IV - **WATERSHED CHARACTERISTICS**

4-01. General Characteristics. The Cerrillos River has a drainage area of 17.5 square miles at the Cerrillos damsite. Between the dam and the debris basin, located 3.6 miles downstream from the damsite, there is a total drainage area of 7.1 square miles. The Rio Bayagan, a tributary stream which joins the Cerrillos River at the debris basin and forms the Bucana River, contributes a drainage area of 4.0 square miles. The Quebrada Ausubo which joins the Cerrillos River above the debris basin contributes a drainage area of 1.0 square mile. The remaining 2.1 square miles of drainage area contributes directly to the main stem of the Bucana River. From the debris basin the Bucana River flows about 5.5 miles to its mouth.

4-02. Topography. The island of Puerto Rico, situated on the Caribbean Tectonic Plate, is just under 110 miles long by 40 miles wide with the longitudinal axis running east and west. A central backbone of mountains rising to a maximum altitude of 4,938 feet extends east-west through the island. North and south of the mountain range are foothills and coastal plains, both of which are much broader on the north side of the island as the crest of the watershed lies nearer the south coast.

The Bucana River basin originates on the southern slopes of the Cordillera Central Mountains with its highest point at Cerro de Punta (elevation 4,390 feet, NGVD) and runs 14 miles to the city of Ponce on the coast. Steep slopes predominate in the basin ranging from 45 degrees in the mountains to about 25 feet per mile in the coastal areas. The watershed is covered by dense tropical vegetation above the damsite, while below the dam some areas have been cleared for agricultural and residential uses. The tributary streams exhibit highly eroded, dendritic drainage patterns with steep walled narrow valleys, and steep, variable gradients of bedrock and boulders. The upper tributaries to the Bucana River have narrow flood plains whereas the lower flood plains are wide and become alluvial near the coast.

4-03. Geology and Soils. Puerto Rico was raised and tilted by a series of uplifts occurring during Middle Miocene, Early Pliocene, and at the end of Pliocene time. This brought about erosional cycles which produced landforms that are evident today. The Quaternary was a period of gentle uplift and tilting to the north and east along with fluctuations of sea level. The Quaternary was predominately a period of erosion. Several uncomformaties are known to exist in Puerto Rico. The most pronounced is between Upper Cretaceous and the younger Tertiaries. The general structural framework of the island is of extensively folded pyroclastics, some sediments, intrusions, and lava flows. The core is uncomformably flanked to the north and south by tilted Tertiaries, which are progressively younger towards the coasts.

On the island, two major fault zones have been delineated. They are the Great Northern Puerto Rico Fault Zone and the Great Southern Puerto Rico Fault Zone. The Great Southern Fault, which passes close to the project site, had been traced for a total length of about 180 km. It has been intermittently active since the early Cretaceous. Both vertical and left lateral movement has occurred. Grabens and horsts occur within the fault zone. This fault zone is not known to be active but inactivity has not been demonstrated.

The stratigraphic sequence represented in the Ponce and Penuelas quadrangles, established by the USGS and others on a broadly regional basis, comprises rocks ranging from Late Cretaceous through Miocene in age. The units range from intrusive and volcanic rocks to limestones and claystones but the entire sequence, excepting certain reefal and bioclastic limestones, may be considered derived from volcanic materials (epiclastic sedimentary rocks). The more coarsely textured rock types are demonstrably volcanistic; the finer-grained clastics, upon petrographic analysis, are seen to be volcanic in origin; and even most limestones are described tuffaceous.

Consistent with the generally accepted geologic history of the island, the Cretaceous sequence comprises mainly lavas, pyroclastic rocks, and a spectrum of derivative lithologic types - breccia, conglomerate, and volcanic sandstone, siltstone, and mudstone. Reasonable inference as to the tectonic settings in which these units formed and to the processes important in their formation, suggest that the Cretaceous sequence is typically poorly stratified and that its internal geometry is complex. Not surprisingly, the lateral and even the vertical relationships among units are imperfectly understood.

The rocks at the damsite are sediments of the Monserrate Formation. The rocks consist of black silty limestones, green marine deposit tuffs, tan siltstones, and an intrusive andesite dike. The limestones are resistant to erosion and form ridges. Tuff and siltstone beds are slightly altered in part and in one area are silicified. Where fresh, the andesite dike is a very hard green-gray rock. It weathers deeply, by chemical decomposition, into red-brown clay. The limestone is thin to thick bedded with thin seams of siltstone along bedding and is fractured with a prominent rhombodial joint pattern. Many joints are open or clay filled, especially near the surface. The welded tuff and siltstone beds are extremely fractured and exhibit an irregular pattern. The fractures are generally small and relatively tight though not sealed. At the surface, the more clayey siltstones slake. The andesite dike and silicified siltstone are the least fractured and, therefore, the least permeable beds at the damsite.

4-04. Sediment. The Cerrillos Reservoir pool is located at the southerly end of a long, narrow drainage basin. The reservoir pool shape forms a classic serpentine gorge-type lake with depths ranging up to about 290 feet at the top of the flood control pool and with a steep average bottom slope of about 70 feet per mile. A sediment distribution study was conducted to predict the volume of sediment expected to be deposited in a pool, i.e. flood control, conservation, and minimum pool levels for a 100-year project life. The sediment deposition study to determine the configuration and volume of sediment accumulation in each pool was computed by use of the HEC computer program "Scour and Deposition in Rivers and Reservoirs - HEC 6". The results of the study showed that the structure site will experience a deposition of about 3 feet over the 100-year project life. At this rate, normal gate operation should be unimpeded by suspended sediment deposition for the entire project life. The final trap efficiency for the reservoir was calculated to 95.1 percent with the following distribution of soil types trapped:
clay - 88.73%; silt - 97.27%; and sand - 100.0%. Table 4-1 shows percent and volume accumulated in each pool.

Table 4-1

Sediment Storage

	Sediment Volume		Original		
Pool	% of Total	Acre-feet	Pool Volume	Volume Acre-feet	Percent Loss
Minimum (311-451)	1.94	95.7	5,635	5,539.3	1.9
Conservation (451-573)	98.06	4,839.3	25,200	20,360.7	19.2
Flood Control (573-611.3)	0.0	0.0	15,975	15,975.0	0.0

Source: Design Memorandum No. 5, General Design Memorandum - Phase II - Cerrillos Dam project Design - September 1980, Page 68

Storage of 700 acre-feet has been allocated to insure water for aquatic life during drought periods, when added to sediment storage, a total of 5,635 acre-feet of minimum storage is provided in the reservoir.

4-05. Climate. The climate of the island of Puerto Rico is tropical. Generally the days are hot and the nights are warm.

a. Temperatures. Mean temperatures in the project area have a very small range between the warmest and coldest months. The mean monthly temperature ranges from 76° F in January to 82° F in July. The mean annual temperature at Ponce is 79° F. For the period of 1955 through 1976, the minimum recorded temperature at Ponce was 55° F and the maximum was 99° F.

b. Precipitation. Annual precipitation in the Ponce area averages about 35 inches, while above the dam site the annual precipitation is about 80 inches. Monthly and annual normal precipitation is shown in Table 4-2. Precipitation in the project area is greatly influenced by orographic effects. The wet season is generally from May through November. Tropical (easterly) waves and cold fronts (associated with upper level low pressure troughs) are the two primary rainfall producing mechanisms in Puerto Rico.

Table 4-2

Monthly and Annual Normal Precipitation (Inches)
(1951 - 1980)

Month	Ponce 4E	Juana Diaz Camp	Guayabal
Jan	0.75	1.25	1.15
Feb	0.68	0.84	0.90
Mar	0.92	1.15	1.79
Apr	1.80	2.72	3.47
May	2.90	3.70	4.59
Jun	2.80	2.93	3.22
Jul	2.85	3.41	3.55
Aug	4.41	5.65	6.73
Sep	5.52	6.89	8.66
Oct	5.95	7.27	8.49
Nov	3.10	4.01	5.34
Dec	1.25	1.89	1.89
Annual	32.93	41.71	48.78

Source: Design Memorandum No. 26, Feature Design Memorandum - Lake Cerrillos Initial Filling Plan - January 1989, Table 3-1, Page 3-2

During the period of May through November, Puerto Rico experiences tropical waves. Tropical waves are migratory wave-like disturbances moving from east to west within the trade winds. An intense tropical wave, especially a slow-moving one, can produce significant rainfall and associated flooding. Floods in the Bucana Basin due to tropical waves include the storms of 6 May 1958, 28 August 1963, 27 August 1970, 12-13 September 1982, and 6-7 October 1985.

Puerto Rico is also affected by tropical cyclones from June through November. Tropical cyclones include tropical depressions, tropical storms, and hurricanes. Tropical cyclones can produce significant rainfall and strong winds. Because of seasonal shifts in favored locations of tropical cyclone development, Puerto Rico is outside the main paths of the most severe tropical cyclones except from August through the first half of October. Hurricanes and other tropical cyclones that severely affect Puerto Rico generally develop over the waters of the southern North Atlantic to the east of the lesser Antilles. Those storms generally move towards the west and northwest. Near misses of intense tropical cyclones may produce little wind damage, but can cause excessive rainfall. Frequency data for tropical storms and hurricanes is shown in Table 4-3. Floods in the Bucana Basin due to tropical cyclones include the storms of 8 August 1899, 13 September 1928, 13 October 1954, 4-9 October 1970, 15-17 September 1975, and 31 August 1979.

Table 4-3

Annual Probability of Tropical Storms and Hurricanes Passing Within 75 Nautical Miles of Puerto Rico

Period	Tropical Storms and Hurricanes	Hurricanes Only
1 May - 15 Jul	0.02	0.00
16 Jul - 20 Sep	0.36	0.18
21 Sep - 30 Nov	0.10	0.05
1 May - 30 Nov	0.48	0.23

Source: NOAA Technical Report NWS 26 (Neuman, 1981)

Another major rainfall-producing situation occurs during the winter months, generally from about November to April, when cold fronts penetrate far enough south to affect Puerto Rico. Strong, active, slowly moving fronts (particularly in combination with upper level low pressure troughs) can produce excessive rainfall. Floods in the Bucana Basin due to rainfall from cold fronts and/or low pressure troughs include the storms of 20-21 May 1969, 17-18 May 1985, and 26-27 November 1987.

The depth-duration frequency data for 24-hour rainfall for the Cerrillos Basin developed in Supplement 1 of Design Memorandum No. 1 (December 1979) is shown in Table 4-4.

Table 4-4

Cerrillos Upper Basin Rainfall
Frequency 24-Hour Duration

	Return Period				
	10-Year	50-Year	100-Year	SPS	PMP
Rainfall (in)	9.95	13.55	15.10	27.27	51.94
Rainfall Excess (in)	5.85	10.26	13.13	25.23	50.29

Source: Design Memorandum No. 1, Basic Hydrology - Supplement 1 - June 1980, Table 2, Page 2

c. Wind. The Puerto Rico wind regime is primarily affected by the steady trade winds which blow almost without exception from an easterly direction (between north-northeast and south-southeast). Wind records available at Santa Isabel Airport are considered representative for the area. Prevailing winds are generally from the northeast, and are in the range of 13.9 mph for the mean maximum and 3.7 mph for the mean minimum.

d. Evaporation. Evaporation in the project area is fairly high, due to warm temperatures and rather constant wind. Interior higher elevation stations have somewhat less evaporation rates than the coastal areas. Evaporation rates for coast stations exceed the average annual rainfall. Table 4-5 lists the pan evaporation rate for various stations in Puerto Rico. Evaporation losses for each site were based on the Aguirre Research Station operated by the U.S. Weather Bureau in cooperation with the Agricultural Experiment Station of the University of Puerto Rico. It is the only station on the south coast and is located about 25 miles east of Ponce. It was assumed that 79.8 inches a year would be the most representative evaporation rate for the conditions at the reservoir.

Table 4-5

Evaporation Rate in Puerto Rico

Station	Pan Evaporation Rate (in)
San Juan	81.59
Lajas	81.40
Aguirre	79.85
Gurabo	62.50
Corozal	53.13
Adjuntas	50.93

Source: Design Memorandum No. 1, Basic Hydrology - May 1972, Table 3, Page 5

4-06. Storms and Floods. The time of greatest likelihood of flooding and the time of maximum rainfall expectancy occur from May through November or December. The hilly nature of this basin and the steep slope of waterways from their headwaters in the mountains to the Caribbean Sea dictate that many of the flood situations will be flash-flood type. The majority of Puerto Rico's rainfall is orographic in nature. That is, moisture-laden air from the ocean is carried by tradewinds inland and forced to ascend over the mountains where it is cooled, thus causing condensation in the form of rainfall. Usually the majority of orographic showers are brief. When the orographic effect is carried to maximum development, large amounts of water can be deposited over the area.

Other rainfall producing storms consist of easterly waves and cold fronts. During the period from May through November, Puerto Rico experiences easterly waves. Tropical storms and hurricanes occasionally develop from easterly waves and may cause torrential rains over the area. Cold fronts generally occurring in winter months from November to April and are the other major rainfall producing weather system effecting Puerto Rico. The severity of rainfall produced by a cold front depends upon the intensity and rate of progress of the system.

Hurricanes and tropical storms are an important feature of the climate during summer and early autumn. The tropical cyclone season in the North Atlantic region extends from June through November. Because of seasonal shifts in favored locations of tropical cyclone development, the island of Puerto Rico is usually outside the main paths of severe tropical atmospheric disturbances except from August through the first half of October. Hurricanes and tropical storms which affect Puerto Rico develop over waters of the southern North Atlantic to the east of the Lesser Antilles.

Major floods on the Caribbean coast at Ponce, as well as in the remainder of Puerto Rico, result mainly from intense rainfall which occurs during severe tropical storms, hurricanes, or cold frontal action. An investigation of past records from the U.S. Weather Bureau and information obtained from the USGS indicates that major flooding was caused in the Ponce area by storms on the following dates: August 8, 1899; September 13, 1928; October 13, 1954; May 6, 1958; August 27, 1961; October 14, 1962; August 28, 1963; October 4 to 10, 1970; September 15-17, 1975; October 6-7, 1985, January 5-6, 1992; September 9-10, 1996. A description of some of these floods is given below (referenced from Design Memorandum dated May 1972).

a. Storm of August 8, 1899. This storm was caused by a hurricane which was probably the most destructive in Puerto Rican history. Twenty-three inches of rain fell on August 8 at Adjuntas, which is in the mountains, about 13 miles northwest of Ponce and 3 miles northwest of the northern limit of the

Portugues River watershed. Flooding along the Portugues River was reported as "terrible". During the flood of 1899, floodwaters were 3 to 6 feet deep in the streets near Playa Degetau, the business center of the city of Ponce.

b. Storm of September 13, 1928. According to National Water Summary 1988-89- Floods and Droughts: Puerto Rico, Hurricane San Felipe II, which crossed the island on September 13, 1928, is considered to be the most violent and disastrous hurricane to affect Puerto Rico. A barometric pressure of 27.50 inches and wind speed of 160 mi/h (miles per hour) were recorded during this storm. About 300 people were killed, and damage was $50-$85 million. During this hurricane, the maximum rainfall at Adjuntas located outside the project area approximated 18 inches on September 13, about 11.6 inches on September 14, and a total of 34.14 inches from September 12 to September 17. The rainfall at Ponce for September 14 was 3.00 inches and the total for September 13 through 15 was only 5.26 inches.

c. Storm of October 13, 1954. This storm was caused by the passage of Hurricane Hazel through the south coast of the island of Puerto Rico. The flood resulting from the hurricane was one of the worst in Puerto Rican history and was reported to be at least as intensive and damaging as the hurricane of 1899. The rainfall during this storm exceeded the extent and duration of rainfall during the hurricane of September 13, 1928, even though the 5-day rainfall was less. The total rainfall at Ponce located within the project area for the period October 11-16, 1954 was 12.47 inches, of which 6.47 inches occurred on October 13 and 2.54 inches on October 14. Floodwaters overtopped the banks of the Rio Bucana in the northeastern part of Ponce, flowed southwestward and entered Rio Portugues upstream from Highway 133. By late afternoon and early evening of October 13, 6 feet of water was standing in some sections of the city of Ponce.

d. Storm of May 6, 1958. During the month of May 1958, rainfall, although not the highest on record, was the highest for that month since 1945. An easterly wave causing heavy rains on the afternoon on May 6, 1958, ceased by early evening. Shortly, thereafter, continued thunderstorms occurred in the south-central portion of the island, north of Ponce, at Juana Diaz, and Villabea, with rainfall approaching a cloudburst. The rivers, which were already swollen, overflowed the channels by 4 a.m. on May 7, and a severe flash flood occurred on Jacaguas, Inabon, Bucana, Portugues, and Canas Rivers, all of which empty into the Caribbean in or near Ponce. Three deaths and serious destruction occurred in the city. The damages occurred mainly in the southern section of Ponce, including areas along the beach and industrial and commercial properties. The heavy damages included 147 houses destroyed, 275 severely damaged, and 170 with minor damage. Commercial warehouses and industrial and communications facilities were also badly damaged.

e. Storm of August 28, 1963. Rainfall which caused this flood in the Ponce area occurred during the early morning hours of August 28. During this easterly wave trough more than 3 inches of rainfall in the city of Ponce, 5 inches at Tibes, and 5 inches at Quebrada Limon were recorded. The heavy rainfall on the higher elevations above Ponce occurred in a period of 4 to 9 hours and fell on soil saturated by previous rains earlier in the week. Portugues and Canas Rivers were at flood stage by 1 a.m. on August 28, and by 7 a.m. all rivers in the area had overflowed their banks. The Tibes bridge at Ponce was destroyed, and large residential sections of the city were inundated. Playa de Ponce was under 2 feet of water. Sections of Ponce most seriously affected by this flood were Playa de Ponce, Barrio Caracoles, San Antonio development, and Villa Grillasca development. Although there was no loss of life, many facilities were evacuated from the south coast.

f. Storm of August 27, 1970. A strong easterly wave passed over Puerto Rico on August 27, 1970, causing unstable weather in the area during the afternoon of the 27th and early morning hours on the 28th. Torrential rain showers and thunderstorms which produced rainfall up to 8.85 inches (Aibonito) within a 6- to 12-hour period. Most of the rain fell within a 6- to 8- hour period. Severe flooding affected the city of Ponce and lower coast.

USGS Gage 50114000 - Rio Cerrillos near Ponce

	Daily Average Flows	
Date	(cfs)	(Acre-feet)
Aug 27	28	56
Aug 28	602	1,194
Aug 29	71	141

The peak instantaneous flow occurred on 28 August was calculated to be 4,400 cfs with a stage of 6.95 feet.

g. Storm of October 4-9, 1970. The most widespread natural disaster in Puerto Rico during recent years struck in the form of prolonged rains over a 6-day period. In certain respects, such as rainfall intensity and total runoff volume, these rains and resulting floods exceeded those associated with the great hurricane disasters of the past, such as San Felipe of September 13, 1928, and San Ciriaco of August 8, 1899. The cause of the rains was a slow-moving and at times stationary tropical depression. The rains generally began in late afternoon October 4. On the second day, October 5, the rains increased over the entire eastern portion of the island with rainfall totals of 10.00 inches at Aguirre, and 9.40 inches at Guayama. Heavy rains continued on the third day over the eastern area. On the fourth day, October 7, there was some decrease in rainfall intensity. The heaviest rains fell on the fifth day, causing the highest 24-hour total for the period; 17.00 inches at Aibonito, and 14.05

inches at Cerro Maravilla. The USGS reports that all gaging stations recorded multiple flood peaks, the maximum peak occurring either October 9 or 10. Many areas in Ponce were flooded due to the excessive rainfall that fell during this period.

USGS Gage 50114000 - Rio Cerrillos near Ponce

Date	Daily Average Flows (cfs)	(Acre-feet)
Oct 4	74	147
Oct 5	172	341
Oct 6	398	789
Oct 7	458	908
Oct 8	639	1,267
Oct 9	2,020	4,007
Oct 10	428	849
Oct 11	244	484
Oct 12	142	72

The peak instantaneous flow occurred on 9 October was calculated to be 9,140 cfs with a stage of 8.70 feet.

h. Storm of September 15-17, 1975. Heavy rains began early in the morning on the 15th in the eastern portions and moved into the western area by early afternoon. The depression was upgraded to a tropical storm named Eloise by noon on the 15th. Major flooding occurred on 21 rivers on the 16th, mostly concentrated in the western portions. Cerrillos River reached its worst flooding in 10 - 15 years. Over 26 inches of rain was recorded over the southwestern slopes near Sabana Grande. In addition to the 34 known dead, more than 275 people were injured, and more than 10,000 people were left homeless from this flooding.

USGS Gage 50114000 - Rio Cerrillos near Ponce

Date	Daily Average Flows (cfs)	(Acre-feet)
Sep 14	112	222
Sep 15	148	294
Sep 16	4,580	9,084
Sep 17	635	1,260
Sep 18	172	341
Sep 19	344	682
Sep 20	162	321

The peak instantaneous flow occurred on 16 September was calculated to be 22,400 cfs with a stage of 11.20 feet.

i. Storm of October 6-7, 1985. A tropical wave that later intensified to become Tropical Storm Isabel produced numerous landslides and created severe flooding. The flooding affected most of southern Puerto Rico. Rainfall at Cerro Maravilla totaled 24.6 inches within 24 hours, which set a new record; peak discharges for the streams in the area had a recurrence interval of 100 years. About 170 lives were lost, and damage to public and private properties was about $125 million. The peak instantaneous flow on 10 October at the USGS Gage 50114000, Rio Cerrillos near Ponce, was estimated to be 24,000 cfs. Due to the excessive rainfall, a landslide occurred in the left abutment, striking the partially completed intake structure of the Cerrillos Dam.

j. Storm of January 5-6, 1992. The deadliest single flood event of Fiscal Year 1992 occurred January 5-6, 1992 across much of the Commonwealth of Puerto Rico. Most of the mountainous interior and several areas along the northern, eastern, and south coasts of Puerto Rico experienced moderate to severe floods. This flood was produced by intense rainfall generated by the unusual combination of a cold front and an upper level pressure trough. As much as 20 inches of rainfall fell on the interior of Puerto Rico. The bulk of rainfall fell in a period of about 6 hour durations of 8.4, 11.2, and 18.4 inches exceeded previous historical wide maximums of 6.73, 7.80 and 10.40 respectively. Damage to houses, businesses, farmlands, livestock, highways, bridges, and other public and private properties were in excess of $150 million. The flooding tragically occurred on Puerto Rico’s most celebrated holiday, Three Kings Eve. The flooding killed 23 people.

USGS Gage 50113800 - Rio Cerrillos Above Cerrillos

	Daily Average Flows	
Date	(cfs)	(Acre-feet)
Jan 4	7	14
Jan 5	331	657
Jan 6	717	1,422
Jan 7	136	270
Jan 8	64	127
Jan 9	50	99

The peak instantaneous flow occurred on 5 January and was calculated to be 8,140 cfs with a stage of 9.65 feet.

k. Storm of September 9-10, 1996. Hortense, a category one hurricane as it crossed the southwestern tip of Puerto Rico and the associated floods killed 21 people. Hortense devastated portions of Puerto Rico but most of the damage was not done by winds or storm surge. Instead, torrential rains produced flash floods and mud slides which killed at least 18 people. A report from FEMA indicated that approximately 11,500 homes were severely damaged by Hortense and agricultural losses were of the order of $127 million. In addition, there was significant inland flooding in the low-lying areas as well as serious coastal flooding in Nagabo, Guayanilla and Ponce. During Hurricane Hortense, nearly 17 inches of rainfall was recorded above the Cerrillos Dam.

While there was only 4.21 inches of rainfall at the Dam site, contributing flows raised the stage behind the Dam approximately 13 feet in a 24 hour period. This event completed the initial filling of the Cerrillos Reservoir and water was stored in the flood control pool for the first time. Daily rainfall amounts recorded by the USGS gaging sites in the area for a 1-day (24 hour) period including the Cerrillos Lake elevations changes for the same period were as follows.

	Daily Precip. Totals 1-Day (24 Hrs) (Inches)	Elevation Pool (ft-NGVD)
Cerrillos Reservoir	4.21	559.97 to 572.66
Cerrillos Above Cerrillos	16.88	
Cerrillos Below Cerrillos	4.39	
Bucana at Highway 14	4.02	
Portugues near Ponce	8.13	

USGS Gage 50113800 - Rio Cerrillos Above Cerrillos

Date	Daily Average Flows (cfs)	(Acre-feet)
Sep 8	20	14
Sep 9	20	657
Sep 10	1580	1,422
Sep 11	388	270
Sep 12	191	127
Sep 13	135	99

The peak instantaneous flow occurred on 10 September and was calculated to be 10,600 cfs with a stage of 10.62 feet.

Without the Cerrillos Dam and the channel improvements in place, it is expected that catastrophic flooding would have occurred in the Ponce region. Damage prevented by works in place associated with the storm is estimated to be in excess of $100 million. It is important to remember this damage prevention is not due solely to the Cerrillos Dam, but to the Cerrillos Dam and constructed channel works.

4-07. Runoff Characteristics. The steep slopes of the mountains and channel gradients of the upper reaches of the Portugues and Bucana Rivers are conducive to very flashy storm runoff. Flash floods resulting from tropical storms and hurricanes have caused serious flooding and the loss of lives within the Ponce area. In the upper reaches, movement of the runoff is very rapid with measured velocities of 10.9 feet per second. Channel velocities, downstream, in the Ponce area have been measured at 7.9 feet per second. Table 4-6 lists flow velocities for various discharges at some of the principal gages within the basin.

Table 4-6

Gages in the P&B Area

Location	Date of Storm	Drainage Area Sq. mi.	Average Flow ft/sec	Discharge in cfs
Station No. 50-1144 Rio Bucana nr Ponce	8/27/61	25.6	10.1	10,200
Rio Bucana at Ponce (Hwy #1)	8/28/63 7/5/64	27.3 27.3	10.3 10.9	10,000 4,200
Station No. 50-1147 Rio Bucana near Playa de Ponce	7/5/64	28.4	7.2(1)	3,140
Station No. 50-1140 Rio Cerrillos nr Ponce	7/5/64	17.8	7.4	3,620
Station No. 50-1159 Rio Portugues at Ponce (Hwy #14)	8/28/63	18.6	7.7	5,380
Station No. 50-1150 Rio Portugues nr Ponce (Hwy #14)	10/21/64	8.82	7.9	2,000

Note: (1) Channel Flow
Source: Design Memorandum No. 1, Basic Hydrology - May 1972, Table 12, Page 19

The lack of long-term records for the Portugues and Bucana Rivers necessitated the development of monthly flows by synthetic means. The average monthly flows computed at Portugues and Cerrillos sites are 560 cfs and 1330 cfs, respectively, for 29 years of record.

The United States Geological Survey (USGS) has operated a recording gage entitled Rio Cerrillos near Ponce (Gage No. 501140) since 1964. The gage is located near the dam site, 2.3 miles upstream from Quebrada Ausubo. Annual peak discharge data for this gage are shown in Table 4-7. The drainage area of this gage is 17.8 square miles.

For the period of record, annual peak (instantaneous) discharges have been 5 to 20 times greater than the annual peak mean daily discharges. For the period October 1965 to September 1984, the mean discharge was 35.8 cfs and the minimum daily discharge was 2.2 cfs. The results of a flow-duration analysis for the period of record are shown in Table 4-8. Flow durations by month are found on Table 4-13 found at the end of section IV.

Table 4-7

Gage 50114000 - Rio Cerrillos near Ponce

Date	Peak Discharge (cfs)	Date	Peak Mean Daily Discharge (cfs)
21 Oct 64	4560	21 Oct 64	418
5 Jun 65	1300	5 Jun 65	222
20 Jul 66	3270	20 Jul 66	458
5 Aug 67	3480	5 Aug 67	282
27 Sep 68	3560	27 Sep 68	681
25 Oct 69	3700	21 May 69	650
7 Oct 70	7900	9 Oct 70	2020
16 Oct 71	1480	16 Oct 71	202
3 Oct 72	2110	24 Sep 72	233
30 Jul 73	3640	30 Jul 73	271
2 Nov 74	2540	12 Nov 74	620
16 Sep 75	22400	16 Sep 75	4580
29 Sep 76	2050	13 Oct 76	400
13 Sep 77	3770	13 Sep 77	277
22 Jun 78	4060	26 Oct 78	756
31 Aug 79	3580	31 Aug 79	586
27 May 80	1420	28 May 80	224
16 Aug 81	4600	23 May 81	400
12 Sep 82	8900	12 Sep 82	450
21 Apr 83	821	21 Apr 83	206
18 Sep 84	865	3 Nov 84	240
7 Oct 85	24000 estimated	7 Oct 85	no record

Source: Design Memorandum No. 26, Feature Design Memorandum - Lake Cerrillos Initial Filling Plan - January 1989, Table 3-4, Page 3-4

Table 4-8

Mean Daily Discharge Percent Time Exceeded

	Percent Time Exceeded						
	95	90	75	70	50	25	10
Mean Daily Discharge (cfs)	4.8	6.0	9.0	10.4	17.9	40.3	80.4

Source: Design Memorandum No. 26, Feature Design Memorandum - Lake Cerrillos Initial Filling Plan - January 1989, Table 3-5, Page 3-4

4-08. Water Quality. Water quality monitoring is being conducted on the Cerrillos River by the U.S. Geological Survey to assist in continuing environmental studies. Conditions measured on a regular basis include pH, dissolved oxygen, temperature, specific conductance, suspended solids, Redox, total phosphorous as P, soluble orthophosphate as P, Kyeldahl nitrogen as N, ammonia nitrogen as N, nitrate nitrogen as N, total organic carbon, chloride, and fecal coliform. Data collected by the USGS at a station just below the Cerrillos dam site show extreme variations in total and fecal coliform counts. For example, during a one-year period in 1981, fecal coliform counts at this station ranged from 120 coliforms per 100 milliliters to 18,000 coliforms per 100 ml. The mean yearly average at this station for fecal coliform is 1,486 coliforms per 100 ml, which is well above the maximum level of 400 coliforms per 100 ml recommended by the 1976 Environmental Protection Agency Criteria for recreational fresh waters. A copy of water quality data for this station for the period 1978-1984 is available at the Jacksonville District, U.S. Army Corps of Engineers.

These data are considered to reflect ambient or existing conditions in the watershed prior to dam construction. Land acquisition for project purposes and relocation of residences, commercial and industrial operations and the accompanying infrastructure have removed a significant percentage of pollution point sources and should result in positive effects on water quality in the Cerrillos Reservoir and River.

4-09. Channel Characteristics and Downstream Structures. The total project includes 10 miles of channel improvements, 16 drop structures, 2 debris basins, and 2 multi-purpose reservoirs. The Lower Portugues Channel extends for a distance of 1.1 miles to the confluence with the Bucana Channel, approximately 1.5 miles from the mouth. The Lower Bucana Channel extends for a distance of 2.6 miles. Both channels are provided with stone protection against high velocity flows. The Upper Bucana Channel improvements extend 2.95 miles as a rectangular concrete channel. The remaining 2.45 miles of channels consists of earth revetted channels with stone protection against high velocity flows on the side slopes. Five 125-foot wide drop structures were constructed in this segment because the low velocities would increase gradually and become erosive as the flows moved downstream. The Upper Portugues Channel Improvements extend for 1.7 miles. The channel consists of 1.0 miles of rectangular concrete channel with the remainder consisting of earth revetted channel. The Cerrillos Dam and Portugues Dam (not constructed yet) impound water to form multi-purpose reservoirs.

Portugues and Bucana (P&B) Rivers are very steep in the upper part of the basins, with slopes in excess of 750 feet per mile near the source and averaging about 300 feet per mile. Bucana River is formed by the Bayagan and Cerrillos River, 6.5 miles above the mouth. The principal tributary of the Cerrillos River is San Patricio River, which joins the Cerrillos River 16 miles above the Bucana River mouth. The principal tributary of the Portugues River is the Chiquito River located 5.5 miles above the mouth. Both the Chiquito and Bayagan Rivers join the main streams at the mountain foothills. Below the foothills, P&B

Rivers flow through the coastal plan without significant tributaries. During large floods, the P&B Rivers form a common inundated area in the lower 3 miles of the coastal plan and join with floodwaters of the Canas River on the west and the Inabon River on the east.

4-10. Debris Basin. Inflow to the debris basin for the 10-, 50-, and 100-year floods comes entirely from the 7.1 square miles of watershed below the damsite. Standard Project Flood (SPF) inflow includes spillway discharges from the Cerrillos damsite which are added to the downstream inflow. Following are the peak inflows into the Bucana Debris Basin:

	10-Yr	50-Yr	100-Yr	SPF
Peak Inflow to Debris Basin (cfs)	8,290	11,230	12,650	21,740

Source: Design Memorandum No. 6, General Design Memorandum - Phase II - Supplement 1 - Upper Ponce Channel Improvements Project Design - April 1984, Table 5, Page 41

4-11. Debris Basin Hydraulic Design. A spillway and drop structure combination was determined to be the most feasible control structure for the debris basin. Hydraulic design data for the debris basin is shown on Table 4-09. The debris basin would provide storage for 110 acre-feet of debris. The debris basin levee crown is three feet above the Probable Maximum Flood (PMF). The drop structure and channels downstream were designed for the SPF.

Table 4-9(a)

OGEE SPILLWAY BUCANA DEBRIS BASIN OUTLET WORKS
TWO STRUCTURE OPTION
SUMMARY OF HYDRAULIC DESIGN DATA[1]

Location	Bucana Debris Basin
Station	317+82
Design Conditions (SPF)	
Discharge (cfs)	21,739
Headwater elevation	159.3
Tailwater elevation	149.9
Stilling basin design	
Discharge (cfs)	21,739
Headwater elevation	159.3
Tailwater elevation	149.9
M.P.F. condition	
Discharge (cfs)	100,700
Headwater elevation	172.9
Tailwater elevation	165.7
Crest	
Shape	Ogee
Elevation	152.0
Design head (ft.)	7.3
Net Length (ft.)	275
Stilling basin	
Beginning of slope elevation	140.9
End of slope elevation	133.5
Slope (ft./ft.)	0.25
Slope length (ft.)	30.2
Horizontal length (ft.)	44.9
Horizontal elevation	133.5
Endsill elevation	134.4
Total length	75.1
Pool drain	
Intake dimensions (WXH, ft.)	5X7
Conduit diameter (in.)	36
Conduit length (ft.)	9.6
Time to drain pool (below fixed crest)	Less than 1 day
Conduit entrance invert	143.0
Conduit exit invert elevation	142.9
Conduit slope (ft./ft.)	0.0092
Training wall elevation	169.0
Channel Section	
Upstream bottom width (ft.)	275
Upstream bottom elevation	146.0
Upstream side slopes	Vertical
Downstream bottom width (ft	275
Downstream bottom elevation	134.2
Downstream side slopes	Vertical
Protection elevation	176.0

Table 4-9(b)

BUCANA DEBRIS BASIN OUTLET
DROP STRUCTURE
TWO STRUCTURE OPTION
SUMMARY OF HYDRAULIC DESIGN DATA[1]

Location	Bucana Debris Basin
Station	315+80
Type	CIT
Design conditions	
Discharge (cfs)	21,739
Headwater elevation	149.9
Tailwater elevation	135.2
Crest	
Elevation	134.2
Length (ft.)	115.0
Stilling basin	
Apron elevation	116.6
Apron length (ft.)	59.0
Endsill elevation	120.2
Channel section	
Upstream bottom width (ft.)	275
Upstream bottom elevation	134.2
Upstream side slopes	Vertical
Downstream bottom width (ft.)	125
Downstream bottom elevation	120.0
Downstream side slopes	1 on 2.5
Downstream	Sides
Protection elevation	138.2

[1] Elevations are in feet and refer to mean sea level (Puerto Rico Datum).

Source: Design Memorandum No. 6, General Design Memorandum - Phase II - Supplement 1 - Upper Ponce Channel Improvements Project Design - April 1984, Table 8 and 8A, Page 70-71

4-12. Economic Data. The drainage basin is confined generally to the municipality of Ponce; however, the economic effects also extend into 10 surrounding municipalities. Much of this activity is located in the city of Ponce, the only urban community in the drainage basin. The Commonwealth is currently involved in a program to convert the agricultural-base economy to an industrial-base economy. Various agencies and public corporations were formed to plan and promote means of increasing production. The island has a large labor force available, but few natural resources.

a. Population. The population of the municipality of Ponce, according to U.S. Census of Housing and Population, has been steadily increasing from 105,000 in 1940, 146,000 in 1960, 159,000 in 1970, 189,000 in 1980, and 188,000 in 1990. The increase in population has been steadily rising with the exception of a small reduction in the census for 1990. The population between 1970 to 1980 was composed of approximately 83 percent urban and 17 percent rural residents, a shift of 4.0 percent from urban to rural during the period 1960 to 1970. High population densities and the emphasis on industrial development are expected to continue increasing under current industrial development plans reaching a projected population of 250,000 in the city and 300,000 in the municipality by the year 2020. Currently, industry and agriculture are the biggest employers, dominating the local economy. Mining also is a significant factor. The economic importance of manufacturing and industry is expected to increase due to ambitious economic programs such as the Southwest Development Plan of the Puerto Rico Planning Board.

b. Agriculture. The greater portion of the agricultural production in the area is from sugarcane cultivation. The crop is concentrated in the rich alluvial coastal plain. Dairy and beef production is confined to the foothills of the Cordillera Central. Coffee and vegetable production is limited to small plots in the higher elevations.

c. Industry. Since colonial days Ponce has been the dominant industrial and commercial center of the south coast of the island. Ponce Harbor serves about 10 municipalities (counties) which are considered economically tributary to Ponce. Manufacturing, mining, trade, and government are major employers in the area. Industries in the area are the Puerto Rico Iron Works, Mercidita Sugar Processing, and Ponce Portland Cement.

d. Flood Damages. The areas subject to flooding are divided into three basic groupings, ie. agricultural, urban, and undeveloped. Almost the entire agricultural area subject to damage was inundated during the 10-year flood. The main variance between flood frequencies in this agricultural area is depth rather than duration; the duration of the spectrum of floods being quite short, less than 6 hours. Under these conditions, the damages sustained by agriculture during storms of varying frequencies are approximately equal. The urban areas flooded include the Playa de Ponce, the southern portion of the city of Ponce, and areas along both banks of the Portugues and Bucana Rivers, particularly the lower reaches of the Portugues. The warehouse district of the Playa de Ponce and the numerous homes along the river banks suffer most from the flooding. Total acres flooded during the 10-year, 50-year, 100-year and SPF floods are shown in Table 4-10.

Table 4-10

Ponce, Puerto Rico
Flooded Areas Without Project

Storm Frequency	No. Acres Flooded
10-Year	5,416
50-Year	5,901
100-Year	6,181
SPF	6,660

Source: Design Memorandum No. 2, General Design Memorandum - Phase I, Plan Formulation and Site Selection - July 1973, Table 6, Page 31

The project would afford protection against the standard project flood. However, small areas above the upstream end of the channel works on both rivers would still be subject to minor flooding. Flooding will occur to the east of the Bucana River channel levee southeast of the city with flood water from the Inabon River inundating an estimated 208 acres of agricultural land during a Standard Project Flood.

A damage-frequency curve for existing land use without project was plotted directly from estimated flood damages and frequencies. Average annual damages were obtained by determining the area under the curve and summarized in Table 4-11.

Table 4-11

Ponce, Puerto Rico
Flood Damages Without Project

Storm Frequency	Damages ($)
10-Year	15,880,200
50-Year	56,375,000
100-Year	85,464,000
SPF	113,343,000

Average Annual Equivalent Flood Damages
100-Year Economic Life ------------ $5,137,600

Source: Design Memorandum No. 2, General Design Memorandum - Phase I, Plan Formulation and Site Selection - July 1973, Table 7, Page 32

Flood damages prevented on existing land use are the difference between annual damages with and without the project. Flood damages prevented on the year 2025 land use are the difference between annual future damages with and without the plan of improvement. The portion of future annual damages prevented in excess of existing annual damages is discounted for 50 years at 5-1/2 percent, using an accelerated-growth factor. The population was a major influence in selecting a growth-rate factor. The population tends to increase at a decreasing rate; however, the provision for future population expansion needs was not the only consideration. Much of the existing population is in need of increased facilities and this need is immediate. There was no way to quantify the time of these needs with any accuracy, therefore, it was assumed adequate to adopt the accelerated growth curve furnished in EM 1120-2-118. The flood damages prevented on existing land use, plus the discounted future flood damages prevented, yield the average annual equivalent flood damages prevented for the first 50 years of the plan of improvement. Average annual flood damages prevented for the second 50 years of the 100-year project life are reduced to present value and converted to average annual equivalent flood damages prevented. Average annual equivalent flood damages prevented total $5,137,600.

Because of the flood hazard, many areas are not developed to their highest and best use. Additionally, the Commonwealth restricted further development within the flood plain. Although some areas have been granted special permission to fill and develop residential areas, extensive restrictions are placed on developers to improve drainage for flood control purposes. With the project, agricultural land use in the flood plain would be displaced by other, more intensive, land use. The benefits derived from this project-induced, increased land use are computed by taking the difference between the market value of the land in pre-project conditions and the market value of the land with project conditions. Table 4-12 contains the original project estimated the benefits for the Cerrillos Dam. The original Project Document included a B/C ratio of 2.4 for the Cerrillos Dam.

Table 4-12

Benefits Derived from the Cerrillos Dam

	Estimate
Flood Control	$1,973,000
Water Supply	375,000
Recreation	283,000
Redevelopment	1/
	$2,631,000

1/ The original Project Document did not include benefits from redevelopment, these were calculated at a later date.

Source: Design Memorandum No. 2, General Design Memorandum - Phase I - Supplement No. I - April 1974, Paragraph 62, Page 13

Table 4-13

Flow Durations for Rio Cerrillos Near Ponce, PR Station 501140
(From USGS Open-File Report 84-127)

CLASS Cubic Feet Per Second (cfs)	DURATION For Period of Record (percent)	Monthly Flow-Durations for Period of Record 1964-1982 (Percent) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2000.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1600.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1300.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1100.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
890.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
720.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
590.0	0.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.5
480.0	0.2	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.3	0.5
390.0	0.4	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.3	0.3	0.7
320.0	0.5	2.2	0.9	0.0	0.0	0.0	0.0	0.0	0.6	1.0	0.3	0.5	0.9
260.0	0.8	3.2	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.2	0.8	0.8	1.4
210.0	1.4	5.4	1.9	0.2	0.0	0.0	0.0	0.2	1.5	1.7	1.1	1.3	3.3
170.0	2.3	9.5	4.0	0.2	0.0	0.0	0.0	0.4	2.8	2.7	1.5	1.6	5.2
140.0	3.7	14.9	7.0	0.3	0.0	0.0	0.0	0.4	4.6	3.3	1.8	2.6	9.6
110.0	6.0	22.1	13.3	1.4	0.0	0.0	0.3	0.5	6.0	4.3	2.9	4.8	15.7
93.0	7.9	28.2	18.6	1.5	0.0	0.0	0.5	0.9	8.3	5.5	4.0	6.8	19.8
76.0	11.1	37.5	26.3	2.9	0.2	0.0	0.7	1.6	12.3	7.7	5.8	10.7	27.3
62.0	15.2	48.2	37.7	3.9	0.3	0.0	0.8	3.2	16.9	10.4	7.8	14.4	37.6
50.0	20.1	59.9	51.6	6.3	0.3	0.4	1.4	3.9	21.9	12.8	12.1	23.3	46.3
41.0	24.7	70.5	63.0	10.0	1.2	0.8	2.1	5.4	23.9	17.4	15.7	29.6	55.6
33.0	30.8	78.3	74.4	17.7	1.9	1.7	2.9	8.1	28.9	22.5	23.3	39.7	68.2
27.0	37.1	85.1	84.2	30.4	3.9	2.4	4.4	10.0	32.3	29.6	33.3	47.5	78.5
22.0	43.3	89.1	88.5	48.9	7.8	4.1	5.9	13.0	37.2	38.6	41.9	56.1	85.3
18.0	50.2	92.7	93.9	66.4	16.7	5.6	9.5	16.5	42.2	45.7	48.7	67.4	92.7
15.0	57.3	94.4	96.3	80.6	35.9	9.9	13.4	20.6	47.4	56.9	56.6	75.0	96.0
12.0	65.9	96.1	98.1	90.5	60.5	25.1	20.9	25.5	53.2	66.6	66.2	85.1	98.8
9.7	72.5	97.1	99.1	93.6	80.6	45.7	30.0	29.9	58.4	72.0	71.5	90.6	99.1
7.9	80.2	97.8	100.0	96.3	93.5	70.4	47.7	38.8	64.6	78.8	80.6	93.0	99.5
6.4	88.2	99.5	100.0	99.8	98.0	92.0	75.7	55.0	71.6	86.0	85.3	95.6	99.8
5.2	92.9	100.0	100.0	100.0	99.2	99.2	91.3	67.5	78.1	89.5	92.9	98.2	100.0
4.3	96.9	100.0	100.0	100.0	99.8	100.0	98.6	88.9	88.2	92.5	97.1	99.2	100.0
3.5	99.4	100.0	100.0	100.0	100.0	100.0	100.0	99.1	96.8	98.0	99.7	99.8	100.0
2.8	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	99.5	100.0	100.0	100.0
2.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Design Memorandum No. 26, Feature Design Memorandum - Lake Cerrillos Initial Filling Plan - January 1989, Table 3-6, Page 3-5

V - **DATA COLLECTION AND COMMUNICATION NETWORKS**

5-01. Hydrometeorology Stations.

a. Facilities. There are currently four gages which are directly tied to the Cerrillos Dam. These stations have been operated by the USGS for the Corps of Engineers as part of the Cooperative Stream Gaging Program. An additional station is part of the gaging network for the Portugues Dam project. This station is also operated by the USGS as part of the Cooperative Stream Gaging Program. These stations are shown in Table 5-1. A location map of the stations is shown on Plate 5-1.

Table 5-1

USGS Gaging Stations

Station No.	Description	Parameters
50113800	Above Lake Cerrillos	Stage, Rainfall
50113950	At Cerrillos Dam	Elevation, Rainfall
50114000	Cerrillos River nr Ponce	Stage, Rainfall
50114390	Bucana River at Hwy 14 nr Ponce	Stage, Rainfall
50115000	Portugues River nr Ponce	Stage, Rainfall

1. Cerrillos Inflow Gage - Rio Cerrillos Above Lago Cerrillos near Ponce - USGS #50113800. Site is located upstream of the dam and is used to measure inflows and rainfall in the upper basin. Also referred to as Cerrillos Above Cerrillos site by the COE.

2. Cerrillos Reservoir - Lago Cerrillos near Ponce - USGS #50113950. Site is located at the dam crest in the vicinity of control tower and is used to measure the pool elevation and rainfall at the dam.

3. Cerrillos Outflow Gage - Rio Cerrillos Below Lago Cerrillos near Ponce - USGS #50114000. Site is located downstream of the dam and is used to measure reservoir outflows and rainfall below the dam. Also referred to as Cerrillos Below Cerrillos site by the COE.

4. Downstream Bucana Gage in Ponce - Rio Bucana at Highway 14 Bridge near Ponce - USGS #50114390. Site is located downstream of the Cerrillos Dam near Ponce and is used to measure confluence of reservoir outflows, local inflows and the Bayagan River basin flows and rainfall near Ponce. Also referred to as Bucana at Highway 14 site by the COE.

5. Portugues Inflow Gage - Rio Portugues near Ponce - USGS #50115000. Site is located upstream of the future Portugues Dam and is used to measure inflows and rainfall in the upper basin. Also referred to as Portugues near Ponce by the COE.

b. Reporting. The gaging stations listed in Table 5-1 are real-time data collection platforms (DCP’s). The gages are configured to record every 15 minutes and transmit data via satellite every four hours. The gages also transmit random alerts based on specified parameters exceeding limit criteria. Data is received, decoded and stored in databases by the Jacksonville District Water Management and Meteorology Section and the USGS in Guaynabo, Puerto Rico.

The gage located at the dam is also equipped with a DCP that has a speech synthesized phone modem. Reservoir elevation and rainfall parameters stored by the DCP can be collected using dial-up phone or computer modem. The DCP is also capable of dialing preprogrammed telephone numbers when specified parameters exceed limit criteria.

c. Maintenance. The gaging stations are maintained by the USGS. The USGS performs monthly streamflow measurements and routine maintenance at the gaging stations. Problems associated with operation of the DCPs should be directed to the USGS in Guaynabo, Puerto Rico. The Jacksonville District Water Management and Meteorology Section, Hydrology and Hydraulics Branch, Engineering Division, can assist in monitoring gaging stations, data collection and flow computations.

5-02. Water Quality Stations. The USGS currently operates three water quality stations in the P&B project area. These stations are Station No. 50114000 Cerrillos River near Ponce, Station No. 50115000 Portugues River near Ponce, and Station No. 50116200 Portugues River at Ponce. These stations measure water temperature, specific conductance, dissolved oxygen, ph, and suspended solids.

5-03. Sediment Stations. Currently there are no sediment stations located at the dam or in the P&B project area. However, the reservoir should be surveyed periodically to determine the amount of sediment being trapped in the reservoir.

5-04. Recording Hydrologic Data. Hydrologic data has been recorded in the Water Management Section using automated processes. Gate change records have been manually entered. The data collected and computed is used by project personnel to generate graphical and text reports as part of a decision support system used to operate the reservoir.

The USGS is responsible for the operation and maintenance of the stations. The USGS is also responsible for archiving and maintaining the official station records. Data are published annually in the Water Resources Data - Puerto Rico, and are also available on the Water Data Storage and Retrieval System (WATSTORE). Meteorologic data collected by NOAA is published in Climatological Data for the Caribbean, Hourly Precipitation for the Caribbean, and Storm Data. Meteorological data and forecasts can be obtained from the National Weather Service.

5-05. Communication with Project. As of August 31, 1997, the Cerrillos project will be managed by DNER.

a. Regulating Office with Project Office. The plan of regulation for the Cerrillos Project was developed by the Jacksonville District in consultation with DNER. Communication between the Jacksonville District and DNER will be done either by phone, facsimile, or in writing. Normal day to day operations will be handled by DNER with communication with the Corps on an "as need" basis. During emergencies, communications would be more frequent. (See Chapter IX - Water Control Management, within this manual for more information).

b. Between Project Office and Others. Visitors to the project area should be kept informed of any impending hazardous reservoir rises or drawdowns by DNER personnel. Communications with affected persons will be by the most direct means available such as telephone or personal visits as appropriate.

5-06. Project Reporting Instructions. Monthly summary report of project operation data shall be submitted to the Jacksonville District Water Management Section. Summary report shall include gate operation time and settings along with hydrometeorological data recorded on daily basis. Any operating machinery failures or other emergencies that affect functional operation of the project should be reported to the Water Management Section as soon as possible.

5-07. Warnings. Warnings concerning the recreational areas of the project will be issued by the DNER. Refer to the "Emergency Action Plan" for related information concerning warnings.

VI - HYDROLOGIC FORECASTS

6-01. General. The main objective of preparing forecasts is to make an early determination of expected inflow into the Cerrillos Reservoir in order that releases may be made in accordance with the approved water control plan.

a. Role of Corps. The Water Management and Meteorology Section monitors weather forecasts of the Caribbean area for unusual meteorological events. This information along with regulating instructions is made available to the DDE for the Antilles, the Antilles Construction Office and the Resident Engineer.

b. Role of Other Agencies. The NWS has responsibility for supplying the public with official information. Also, the NWS prepares weather forecasts which serve as an early indication of flood events. These forecasts are described below.

6-02. Flood Condition Forecasts.

a. Requirements. During flood times, forecasts could be prepare on an as-needed basis. These forecasts will include the time, date, and height of the expected reservoir crest elevation.

b. Methods. The amount of runoff produced during a given rainfall over a specific area of the watershed is dependent upon such variable conditions as the type of soil, the soil-moisture conditions, vegetative covering, geologic conditions, the season of the year, antecedent rainfall, and rainfall intensity. Accurately determining the rainfall-runoff relationship for a given storm is the key factor in properly analyzing the reservoir performance. The reservoir performance is the basis for making the decision for discharges from the reservoir that will be in accordance with the approved water control plan.

6-03. Conservation Purpose Forecasts. Forecasts for conservation purposes will be updated as often as necessary during critical periods to keep all entities with direct responsibilities informed of changing situations. These forecasts will be based on current hydrologic conditions, commitments to the Commonwealth, requirements for water quality and low flows, and any other known commitments. Refer to Chapter VII for actual operation of the project for water control.

6-04. Long Range Forecasts. Long range forecasts for the Cerrillos Reservoir are not made. Rather a statistical analysis of historical data gathered in the basin have been incorporated into the design of the project.