US$ 6,307.5 million of goods and services which were 11.7% lower than last year's export of US$ 7,142 million. Imports declined by 11.2% during the same period. Trade deficit, however, improved by 8.6% and stood at $1,028 million as against $1,322 million of the comparable period of last year.

Outstanding external debt is close to $23 billion in 1998-99, and registered an increase of only 1.6% over 1997-98. The debt servicing liability increased by 9.5% over 1997-98 to $ 2,577 million.

2.10 Consumer Price in Pakistan

Inflation continued to decelerated in 1998-99 period at 6.1%, following the 8.2% in the previous period. This development has reversed the trend during the last several years which witnessed double-digit inflation rate as measured by the Consumer Price Index (CPI).

Inflation Table

	1994	1995	1996	1997	1998
Domestic GDP Deflator	14.16%	8.04%	13.34%	7.82%	6%
International GDP Deflator	2.2%	2.2%	1.7%	1.6%	1.4%

(Source : Primary Data Collected by the Study Team)

2.11 Public Finance for Development

The total budget for the Public Sector Development Program (PSDP) in 1999-2000 is Rs.116.3 billion, an increase of 5.15% in nominal terms, and a decrease of 1.26% in real terms after considering an inflation rate of 6.1% in fiscal year

1998-99. The real amount for NWFP decreased from Rs. 5.4 billion to 4.6 billion in real terms during the same period, and the share of NWFP in the total PSDP decreased from 4.9% in the previous year to 4.2% in 1999-2000. However, even this reduced budget amount was not able to be fully provided. During the first eight months of 1998-99, the province has only been provided about 62.7% of the budgeted amount.

Lower provision of finances to NWFP reflects the reduced size of the development budget in real terms over the years. This reduction in Annual Development Plan (ADP) hurts NWFP disproportionately since private sector investment is limited in the region.

2.12 Economic Development Plan

2.12.1 National Development Plan

GOP has accepted the challenge on the development of the 21st century and has launched a long term agenda for growth and stabilization, the Pakistan 2010 Program. The program calls for the real GDP to grow at an average rate of 7.4% per annum. Population would grow at an average of 2.1% thereby doubling the per capita income from the current level of US$ 457 to around US$1,000 by the year 2010. Saving rate must average 23% of GDP, investment must average 26% of GDP, with foreign investment and lending covering the difference. Export-to-GDP ratio must increase from the current level of 17.5% to about 25%, implying an annual growth rate of 9%.

In the social sector, universal primary education should be adopted by the year 2010 with 50% secondary enrollment.

According to the revised Ninth Five-Year Plan prepared in 1999, the demand for energy consumption (GWh) is projected to grow at an average annual growth rate of 7.4% during the 9th plan, 9.0% during the 10th to 12th plan based on the normal economic growth of 6% per annum. However, referring to the recent situation of the economy a more realistic forecast was prepared based on the low economic growth of 5% per annum, 5.74% during the 9th plan, 6.79% during the 10th plan, 7.75% during the 11th plan, and 7.88% during the 12th plan. The low scenario forecast is very close to the World Bank forecast.

2.12.2 Regional Development Plan

NWFP lags behind in the national development indicators.

National Development Indicators

	Pakistan	NWFP	FATA
Population	130.580	17.55	3.138
Area Sq. km	796095	74521	27220
Cultivated Area (000 ha)	21550	1742	184.8
Irrigated Area (000ha)	17200	792	98.7
Total Literacy	45	37.3	5
Per capita electricity consumption	317	266	567
Per capita gas consumption	82	17	Nil
Road Network Density	0.27	0.13	0.15
Population per telephone	55	95	251

(Source : Economic Survey 1999)

According to the NWFP Development Strategies, NWFP remains a food deficient province. Out of a total of 1,742,000 hectares of cultivated land, only 792,000 hectares are irrigated. The target is to add 433,468 hectares to the existing irrigated land. On water resources development, several dams, including the Munda Dam, have been proposed. In the infrastructure sector, major road projects are underway, such as Provincial Highways project (Cost Rs. 393 million), Rural Access Road Project (Cost Rs. 1146.89 million) and 106 ongoing locally funded projects.

With abundance in hydro potential, NWFP could be a national hydro power base, 16 projects with an estimated total capacity of 1,204 MW are under various stages of study for private investment and the total cost is estimated at $ 1,203 million. All the details are referred to Subsection 4.5.4.

CHAPTER 3 SITE CONDITIONS

3.1 Location and Topography

The Munda Dam Project is proposed on the Swat River, which is a major tributary of the Kabul River, about 5 km upstream of the existing Munda Headworks and about 37 km north from Peshawar. The dam site is located approximately at coordinates, 34°21' N and 71°32' E.

The total catchment area of the Swat River basin is 13,650 km^2 at the proposed dam site. The basin lies between latitudes 34°20' N to 35°56' N and longitudes 71°20' E to 72°50' E and is about 137 km long and 110 km wide. The Swat River originates from a confluence of Gabral and Ushu at Kalam in the Swat Kohistan with an average elevation of 4,500 m.

The proposed Munda reservoir is extended from south to north in a steep gorge of the Swat River. The Munda Dam site is situated at the downstream end of the mountainous area of the Swat basin, from which the valley widens forming a fan configuration.

3.2 Geology

3.2.1 Regional Geology

The contemplated Munda dam and reservoir on the Swat River is situated in a tectonic zone developed in the southern foothills of the Himalayan range where the Indian plate submerges northward under the Eurasian plate. The Swat river, a tributary to the Kabul river in the Indus basin, rises north in Kohistan zone of Himalaya and flows southward through a winding valley.

According to the Tectonic Map of Pakistan by Kazmi and Rana (1982), the project area is located in Himalayan Crystalline Schuppen Zone between a couple of east-west trending major thrust faults, that is, Main Mantle Thrust (MMT) on the north and Main Boundary Thrust (MBT) on the south. The bedrock is largely composed of crystalline schists and the terrain is repeatedly cut by north-dipping thrusts that form a shingle block structure.

Bedrocks between those two thrust faults are considerably distorted and disturbed, with bedding planes generally striking north to south but with many and varied local deviations. Folding and fracturing of diverse sizes are common as indicated by the frequent and irregular changes in strike and dip of strata, ranging from N70°E/80°SE at Malakand Pass to N60°W/40°NE at the Munda Dam site. The tectonic movement is reflected also in development of

Mesozoic melange zones, a mixture of volcanic rocks, ultrabasic rocks, and other oceanic sediments.

The prevailing rock type is crystalline schist of Palaeozoic to Mesozoic, that includes graphite schist, chlorite schist, mica schist with garnet. Calcareous schist and crystalline limestone are also important local members. The schists are intruded at places by basic rocks and granitic rocks, of which the latter is metamorphosed to gneiss in marginal zones (see following figure).

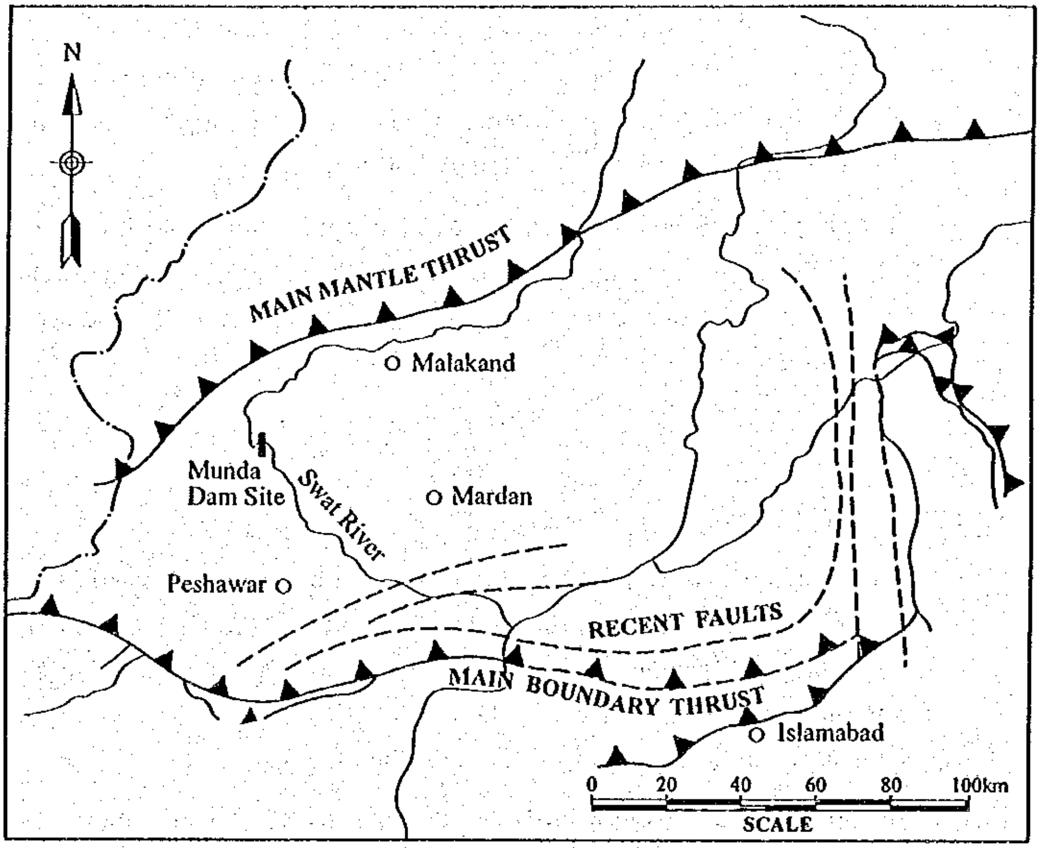

Figure 3.2.1 Tectonic Sketchmap of Project Site

3.2.2 Project Site Geology

(1) Dam Site

The Munda dam site is located approximately 5 km northwest of the Munda Headwork on the Swat river, where the river flows east-northeast for a section of about 2 km in length while its general course is oriented southeast.

Under the present field investigation of this Study, the dam site was newly geologically mapped. Core drilling at twenty locations and for a total length of 1,300 m has been done at the dam – powerhouse site, including a 180 m deep drilling and a drilling of the river bed from a raft on the water. Water pressure tests were conducted at 5 m internals in the bore holes. Details of the drilling locations are shown in Figure 3.2.4. Exploratory adits were driven horizontally at four locations around the dam axis, that is, lower parts and higher parts of the dam abutments on both banks. A series of seismic refraction prospecting was conducted by WAPDA on eight lines with 6,000 m of total length for the dam site. The records of the seismic refraction prospecting was interpreted by WAPDA following the Generalised Reciprocal Method (GRM), and then reviewed through the Hagiwara Method by the JICA Study Team, taking into consideration the outcomes of the core drilling.

The bedrock is composed of crystalline schists of Permian Duma Formation that strikes at N30° to 70°W across the river nearly at right angle and dips more than 40 degrees northeast or downstream, as presented in Figure 3.2.3. Strong joints of one group are nearly parallel with the schistocity or the bedding plane, and those of the other group strike at ENE-WSW in the direction similar to the river course dipping either southeast or northwest. The crystalline schists include chlorite-mica schist, quartz-mica schist, chlorite-mica schist and carbonatious graphitic schist with intercalation or intrusion of talcosic bands, limestone layers and doleritic rock.

Considering the complexity in mineral composition of the schist, the following classification is used in this report:

- coarse pelitic schist or psammitic schist,
- fine pelitic schist,
- calcarcous pelitic schist,
- green schist (coarse and fine),
- siliceous schist,
- limestone or marble.

The classification of pelitic schist is for the metamorphosed rock originating in muddy sedimentary rock, which is correlated with a major part of the chlorite-mica schist in the Pre-Feasibility Report. The green schist covers the doleritic rock that is more or less metamorphosed and schistose, and schists that are formed by alteration of tuff or other rocks of volcanic origin. The siliceous schist, composed largely of quartz, is nearly correlative with the quartz-mica schist of the Pre-Feasibility Report.

The dam will found mainly on the hard siliceous to psammitic schist on the left bank and the green schist on the right bank. The spillway weir and chute will be put on the siliceous schist and the green schist. The plunge pool will be situated in the calcareous pelitic schist. The pelitic schist with limestone band will be foundation of the power house.

At any classification, the bedrock in fresh and intact condition is hard or moderately hard. While the rock appears weaker, weathered and slacked on the surface, the weathering is not so deeply developed, sometimes even to the depth of only 5 m from the ground surface, especially near the valley floor. In the adit No.1 on the left bank terrace, the rock was found slacked only in the superficial 2 m section and sufficiently solid in the other part.

In the lower part of the right bank slope, a series of water pressure tests in boreholes show low or moderate permeability less than 10 Lugeon unit in the zone deeper than 15 m. In the meantime, the hole M98-1 at El. 603 m near the contemplated dam crest showed 128 to 42 Lugeon unit to the depth of 20 m and 10 to 20 Lugeon unit to the depth of 65 m. This reflects relatively intensive slacking of the rock in the parts of the slope higher than the level around El. 560 m. Higher than this level, the bedrock is visibly more slacked and unstable as is represented in thin and winding ridges.

On the left bank, the borehole M98-14 on the terrace, 20 m higher than the river, is watertight for its 180 m length except for the top 5 m section. In the higher part of the left abutment, however, high permeability of 20 to 30 Lugeon units is recorded within a depth of 35 m.

It is the general condition of the foundation rock in the dam site that very high Lugeon values over 25 are not observed in the zone deeper than 15 m, and the bedrock deeper than 35 m shows Lugeon values lower than 5. So the foundation rock deeper than 35 m is highly impervious and will neither take cement grout nor require grouting. (Ref. Figures 3.2.5 and 3.2.6)

In the seismic refraction prospecting, the bedrock under the dam axis is classified into four velocity layers as shown below in descending order from the ground surface:

- Layer 1 the velocity 0.6 – 2.0 km/sec for surface soil and zones of completely to highly weathered rock (Grade D and CL) or slacked rock,
- Layer 2 the velocity 2.1 – 2.9 km/sec for moderately weathered rock and moderately slacked, cracky and/or highly pervious rock zone (Grade CM),

Layer 3 the velocity 3.0 – 3.9 km/sec for slightly weathered with open cracks for noticeable permeability (poorer part of Grade CH),

Layer 4 the velocity 4.0 – 5.4 km/sec for slightly weathered or fresh rock zone, practically watertight with closed cracks.

The surface zone of very high Lugeon value corresponds with the Layers 1 and 2 mentioned above, of which bottom reaches to depth of 15 m at places. The Layer 3 represents the zone of 5 to 25 Lugeon unit and the Layer 4 meet the deep sound rock zone with Lugeon value less than 5.

River gravel deposit has thickness of approximately 8 m, according to the drilling M98-5 at the middle part of the river bed on the dam axis. It shows a 1.5 km/sec wave velocity in the seismic prospecting. Soft and closely foliated schist underlies the river deposit. Sound rock was reached at the depth of 13.55 m from the bottom of the river. The inclined borehole M98-4 did not find any fractured zone of substantial size under the river bed.

In the vicinity of the upstream edge of the dam, or around the location of a plinth in case of the concrete facing rockfill dam, the solid rock is reached at the depth of 15 m, though the rock condition changes irregularly at less depths. In the higher part of the slope, the solid rock is reached at the depth of 1.4 m in the borehole M98-19 though a few sections of high permeability are intercalated in the deeper zone.

All the drill logs and seismic prospecting data are compiled in Volume IV Data Book.

(2) Powerhouse site

The powerhouse on the right bank will be placed on the pelitic schist, of which surface zone is highly weathered into the rock class CL to the depth around 3 m. The weathered rock, however, is strong enough to support the powerhouse, which has no severe foundation engineering requirement.

(3) Diversion/power tunnel

A power tunnel is planned on the right bank, and two diversion tunnels are on the left bank. Most of the lengths of tunnel routes consist of intact rocks, and no serious problem is envisaged on stability of tunnel faces and spring water during the excavation. Outlets of the three tunnels are located on a stable rock bed with dip-slope. The existing balance of stability should not be disturbed by careless uncontrolled excavation.

For the outlet of the power tunnel on the right bank, the rock is solid below El. 373 m, or the depth of 8 m from the bottom of the gully near the powerhouse site.

(4) Spillway site

The spillway chute on the left bank is underlain by siliceous schist, green schist, and pelitic schist. At the higher portion of the chute, the siliceous schist is flaky and slippery, containing much mica. Occurrences of many local rockslides are seen on the east-facing dip-slopes.

For the plunge pool, a substantial quantity of excavation will be required at an existing steep slope of the pelitic schist that will in turn create a new steep slope on its left side. The new slope will have joint planes dipping toward riverside among joints of other orientations. Rock sliding may occur along the joint planes, if the slope is high and steep. Therefore, layouts causing high cut-slopes should be avoided. High and steep slopes should be minimised.

As revealed by the drilling at M98-17, the foundation of the spillway weir will be on the siliceous schist, which shows high Lugeon values over 20 till the depth of 25 m, or El. 547 m. If the foundation of the spillway weir is lower than this elevation, it will be in sound rock that may take little grout. At the lower end of the spillway chute, the moderately weathered pelitic schist lies under colluvial deposit with thickness of 2 m, and a good foundation of sound rock is reached at the depth of 5 m, according to the drilling M98-12.

(5) Reservoir

The reservoir will develop in the long narrow gorge of the Swat river, where the bedrock is widely exposed and the overburden is limited and thin (see Figure 3.2.2). Crystalline limestone beds that may have question of water leakage through karst cavities occur in the calcareous schist of the Lower Triassic Kashala Formation and are also a member of the Permian Duma Formation.

The Kashala Formation is met by the reservoir a few kilometers upstream of the dam site and in two parts farther upstream. Solution cavities are seen on the ground surface in some area, e.g. on the Ambahar river, a right bank tributary. These cavities, however, appear to develop only in the surface zone of the bedrock within an extent of rain water infiltration and drainage. Thickness of ridges separating the reservoir from adjacent basins is as thick as several kilometers to 10 kilometers. The Kashala Formation nearest to the dam site is contained inside the barrier of other formations of Saidu and Duma to stop direct water leakage.

The dam site is on the Duma Formation that is composed mainly of schists. Limestone beds are intercalated at places as mentioned above but make minor components in the formation. Signs of limestone solution are seen at places but seemingly within the surface zone where rain water circulates.

Bore hole water pressure test was performed in the limestone beds at Sappare quarry site, 3 km east-northeast of the dam site, to examine seepage potential of limestone. In a 50 m deep borehole Qs-1, a 5 m section below the depth of 45 m indicated only 7.1 Lugeon. In the meantime, a 100 m deep hole Qs-2 showed low Lugeon values less than 5 in test sections deeper than 10 m. All these conditions indicate that development of the limestone solution is limited within several tens of m in depth where the infiltrated surface water circulates underground and drains again to the ground surface.

The limit of localised water seepage paths is also indicated by quick disappearance of water springs at Sappare every dry season. The aerial photograph also shows discontinuity of the limestone bed between the reservoir area and Sappare.

The limestone beds, therefore, is deemed to provide no serious passage for water leakage from the reservoir. The reservoir is deemed practically watertight.

3.2.3 Construction Material

Construction material required for the Munda dam consists of (1) earth material for the impervious core zone of the rockfill dam, (2) pervious material for the filter zone of the rockfill dam, (3) rock material for the rockfill dam, and (4) coarse and fine concrete aggregates. A considerable amount of investigation and laboratory tests were done in the pre-feasibility study. The pit logs and the laboratory test data are compiled in Volume IV Data Book. The present circumstances for prospect of material sources are as follows:

(1) Earth Core Material

In the Pre-Feasibility study, clayey deposits on both sides of the Swat river within 6 km downstream of the existing Munda headwork, that is, "Abazai clayey silt source" on the left bank and "Sadar Gari sandy silt source" on the right bank were contemplated as sources for the earth core material. Using these borrow pits, however, would mean sacrificing extensive and fertile farm lands.

In this Feasibility Study, the investigation was extended to other potential borrow areas, that is, the low hills of Kas Koruna and Tangi around the Lower Swat Canal and the plain to the west of Sadar Garhi village, to be called West Sadar Garhi, on the right bank of the Munda Headwork. The haul distance to the dam site ranges from 10 km to 13 km.

Eight test pits named P-8 through P-15 were dug to the depth of 5 m except one P-14 that was 2.5 m deep. (Figure 3.2.8)

Fifteen samples were taken from these pits and tested on the characteristics of the earth material for impervious core zone of the rockfill dam. The test items covered the grain size analysis, Atterberg limits, compaction, and then, triaxial compressive strength and permeability of the compacted material. The results are summarised in Table 3.2.1.

Dispersion test was made for samples of P-10 at Kas Koruna, P-13 at Tangi, and P-15 at West Sadar Garhi, proving that the soils are not dispersive.

Earth material of the Kas Koruna borrow site is classified into SM and CL of the Unified Soil Classification by USBR and will be usable for the earth core zone of rockfill dam, except for the coarse material in the northern part represented by the pit P-8. The diversity in its quality, as represented by the varied grain size distribution, may cause some difficulty in quality control of the embankment. The optimum moisture content varies between 10 and 20, that is generally higher than natural moisture contents.

As for Tangi borrow site, the material of the pit P-12 in the western part is classified to GW with gravel contents of 60 to 80%, and is not suitable for the earth core zone. The material of the pits P-13 and P-14 falls under CL and can be used for the earth core, except the upper layer of P-13 that is too gravelly. Only in the material of P-14, the optimum moisture contents are lower than the natural moisture contents. This borrow area has drawback in the longer haul distance and the possible interference with cultivated land and housing areas.

West Sadar Garhi is topographically characterised by an extensive plain or a single sedimentary environment between the Swat river and the hills to the west, not divided by low hills as other borrow areas. The sample from the pit P-15 falls under the category of SM in the Unified Soil Classification, suitable for embankment material and easy to compact. The hauling distance is the shortest of all the borrow areas. As this borrow site is in deserted land it appears to have a merit of less interference to lands cultivated or inhabited.

(2) Concrete Aggregates and Filter Material

For concrete aggregates and filter material, five test pits, P-1 to P-5, were dug in the sand-gravel bar on the Swat river bed downstream of the Munda Headwork. Other two pits, P-6 and P-7, were also dug in the terrace gravel beds on the hills on the left bank of the Munda Headwork (see Figure 3.2.8). The samples taken in those pits were tested in the laboratory. The results are presented in Table 3.2.2.

The sand contents in those deposits are rather low, 15 - 27.4%. Gradation curve shows especially low percentages for the medium and coarse sand. Sand for fine concrete aggregate will have to be artificially produced by crushing the gravel.

Gravel of the Swat river bed can be competent for coarse aggregate of concrete, as judged from the test results. All the samples fell under the area of innocuous aggregate in the chemical alkali reactivity test.

Gravel deposit on the left bank hill is inferior for concrete aggregates to the Swat river gravel, in its high water absorption and contamination with fine material. It, however, could be used as filter material if boulders over 200 mm are removed.

(3) Rock Material

As the result of field reconnaissance and study of previous investigation, two quarry sites were selected. One is a Sappare quarry site with 6 million m^3 of limestone reserve estimated, and the other is a Todobo Banda quarry with sufficient quantity of quartzite and siliceous schist. The former is located around an old and deserted village of Sappare on a 200 m high hill on the left bank of the Swat river and approximately 3 km northeast of the dam site. The latter is located on the right bank of the Swat river approximately one kilometer upstream of the dam site.

The core drilling for the total length of 450 m and the seismic refraction prospecting for 2.45 km were conducted for these quarry sites (see Figure 3.2.9 and 3.2.10). Results of the laboratory rock tests are shown in Table 3.2.3.

In the Sappare quarry site, the zone with seismic wave velocity of 3.5 to 4.0 km/sec, under a few m thick overburden, will produce sufficiently solid limestone material as indicated by the core drilling. The outstanding merit of the Sappare quarry is the availability of boulders or big rock blocks, while quantity of the hard limestone is limited.

In the Todobo Banda quarry with quartzite and quartz mica schist, the rock is characterised by diversity in quality and a tendency to break into small fragments of 5 to 15 cm of diameter by schistose foliations. Quantity is sufficient.

The rock at Sappare is superior in quality but limited in quantity, while the Todobo Banda rock is in the reverse condition. Both quarries are to be utilised. These two sites are not alternatives.

3.2.4 Seismicity

The project area is located in a highly active tectonic zone with thrust faults in the Himalayan foot-hills, and in a region of high seismicity. Records of massive and various earthquakes that had been collected for other projects by WAPDA did not always cover the area exactly relevant for the Munda Dam Project. Earthquake risk of the dam was evaluated based on earthquake records obtained through the internet from the US Geological Survey. Those are data of:

i) 26 significant earthquakes with epicenters within 300 km from the Munda dam site (34.35°N/71.33°E), recorded from 1896 to 1992, and
ii) 2,259 earthquakes over Magnitude 1.0 on the Richter scale with epicenters within the same area as above, recorded in 25.5 years from 1973 to 1998. (Ref. Data Book)

The latter data of 2,259 earthquakes were mainly used for evaluation of seismicity. For each earthquake the intensity that could have been felt at the Munda dam site was estimated by use of formulae of attenuation relationship; one from Cornell (Cornell, C.A., 1968, Engineering seismic analysis, Bull. Seism. Soc. Am. Vol.58, pp. 1583-1606) and the other by Kawasumi (Kawasumi, H., 1951, Measures of earthquake danger and expectancy of maximum intensity throughout Japan as inferred from the seismic activity in historical times, Bull. Earthq. Res. Inst., 21, pp. 469-482.).

Number of earthquakes was counted for each intensity (I), which was then converted into the accumulated number of earthquake for each intensity step, then to the annual number of earthquake (Nc) as shown in Figure 3.2.11.

With Gutenberg's relationship between Nc and I, that is:

$$\log Nc = p + q.I,$$

The constants p and q were determined for the recorded earthquakes, and then the probable maximum earthquake intensity for the return period of 100 years was estimated by applying 1/100 for Nc.

The result is as follows:

Maximum Intensity and Peak Acceleration

	Maximum Intensity in MM Scale	Maximum Intensity in JMA Scale	Maximum Peak Acceleration
According to Cornell	7.3	-	154 gal
According to Kawasumi	-	4.5	80 gal

On the other hand, it is assumed that Maximum Credible Earthquake is generated at the distance of 10 km on the Main Mantle Thrust and has Magnitude of 7.0 and focal depth of 40 km. Intensity and peak acceleration are estimated at 9 and 500 gal, respectively.

The peak acceleration only lasts for a fraction of a second and is virtually unable to effect any damage upon dam structures. Substantially durable acceleration is far lower than the peak value, for example a third the peak acceleration. Meanwhile the maximum credible earthquake is the conceivable strongest earthquake of which probability of occurrence is very low. It is defined that some damages upon structures by Maximum Credible Earthquake should be accepted if those damages do not lead to serious hindrance of their function.

With all these results of evaluation in mind and also considering examples in highly tectonic zones including some dams in Pakistan and dams in Japanese archipelago, the appropriate design earthquake acceleration in the pseudo-static approach is proposed at 0.15g.

Situated in the tectonic zone, the possibility of reservoir-induced earthquake cannot be eliminated. However, there is no major fault in the reservoir area that might generate earthquakes of high magnitude. The assumption for the estimate of the Maximum Credible Earthquake mentioned above, i.e., an earthquake of Magnitude 7 at the distance of 10 km and the depth of 40 km, will well cover a possible earthquake that may occur in the reservoir. The maximum peak acceleration less than 500 gal or 0.5g that lasts only a fraction of second will be coped with by the proposed design acceleration of 0.15g.

3.3 Hydrology

3.3.1 Basin Description

(1) Physical Features

The proposed Munda Dam site is located on the Swat River. Up to the Munda Dam site, the total catchment area of the Swat River basin is 13,650 km^2 as shown in Figure 3.3.1 and can be divided among three major subbasins of upper and lower Swat (6,579 km^2), Panjkora (5,724 km^2) and Ambahar (1,347 km^2) river subbasins. Elevation of the river bed at the proposed Munda Dam site is about 360 m.

(2) Climatic Features

The climate varies considerably over the catchment. In the upper basin the winter is very cold and freezing weather prevails from November to March with snowmelt temperatures occurring between April and September. The snow line descends to 2,500 m during winter and recedes to about 4,000 m during summer. The Swat River consequently carries perennial flow, which is generated from snowmelt and rainfall.

On average, the rainfall over the catchment varies from 500 mm to 1,500 mm as shown in Figure 3.3.1. Rain occurs over the basin in both summer and winter with two maximums occurring in March and August. In summer, rainfall is largely due to monsoon influences and storms, which produce significant runoff, and occur mainly at the central and lower basin.

(3) Present development

The first significant water resources development on the Swat River took place in 1885 when the Lower Swat Canal (LSC) was opened to irrigate 510 km^2 with a designed capacity of 29.9 m^3/sec as seen in Figures 3.3.1 and 3.3.8. During 1915-19 the canal was renovated by additional barrage to provide extra 23.5 m^3/sec discharge from the left bank. Simultaneously, Doaba Canal with a designed capacity of 10 m^3/sec was constructed to be fed from the right-bank of the barrage and hence increased the total command area to about 650 km^2.

3.3.2 Hydro-meteorological Data

(1) Rainfall Data and Other Meteorological Parameters

Inventory on the meteorological data conducted during the field investigation of this Feasibility Study showed that several agencies are responsible for maintaining meteorological data within and around the Munda catchment area. Principal sources are listed as follows:

- Pakistan Meteorological Service (PMS)
- Irrigation Department at NWFP (ID)
- Provincial Authorities at NWFP (PRO)
- Surface Water Hydrology Project at WAPDA (SWHP)
- Pakistan Forest Institute at Peshawar (FOR)

Stations maintained within and around the Munda catchment area by PMS and other provincial departments are listed in Table 3.3.1. The locations of these stations are shown in Figure 3.3.1. Rainfall records are available from all the meteorological stations. Peshawar station has records for 7-climatic parameters and is considered a synoptic station. For the purpose of this Feasibility Study, records of daily/hourly rainfall and daily/monthly meteorological data were collected and encoded during the site investigations. Inventory of the collected meteorological data is shown in Figure 3.3.2 and the data are compiled in Volume IV Data Book.

(2) Flow Data

Inventory of the water level stations maintained within and around the Munda catchment area by SWHP and ID is listed in Table 3.3.2. The locations of these stations are shown in Figure 3.3.1 along with the meteorological stations.

During the field investigations, hydrological data were collected and encoded for five stations and two diversion canals. Inventory of the collected hydrological information is shown in Figure 3.3.3 and the data are compiled in Volume IV Data Book.

In summary, within the catchment of Swat River basin up to the proposed dam site, the hydro-meteorological data are available from eight rain gauging stations and three water level gauging stations as shown in Figure 3.3.1. As shown in the figure, the existing rain and water level gauging stations are inconsistently located along the main stem of the Swat River with no single station available in the Panjkora River basin, which represents approximately 40% of the total catchment area of the proposed Munda Dam. To supplement the hydrological information for the Project, it was recommended that new rainfall and water level gauging stations be established and those are currently under construction by WAPDA at:

1) Approximately 2 km downstream of the proposed dam site where the river channel is relatively straight and narrow, and
2) Near existing Zulam Bridge in the Panjkora River basin.

(3) Flow Records at Upstream of Existing Munda Headworks

There are daily flow records for the upstream site of the existing Munda Headworks, which are annually compiled as an annual data book, "Stream Flow and Rainfall Data, Peshawar Zone" published by Hydrology Division, Irrigation Department, NWFP. However, there are some disputable records and ambiguity involved regarding application of rating curve, frequency of discharge measurement, backwater effects from the Headworks, etc.

Based on the site observations, the results of interviews carried out during the field investigations, and the above perceptions it was concluded that the flow records at the existing Munda Headworks are not reliable and cannot be adopted for the hydrological study for the Project as they are.

(4) Flow Records at Other Stations

There are four other flow gauging stations in and near the Swat River basin. These stations are Kalam (Swat River), Chakdara (Swat River), Warsak (Kabul River) and Nowshera (Kabul River). The four stations have been in operation by the Surface Water Hydrology Project (SWHP) of WAPDA since 1960 up till now, except Warsak, which was abandoned after the construction of Warsak Dam in 1970. According to SWHP, they follows the procedures used by US Geological Survey, and standard SWHP practice at gauging stations is to measure river level several times a day during low flow periods and more frequently during those of high flow periods.

In order to compare the daily flow trends among the different stations, daily records from 1990 and 1991 at Kalam, Chakdara and Nowshera were examined. The maximum daily flow occurred within the summer season for the three stations in both 1990 and 1991. Mean monthly discharges for the period 1964 to 1995 at Kalam, Chakdara, Nowshera and Warsak are shown in Figure 3.3.4.

At these stations, discharge measurements are generally made twice a month during low flows and more frequently during high flows. The average numbers of discharge observations during the period from 1961 to 1981 (for Warsak, 1961 to 1971) are 26 for Kalam, 42 for Chakdara, 21 for Warsak and 28 for Nowshera.

Rating curves for Kalam (1965-1988), Chakdara (1964-1988) and Nowshera (1964 – 1987) stations collected during the field investigation indicated that the respective rating curves were updated every year.

Further, to investigate and find the relationship between these flow patterns within the Swat and Kabul basins, correlation analysis was carried out on the basis of the monthly flow data. Cross correlation among each pair of stations was calculated and results are tabulated below.

Correlation Coefficient for Monthly Discharge Among Water Level Gauging Stations

Name of Station (Catchment Area)	Kalam (1961-1995)	Chakdara (1961-1995)	Warsak (1961-1971)	Nowshera (1961-1995)
Kalam (2,020 km^2)	-	0.9445	0.9165	0.9086
Chakdara (5,766 km^2)	-	-	0.9743	0.9716
Warsak (67,340 km^2)	-	-	-	0.9914
Nowshera (88,578 km^2)	-	-	-	-

The correlation is quite high among monthly flow data at the four stations, especially between Chakdara, Warsak and Nowshera for which the correlation coefficients are more than 0.97. In summary, the flow records of the four stations maintained by SWHP-WAPDA are reliable and acceptable.

On the other hand, the correlation coefficients of data at Munda Headworks with the above stations are rather low from 0.68 to 0.83.

In order to obtain long-term monthly flow data at the Munda Dam site, available records at Kalam, Chakdara, Nowshera and Warsak were utilized. The long-term flow records (available and supplemented) at Kalam, Chakdara and Nowshera are listed in Tables 3.3.3, 3.3.4, and 3.3.5, respectively.

3.3.3 Meteorology

(1) General Climatological Characteristics

The climate of the Swat River basin is classified as sub-humid tropical continental high lands. Precipitation over the catchment area is received in the form of both rain and snow. Rainfalls occur within two seasons, monsoon (July to September) and spring (February to May). The monsoon rains brings 30% of annual rainfall in the basin and prevail with moisture brought by winds from Arabian Sea and the Bay of Bengal.

According to the normal isohyetal map prepared by PMS, the annual rainfall within the catchment area varies locally from 380 mm to 1,270 mm with 810 mm average annual rainfall (ref. 3).

Temperature varies within the region extensively. The maximum temperature usually occurs in July and minimum in January. The long-term average annual temperature values at the four meteorological stations are listed below:

Long-term Mean Monthly Maximum and Minimum Temperatures

Units: °C

Station	Maximum	Minimum	Average	Period
Kalam	19.2	-1.1	10.6	1986 - 1996
Saidu Sharif	28.7	8.2	19.1	1974 - 1991
Mardan	31.9	9.2	21.1	1985 - 1996
Peshawar	33.1	11.2	22.7	1961 - 1991

(2) Rainfall Analysis

In Swat River basin, generally the months of July and August have the highest magnitude of rainfalls, while November has the lowest rainfall throughout the year.

The long-term mean monthly and annual rainfalls at each respective station are summarized in Table 3.3.6 and Figure 3.3.5. Double mass curves among some selected stations are shown in Figures 3.3.6 (a) to 3.3.6 (d). They show intensive rainfall in the years 1987 and 1988 were encountered at Charbagh station.

(3) Evaporation

Evaporation records are available at Peshawar meteorological station, which is the closest station to the Project site. The annual/monthly pan evaporation records have been observed by Pakistan Forest Institute, Peshawar, and available for the periods from 1967 to 1985 and from 1986 to 1997. Long-term evaporation time series for the period 1967 – 1997 are shown in Table 3.3.7.

To estimate the evaporation loss from the reservoir, the values of monthly pan evaporation records were multiplied by the conversion factor of 0.7 to convert the pan evaporation to the reservoir evaporation. The converted data is used to estimate the evaporation loss from the Munda Dam reservoir for the different proposed water levels during the reservoir operation study.

3.3.4 Stream Flow

(1) Analysis of Available Data

The Munda Dam Project is proposed on the Swat River basin with a catchment area of 13,650 km^2 and traverses a river length of about 250 km. The catchment area was calculated and examined by dividing the total basin into four regions as illustrated in Figure 3.3.7. Based on the calculated catchment areas for each region, the upper Swat catchment area up to Chakdara water level station (region B1, 5,776 km^2) together with the Panjkora River basin (region B2, 5,724 km^2) form about 85% of the total catchment area. Flow from Panjkora River basin, which alone forms about 40% of the total catchment area and contributes an average of 50% runoff to the Swat River, is not being monitored. Because of low degree of reliability of flow records at the Munda Headworks, alternative methodologies that included rainfall-runoff and regional analysis were investigated in order to estimate the long-term flow values passing the Munda Dam site.

Analysis of flow records indicates no direct relationship between rainfall and the corresponding runoff on both a monthly and annual basis.

With the limited rainfall and snow information, the regional analysis was destined to be the most suitable procedure to be applied for water availability estimates at the dam site. In order to carry out regional analysis, the flow records of Kalam and Chakdara at the Swat River basin, and Nowshera and Warsak at the Kabul River basin were utilized. Procedures of the regional analysis are described in details in Appendix C with a flow chart.

(2) Flow Estimation at Munda Dam Site

Flow estimation was carried out based on flow-catchment area relationships using flow records at the four stations of Kalam, Chakdara, Nowshera and Warsak. The relationships have been developed for each month based on average monthly records in each station, details being described in Supporting Report, Volume III, Appendix C.

To estimate the flow at the Munda Dam site, present and future water diversions in the basin for irrigation schemes should be taken into consideration. The estimate was conducted based on the schematic diagram of irrigation schemes shown in Figure 3.3.8 and the water use of each irrigation scheme prepared by Swabi SCARP listed in Table 3.3.8, in the following steps:

1) The Chakdara historical flow records are adjusted by adding the diverted water to the existing irrigation schemes such as Nipkikhel and Fatehpur which are located in the Chakdara basin.
2) Following these adjustments, the monthly synthesized flow at the Munda Dam site is estimated utilizing the relationship established above. This estimated flow represents the natural flow at the Munda Dam site.

3) The present (historical) flow at the Munda Dam site is calculated by subtracting the diverted water to USC and various existing irrigation schemes are from the above synthesized flow (natural flow). Where diversion records to USC are missing, those were supplemented by the average of the records during the period 1956 – 1964 (ref. 2) so that continuous diversion records were available. The results are shown in Table 3.3.9.
4) In order to reflect future diversions of water for USC and other water uses, the future monthly inflows at the Munda Dam site after the extension of these schemes are calculated by subtracting the monthly expected diversion flow rates to USC in the future and the water use by locals which was assumed to be 5.66 m^3/sec. The expected diversion flow rates were based on the assumption that the maximum water use for USC during the dry season is limited to the difference of the inflow at the Chakdara station and the water use by locals downstream of the Amandara Headwork. The results are shown in Table 3.3.10.

Since the extension of USC is expected to be implemented soon, the estimated flow at the Munda Dam site after the extension of these schemes was applied for optimization study of the Munda Dam.

3.3.5 Flood Studies

The prime objective of the flood studies is to estimate a series of flood values for the design of the various structures of the Project. There are two principal requirements for flood calculation, one is the design of the dam and spillway, and the other the design of the other relevant structures including river diversion arrangement. In view of the large scale of the Project (both financial and physical), considerable care is required in the study of flood hydrology and the selection of the appropriate design floods as the risk of overtopping the dam embankments is of significant importance. Because of these two principles, it was decided to estimate probable maximum flood (PMF) based on probable maximum precipitation (PMP) for the dam and spillway design. On the other hand, probable flood calculations based on rainfall frequency analysis for different return periods were considered for the design of powerhouse, downstream structures of spillway and the diversion facilities. Details of the flood studies are described in Appendix C with a flow chart.

(1) Probable Maximum Flood (PMF)

The proposed Munda Dam is a major structure that requires estimation of flood values for dam and spillway design based on PMF that may be expected from the most possible severe combination of critical meteorological and hydrological conditions in the region. PMF can be estimated using the following physical-based procedures:

1) Catchment area division to subbasins
2) Estimation of PMP
3) Storm distribution among the subbasins
4) Estimation of storm losses
5) Estimation of maximum snowmelt rates
6) Construction of unit hydrograph
7) Flood routing and composite PMF calculations

(2) Computation of Composite PMF

1) Catchment area division to subbasins

In the present feasibility study, the total catchment area of the Swat River up to Munda Dam site can be divided into four subbasins. The boundary of each subbasin is shown in Figure 3.3.7.

2) Estimation of Probable Maximum Precipitation (PMP)

PMP can be defined as "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year" (ref. 5). The more common methodologies to estimate PMP are the meteorological and statistical approaches. The statistical approach may be used wherever sufficient historical rainfall data are available or where other meteorological data such as dew point and wind speed are lacking. The statistical approach is of particular importance for making quick estimates for PMP and provides a check guide for the estimated values by the meteorological approach. In this Study, both approaches were applied to predict the most relevant PMP value for PMF estimate at Munda Dam site.

a) Statistical Estimates of PMP

The statistical methodology for estimating PMP is based on statistical analysis of maximum rainfall records within gauging station. The methodology is to yield only point PMP estimates and thus requires area-reduction factor for converting to basin PMP. The methodology is documented in the report of World Meteorological Organization (WMO) (ref. 6).

According to the estimated PMP for each station, the calculated value for Charbagh station was the highest value among other stations, therefore, the PMP for calculation will be considered as 544 mm.

b) Meteorological Approach

The meteorological approach relies on the theoretical interrelation of convergence, vertical motion and condensation of the air mass in the atmosphere. Briefly summarized, the assumption is that PMP can be computed from optimum storm maximization by moisture maximization factor and storm transportation of wind coverage. For estimation of PMP, the most severe mechanism by which moisture is converted from water vapor into rain or snow is considered with the maximum moisture content in the air. As the precipitation efficiency of storms cannot be estimated directly, a series of major historic storms should be examined to indicate the extreme historical storm event.

- Review of historical storm in the basin

  The rainfall and storm records were reviewed from the available previous studies to indicate the largest storm over the Swat River basin. The principal storms identified in the review process are as listed below:

Principal Historical Storms

27-29 July 1882	8-10 August 1940	15-17 July 1958
25-27 August 1910	9-11 July 1942	3-5 July 1959
23-28 July 1924	19-23 August 1948	31 July – 3 August 1976
26-29 August 1929	1-3 August 1950	2-7 August 1987

Source: Reference 4) Appendix E.2

Inspection of these storms from the available reports revealed that the storms of August 26 – 29, 1929 and July 31 – August 3, 1976 were outstanding extreme storms compared to the other recorded storm events.

Based on the above reviews, the storm of August 26 – 29, 1929 is clearly a candidate for the assessment of the PMP value in the Swat River basin.

- Isohyetal of August 26 – 29, 1929

  The isohyetal map for the storm of 1929 was available from both of the studies mentioned above of the Pakistan Meteorological Department (PMD) in connection with the proposed Munda Dam project (ref. 1) and the Kalabagh Consultant Study (KCS) in connection with Kalabagh Dam Project (ref. 4).

  After examination of all the details, it was decided to adopt the isohyetal map provided by PMD study for the 1929 storm shown in Figure 3.3.9 for the PMF estimates.

- Storm Moisture Maximization Factor

  Moisture maximization of storms in place, i.e., without change in location, consists simply of multiplying the observed storm rainfall amounts (storm of 1929) by the ratio of the maximum precipitable water indicated from the storm location to the precipitable water estimated for the storm (ref.6).

  In view of station location and approximate elevation of the Swat River basin (1,000 m), dew points data from Gilgit and Peshawar meteorological stations were considered.

  With elevation adjustment, the moisture maximization factor of 1.38 was obtained. It should be noted that the estimated moisture maximization factor is identical to the value estimated by the PMD study. So the estimated PMP values by PMD were considered.

- Depth-Area-Duration for PMP

  In the PMD study, spatial and temporal storm analysis was carried out in order to estimate the Depth-Area-Duration (DAD) curves for probable maximum precipitation. The methodology was obtained by applying the standard procedures of US Weather Bureau " Manual for Depth-Area-Duration Analysis of Storm Precipitation"

  From the DAD table in the procedure, the 24 hour PMP at Munda Dam site, catchment of 13,650 km^2, is estimated at 173.08 mm and 174 mm is used for the PMF calculation.

  In order to compare this value with the statistically estimated point PMP value of 544 mm, an area reduction factor should be estimated to convert point PMP to its equivalent basin PMP. The area reduction factor can be estimated as 0.326 from the PMD study. With this value, the basin PMP can be calculated as $544 \times 0.326 = 177.34$ mm which shows that the estimated PMP value of 174 mm for the Project is relevant and acceptable.

3) Estimation of short-duration storm rainfall

In order to estimate flood hydrograph, a short-duration of 6-hour rainfall or less should be estimated. Different aerial rainfall patterns and storm profiles could produce the average 72 hour design storm rainfalls, but for a short-duration, pattern information and review of storm characteristics should be investigated. Information on 6-hour storm increments were available mostly for the recent storms but with less reliability than those for older ones. After detailed review of the available materials, the values from DAD table developed by PMD study were found more reliable and applicable.

4) Storm distribution among the subbasins

The calculation of the composite flood hydrograph is more dependent on how the basin total storm can be distributed among the different subbasins. Using the isohyetal map of 72-hour 1929 storm (Figure 3.3.9), the basin as well as subbasins rainfalls were estimated by calculating the area between each pair of isohyets within the basin (or subbasins) boundary and multiplying by the average rainfall depths of the two boundary isohyets. Summary results of calculating rainfall for each subbasin are shown below:

Summary of Rainfall Calculation Based on 3-Days 1929 Storm

Subbasin	Catchment Area km^2	3-day [a] 1929 Storm, mm	Ratio to Basin Storm	1-day [b] PMP mm	3-day [c] PMP mm
B1	5,776	161.5	0.93	161.8	226.5
B2	5,724	181.8	1.05	182.7	255.8
B3	1,347	115.1	0.66	114.8	160.7
B4	803	270.8	1.56	271.4	380.0
Total Basin	13,650	173.2	1.00	174.0	243.6

1) Values calculated from the 3-days 1929 storm isohyetal map (Figure 3.3.9)
2) Values adopted based on estimated basin 24-hours PMP value of 174 mm
3) Values adopted based on maximization of 24-hours PMP by 1.4

The value for 72-hour PMP can be estimated as 243.6 mm. The estimated value of PMP for 24 hours and 72 hours can be distributed among the subbasins based on the relative rainfall distributions as shown in the above table.

5) Estimation of storm losses

In this Study, rainfall losses were estimated from available flood record and corresponding storm value and distribution using an optimization technique. In view of the data availability, the flood of July 25, 1995 was considered to provide the necessary data for the rainfall loss estimates. The hourly flood records were available at Chakdara water level station and hourly storm distributions were available at Kalam and Mardan rainfall gauging stations. The optimization processes were carried out with the HEC-1 model (ref. 7) in which initial and uniform loss rate values were calculated after several optimization trials. The initial loss and the constant loss rate were best optimized as 5.5 mm and 4.5 mm/hour, respectively.

6) Estimation of maximum snowmelt rates and base flow

Although snowmelt has significant impacts on flood hydrograph especially during monsoon season, snow data and information within the Swat River basin are not available. Due to the lack of snow data, it is difficult to accurately identify the portion of the snowmelt that may contribute to the design flood at the proposed Munda Dam site.

In the present study, snowmelt effect is considered as the base flow for the calculation of PMF and its flood routing among the different basins. After review of the available methodologies and appropriate techniques, it was decided to adopt the average of estimated long term flow records (1956 – 1997) at Munda Dam site (Table 3.3.9) for July as base flow and snow effect when performing PMF estimates. This value can be considered as 650 m^3/sec and will be distributed between Upper Swat and Panjkora river subbasins (B1 and B2) as 400 and 250 m^3/sec, respectively. The value adopted for Upper Swat River basin was based on the long term flow records (1956 – 1997) at Chakdara station (450 m^3/sec) after subtracting the diversion water for Upper Swat Canal and local users (50 m^3/sec).

7) Construction of unit hydrograph

To estimate the probable maximum flood passing the Munda Dam site, the unit hydrograph at each subbasin should be constructed based on recorded floods and storm events. The Swat River basin up to Munda Dam site was divided into three subbasins of Upper Swat, Panjkora and Ambahar and one region contributes inflow directly to the river (Lower Swat). The boundaries of these divisions are shown in Figure 3.3.7.

The unit hydrograph for Upper Swat was constructed using data of five flood hydrographs observed at Chakdara station for the years 1985, 1986, 1988, 1991, and 1995. The hourly hydrograph distributions of the five floods for 48 hours are shown in Figure 3.3.10. As shown in the figure, all five floods occurred in July basically due to monsoons of the summer season. The flood of 1995 is the most significant as it has the maximum value (2,772 m^3/sec) and the shortest time to peak (6 hours) compared to the other flood events. The flood of 1991 had the largest base flow of 1,366 m^3/sec and undefined sudden drop after 24 hours from 1,156 m^3/sec to 829 m^3/sec.

Storm data during the five floods were obtained from the available rainfall records. Equivalent 24-hour rainfalls were estimated from the rainfall records at eight rainfall stations while their hourly distributions were assumed based on the hourly rainfall records from Kalam and Madran rainfall stations.

In the present study, the unit hydrographs of 1988, 1991, and 1995 were calculated using HEC-1 model (ref. 7) while using the optimization capabilities of HEC-1 and data of the 1995 flood, parameters of unit hydrograph and rainfall loss were estimated. The unit hydrograph parameters were optimized based on Clark unit hydrograph method, on the other hand, the rainfall loss parameters were optimized based on uniform loss rate method.

Having obtained the rainfall loss parameters for the Upper Swat subbasin based on characteristics of the 1995 flood, HEC-1 model was applied to estimate the unit hydrograph parameters for 1991 and 1988 flood events. After several optimization trials, the unit hydrographs for each flood event were determined. The estimated unit hydrograph results show that the unit hydrographs of 1991 and 1995 are quite similar while the unit hydrographs of 1985, 1986, and 1988 are also similar in their shape. Therefore, this Study, two sets of average unit hydrographs were adopted and applied to estimate the design flood. The hourly ordinates of these two sets of unit hydrographs are presented in Figure 3.3.11.

In view of the limited storm and flood data at Panjkora and Ambahar subbasins, the unit hydrograph of Panjkora subbasin was considered identical to the estimated unit hydrograph of Upper Swat assuming both subbasins are physically the same (ref. 3). For Ambahar subbasin, a synthetic unit hydrograph was derived using the US Soil Conservation Service method (ref. 8 and 9).

The final estimated unit hydrograph ordinates for Ambahar are shown in Figure 3.3.12.

8) Computation of composite PMF

The principal procedures used to estimate the composite PMF at Munda Dam site include:

- Calculation of PMF hydrographs at each subbasins utilizing calculated PMP and storm characteristics, loss rate, base flow and unit hydrograph data.
- Flood routing in three stream reaches between confluence points (junctions) to the proposed dam site i.e. from Upper Swat to Panjkora as reach 1, from Panjkora to Ambahar as reach 2 and from Ambahar to the Munda dam site as reach 3.

The HEC-1 model was used to carry out these procedures through construction of a stream network representing the watershed up to the proposed dam at Munda.

In this Study, PMF values were calculated for 24-hour and 72-hour time span and two sets of average unit hydrographs of 1991 and 1995 and 1985, 1986, and 1988. The combination of these sets leads to four case result sets to be examined in estimation of PMF. These cases are as follows:

- Case 1: using average unit hydrograph of 1991 and 1995 with 24-PMP
- Case 2: using average unit hydrograph of 1985, 1986, and 1988 with 24-PMP
- Case 3: using average unit hydrograph of 1991 and 1995 with 72-PMP
- Case 4: using average unit hydrograph of 1985, 1986, and 1988 with 72-PMP

Table below summarizes the PMF estimates at Munda Dam site for each case:

Estimated Probable Maximum Flood Values

Case	Probable Maximum Flood (PMF), m^3/sec	
	Peak	Time to Peak
1	18,170	11
2	19,390	16
3	15,990	13
4	16,710	18

Ordinate of the computed PMF at Munda Dam site for these four cases are illustrated in Figure 3.3.13.

From the estimated values of PMF, it is evident that 24-hour PMP cases (Case 1 and Case 2) are more critical for the dam design than the 72-hour cases. Therefore, these two cases will be considered as PMF values used for the design of the dam and spillway, where eventually case 2 was found to be the most critical. Figure 3.3.14 illustrates specific design floods for dam and hydropower projects in Pakistan as well as Munda Dam. The estimated Munda PMF peak of 19,390 m^3/sec (1.42 m^3/sec/km^2) falls in the reasonable range in this figure. Therefore, the Munda PMF is considered acceptable.

(3) Estimates for Probable Flood Frequencies

The purpose of the probable flood frequency study is to obtain a range of floods of various magnitudes and probabilities of exceedence for different return periods for the purpose of design of structures other than dams. Flood frequency analysis is usually carried out by utilizing the annual instantaneous maximum flow records. In case such flow records are not available, flood frequency values are obtained based on rainfall frequency values converting the results to equivalent flood values using rainfall-runoff relationship. In view of flow records at the Munda Headworks, being insufficient it was decided to carry out the flood frequency analysis based on rainfall frequency analysis. Rainfall frequency values for different return periods were estimated based on basin 24-hour maximum rainfall. The rainfall duration of 24-hour was applied for the flood estimates since the study of PMF revealed the maximum peak discharge for 24-hour PMP and recorded maximum 1929 storm shows the principal duration of 24-hour. In order to estimate basin 24-hour maximum rainfall, rainfall records from four stations during the period 1961 – 1997 were selected (Kalam, Charbagh, Amandara and Abazai). The total basin catchment area up to the Munda Dam site was divided applying Thiessen polygon as shown in Figure 3.3.15.

Having the annual series of basin maximum daily rainfall, frequency analysis using six distributions were examined. These distributions were: Normal, Log-Normal type II, Log-Normal type III, Pearson type III, Log-Pearson type III, and Gumbel Extreme type I. Among the six distributions, Pearson type III distribution was selected as it produced the best fitted results compared to the recorded data with a correlation coefficient of 0.9869. The frequency curve and estimated values for different return periods are listed in Figure 3.3.16.

Maximum flood and flood hydrograph for each return period were calculated using the HEC-1 model by utilizing the basin characteristics based on case 2 (i.e. Unit hydrograph, base flow, rainfall losses, rainfall hourly distribution, etc.).

Figure 3.3.17 presents the hourly flood hydrograph distribution for each return period.

The results are summarized as follows:

Probable Flood for Different Return Periods

Return Period, (Years)	24-Hour Basin Maximum Rainfall, (mm)	Probable Flood, (m^3/sec)
2	35.7	1,050
5	46.3	2,050
10	53.1	2,740
20	59.4	3,400
25	61.2	3,630
50	67.4	4,370
100	73.3	5,010
200	79.1	5,720
500	86.9	6,610
1,000	92.7	7,280
10,000	112.6	10,050

The estimated probable floods fall within reasonable range in Figure 3.3.14, therefore, the probable floods are considered acceptable.

3.3.6 Sedimentation

(1) Suspended Load

In the published reports of Hydrology Division, Irrigation Department, NWFP the suspended sediment records at the Munda Headworks are available for six years within the period 1964 to 1973. However, there are various examples of discrepancy in these data that raise doubts about the accuracy of the records especially during high flow period records. So, the recorded suspended sediment at the Munda Headworks could not be utilized in this Study. According to the availability of the data, it was decided that the most appropriate method to estimate the sediment inflow at the Munda Dam site is to carry out the regional analysis based on the available sediment records at the four gauging stations of Kalam, Chakdara, Warsak and Nowshera.

During the field investigation stages, daily-suspended sediment records at Kalam and Chakdara were collected from SWHP of WAPDA for the period 1960 – 1995 (ref. 10, pp. 31 - 40) as compiled in Volume IV Data Book. Also, annual sediment load records at Kalam, Chakdara, and Nowshera stations for the period 1961 – 1990, and that of Warsak station for the period 1961 – 1970 are available. The annual water yield and suspended sediment for these stations are shown in Table 3.3.11 (ref. 10, pp. 141 – 145)

Using these data, sediment concentration at the Munda Dam site was computed by establishing relationship between sediment and water yields. The annual average values of each gauging station is given below:

Average Annual Sediment and Water Yields

Station	Catchment Area CA km^2	Annual Flow[1] Q m^3/sec	Water Yield Q/A $m^3/sec/km^2$	Sediment Load[2] Qs ton/day	Sediment Yield Qs/A $ton/day/km^2$
Kalam	2,020	92	0.0455	789	0.3906
Chakdara	5,776	180	0.0317	3,305	0.5722
Warsak[3]	67,340	706	0.0105	46,667	0.6930
Nowshera	88,578	858	0.0097	100,767	1.1376

1) Based on records of 1956 – 1997
2) Based on records of 1961 – 1990
3) Based on records of 1961 – 1970

Average annual sediment and water yields for the period 1961 – 1990 at the four stations are plotted, and the regression analysis was carried out as shown in Figure 3.3.18.

For the Munda Dam site with average annual inflow of 228.58 m^3/sec and a catchment area of 13,650 km^2, the sediment yield of 0.85 $ton/day/km^2$ can be estimated based on the regression formula (Y=-16.635 X + 1.1307) shown in the Figure 3.3.18. Where Y and X are the sediment and water yields in units of $ton/day/km^2$ and $m^3/sec/km^2$, respectively.

The equivalent average annual suspended sediment value is then estimated to be 311 ton/km^2.

(2) Bed Load

Up to now, no bed load measurements have been performed in the Swat River basin, therefore, the bed load is to be estimated based on suspended load value. For preliminary estimation, bed load can be estimated based on the table showing Bed Load Preliminary Ratios to Suspended Sediment Load suggested by Mutreja (ref. 11, pp. 842).

Since the average sediment load is valued therein as 535 ppm (equivalent to 11,630 tons/day sediment and 228.56 m^3/sec flow), the estimated rate of bed load is about 5 to 12% of the total sediment load (case 2 in the above table). In this Study, with safety consideration, the proportion of bed load was conservatively assumed to be 20% of the suspended sediment load. Therefore, the annual bed load yield at the Munda Dam site was estimated to be 62 ton/km^2.