| Station Name | River Name | Base or Forecasting Station | Forecasting Items | Treatment of Flood Forecasting System |
|---|---|---|---|---|
| 1822 | Upper Zamantı | Base Station | - | Computation of Outflow from Subbasin |
| 1806 | Lower Zamantı | Base Station | - | Computation of Outflow from Subbasin |
| 1801 | Upper Göksu | Base Station | - | Computation of Outflow from Subbasin |
| 1805 | Lower Göksu | Base Station | - | Computation of Outflow from Subbasin |
| 1818 | Seyhan | Base Station | - | Computation of Outflow from Subbasin |
| 1825 | Eğlence | Base Station | - | Computation of Outflow from Subbasin |
| 1820 | Körkün | Base Station | - | Computation of Outflow from Subbasin |
| 1828 | Çakıt | Base Station | - | Computation of Outflow from Subbasin |
| Seyhan Dam | Seyhan | Forecasting Station | Discharge and Water Level | Forecasting of Inflow into Reservoir |
| Çatalan Dam | Seyhan | Forecasting Station | Discharge and Water Level | Forecasting of Inflow into Reservoir |

## 4.3 Flood Control Facilities

The river structures which are treated for the Flood Forecasting and Warning System are explained below.

(1) Seyhan Dam

Seyhan Dam is the multipurpose dam which shall be regulated for flood control. Based on the forecasting of the inflow into the reservoir, the outflow shall be input in the forecasting system.

(2) Çatalan Dam

Çatalan Dam is also the multipurpose dam which shall be regulated for flood control. Based on the forecasting of the inflow into the reservoir, the outflow shall be input in the forecasting system.

## 4.4 Flood Forecasting Time

Flood is a natural phenomenon caused by rainfall alone or combined with snowmelt in the Seyhan River basin. There exists a lag time within the rainfall - runoff and snowmelt runoff processes. Therefore, the flood runoff forecasting can be made by estimating the rainfall - runoff process or/and snowmelt runoff process.

The lag time can be considered to be nearly the same with the flood concentration time. The future's inflows in a few hours into the Seyhan and Çatalan Dams can be forecast by the measured rainfall and forecast rainfall.

## 4.5 Rainfall Forecasting

Necessity of the rainfall forecasting is categorized into the following.

(1) To forecast the flood from the main river for longer hours

(2) To forecast the flood from the tributaries with the shorter lag time

For the flood forecasting in the Seyhan River basin, the latter case shall be considered as a rainfall forecasting.

## *4.6 Method of Flood Forecasting*

To take into consideration the runoff from the subbasins and the routing effects of the river channels, the following non-linear hydrological models are applied.

(1) Storage function basin model for rainfall-runoff process in the subbasins

(2) Storage function river model for river channel routing effects

The simple snowmelt runoff model is also constructed and combined with the above models.

The method of flood forecasting is summarized below:

(1) To compute the flood runoffs based on the flood runoff models

(2) To evaluate the past forecasting errors by the updated telemetered information

(3) To forecast the future flood runoff with the presently measured and telemetered information

## 4.7 Design of Flood Forecasting and Warning System

The following lists basic ideas for flood forecasting and warning system in Seyhan River basin.

(a) Hydrometeorological data is collected from hydrologic standpoint for flood control in Seyhan River basin and flood forecast is executed. DSİ 6th regional directorate is agency which administer river control on the basis of processed data.

(b) Seyhan Dam and Çatalan Dam (under construction) are the most important flood protective facilities for flood control in Seyhan River basin, and therefore, it requires fast and high quality system to transmit data and information regarding operation and management of these facilities.

(c) It requires the system to collect Hydrometeorological data fast and certainly, to process fast flood forecast and transmit certainly flood warning.

Flood forecasting and warning system is composed of system to collect data, to process data and to transmit data. It requires system design to combine these organically. Basic policy of design is as follows;

### (1) Data collection system

The system is to collect fast and certainly hydrometeorological data from rainfall and water level gauging station at flood control committee of DSİ 6th regional directorate where is control center for data processing.

### (2) Data processing system

The system is to input data collected to a computer in on-line process, to make primary processing of collected data, data display processing, flood forecast processing and file processing on real time. The system is provided for back-up function against abnormal events such as outage, etc.

### (3) Data transmission system

The system is to transmit fast and certainly forecast information to related agencies needed it. As transmission media and its content are dependent on content of data and information, data transmission system is established to meet conditions of Turkey.

# 5. FORMULATION OF OPTIMUM FLOOD FORECASTING AND WARNING SYSTEM

## 5.1 Formulation of Hydrometeorological Observation Plan

### 5.1.1 Formulation of water level gauging station

(1) Basic approach

To formulate the water level gauging station which shall be telemetered for flood forecasting, the existing gauging stations are evaluated by several requirements for an ideal base station. The water level gauging station at flood control structures such as Seyhan Dam and Çatalan Dam is also considered to be a forecasting station for flood forecasting.

(2) Requirements for an ideal base station

The requirements for an ideal base station are outlined as below:

(a) It must be strategically located,
(b) It must be equipped with an automatic water level recorder,
(c) The gauge should be easily accessible,
(d) The gauge should be located in a straight reach of the river without the influence of back-water from downstream reservoir, and
(e) It must have sufficiently long-term flood records with continuous water level recording charts.

(3) *Subdivision of Göksu and Zamantı River basins*

The entire basins of Göksu and Zamantı River are subdivided into two subbasins at 1801 and 1822 water gauging stations since the upstream and downstream subbasins are regarded as independent and homogenous ones based on the geographical, geological, topographical, and hydrological observations. Also, the basin size of each subbasin is suitable for storage function basin model.

(4) Selection of base water level gauging station to be telemetered

The several water level gauging stations are selected, based on the above criteria mentioned in (2), as *given below:*

Base Water Level Gauging Stations to be Telemetered

| No. of Gauge | Type of Gauge | Name of River | Catchment Area (km$^2$) | Operated by | Main Purpose of Estimate |
|---|---|---|---|---|---|
| 1822 | Automatic | Zamantı | 6,990 | EİE | Outflow from middle and upstream of Zamantı River |
| 1806 | Staff *1 | Zamantı | 1,833 | EİE | Outflow from downstream of Zamantı River |
| 1801 | Automatic | Göksu | 2,298 | EİE | Outflow from middle and upstream of Göksu River |
| 1805 | Staff *1 | Göksu | 2,099 | EİE | Outflow from Göksu River |
| 1818 | Automatic | Seyhan | 858 | EİE | Inflow into Çatalan Dam |
| 1825 | Automatic | Eğlence | 506 | EİE | Inflow into Çatalan Dam |
| 1820 | Automatic | Körkün | 1,427 | EİE | Inflow into Seyhan Dam |
| 1828 | Automatic | Çakıt | 1,797 | EİE | Inflow into Seyhan Dam |

Note: *1 Type of gauge shall be changed to be automatic for flood forecasting system plan.

(5) Selection of forecasting water level gauging station

To forecast the flood runoff into the reservoir and to operate the dam, the water level gauging station shall be installed at Seyhan and Çatalan Dams.

### 5.1.2 Formulation of rainfall gauging station

(1) Basic approach

To forecast the flood runoffs draining into the flood control structures such as Seyhan and Çatalan Dams from several sub-basins of the Seyhan River basin, it is of importance to estimate the mean basin rainfall when a rain storm occurs in the basin.

The rainfall gauging station to be telemetered is a group of the minimum rainfall gauging stations required to represent the mean basin rainfall amount within the acceptable range of estimate error, and it is defined to be representative rainfall gauging station. For the purpose of estimating the basin rainfall, the representative rainfall gauging station is selected among the existing rainfall gauging stations by the statistical method, namely, the multiple linear regression analysis on the observed rainfall records.

Since the Seyhan River basin is needed to be divided into several sub-basins for the flood runoff analysis, the representative rainfall gauging station shall be selected on the basis of the sub-basins.

### (2) Evaluation of major rain storms

Following 24 storm rainfall records are picked up as the representative storm rainfall among the past observation records when the storm caused flood in the Seyhan River basin.

| Month | Year | Month | Year |
|---|---|---|---|
| Dec. | 1937 | Dec. | 1957 |
| May | 1946 | Dec. | 1961 |
| Nov. | 1947 | Dec. | 1969 |
| Dec. | 1947 | Jan. | 1970 |
| Feb. | 1948 | Jun. | 1972 |
| May | 1950 | May | 1973 |
| Feb. | 1952 | Jun. | 1973 |
| Mar. | 1952 | Apr. | 1975 |
| Apr. | 1952 | May | 1975 |
| Apr. | 1953 | Mar. | 1980 |
| Jun. | 1957 | Apr. | 1980 |
| Jul. | 1957 | Dec. | 1987 |

The above storm records are used for the evaluation of allocation plan of representative rainfall station.

### (3) Interpolation of missing data

The missing data of daily and hourly rainfall are interpolated by the following method using the rainfall data of the nearby stations.

(a) The simple linear regression analysis is made among all the rainfall gauging stations in and around the Seyhan River basin on a daily basis. The correlation coefficient (r) between two stations is calculated and summarized in the correlation matrix as shown in Table 5.1.1.

The correlated stations having a correlation coefficient (r) greater than or equal to 0.8 are shown in Figure 5.1.1. Also, the uncorrelated stations having (r) less than or equal to 0.2 are shown in Figure 5.1.2. Two figures clearly suggest that the results of this analysis are in agreement with the topographical and climate conditions in the Seyhan River basin.

(b) The nearby station correlated with the station with missing data, having the highest value of correlation coefficient, is selected to interpolate the missing data.

The minimum requirement of correlation coefficient is set to be greater than or equal to 0.8.

The linear regression equation adopted as below:

$$Y = aX + b$$

where,
$Y$ = Missing daily rainfall
$X$ = Daily rainfall at correlated station
$a$ = Simple regression coefficient
$b$ = Constant

(c) In case that missing data cannot be interpolated by the simple linear regression analysis explained in (b), the multiple linear regression using the forward stepwise regression method is adopted. The multiple linear regression equation is described as below:

$$Y = a_1 X_1 + a_2 X_2 + \ldots\ldots. + a_n X_n + b$$

where,
$X_i$ = Daily rainfall at correlated stations
$n$ = Number of station
$a_i$ = Multiple regression coefficients ($i$ = 1 to n)
$b$ = Constant

For the purpose of illustration the sample computations are summarized only for Karsantı rainfall gauging station as below.

The Results of Multiple Linear Regression

| | Selection of Stations | | |
|---|---|---|---|
| | Step 1 | Step 2 | Step 3 |
| Selected Station | • Şıhlı | • Sıhlı<br>• Seyhan Brj. | • Şıhlı<br>• Seyhan Brj.<br>• Pozantı |
| a (for Sıhlı) | 0.805 | 0.605 | 0.517 |
| a (for Seyhan Brj.) | | 0.671 | 0.630 |
| a (for Pozantı) | | | 0.118 |
| b (mm) | 1.607 | 0.115 | 0.013 |
| r | 0.783 | 0.875 | 0.882 |

### (4) Estimation of mean basin rainfall

The selection of representative rainfall gauging station requires knowledge of true value of mean basin rainfall. The hypothetical true value of mean basin rainfall is calculated by Thiessen Method which weights each existing station in direct proportion to the area it represents.

Polygons are constructed by drawing perpendicular bisectors to lines connecting the existing stations as shown in Figure 5.1.3.

### (5) Selection of representative station

The representative rainfall gauging station is selected, using the daily rainfall data prepared by (2) and (3), based on the following procedure.

(a) Multiple linear regression using the backward stepwise regression method is adopted to determine the required number of representative station.

(b) The effective area for each station obtained by Polygons is allocated to sub-basins as shown in Table 5.1.2.

(c) Hypothetical true value of mean basin rainfall is calculated by total number of existing stations of which rainfall amount is effective to the sub-basin given in Table 5.1.2.

(d) Multiple linear regression equation is described below:

$$Rs = \sum_{i=1}^{n} (ai \times Ri) + b$$

where, $Rs$ = Hypothetical true value of mean basin rainfall
$Ri$ = Point rainfall of representative rainfall gauging station
$n$ = Number of representative rainfall gauging stations
$ai$ = Multiple regression coefficient
$b$ = Constant

(e) The accuracy of estimate of mean basin rainfall depends on the number of representative rainfall gauging station.

The degree of accuracy is indicated by the correlation coefficient given by multiple linear regression. Relationship between the degree of accuracy of estimate and the number of representative station for the plan of Alternative 2 is shown in Figure 5.1.4 and also Figure 5.1.5 as an example for the Göksu River basin.

(f) As indicated in Figure 5.1.4, there is a point from which the curve inclines drastically depending on the decrease of the number of station.

The point indicates the minimum number of representative rainfall gauging station required to estimate the mean basin rainfall within the acceptable range of accuracy.

(6) Alternative plan of representative rainfall gauging station to be telemetered.

(a) The alternative plan of representative rainfall gauging station to be telemetered is studied only for the Zamantı and Göksu River basins because of the following reasons.

- The Zamantı and Göksu River basins are composed of two sub-basins characterized by the noticeable different climate and topography as below:

| Sub-basin | Basin Characteristics |
|---|---|
| (1) The upstream and middle-stream basins (Approximately up to 1822 and 1801 stream gauging stations) | - Flat river basin<br>- Comparatively less storm rainfall |
| (2) Downstream basin (Approximately after 1822 and 1801 stream gauging stations) | - Steep river basin<br>- Comparatively more storm rainfall |

- The other small tributaries have no remarkable characteristics of differen climate and topography within the basin.

(b) Therefore, the alternative plans are conceived as below:

- Alternative 1: The Zamantı and Göksu basins are divided into two sub-basins before and after 1822 and 1801 stream gauging stations.

- Alternative 2: The Zamantı and Göksu basins are treated as one whole basin.
  1822 and 1801 stream gauging stations are not installed as the result of the treatment.

(c) The results of the selection of representative rainfall gauging station for the above Alternative 1 and Alternative 2 are summarized in Figures 5.1.6 and 5.1.7 and Tables 5.1.3 and 5.1.4.

Considering the lesser influence of the rainfall in the middle and upstream basins of the Zamantı River basin observed by rainfall study in the case of flood events in the Seyhan River basin, the Alternative 3 is additionally conceived as below.

- Alternative 3: No telemetering rainfall gauging stations are installed above 1822 stream gauging station.

  1822 stream gauging station is only installed with telemetry to observe the secondary flood runoff.

### 5.1.3 Formulation of temperature gauging station

(1) Representative meteorological gauging stations

To select the representative temperature gauging stations to be telemetered for the purpose of forecasting the snowmelt runoff in the subbasins, the representative meteorological gauging stations that were formulated for the hydrometeorological observation network to be telemetered for the Seyhan River basin are evaluated on the basis of hydrometeorological criteria. The locations of the representative stations are shown in Figure 5.1.6.

(2) Meteorological gauging stations with available daily mean temperature data

Among the representative meteorological gauging stations, daily mean temperature data are obtained at the following stations.

(a) Pozantı ( 778 El.m )
(b) Çamardı ( 1500 El.m )
(c) Feke ( 620 El.m )
(d) Tomarza ( 1400 El.m )
(e) Pınarbaşı ( 1470 El.m )

(3) Criteria to select the representative temperature gauging stations

To estimate the accurate and reliable temperature at the snow-covered area, the following criteria are considered.

(a) The gauging stations situated at relatively higher elevation are to be selected to minimize the estimate errors.

(b) The gauging stations are to be representatively situated in the subbasin.

(c) The selected gauging stations are recommended to possess the past records of daily temperature.

(d) The nearest gauging station is to be selected in case that no gauging stations are available within the subbasin.

(4) Selected representative temperature gauging stations

Based upon the above-defined criteria, the representative temperature gauging station is evaluated for each subbasin. Seven stations are selected and shown below.

Selected Representative Temperature Gauging Stations

| Basin No. | Basin Name | Selected Station | Elevation (El.m) |
|---|---|---|---|
| 1 | Upper Zamantı ( above 1822 ) | Tomarza | 1,400 |
| 2 | Lower Zamantı ( 1806 - 1822 ) | Şıhlı | 1,400 |
| 3 | Upper Göksu ( above 1801 ) | Tufanbeyli | 1,350 |
| 4 | Lower Göksu ( 1805 - 1801 ) | Mansurlu | 1,050 |
| 5 | Seyhan (1818 - Confluence) | Karsantı | 860 |
| 6 | Eğlence ( above 1825 ) | Kamışlı | 1,225 |
| 7 | Eğlence ( below 1825 ) | Not necessary | |
| 8 | Seyhan ( Çatalan - 1818 ) | Not necessary | |
| 9 | Körkün ( above 1820 ) | Kamışlı | 1,225 |
| 10 | Körkün ( below 1820 ) | Not necessary | |
| 11 | Ucurge | Pozantı | 778 |
| 12 | Seyhan ( Seyhan - Çatalan ) | Not necessary | |
| 13 | Çakıt ( above 1828 ) | Pozantı | 778 |

### 5.1.4 Formulation of hydrometeorological observation network

Based on the above studies to formulate the representative water level and rainfall gauging stations to be telemetered, three alternative plans are conceived as summarized below:

Alternative Plans of Hydrometeorological Observation Network

| Alternative | No. of water level gauging station | | No. of rainfall gauging station | No. of temperature gauging station | Note |
|---|---|---|---|---|---|
| | Base station | Forecasting station* | | | |
| 1 | 8 | 2 | 16 | 7 | Zamantı and Göksu Rivers are divided into two subbasin at 1822 and 1801 |
| 2 | 6 | 2 | 13 | 7 | Zamantı and Göksu Rivers are treated as one basin |
| 3 | 7 | 2 | 10 | 7 | Zamantı River is divided into two subbasins at 1822, but no rainfall stations are installed for sub-basin above 1822 |

Note *: Forecasting station is installed at Seyhan and Çatalan Dams.

Among three conceivable alternative plans studied by the statistical methods and hydraulic consideration, Alternative 1 is the most suitable plan for the Seyhan River basin taken into consideration the unpredictable natural phenomenon as below.

- The unilateral area of storm rainfall,
- The changeable distribution of storm rainfall, and
- The changeable magnitude of storm rainfall.

Optimum Plan of Hydrometeorological Observation Network

| Base Water Level Gauging Station | Forecasting Water Level Gauging Station | Rainfall Gauging Station | Temperature Gauging Station |
|---|---|---|---|
| 1822 (Zamantı upstream) | Seyhan Dam | Çatalan Dam | Karsantı |
| 1806 (Zamantı downstream) | Çatalan Dam | Karsantı | Pozantı |
| 1801 (Göksu upstream) | | Çiftehan | Kamışlı |
| 1805 (Göksu downstream) | | Pozantı | Mansurlu |
| 1818 (Seyhan River) | | Karaisalı | Tufanbeyli |
| 1825 (Eğlence River) | | Kamışlı | Şıhlı (Şeyhli) |
| 1820 (Körkün River) | | Çamardı | Tomarza |
| 1828 (Çakıt River) | | Feke | |
| | | Mansurlu | |
| | | Saimbeyli | |
| | | Tufanbeyli | |
| | | Kazancık | |
| | | Pınarbaşı | |
| | | Şıhlı (Şeyhli) | |
| | | Toklar | |
| | | Tomarza | |

## 5.2 Basic Study of Alternative Plans

This section describes the basic items of study as to the sub-systems of the flood forecasting and warning system that are common to the alternative plans presented below; the sub-systems referring to a data collection system, a data processing system and a data transmission system.

### 5.2.1 Basic study of the data collection system

Based on prior studies of a hydrometeorological observation network plan, basic studies are made for the hydrometeorological data collection system that covers the area from hydrometeorological gauging sites to the DSİ 6th regional directorate and related agencies. These basic studies relate to those basic items of the data collection system that are common to each alternative plan. More specifically, the following items are studied:

(1) Basic study policies

During study of a data collection system for the flood forecasting and warning system in Seyhan River basin, further studies are made for the results of survey of the current data collection system, for the purpose and functions of the flood forecasting and warning system to be structured, and for the geographical conditions of the areas covered. The basic design concept for the new data collection system is established using those analyses.
The basic design concept for the new data collection system is to be set on the study policies described below.

(a) The data collection system is capable of collecting and hydrometeorological data both accurately and rapidly from hydrometeorological gauging sites into a flood forecasting and warning control center. The flood forecasting and warning control center is to act as the center of flood forecasting and warning control information that collects, processes, and distributes and hydrometeorological data. The Seyhan Dam office and the DSİ 6th regional directorate are selected as the promising setup locations for the control center. The flood forecasting and warning control center, however, is to be set up in the DSİ 6th regional directorate since the flood control committee is organized in DSİ 6 th regional directorate during floods.

Collection of necessary data in related agencies is discussed in Section 5.2.3, Basic study of the data transmission system.

(b) The types of data to be collected using the data collection system are rainfall, water level and air temperature. The maximum gauging stations for these three types of data are listed in Table 5.2.1, and alternative plans are to be set up from the listing.

(c) In principle, data collection intervals are as listed below.

| Gauging item | Collection Intervals | Remarks |
|---|---|---|
| Rainfall | Every hour on the hour | Calculations of hourly rainfalls, every hour on the hour, become the minimum unit. |
| Water level | Every hour on the hour | It is preferable that whenever necessary, collection of any data is possible. |
| Air temperature | Every hour on the hour | It is preferable that whenever necessary, collection of any data is possible. |

(d) Use of radar rain gauge data, described in this section, is discussed as one alternative method for rainfall data collection.

(e) If terrestrial communications circuits are to be used to collect data, since continuous collection of hydrometeorological data is not required, those communications circuits are of the half-duplex type that uses VHF radio communications links of high circuit design efficiency. Also, the optimum link configuration is designed by combining those links with the multiplex radio communications links mainly intended for data and information transmission purposes. In addition, considering the topographical conditions of the Seyhan River basin, the VHF radio communications links use a frequency band of 70 MHz, which is ideal for mountainous propagation, while at the same time being high in circuit design efficiency and allowing its use in the Republic of Turkey to be licensed.

(2) Study of the circuits schemes

During study of the data collection methods, the available circuit schemes can be broadly divided into the terrestrial communications circuit scheme and the satellite communications circuit scheme. Comparative studies on these two schemes are listed in Table 5.2.2. The satellite communications circuit under the comparative study plan is the VSAT (Very Small Aperture Terminal) system that uses a Turkish satellite. The VSAT system, although not yet usable, is to be studied in comparison with the terrestrial communications circuit, on the assumption that the system will become usable in the near future. For the flood forecasting and warning system, further studies that assume use of the terrestrial communications circuit are to be performed for the following reasons:

(a) To use the VSAT system, users should install VSAT equipment. Also, considering circuit usage charges, the equipment costs are more expensive than the same as those of the terrestrial communications circuit

(b) In areas that suffer from snow fall, snow-melting equipment is required against the accumulation of snow on the antennas. In view of the electrical power supply situation in the Seyhan River basin areas, measures for stabilized supply of power should be undertaken since missing-data is likely to occur very frequently.

(c) In terms of maintenance and management, if failures occur in the satellite communications circuit, significant amounts of time will need to be spent in restoration.

(d) The frequency band used for the VSAT system is susceptible to attenuation due to rainfall, and thus missing-data is likely to occur.

### (3) Study of data collection methods

Either centralized collection or distributed collection is usually used to collect data. Centralized collection is a method intended to directly collect data at flood forecasting and warning centers, and distributed collection is a method intended to collect data at sub-supervisory stations and then transfer the data to the flood forecasting and warning centers. Judging from comparative studies on these two methods, a distributed collection method approximate to the centralized collection method should be used for the system, mainly for the following reasons:

(a) In the Seyhan River basin, river management, dam management and flood control are centralized at the DSİ 6th regional directorate.

(b) For ideal centralized collection, a supervisory station is installed at the flood forecasting and warning center. To allow for the structuring of an integrated dam management system in the future, however, setup of a supervisory station at the Seyhan Dam office increases the extendibility of the system.

### (4) Study of telemetering methods

Rainfall, water levels and other river management data, including flood forecasting and warning information, are usually collected using one of the following two telemetering methods :

- Polling
- Event reporting

Judging from the comparative studies, it is preferable that the flood forecasting and warning system should use the polling method for the following four main reasons:

(a) It is necessary that radio waves are effectively used under appropriate circuit control of the radio waves, because the area to be covered is very wide and because the total number of intended stations is large.

(b) The system correctly performs the functions that become effective in the event of flooding, and thus high system reliability is demanded.

(c) Since the area to be covered is very wide, not only circuit configuration becomes sophisticated, but also is demanded a very wide span. A method advantageous for the prevention and reduction of noise, therefore, is required. In view of this, polling is effective since, if data cannot be collected because of noise, automatic recollection becomes possible with the polling method.

(d) The telemetering method demands one effective in terms of maintenance. Unlike event reporting, polling allows data to be checked and thus becomes effective in terms of maintenance.

### (5) Radar rain gauges

Radar gauges is rainfall data collection system which emits radio waves, receives and amplifies reflected waves from rain drops and measures rainfall intensity indirectly by receiving power. This paragraph describes the roles, functions and location plan of radar gauges in the flood forecasting and warning plan.

(a) Roles of radar rain gauge

- To grasp the basin rainfall
- To monitor rainfall on real time

- To be possibility of rainfall area forecast

(b) Functions of radar gauges

- Gauging range
  - Quantitative gauging within a radius of 120 km
  - Qualitative gauging within a radius of 198 km
- Processing
  - Processing of the intensity of five-minute rainfall within a mesh of 3 km, five levels of qualitative display data, and ten levels of quantitative display data
- Display

  Gauged rainfall, history replay of rainfall and rainfall forecast are displayed in four split patterns:
  - Qualitative river chart

    km-meshed five-level display of the qualitative data that is measured within a radius of 198 km
  - Quantitative river chart

    km-meshed ten-level display of the quantitative data that is measured within a radius of 120 km
  - Quantitative basin chart

    Quantitative display for each river basin
  - Basin-dependent rainfall depth chart

    Display of split river basin rainfall for each basin
- Transmission

  Simultaneous transmission of data to multiple remote sites

(c) *Study of prospective radar sites*

Here, the radar sites where radar rain gauges for the system is located are studied.

During study of prospective radar sites, it is necessary that the intended basin belongs to the area where data can be measured as accurately as possible. In these terms, judging from the topographical conditions of the Seyhan River basin, Ziyaret T. and Feke Daği can be selected as promising candidates. Comparative studies on these two places are listed in Table 5.2.3. Figure 5.2.1 shows the gauging ranges obtained by setting of a radar site in the two candidates, and Figure 5.2.2 shows the system configuration of radar rain gauges in that case.

### 5.2.2 Basic study of the data processing system

(1) Basic items of study

The data processing system is intended to support flood control activities both smoothly and efficiently by processing collected data and then rapidly supplying the appropriate and accurate data. To fulfill these objectives, the data processing system having various processing functions is required. This section describes the basic requirements of the data processing system that are common to each alternative plan: The following lists study items that are likely to be required at control centers:

- Display processing
- Record processing
- Computing
- File processing and data storage

(2) Display processing

The following lists display items that are usually required for a flood forecasting and warning system:

(a) Display items on graphics and tables

- River basin status charts
- Water level data lists
- Rainfall data lists
- Discharge data lists
- Air temperature data lists
- Water level data chronological graphs
- Rainfall data chronological graphs
- Water level and discharge data chronological graphs
- Air temperature data chronological graphs
- Simulation display of flood forecast
- Other necessary items

(b) Display items on numeric data and states

- Hourly rainfall data
- Cumulative rainfall data

- Average basin rainfall data
- Current water level data
- Current discharge data
- Water level warnings
- Rainfall warnings
- Other necessary items

(3) Record processing

The following lists recording items that are usually required for a flood forecasting and warning system:

- Daily management reports
- Monthly management reports
- Operation/operating logs
- Warning logs
- Others required

(4) Computing

The computing items required for the display and recording operations described in Paragraphs (3) and (4) above are listed below.

- Hourly rainfall processing
- Daily rainfall processing
- Average basin rainfall processing
- Rainfall warning judgment processing
- Water level warning judgment processing
- Discharge processing
- Statistical processing
- Flood forecast processing

(5) File processing and data storage

File processing and data storage refers to storing various types of data and files into hard disk drives or other storage units in the required formats after providing filtering, such as abnormal data detection and necessary computing to the input data from a telemetering facility Storage data forms databases in the flood forecasting and warning system. To store data that becomes the core of databases, files of a relatively large capacity are required since various types of data are to be filed in large amounts. The types of files that are likely to be required for the flood forecasting and warning system, and the approximate periods of filing are listed below.

(a) Hourly data and daily files

The amounts of data that consider file extendibility are estimated. In terms of the periods of filing, two months are usually good enough for monthly reporting. Although it may be necessary to prepare files of a larger capacity that allows annual reporting, two months are usually the maximum periods of filing in taking account of reliability and restoration against troubles.

(b) Data files for annual reporting

A capacity that allows one year of daily data to be stored is required.

(c) Supervisory information files

Alarm information on hydrometeorological data and information on any hardware unit abnormalities are to be stored as supervisory information files. These files will be created in the order that alarms or abnormalities have occurred. The number of such events likely to occur are to be registered beforehand, and the capacity is to be determined from this registered number of events.

(d) Data files for flood forecast simulation

Evaluation files for flood forecast simulation are to have their respective capacities and periods of storage reserved beforehand.

(e) Working data files for analysis

The amounts of data required for flood forecast and analysis are estimated and reserved. Any other necessary file capacities are also to be estimated and reserved.

### 5.2.3 Basic study of the data transmission system

(1) Current situations of flood control and information transmission

The rivers in the Seyhan River basin are now managed by the DSİ 6th regional directorate. In the event of floods, the flood control committee and the ASO, shown in Figures 2.3.2 and 2.3.3, respectively, are organized in the DSİ 6th regional directorate and carry out flood control activities. Flood control activities against flooding of the relevant rivers are undertaken by flood teams, and if there are any signs of flooding, then evacuation information is given to the Adana provincial governor. Figure 2.3.6 shows the current information transmission routes.

(2) Basic study conditions

The data transmission system is studied under the conditions described below.

- After collecting rainfall, water level, and air temperature data and then obtaining flood forecast information by processing the data, the data transmission system, in principle, creates dam operations, flood control, and evacuation information from analyses of the data, and transmits the information from the flood control committee of the DSİ 6th regional directorate to related agencies.

(3) Selection of related agencies

Twenty-eight (28) agencies should be involved in the flood control system of the Seyhan River basin: eight (8) Governmental, one (1) Provincial, seventeen (17) district-administrative, and two (2) municipalities.

The necessity for current and future tie-up between, and transmission of information to, those agencies during flood control activities, is examined. Table 5.2.4 lists obtained results of examination. Judging from the results, it is likely to be good enough just to transmit information to only 16 agencies among the 28 agencies. Table 5.2.4 is a listing of evaluations on the degree of importance of each such agency. The following describes the criteria for selection of related agencies:

(a) Since the flood control committee of the DSİ 6th regional directorate is an important information source for the flood control of the Seyhan River basin, all eight governmental agencies is ranked A in terms of the degree of importance.

(b) The provincial governor receives information and then transmits the information to its subsidiary agencies. The provincial governor, although originally likely to be ranked B in the degree of importance, also is ranked A since it is an agency that gives and transmits particularly important information.

(c) Since, during actual evacuation activities, they give direct directions based on received information, the administrative districts and municipalities are originally equivalent to rank B in the degree of importance. These administrative districts and municipalities, however, are either ranked C or excluded from selection, since, administratively, they are all placed under the control of the provincial governor.

## (4) Types and definitions of information

The data transmission system handles the following data, and the current flood information is shown in Table 2.3.2.

### (a) Hydrometeorological information

Hydrometeorological information refers to the rainfall data, water level data, and air temperature data that are sent from rainfall gauging stations, water level gauging stations, and meteorological gauging stations, respectively, and to the rainfall distribution data obtained from radar rain gauges. Hydrometeorological information is continually transmitted, irrespective of whether a flood occurs.

### (b) Flood control information

Flood control information is needed to judge whether the water level at the particular water level gauging station reaches a predetermined alert water level or estimated design water level, then estimate that state, and inform the state to related agencies. The information is transmitted only during flood periods.

### (c) Evacuation information

Evacuation information is needed for related agencies to take evacuation activities for the people living in any areas that are likely to suffer from floods.

### (d) Dam information

Dam information relates to dam operating commands.

## (5) Information transmission routes and media

Selection of transmission routes and media to each related agencies is studied as follows:

### (a) General study of the transmission media

The data transmission media (methods) that are most commonly used in a flood forecasting and warning system include the following:

- Image information display (CRT, projector, etc.)
- Data display (CRT, projector, data display panel, etc.)
- Facsimile transmission (FAX)
- Recording (Printer, hard copy units, etc.)
- Telex
- Voice transmission (through the phone)
  - Private phones
  - Independent contact
  - Group contact
  - General contact phones
- Loudspeaker warning equipment (except sirens, which are only for air-raid warning use)
- Electronic display boards
- Warning lights

### (b) Prerequisites for study

Selection of the transmission media actually used for related agencies is based on the following prerequisites:

- Selection of related agencies is shown in Table 5.2.4
- Transmission of information between the flood control committee of the DSİ 6th regional directorate and related agencies is studied.

### (c) Study of the information transmission media for each information type

Those preferable methods of transmission for each information type are summarized together with priority levels in Table 5.2.5. During planning for the routes and methods of information transmission to related agencies in the flood forecasting and warning system, the general study results discussed above are analyzed in further detail, and then the system that gives best results is structured.

(d) Selection of transmission media for each related agency

The information transmission media required for each related agency can be selected by arranging the study results shown in Tables 5.2.4 and 5.2.5. The media required for information transmission from the flood control committee of the DSİ to related agencies are listed in Table 5.2.6. Also, the basic plan for the data transmission system is shown in Figure 5.2.3

(6) Study of the methods of information transmission

Those methods of information transmission that are common to each alternative plan are studied here.

(a) Study of the methods of information transmission in voice communication

Ideally, a multiplex radio communications network that covers all sections from the flood control committee of the DSİ to related agencies are structured to perform information transmission in voice communications. The feasibility study here, however, is performed from the viewpoint that UHF and other radio communications links are provided to transmit information from a nearby multiplex communications station to related agencies. Methods of information transmission in voice communication in that case are studied below.

The following lists typical methods of voice radio communication:

- Voice call radio communication
- Selective call radio communication
- Single-channel dial radio communication
- Frequency division multi-channel communication
- Time division multi-channel communication

Of all the methods above, selective call radio communication and single-channel radio communication are to be used for the three main reasons listed below.

- A method is used that allows dial calling that matches to the exchange circuit network of multiplex communications links.

- Selective call radio communication is possible for group contact that is useful to inform message of discharge from the dam.
- Under the radio wave administration of the Republic of Turkey, it is possible to get a license to use a frequency band of 400 MHz, and for this frequency band, communication is possible with equipment that most commonly uses the frequency division multichannel communications method, and such communication is very economical.

## 5.3 Evaluation of Alternative Plans

### 5.3.1 Basis for the setup of alternative plans

The flood forecasting and warning system consists of three subsystems: the data collection system, the data processing system, and the data transmission system:
During setup of alternative plans, combinations that allow these sub-systems to exist as alternative plans in terms of the relationship between the functions and processing capabilities of each sub-system, the scale of facilities, and costs, are studied. The following describes the results of study:

(1) Alternative plans for the data collection system

The data collection system collects rainfall, water level and air temperature data from hydrometeorological gauging stations into the flood control committee of DSİ 6th regional directorate, which is the control center that processes data both accurately and rapidly. The basic concepts for alternative plans are described below.

(a) Water level telemetering stations

Water level telemetering data is the most important data in flood forecast. The water level gauging stations required for the forecast of floods in the Seyhan River basin are located in a downstream section of the Zamantı River, a downstream section of the Göksu River, and along the river that leads to the Çatalan Dam and the Seyhan Dam. Although the gauging stations in upstream and middle sections of the Zamantı River do not directly affect flood forecast, these gauging stations are needed to monitor the indirect runoff due to the dividing of the Zamantı River basin. The number of water level telemetering gauging stations is therefore likely to become one object of alternative plan setting.

(b) Rainfall depth telemetering stations

The purpose of rainfall telemetering data is to calculate basin rainfall within range of allowable errors by typical rainfall gauging. The available alternative plans, therefore, depend on the manner of dividing of the intended river basin.

(c) Radar rain gauges

The main purposes of radar rain gauges are to understand the current rainfall situation in areal form and to estimate both the situation of the rainy area and its subsequent situation from those results. For the flood forecasting and warning system, it becomes important to correctly understand the basin rainfall and accurately estimate the subsequent situation of the rainfall. Alternative plans can therefore be set up in terms of functional improvement of the rainfall gauging. Also, considering the accuracy of radar rain gauges, rainfall gauging stations of the minimum level required are provided since calibration is required for operation.

(2) Alternative plans for the data processing system

The data processing system, after performing abnormal data checks, missing-data compensations, and other processing operations on the gauged data that is sent from the data collection system, arranges collected data for tabulation and display of data and performs flood forecast processing operations. Basically, data is to be processed on-line. The configuration of the processing system, however, is likely to depend on the size of the flood forecast program to be used, the particular scales and capabilities of the computers, and the configuration of peripheral hardware units. Thus, the available alternative plan is to use either centralized processing or distributed processing.

(3) Alternative plans for the data transmission system

The data transmission system transmits, from the flood control committee of the DSİ 6th regional directorate to related agencies, the dam operations information, flood control activities information, and evacuation information that are judged from collected hydrometeorological data and processed flood forecast information. First, constructing data transmission facilities that accommodate multiplex radio communications links, UHF radio communications links PTT private lines, or any other appropriate lines, are considered as one alternative plan for the data transmission system. Next, to what subsidiary administrative units of each related agency the system is to transmit data are compared and studied from the necessity for information transmission.

### 5.3.2 Comparative study of the alternative plans for the data collection system

Alternative plans for the data collection system are presented below, and then comparative studies are performed on these alternative plans to formulate the final alternative plan.

(1) Alternative plan setup

For the data collection system, three (3) alternative plans that use water level telemetering stations, rainfall telemetering stations, rainfall and temperature telemetering stations, and radar rain gauges. Table 5.3.1 lists the alternative plans of telemetering gauging stations.

(2) Functional outline for each alternative plan

The components and functions of the data collection system under each alternative plan are listed in Table 5.3.2. An outline of each alternative plan is given below.

(a) Each alternative plan has been set up from two factors: the number of rainfall gauging stations to be provided for collecting rainfall data automatically, and whether radar rain gauges are to be provided. Functions, therefore, are to be evaluated by evaluating the reliability of flood forecast according to the particular number of gauging stations, and by evaluating added functions in case radar rain gauges are provided.

(b) Alternative plan 1 assumes dividing of the Zamantı River basin into two sub-basins. It therefore assumes selection of the rainfall gauging stations required for flood forecast analysis, and is excellent in the following respects:

- Any slight changes in regional runoff can be checked during the initial phase of flooding.
- Flooding can be forecasted very accurately over the entire flood continuation period.
- Forecast accuracy is not dependent on the scale of flooding.

(c) Alternative plan 2 assumes no dividing of the Zamantı River basin. Since a 1822 water level gauging station is not to be set up that monitors the runoff in the upstream or middle areas, this alternative plan is likely to lack the characteristics listed in Item b) above.

(d) Alternative plan 3 assumes that the rainfall gauging stations in upstream and middle areas of the Zamantı River basin are to be removed under alternative plan 1. This Alternative plan, therefore, is estimated not to give sufficient gauging accuracy in terms of the rainfall distributions obtained if the areas of heavy rain change according to the particular climate or topographical characteristics of the intended river basin.

(e) Alternative plan 4 is the same as alternative plan 3 in terms of the setup of rainfall gauging stations and temperature gauging stations. In addition, alternative plan 4 assumes that radar rain gauges are to be provided to complement the functions of the rainfall gauging stations. Two factors, therefore, become the criteria for selection: whether the sufficient accuracy of basin rainfall gauging under alternative plan 1 can be compensated for with the radar rain gauges, and evaluation of the facilities costs for the radar rain gauges.

(3) Evaluation and study of the alternative plans

The items required for evaluation of each alternative plan are as studied above. Studying each alternative plan synthetically, alternative plans 2 and 3 do not need to be further studied for the three main reasons listed below and only alternative plans 1 and 4 need further comparative study towards the selection of the final alternative plan.

(a) *Alternative plans 2 and 3 are not sufficient in flood forecast reliability.*

(b) Radar rain gauges can act as a powerful means against the corresponding function of the flood forecasting and warning system. During further comparative study of the alternative plans, therefore, use of these gauges is to be studied because of the relationship to future planning.

(c) Considering the operational results of the current flood forecasting and warning system, data collection is the most important factor of all those conceivable, and the first priority is assigned to data collection. Introducing the radar rain gauges under alternative plan 4 requires complementing the accuracy of forecast under alternative plan 3 and synthetically studying the facilities costs and other factors of the gauges.

It is judged from the above studies that alternative plans 2 and 3 are not appropriate. Only alternative plans 1 and 4, therefore, are to be further studied as the alternative plans for the data collection system.

### 5.3.3 Comparative study of the alternative plans for the data processing system

Alternative plans for the data processing system are presented below, and then comparative studies are performed on these alternative plans to formulate the final alternative plan.

(1) Setup of alternative plans

Two alternative plans are available for the data processing system: alternative 1; centralized processing, which assumes use of minicomputers, and alternative 2; distributed processing, which assumes use of workstations.

(2) Hardware configurations under and hardware functional comparison between the alternative plans

Another probable alternative plan for the data processing system in the flood forecasting and warning system is to split the data processing section into parts. Considering the purpose of the flood forecasting and warning system, however, such an alternative plan is not likely to be appropriate for the current operational form of the flood control committee of the DSİ 6th regional directorate. During alternative plan setup, therefore, any differences in the configuration method of the data processing equipment of control centers between alternative plans 1 and 2 are to be studied. Basically, alternative plans 1 and 2 are almost the same in function since both have the functions required for the flood forecasting and warning system.

(3) Evaluation criteria for alternative plan selection

It is judged from the study results of Items (1) and (2) above that since there are no functional differences between alternative plans 1 and 2, operational convenience, reliability, extendibility, and maintainability, etc. become the criteria for evaluation of the two alternative plans.

(4) Selection of the final alternative plan

Table 5.3.3 lists comparative studies on the centralized processing method that uses minicomputers, and the distributed processing method that uses workstations with LAN. It is judged from the study results of Table 5.3.3 that distributed processing should be used for three main reasons:

(a) It is estimated that the data processing system undertakes overall status display, which is one feature of the flood forecasting and warning system, and that persons specializing in various tasks, such as flood forecast processing, carry out their respective analytical jobs. Also, it becomes absolutely necessary that image display is used very frequently in necessary sections for various purposes, such as status checking by the system administrator. The centralized processing method, if used for those purposes, imposes a significant load on the system, and in this respect, the distributed processing method is also excellent.

(b) System feedback by analysis of each flood is essential in the flood forecasting and warning system. While, in general, distributed processing allows separate tasking with each workstation, centralized processing significantly affects the operation of the entire system partly because this method stops the system during operation.

(c) The recent technological progress of both hardware and software is currently spreading the use of further sophisticated and higher-capacity workstations, and general-purpose software has also become usable in some cases. Also, distributed processing that covers a LAN has come to be most commonly used.

### 5.3.4 Comparative study of alternative plans for the data transmission system

Alternative plans for the data transmission system are presented below, and then comparative studies are performed on these alternative plans to formulate the final alternative plan.

(1) Setup of alternative plans

Based on the evaluations listed previously in Section 5.2.3 (3) as to the degree of importance of related agencies, three alternative plans are to be set up as the range of data transmission. Evaluations on related agencies, and the three alternative plans are shown in Table 5.3.4.

(2) Configurations under and functional comparison between the alternative plans

As listed above, alternative plans 1 to 3 are to be established from the basic philosophies of flood forecasting and warning system planning for the Seyhan River basin, and from the data transmission system design concepts based on those basic philosophies. The configurations and functions of the data transmission system under the three alternative plans are summarized in Table 5.3.5. An outline of each alternative plan is given below.

(a) All three alternative plans are presented in terms of the information transmission range. Under each of the alternative plans, information is to be transmitted to the DSİ general directorate, the Seyhan Dam office, the Çatalan Dam office, the Adana EİE regional directorate, the Adana DMİ regional directorate, and the provincial governor of Adana, because all these agencies are the most important administrative units among all related agencies in the area that the flood forecasting and warning system is to cover. Similar common information is also to be transmitted to the offices of towns and villages' head along the downstream area of the Seyhan Dam, because these offices of towns and villages' head are necessary ones in letting their respective residents know beforehand the discharge from the dam. Alternative plan 1 assumes transmission only to this administrative level, and it can be said that this administrative level is the minimum level that requires information transmission.

(b) Alternative plan 2 is plan under which information also is transmitted to heads of official districts as well as to the agencies of alternative plan 1.

(c) Alternative plan 3 is plan under which information also is transmitted to municipalities as well as to the agencies of alternative plan 2.

(3) Criteria for evaluation of the alternative plans

Since the three alternative plans for the data transmission system are identified by their respective ranges of information transmission, each alternative plan is to be evaluated by analyzing to which levels the individual ranges are improved after the current transmission method is checked against the purpose of the flood forecasting and warning system.

(4) Selection of the final alternative plan

Of course, it is preferable that the final alternative plan selected in terms of the information transmission range is that which allows accurate information to be transmitted over a wider range as possible. Such selection is performed considering the limitations on facilities costs and the effectiveness of the costs. For the moment, however, only alternative plan 1 is to be further studied for the reasons listed below.

(a) Alternative plan 1 assumes that information on flood control activities, dam operations, etc., is to be transmitted to the related agencies located in the territory of the DSİ 6th regional directorate and to the DSİ general directorate, and that evacuation information is to be transmitted to the provincial governor. Also, the agencies that require rapid transmission of information are selected under the alternative plan.

(b) Evacuation information to the heads of the towns and villages along the downstream section of the Seyhan Dam are to be transmitted on the basis of dam operations information.

(c) Alternative plans 2 and 3 assume that transmission of evacuation and other information is to cover a range as far as heads of official districts and municipalities, and considering the current administrative organizations of the Republic of Turkey, such a transmission range is too wide. Also, compared with alternative plan 1, alternative plans 2 and 3 are both high in facilities costs.

## 5.4 Formulation of Optimum Plan

Two alternative plans can be derived from the studies described in up to Section 5.3. These two alternative plans are studied in comparison below.

### (1) Alternative plan A

Alternative plan A is combinations of alternative plan 1 for the data collection system, alternative plan 2 for the data processing system and alternative plan 1 for the data transmission system.

### (2) Alternative plan B

Alternative plan B is combination of alternative plan 4 for the data collection system, alternative plan 2 for the data processing system and alternative plan 1 for the data transmission system.

### 5.4.1 Comparative study in terms of function

Alternative plans A and B are derived from the results of evaluation of the basin rainfall calculation accuracy of collected rainfall gauging stations and the support functions of calculation accuracy by radar rain gauges. These two factors are studied in Section 5.3.2 (2). It is considered that alternative plans A and B differ in the functions of the corresponding facilities. The degree of application to various needs for system functions also is considered. If the information obtained from the flood forecasting and warning system is to be divided into direct information and indirect information, then although the former would usually become higher in the degree of needs, the latter would also be required. Overall judgments therefore are performed, including the comparison of facilities construction costs.

### 5.4.2 Comparison in terms of facilities configurations

Under Alternative plans A and B that are set up for the formulation of the optimum plan facilities configurations are to differ according to the particular differences in the functions of the data collection systems. For this reason, comparison in terms of facilities configurations is limited to the data collection system, and thus only telemetering facilities are selected, station-by-station, and comparative studies are performed. The results give that both alternative plan A and alternative plan B are exactly the same in the numbers of telemetering supervisory stations, water level gauging stations, dam water level gauging stations and dam rainfall gauging station, and the only difference between both alternative plans is in the number of rainfall gauging stations, rainfall/temperature gauging stations, repeater stations, and that of radar rain gauges.

### 5.4.3 Comparison in terms of maintainability

Maintainability depends on the number and the scale of the corresponding entire facilities. Compared to alternative plan A, alternative plan B may become less expensive since it assumes a smaller number of rainfall gauging stations. Since, however, alternative plan B assumes setup of one radar gauging station, economical burdens associated with maintenance are not likely to differ too significantly between both alternative plans.

### 5.4.4 Comparison in terms of cost estimates

The studies described previously in Section 5.4.2 imply that the difference in facilities costs between alternative plans A and B becomes the differences in the numbers of rainfall gauging stations, rainfall/temperature gauging stations, repeater stations and a radar rain gauge. This makes it necessary that the approximate construction costs for the rainfall gauging stations, rainfall/temperature gauging stations, repeater stations and radar rain gauge facilities are calculated for comparison. Alternative plan B is more expensive cost of $6,661,320 than alternative plan A.

### 5.4.5 Formulation of optimum plan

It is judged to be appropriate from the above studies that alternative plan A should be formulated for the intended system for the moment. As studied previously in the section on radar rain gauges, it can be said that for the flood forecasting and warning system, radar rain gauges also become powerful equipment that complements the functions of ground rain gauges. It is desirable, therefore, that use of radar rain gauges will be included in future plans and that the facilities costs for these rain gauges will be improved in steps. Alternative plan A should be formulated as the optimum plan for the reasons listed below.

(1) The studies discussed previously in Section 5.4.4 indicate that the difference in facilities costs between the two Alternative plans becomes about $6,661,320 under the cost estimation conditions, and compared with alternative plan A, alternative plan B brings about significant total system cost burdens.

(2) In actual forms of system operation, a majority of existing flood forecasting and warning systems use ground rain gauge data, not radar rain gauge data, as the basis for judgment. Since, however, radar rain gauges have the feature that they can analyze the areal and dynamic characteristics of rainy regions, many systems actually use them as one powerful component that complements such function of the systems.

(3) Although improvement of the accuracy of radar rain gauges is likely to become possible by carrying out analytical studies based on after-installation data storage, it is judged to be appropriate that for the moment, ground rain gauges should be used to perform flood forecasts and warnings, because the ground type surpasses the radar type very significantly in terms of the history of actual data storage.

# 6. HYDROMETEOROLOGICAL ANALYSES

## 6.1 Data Collection and Flood Characteristics

### 6.1.1 Data collection

(1) *Rainfall data*

There are totally 46 rainfall gauging stations of DSİ and DMİ in and around the Seyhan River basin as shown in Figure 6.1.1. The available daily rainfall records observed when several major floods occurred in the Seyhan River are collected as listed in Table 6.1.1. The number of rainfall gauging station of which daily data are available is thirty two (32) in total.

The available periods of daily rainfall records are mainly from 1969 to 1987 as shown in Table 6.1.1.

The number of rainfall gauging stations with a pluviograph is reported to be fourteen (14) in total in and around the Seyhan River basin. The available hourly rainfall records observed at the occurrence of major floods are collected only from ten (10) stations as shown in Table 6.1.1.

(2) Runoff data

The stream gauging stations operated by DSİ and EİE are listed in Tables 6.1.2 to 6.1.5 and the location of the stream gauging stations are shown in Figure 6.1.2.

The daily water level and runoff records observed at the occurrence of major floods in the Seyhan River basin were collected during the Site Investigation (Stage I). Since the staff gauge reading is carried out twice a day (at 8 a.m. and 4 p.m.), the flood water level records observed by staff gauge reading are used mainly for the purpose of reference or supplemental to the flood analysis.

The hourly water level records observed by the automatic recorder (float type) are required to be collected for flood analysis and flood forecasting model. The collected hourly water level records are listed below.

| Date of Flood | No. of Gauging Station | | | |
|---|---|---|---|---|
| | 1801 | 1818 | 1820 | 1822 |
| Mar. 1968 | √ | | | |
| Apr. 1972 | √ | | | |
| May 1973 | | √ | | |
| Mar. 1974 | √ | √ | | |
| Oct. 1974 | √ | | | |
| Dec. 1974 | | √ | | |
| Apr. 1975 | √ | √ | | |
| May 1975 | | √ | | |
| Apr. 1977 | √ | √ | | |
| Jan. 1978 | | √ | | |
| Jan. 1979 | √ | √ | | |
| Dec. 1979 | √ | √ | | |
| Mar. 1980 | √ | | | |
| Dec. 1987 | √ | √ | √ | √ |

### (3) Data for snowmelt runoff analysis

#### (a) Snow depth data

The snow depth data measured at DSİ, EİE and DMİ snow gauging stations in the Seyhan River basin in the case of major spring floods occurred by snowmelt runoff alone or combined with storm rainfall in the past decades such as spring floods in 1975 and 1980. The location of the snow gauging station is shown in Figure 6.1.3.

#### (b) Temperature data

The daily mean air temperature values observed at DMİ meteorological stations are collected in spring months in 1975 and 1980.

#### (c) Daily discharge data

The mean daily discharge data observed at EİE stream gauging stations in spring months in 1975 and 1980 are collected.

### 6.1.2 Flood characteristics

#### (1) Precipitation

The precipitation characteristics are grasped to formulate the allocation plan of rain gauge observation network and to prepare the rainfall data as an input for rainfall-runoff model.

(a) Rain storm area

The isohyetal map of rain storm experienced in the Seyhan River basin is constructed to grasp the rain storm area in the case of major flood. The floods are selected as follows, based on the flood magnitude and data availability:

- Flood in April 1975,
- Flood in March 1980, and
- Flood in December 1987.

The isohyetal map of rain storm for each flood is shown in Figures 6.1.4 to 6.1.6. Each isohyetal map is in agreement with the topographical features and the general inflow direction of the moist air masses to the basin. The major rain storm areas are described below:

- The middle reach of Çakıt, Körkün and Eğlence Rivers,
- The downstream of Zamantı River, and
- The downstream of Göksu River.

(b) Distribution of rainfall

The critical duration of storm rainfall is preliminarily estimated on a daily basis by the estimate of basin rainfall of each subbasin in the Seyhan River basin. The results of the study are summarized below:

| Sub-basin | Critical Duration of Rainfall | | |
|---|---|---|---|
| | 1975 Flood | 1980 Flood | 1987 Flood |
| Zamantı River | 1.5 - day | 1 - day | 1 - day |
| Göksu River | 2 - day | 1 - day | 1 - day |
| Eğlence River | 1 - day | 1 - day | 1 - day |
| Körkün River | 1 - day | 1 - day | 1 - day |
| Çakıt River | 1 - day | 1 - day | 1 - day |

(2) Flood runoff

The following studies are carried out to grasp the flood runoff characteristics which shall be the basic data for flood runoff model.

(a) Schematization of Seyhan River system

Considering the river system's characteristics and the location of the flood control structures and water level gauging stations, the Seyhan River system is schematized based on the following two conditons:

- Without Çatalan Dam condition, and
- With Çatalan Dam condition.

The results of the schematization are shown in Figures 6.1.7 and 6.1.8.

(b) Subdivision of Seyhan River basin

Based on the above schematization study, the catchment area of each sub-basin is calculated and shown below:

| No. of Sub-basin | | | Catchment Area ($km^2$) | |
|---|---|---|---|---|
| | | | Without Çatalan | With Çatalan |
| 1. | Zamantı | (above 1822) | 6,990 | 6,990 |
| 2. | Zamantı | (1822 to 1806) | 1,833 | 1,833 |
| 3. | Göksu | (above 1801) | 2,298 | 2,298 |
| 4. | Göksu | (1801 to 1805) | 2,094 | 2,094 |
| 5. | Seyhan | (up to Çatalan HWL) | 858 | 858 |
| 6. | Eğlence | (above 1825) | 506 | 506 |
| 7. | Eğlence | (after 1825) | 167 | 84 |
| 8. | Seyhan | (after Çatalan HWL) | 572 | 655 |
| 9. | Körkün | (above 1820) | 1,427 | 1,427 |
| 10. | Körkün | (up to Seyhan HWL) | 120 | 120 |
| 11. | Üçürge | | 263 | 263 |
| 12. | Çatalan B. - Seyhan B. | | 435 | 435 |
| 13. | Çakıt | (above 1828) | 1,769 | 1,769 |

(c) Subdivisin of Seyhan River course

Based on the selected water level gauging station as a base point for caliblation of flood runoff model and the flood control structures such as Seyhan and

Çatalan Dams, the river length and channel slope are calculated and summarized below:

River Length

| No. of River Course | River Length (km) | |
|---|---|---|
| | Without Çatalan | With Çatalan |
| 1 | 94.0 | 94.0 |
| 2 | 60.5 | 60.5 |
| 3 | 39.6 | 35.0 |
| 4 | 22.7 | 10.0 |
| 5 | 21.0 | 21.0 |
| 6 | 49.9 | - |

River Channel Slope

| No. of River Course | River Channel Slope | |
|---|---|---|
| | Without Çatalan | With Çatalan |
| 1 | 1/109 | 1/109 |
| 2 | 1/169 | 1/169 |
| 3 | 1/220 | 1/200 |
| 4 | 1/223 | 1/130 |
| 5 | 1/263 | 1/263 |
| 6 | 1/998 | - |

## (3) Flood concentration time

### (a) General

Flood concentration time is the time required for flood runoff to travel hydraulically from one point of the watershed outlet to the other point of reference downstream.

To estimate the travel time the approaches commonly used are: (a) stream routing, (b) Kirpich formula, and (c) study of historical record.

Kirpich gives a formula for time of concentration as below:

$$tc = 0.00032 \times L^{0.77} \times S^{-0.385}$$

where, $tc$ = time of concentration (hr)
L = maximum length of travel of water (m)
S = slope, equal to H/L where H is the difference in elevation between the most remote point on the basin and the outlet (m)

The formula is basically for computing the time of concentration but it has been used for estimating the travel time between two stations by taking L and S of this reach. However, the results so obtained are generally very approximate.

(b) Travel time of past flood events

Travel time of past historical events is studied between different reaches. Travel time changes from flood to flood. The travel times of several observed floods are computed. However, this alone does not give very convincing results due to contributions from different tributaries at the station downstream.
The travel times observed at historical events are given as below:

| Station Upstream | Station Downstream | Travel time (hr) | Note |
|---|---|---|---|
| 1801<br>(Göksu) | 1818<br>(Seyhan) | 6.0 | • Jan. '79 Flood<br>• Automatic Recorder be installed at both stations. |
| 1805<br>(Göksu) | 1818 | 1.0 | • Mar. '80 Flood<br>• Peak water levels be observed by staff gauge reading. |
| | | 1.0 | • Dec. '87 Flood<br>• Staff gauge reading at 1805 |
| 1826<br>(Zamantı) | 1818 | 1.0 | • Dec. '87 Flood<br>• Staff gauge reading at 1826 |
| 1818 | Seyhan Br. | 4.0<br>10.0 | • Apr. '75 Flood<br>• Jan. '79 Flood |

The observed hourly and daily flood runoffs and its relevant estimated daily mean rainfall in the sub-basins are shown in Data Book A.

## 6.2 Flood Runoff Analysis

### 6.2.1 General

The several hydrologic models to be needed for flood runoff analysis are shown below. Snowmelt runoff model is separately explained in 6.3.

(1) Mean basin rainfall model
(2) Sub-basin rainfall runoff model

(3) River routing model

(4) Rainfall-runoff event simulation model

### 6.2.2 Mean basin rainfall model

(1) Estimate of daily mean rainfall in subbasins

The Thiessen method was applied for calculating areal rainfall averages in sub-basins in the Seyhan River basin even though this procedure is not suitable for mountainous areas because of orographic influences. The main reason for its use for the Project is that there are very few available daily rainfall data in and around the Seyhan River basin.

For the purpose of estimating the basin mean rainfall, the representative rainfall gauging station is selected among the existing rainfall gauging stations by the statistical method, namely, the multiple linear regression analysis on the observed storm rainfall records.

(2) Estimate of hourly mean rainfall in subbasins

The number of rainfall gauging stations with a pluviograph is reported to be fourteen (14) in total in and around the Seyhan River basin. The available hourly rainfall records observed at the occurrence of major floods are collected only from ten (10) stations. The available periods of hourly rainfall records are very limited to be only from 1975 to 1987.

The hourly patterns of daily rainfall data for the representative stations that have no hourly records were estimated by the following procedure.

(a) The number of rainfall gauging stations with hourly data for the past major storms, such as 1975, 1980 and 1987 floods is nine (9) in total.

(b) The accumulated hourly rainfall curve of each storm for nine stations is drawn to know the time distribution of storm rainfall.

(c) The accumulated daily rainfall curve of each storm for the representative rainfall stations is also drawn. The number of the representative rainfall stations is sixteen (16) in total.

(d) The hourly patterns of the representative rainfall stations are estimated by careful comparisons between its daily pattern and several available hourly patterns of above-mentioned stations taken into consideration the following points.

- To select the most critical pattern
- To check results of daily simple regression analysis
- To consider the regional and areal rainfall distribution

Results of the estimate of hourly rainfall patterns of the representative rainfall stations are shown in Table 6.2.1.

(3) Mean basin rainfall model

The model to calculate the mean hourly basin rainfall as an input for the rainfall-runoff model is constructed. The multiple linear regression equation obtained for the estimate of mean daily basin rainfall is applied for the estimate of mean hourly basin rainfall. The multiple linear regression equation is described below.

$$Y = a_1 X_1 + a_2 X_2 + \ldots\ldots\ldots\ldots + a_n X_n$$

where,
$Y$ = Mean hourly basin rainfall
$n$ = Number of selected representative rainfall station
$a_i$ = Multiple regression coefficients ($i = 1$ to $n$)

The constant b of the equation is omitted since it can be theoretically negligible for rainfall estimates.

The results of the computations are shown in Table 6.2.2.

### 6.2.3 Subbasin rainfall-runoff model

(1) General

Unit hydrographs have been commonly used for design flood calculation as a simple rainfall-runoff model. It hypothesizes that rainfall-runoff process is linear transformation. However, actual runoff phenomenon is non-linear process. Unit hydrographs method has difficulties to be used for the practical model of flood forecasting and warning system.

Non-linear rainfall-runoff model, so called, Storage Function Model, was introduced by Dr. Kimura in 1961, which has been used extensively as a practical model both in Japan and overseas for more than three decades.

The main characteristics of Storage Function Model are summarized as follows.

(a) The basin storage process is additionally introduced between rainfall-runoff process.

(b) The basin storage is expressed as a catalytic function. The relationship between rainfall and runoff is expressed as an equation.

(c) By this equation, water budget of storage volume can be calculated. Finally, runoff hydrographs can be obtained.

## (2) Description of Storage Function Basin Model

As is briefly explained in (1), basin storage $S_l$ is exponentially expressed by basin runoff $Q_l$ as follows.

$$S_l = K\, Q_l^{p}$$

where, $S_l$ : Basin storage ($m^3$)

$Q_l$ : Basin runoff ($m^3/sec$)

K, p : Constants for basin

Besides the above equation of motion as storage function, the equation of continuity is introduced as follows.

$$dS_l/dt = (1/3.6)\, f\, r_{ave}\, A - Q_l$$

where, f : Runoff ratio

$r_{ave}$ : Basin mean rainfall (mm/hr)

A : Catchment area ($km^2$)

$Q_l$ : Direct runoff from basin with time lag ($m^3/sec$)

$Q_l(t) = Q_l(t + T_l)$

$T_l$ : Lag time (hr)

$S_l$ : Basin storage ($m^3/sec \cdot hr$)

Storage function between basin storage S and basin runoff Q, namely, constants K and p can be determined by the past rainfall and runoff records. If the relationship between S and Q is determined, Q can be calculated by inputting basin mean rainfall $r_{ave}$ into the equation of continuity and by using S as a catalytic function.

### 6.2.4 River routing model

#### (1) General

Flood forecasting projects generally utilize some form of routing technique. Routing is used to predict the temporal and spatial variations of a flood wave as it traverses a river reach or reservoir. Routing techniques can be classified into two categories, namely, hydrologic routing and hydraulic routing. Hydrologic routing employs the equation of continuity with either an analytic or an assumed relationship between storage and discharge within the system. Hydraulic routing, on the other hand, uses both the equation of continuity and the equation of motion, customarily the momentum equation. This particular form utilizes the partial differential equations for unsteady flow in open channels. It more adequately describes the dynamics of flow than does the hydrologic routing technique.

Applications of hydrologic routing techniques to problems of flood prediction are numerous. Most flood forecasting and warning systems instituted by Ministry of Construction in Japan or other organizations overseas incorporate some form of this technique to predict flood stages in advance of a severe storm. Additionally, the synthesis of runoff hydrographs from gauged and ungauged watersheds is possible by the use of basic assumption inherent in this approach.

Non-linear hydrologic river routing model was also introduced by Dr. Kimura with an assumption of the river channel storage. The main characteristics of Storage Function River Model are basically the same with Storage Function Basin Model.

#### (2) Description of storage function river model

River channel storage $S_l$ is also exponentially expressed by river channel runoff $Q_l$ as follows.

$$S_l = K\,Q_l^{p}$$

where, $S_l$ : River channel storage (m$^3$)
$Q_l$ : River channel runoff (m$^3$/sec)
K, p : Constants for river channel

Besides the above equation of motion as storage function, the equation of continuity is introduced as follows.

$$dS_l/dt = f\, I - Q_l$$

where, $f$ : Inflow coefficient
$I$ : Inflow into the river channel ($m^3$/sec)
$Q_l$ : Outflow from river channel with time lag ($m^3$/sec)
$Q_l(t) = Q_l(t + T_l)$
$T_l$ : Lag time (hr)
$S_l$ : River channel storage ($m^3$/sec•hr)

Storage function between river channel storage S and river channel runoff Q, namely, constants K and p can be determined by the past rainfall and runoff records. If the relationship between S and Q is determined, Q can be calculated by inputting inflow I into the equation of continuity and by using S as a catalytic function.

### 6.2.5 Rainfall-runoff event simulation model

(1) General

Sequential simulation consists of step-by-step computation through the entire time period. Simulation of monthly or yearly streamflow or rainfall events is satisfactorily accomplished through this type of operation. However, for many hydrologic events that occur in shorter time intervals, the sheer amount of computation prohibits the sequential generation of these data for large-scale simulations. For example, the calculation of simulated rainfall depths hour by hour required 8760 hourly items for each year of record. To achieve efficiency in computation, including only short events significantly reduce the length of simulation time. Such a technique is called event simulation.

Event simulation model structures closely imitate the rainfall processes. Lumped parameter approaches, such as unit hydrograph method and storage function method, are generally incorporated even though a greater opportunity to use distributed parameter approaches is present. Preparation for implementing most event simulation models begins with a watershed subdivision into homogeneous subbasins. Computations, using processes, proceed from the most remote upstream subbasin in a downstream direction.

Simulation of one or more storm events over the basin is accomplished by conventional hand techniques that have been programmed for a digital computer. For example, the computer accepts parameters for upstream subbasin A; and computes the hydrograph resulting from the storm event; repeats the hydrograph computation for other upstream subbasin B; combines the two computed hydrographs into a single hydrograph; routed the hydrograph by conventional techniques through reach C to the upstream end of reservoir R, where it is combined with the computed hydrograph for residual subbasin C; then at the reservoir R the combined hydrograph is routed through reservoir R.

Hydrograph computations for subbasins are determined using storage function method. The rainfall hyetograph is input uniformly over the subbasin area, and rainfall losses are abstracted, leaving an excess rainfall hyetograph that is convoluted with the storage function to produce a surface runoff hydrograph for the subbasin. Subsurface flows and waters derived from groundwater storage are transformed into a subsurface runoff hydrograph that, when combined with the surface runoff hydrograph, form the total streamflow hydrograph at the subbasin outlet. This hydrograph can then be routed downstream, combined with another contributing hydrograph, or simply output if this subbasin is the only, or the final, subbasin being considered. River routing can be determined using storage function method.

(2) Storage function basin and river model for the entire Seyhan River basin

The rainfall-runoff event simulation model by storage function method is constructed for the Seyhan River basin as a main flood forecasting computer program. The parameter setting of the models is undertaken based on the comparison of observed and simulated values at the base points for the calibration of the models.

(3) Use of interactive computer software for simulation

For the purpose of creating an easy-to-use model, the interactive computer software for simulation, namely, Extend, version 2.0 is used.

## 6.3 Snowmelt Runoff Analysis

### 6.3.1 Area elevation relationship of subbasins

How the area within a drainage basin is distributed between contours is of interest for comparing drainage basins and gaining insight into the snowpack and snowmelt characteristics of the basin. For such studies, an area distribution curve is used. The curve can be obtained by planimetering the areas between adjacent contours. The area elevation relationships of subbasins are shown in Figures 6.3.1 to 6.3.3. Figure 6.3.4 shows the topographical map of the Seyhan River basin with the contour lines, such as, 1000, 1500 and, 2000 El.m.

### 6.3.2 Determination of snow line elevation

(1) Estimate of snowmelt starting elevation

The several estimates of the snowmelt starting elevation at the beginning of snowmelt season are made by the following previous studies in and around the Seyhan River basin. Recommended value by U.S. Army Corps of Engineers is also shown as a reference one.

Estimates of Snowmelt Starting Elevation

| Name of Study | Snowmelt Starting Elevation |
|---|---|
| Lower Seyhan Basin Master Plan ( 1980 ) | 1,500 El.m |
| Sir Dam and Hydroelectric Project<br>Design Flood Studies ( Revised, 1985 ) | 1,250 or 1,500 El.m |
| Ermenek Dam and Hydroelectric Project<br>Hydrological Study, EIE | 1,250 El.m |
| U.S. Army Corps of Engineers<br>Snow Hydrology, ( 1956 ) | 1,500 El.m |

As seen in the above table, either 1,250 or 1,500 El.m is adopted as a general snowmelt starting elevation for design flood studies.

### 6.3.3 Average temperature of snow-covered area above snow line elevation

(1) General

Basin cannot be assumed to be a homogeneous system because of the fact that in that case when only snowmelt flows, the contributing area is not the entire drainage area, but only the portion of area with a snow cover. Therefore, it is needed to establish the formula for the estimate of average temperature of snow melting zone of the subbasins.

(2) Relationship between temperature and elevation

(a) Freezing level

Highest elevation of melting zone at which freezing temperature of 0 °C is given can be estimated by the following formula.

$$Ef = Ei + (Ti - 0)/t \times 100$$

where,

$Ef$ : Freezing level with temperature of 0 °C ( El.m )
$Ei$ : Elevation at temperature index station ( El.m )
$Ti$ : Temperature at temperature index station ( °C )
$t$ : Temperature decrease per 100 m increase in elevation ( °C )

The several estimates of the temperature decrease per 100 m increase in elevation, t are made by the following previous studies in and around the Seyhan River basin. Recommended value by U.S. Army Corps of Engineers is also shown as a reference one.

Estimates of t

| Name of Study | Value of t |
|---|---|
| Lower Seyhan Basin Master Plan ( 1980 ) | 0.7 or 1.0 °C per 100 m |
| Sir Dam and Hydroelectric Project Design Flood Studies ( Revised, 1985 ) | 0.7 °C per 100 m |
| Ermenek Dam and Hydroelectric Project Hydrological Study, EIE | 0.7 °C per 100 m |
| U.S. Army Corps of Engineers Snow Hydrology, ( 1956 ) | 0.5 °C per 100 m |

As seen in the above table, 0.7 °C per 100 m is commonly adopted as a general value of t for design flood studies.

The temperature index station in each subbasin is considered to be the selected representative temperature gauging station.

(b) Temperature at snow line

The temperature at snow line is given by

$$Ts = Ti + t/100 \times (Es - Ei)$$

where,

$Ts$ : Temperature at snow line ( El.m )
$Es$ : Elevation at snow line ( El.m )

(c) Average temperature over melting zone

The average temperature over melting zone is given by

$$T_{ave} = ( T_s + 0 )/2$$

where,

Tave : Average temperature over melting zone (°C)

### 6.3.4 Critical area of snowmelting

(1) General

The area between the snow line and the freezing level is regarded as a critical area of snowmelting. Furthermore, it is essential to obtain the updated and reliable estimate of snowmelting zone in each subbasin.

(2) Computation method of critical area of snowmelting in the subbasins

The critical area of snowmelting in the subbasins can be computed by the use of the area-elevation distribution curve of a subbasin which is shown in Figures 6.3.1 to 6.3.3. The critical snowmelting area is given by

$$Am = As - Af$$

where,

Am : Area between snow line and freezing level in a subbasin ( $km^2$ )

As : Area above snow line in a subbasin ( $km^2$ )

Af : Area above freezing level in a subbasin ( $km^2$ )

### 6.3.5 Determination of basin snowmelt rate and snowmelt runoff in the Seyhan River basin

(1) General

The rate of snowmelt is defined as the rate of conversion of ice into water within the snowpack rather than the rate of drainage. The rate of snowmelt tends to vary greatly, causing rapid changes in the introduction of the liquid water into a snowpack. This fluctuation is dampened, however, in passing through the snow so that the rate of drainage from the snowpack is often relatively steady.

(2) Previous studies on snowmelt rate

Atmospheric temperature is one of the most useful parameters. This one parameter not only reflects the extent of radiation and vapour pressure of the air, but also gives an idea of air motion indirectly. Its use is made in computations of snowmelt runoff through an index known as degree-day. A degree-day, in its broadest sense, is a unit expressing the amount of heat in terms of the persistence of a temperature for a 24-hour period 1 of °C from a reference temperature. In snowmelt computations the reference temperature is usually taken as 0 °C. Thus, the degree-day for snowmelt studies is often computed by subtracting the average of the daily maximum and daily minimum temperatures from 0 °C.

The standard practice is to correlate degree-days with the basin runoff. However, in some cases, other factors are also introduced into the above relationship to take care of the forest cover effects and other influences.

The point melt rate in centimeters per degree-day above 0 °C varies between 0.038 and 0.5 cm/degree-day. For a spring snowmelt period, an average of 0.13 cm/degree-day may be used, but with discretion. Such point melt values for centimeter of melt per day must, however, be distinguished from the basin-index melt values.

Linsley and others state that the basin melt rate in centimeters per degree-day above 0 °C varies between 0.15 and 0.38 cm/degree-day under conditions of continuous snow cover and at melting temperatures.

The several estimates of the basin snowmelt rate at the beginning of snowmelt season were made by the following previous studies in and around the Seyhan River basin.

Estimates of Basin Snowmelt Rate, Rs

| Name of Study | Basin Snowmelt Rate, Rs |
|---|---|
| Lower Seyhan Basin Master Plan ( 1980 ) | 0.1 or 0.15 cm/°C-day<br>( as the maximum basin snowmelt rate ) |
| Sir Dam and Hydroelectric Project<br>Design Flood Studies ( Revised, 1985 ) | 0.128 cm/°C-day<br>( as the maximum basin snowmelt rate ) |
| Ermenek Dam and Hydroelectric Project<br>Hydrological Study, EIE | 0.388 cm/°C-day<br>( as the maximum basin snowmelt rate ) |

As seen in the above table, the values between 0.1 and 0.388 are adopted as a general basin snowmelt rate for design flood studies.

(3) Basin snowmelt runoff in the Seyhan River subbasins

The snowmelt runoff in each subbasin can be computed by the above-explained temperature index utilized as a prediction equation. The computation procedure is described as follows.

First, the average degree-days above 0 °C over the critical melting zone is given by

$$Td = Tave - 0$$

where,

Td : Average degree-days above 0 °C

Then, the total snowmelt therefore is given by

$$Qs = Td \times Rs \times Am$$

where,

Qs : Total melt in subbasin ( cm•km$^2$ )
Rs : Degree-day factor ( cm/degree-day )

### 6.3.6 Simple snowmelt runoff model

(1) General

So far in the previous chapters, the several factors, such as, snow line, relationship between temperature and elevation, snowmelting zone and snowmelt rate in a basin are discussed regarding the snowmelt runoff process and the prediction equations to estimate the snowmelt due to the temperature increase in a basin are presented.

Various approaches have been applied to determine the runoff from snowmelt ranging from the simple technique of regression analysis ( ignoring the physics of the snowmelt process ) to more sophisticated techniques based on degree-day or various indexes. The techniques used are:

- (a) Regression analysis
- (b) Physical equations for basin snowmelt
- (c) Analysis of hydrograph recessions
- (d) Hydrograph syntheses

However, reflected upon the availability of data required for the snowmelt runoff estimate, the simple snowmelt runoff model by regression analysis is adopted for the Seyhan River flood forecasting system.

### (2) Adopted snowmelt runoff model

#### (a) General

To perform regression analysis for the computation of snowmelt runoff, certain independent variables called indexes need to be selected. The advantage of indexes is that they are more easily measured than the dependent snowmelt runoff. The adequacy of an index is based on:

- Ability of the index to adequately describe the physical process it represents
- Degree to which point observation is typical of actual conditions
- Random variability of the observation
- Nature of variability between point measurement and basin means

Indexes could be equations or simple coefficients, and variables or constants. The common indexes are:

- Thermal budget indexes
- Temperature indexes

However, in most cases, the data required for the thermal budget indexes are generally not available and considered not to be suitable for the Study. Therefore, the temperature indexes are selected to estimate the snowmelt runoff because of the easiness of data availability.

#### (b) Snowmelt runoff model by temperature indexes

The flow chart of snowmelt runoff determination by the temperature indexes is described in Figure 6.3.5.

The several data required for the snowmelt runoff model are categorized below:

- Data eventually given by the location

Ei : Elevation at the index temperature station ( El.m )

- Data estimated hypothetically

t : Temperature decrease per 100 m increase in elevation ( °C )
Es : Elevation at snow line ( El.m )
Rs : Degree-day factor ( cm/degree-day )

The hypothetical values for t, Es and Rs are determined for the Study below, taking consideration the previous studies:

t = 0.7 ( °C )
Es = 1,250 ( El.m )
Rs = 0.1 (cm/degree-day )

- Data measured at the index temperature station

Ti : Temperature at temperature index station ( °C )

- Data computed by the snowmelt runoff model

Ef : Freezing level with temperature of 0 °C ( El.m )
As : Area above snow line in a subbasin ( $km^2$ )
Af : Area above freezing level in a subbasin ( $km^2$ )
Ts : Temperature at snow line ( El.m )
Tave : Average temperature over melting zone ( °C )
Am : Area between snow line and freezing level ($km^2$)
Td : Average degree-days above 0 °C
Qs : Total melt in subbasin ( cm•$km^2$ )

(c) Estimate of snowmelt runoff in 1980 flood

Based on the flow chart and data hypothetically estimated in a subbasin and measured at the meteorological gauging stations, the estimate of snowmelt runoff in 1980 flood is made as a typical example of the snowmelt runoff in the Seyhan River basin. The results of the estimate are summarized below.

Estimated Snowmelt Runoff in 1980

Unit : (m$^3$/s)

| Date | Basin No.1 | Basin No.2 | Basin No.3 | Basin No.4 | Basin No.5 | Basin No.6 | Basin No.9 | Basin No.11 | Basin No.13 | Total Basin |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/24 | 236 | 37 | 88 | 52 | 8 | 7 | 33 | 2 | 35 | 498 |
| 3/25 | 347 | 56 | 115 | 67 | 12 | 12 | 52 | 3 | 54 | 718 |
| 3/26 | 369 | 60 | 121 | 70 | 13 | 12 | 55 | 3 | 57 | 760 |
| 3/27 | 364 | 60 | 62 | 37 | 12 | 11 | 49 | 3 | 51 | 649 |
| 3/28 | 224 | 35 | 20 | 14 | 7 | 6 | 27 | 2 | 29 | 364 |
| 3/29 | 129 | 21 | 36 | 23 | 5 | 4 | 18 | 2 | 20 | 258 |
| 3/30 | 236 | 37 | 53 | 32 | 7 | 7 | 30 | 2 | 32 | 436 |
| 3/31 | 249 | 39 | 69 | 41 | 9 | 9 | 38 | 3 | 40 | 497 |

(d) Calibration of snowmelt runoff and setting of parameters of the model

The calibration of snowmelt runoff and setting of parameters of the model are carried out by the combination of rainfall flood runoff and explained in 6.4.2.

## 6.4 Simulation of Flood Flow and Forecasting

### 6.4.1 Calibration of runoff calculation models

(1) General

The calibration of flood runoff models in the Seyhan River basin is carried out by the following procedures.

(a) Selection of typical floods

The typical floods are selected for the evaluation of the models for non-snowmelt season and snowmelt season as follows.

- Flood in December 1987 for non-snowmelt season
- Flood in March 1980 for snowmelt season

### (b) Parameter settings for storage function basin and river models

The parameter settings for storage function basin and river models are made based on the following procedures.

- Parameter settings for basin model
  The hydrological and hydraulic parameters of the basin model for the gauged subbasins can firstly be determined by the method explained in Chapter 5. The parameters of the basin model for the ungauged subbasins are roughly estimated by the basin characteristics.

- Parameter settings for river model
  The hydraulic parameters of the river model for the river channels can be determined by the river channel characteristics.

### (c) Calibration methods

The calibration of the event simulation model presented in 6.2 is carried out by the following basic consideration.

- The calibration of the event simulation combined with basin and river models in the entire Seyhan River basin is mainly carried out at the gauged base points.

- The calibration of the event simulation is mainly carried out at the Seyhan Dam taken into consideration the consistency of the parameters in terms of the basin and river characteristics.

## (2) Parameter settings for storage function basin model

### (a) Collection of river cross section

The reliable river cross section data are collected at the following stream gauging stations.

- 1801 in upper Göksu River basin
- 1805 in lower Göksu River basin
- 1818 in middle Seyhan River basin
- 1825 in Eğlence River basin

### (b) Estimate of average river cross section at river channels

The estimate of average river cross section at the proposed river channels are preliminarily made utilizing the above available cross section data.

Estimate of Average River Cross Section at River Channels

| No. of River Channel | Applied River Cross Section |
|---|---|
| 1 | Same cross section as No. 2 |
| 2 | Ave. cross section of 1801 and 1805 |
| 3 | Ave. cross section of 1805 and 1818 |
| 4 | Cross section of 1825 |
| 5 | Same cross section as No. 4 |
| 6 | Cross section of 1818 |

### (c) Determination of K and p

Based on the estimate of average river cross section at river channels, river channel storage, s and uniform flow, Q can be calculated as equations by water depth, H. Then, hydraulic parameters, K and p can be computed by the least square method.

Several conditions for the calculation of uniform flow are as follows.

- Manning's roughness coefficient $n = 0.040$ for meandering river
- $i$ = average river gradient
- $L$ = river length ( km )
- Lag time $T_l = 7.36 / 10000\, L\, i^{-0.5}$

The values of K, p and Tl are summarized in Table 6.4.1.

## (3) Parameter settings for storage function basin model

### (a) Calibration by gauged base points ( Case 1 )

The calibration method by the gauged base points in the Seyhan River is applied for the parameter settings.

The gauged base points utilized for the calibration are summarized below.

| Station No. | 1980 Flood | 1987 Flood |
|---|---|---|
| 1801 | √ | √ |
| 1805 | √ | √ |
| 1822 | √ | √ |
| 1806 |  | √ |
| 1818 | √ | √ |
| 1820 | √ | √ |
| 1825 |  | √ |
| Seyhan Dam | √ | √ |

(b) Calibration by integrated storage function method ( Case 2 )

The calibration by the integrated storage function method in the entire Seyhan River basin is applied for the parameter settings.

The parameter settings are made mainly by the comparison of DSİ's previous estimate of inflow into the Seyhan Dam and calculated inflow by the storage function model. Parameters are integrated by the subbasin's characters and locations.

(c) Comparison of calibration methods

Results of the calibration by two methods are shown in Table 6.4.1. and Figures 6.4.1 to 6.4.2.

The comparison of calibration results by two methods are made by several indexes and summarized below.

| Index | '87 Flood Observed | '87 Flood Case 1 Simulated | '87 Flood Case 2 Simulated | '80 Flood Observed | '80 Flood Case 1 Simulated | '80 Flood Case 2 Simulated |
|---|---|---|---|---|---|---|
| Deviation of Peak Time ( hr ) |  | + 1 hr | + 4.7 hr |  | + 3 hr | + 2 hr |
| Peak Inflow ( $m^3/s$ ) | 2,442 | 2,538<br>(+ 3.9 %) | 2,587<br>(+ 5.9 %) | 6,040 | 5,682<br>(- 6.6 %) | 5,679<br>(- 6.4 %) |
| Inflow Volume Ratio |  | 1.23 | 1.27 |  | 1.18 | 1.20 |
| R |  | 0.92 | 0.92 |  | 0.95 | 0.94 |

### 6.4.2 Determination of runoff models

(1) General

The proposed flood runoff model in the Seyhan River basin is selected by the evaluation of the results of the comparative study on the calibration methods. The selection is made for non-snowmelt season and snowmelt season.

(2) Runoff model for non-snowmelt season

(a) Evaluation of models by different calibration methods

The several points are observed by comparative study on the calibration methods.

| Point of Evaluation | Calibration by Gauged Base Points | Calibration by Integrated Storage Function Method |
|---|---|---|
| Estimate of first degree runoff ratio, f1 in subbasins | Having a tendency to underevaluate f1 in subbasins with less rainfall | Having a capability to set safer parameter of f1 in subbasins with less rainfall |
| Degree of influence by unreliable flood water level records | Having a tendency to set inconsistent parameters | Having a capability to set consistent parameters |
| Flood water balance at gauged base points | Having a tendency to set inconsistent parameters | Having a capability to set consistent parameters |

Based on the above evaluation, the calibration method by the integrated storage function is considered to be much more reliable and safer than the calibration method by the gauged base points.

(3) Runoff model for snowmelt season

The proposed flood runoff model for snowmelt season is composed of the following models.

(a) Storage function basin and river model for snowmelt season
(b) Snowmelt runoff model

Two models (a) and (b) can be combined by the event simulation of Extend. Results of computation for flood in 1980 are shown in Figure 6.4.2.

# 7. OPTIMUM COMPREHENSIVE RIVER CONTROL

## 7.1 *Flood Inundation and Damage*

### 7.1.1. General

The Seyhan River levee had been constructed from 1949 to 1953. The downstream river stretch of Adana City is remained mostly as same after the levee construction. The river section consists of low water channel (natural river section) and high water channel formed by the levee. The general plan of the river is shown in Figure 7.1.1. The river channel width varies as follows.

| (Unit : m) | Min. | Max. | Avg. |
|---|---|---|---|
| Low water channel | 68 | 238 | 119 |
| High water channel | 1,097 | 2,426 | 1,841 |

The river stretch in Adana city was improved at some length. Namely, concrete wall was constructed between the Stone Bridge and the downstream regulatory structure. The general plan in Adana City is shown in Figure 7.1.2. The river stretch in Adana City is scheduled to improve moreover to utilize the present high water channel as a shopping or recreation zone. The typical river cross section is shown in Figure 7.1.3. The typical section-1 was applied for the stretch between Girne Bridge and the downstream regulatory structure, and for the left bank between the Girne Bridge and the Section 7. The typical section-2 will be applied for the remaining stretch up to the upstream regulatory structure as shown in Figure 7.1.2.

### 7.1.2. Water surface routing

River cross sections at the downstream stretch are shown in Supporting Report C. The coordinates of the sections are listed in Supporting Report C. As seen in the cross section figures, the width of low water channel and high water channel, as well as river slope gradient, vary at every section. Non-uniform flow analysis method is applied to routine the river water surface to the above irregular river cross section. Assuming the section-I and section-II at the downstream and the upstream, the following equation can be applied.

$$Z_I + H_I + ßQ/(2gA_I^2) = Z_{II} + H_{II} + ßQ/(2gA_{II}^2) - hf$$

Where is,

Z : River bed elevation at Section-I and -II
H : Water depth at Section-I and -II
Q : Discharge
g : Gravity acceleration

$A$ : Sectional area under water
$\beta$ : Energy adjustment coefficient
$h_f$ : Friction head loss between Section-I and -II

Friction head loss, $h_f$, can be calculated by the following formula which is introduced by Manning's formula.

$$h_f = (n^2/R_I^{4/3}/A_I^2 + n^2/R_{II}^{4/3}/A_{II}^2) \times Q^2 \times L/2$$

Where is,

$R$ : Wetted perimeter
$n$ : Manning's roughness coefficient
$L$ : Length between Section-I and -II

In accordance with DSİ's experience, low water channel capacity is estimated at about 500 $m^3/s$. That of high water channel is experienced at 1,200 $m^3/s$ with 1.0 m free-board and at 1,800 $m^3/s$ without free-board. The discharges of 200, 300, 400 and 500 $m^3/s$ are examined for the low water channel. Those of 1,200, 1,600 and 2,000 $m^3/s$ are examined for the high water channel. Manning's roughness coefficient is assumed at 0.03 for the low water channel in compliance with Japanese practice. Because some farming vegetables or trees are planted at the high water channel, that coefficient is assumed at 0.04 for the high water channel.

The section No., Sec-26A, is the most downstream section among the available cross sections. The section is located at about 11 km far from the river mouse. Uniform flow depth at the section is shown in Figure 7.1.4. The initial water surface elevation is assumed upon the figure as follows.

| Discharge ($m^3/s$) | 200 | 300 | 400 | 500 | 1,200 | 1,600 | 2,000 |
|---|---|---|---|---|---|---|---|
| Initial water surface El. (m) | 0.75 | 1.92 | 2.11 | 2.25 | 2.65 | 2.96 | 3.27 |

The hydraulic energy at this section is calculated and shown in Figure 7.1.5. The water surface elevation with minimum energy corresponds to critical depth, which classifies super-critical flow or sub-critical flow. The critical depth upto 500 $m^3/s$ discharge does not appear for the low water channel, which indicates that water flow is at sub-critical flow status always. While, critical depth at the high water channel appears at the water surface elevation of 2.1 m, 2.2 m and 2.25 m to the discharges of 1,200 $m^3/s$, 1,600 $m^3/s$ and 2,000 $m^3/s$. Depending on sea water level, river flow status changes to super-critical flow. However, the section is so far as about 11 km away from the sea, hydraulic jump may take place at just near the sea. Trial calculation proves that variation of initial water surface elevation effects upstream water surface within a few km only.

### 7.1.3. River capacity

The calculation results of the above analysis are listed in Supporting Report C, and water surface is shown in Supporting Report C. The calculation results are summarized in Supporting Report C. The calculated water surface profile is shown in Figures 7.1.6 and 7.1.7.

As seen in Figure 7.1.6, the clearance between the river water surface and low water channel shoulder is bigger where the low water channel width is wider and the channel depth is deeper. The river flow discharge less than 300 $m^3/s$ does not inundate the high water channel. The discharge of 500 $m^3/s$ inundates the high water channel until 20 km from Sec-26A. The inundated area is shown in Figure 7.1.1. The river flow discharge above 700 $m^3/s$ inundates the high water channel at the full stretch.

The Japanese criteria stipulates the levee free board as follows.

| River flow discharge | | Free board (m) |
|---|---|---|
| Less than 200 | $m^3/s$ | 0.6 |
| 200 to 500 | $m^3/s$ | 0.8 |
| 500 to 2,000 | $m^3/s$ | 1.0 |
| 2,000 to 5,000 | $m^3/s$ | 1.2 |
| 5,000 to 10,000 | $m^3/s$ | 1.5 |
| More than 10,000 | $m^3/s$ | 2.0 |

The free board to the calculated river water surface is listed in Supporting Report C and summarized as follows.

(Unit : m)

| Discharge | Min. | Max. | Avg. |
|---|---|---|---|
| 1,200 $m^3/s$ | 0.59 | 1.31 | 0.98 |
| 2,000 $m^3/s$ | 0.07 | 0.88 | 0.48 |

The bankfull discharge is estimated at 2,000 $m^3/s$ or river flow may over-flow at some stretch. If the above Japanese criteria is applied, the designed discharge is attained at 1,200 $m^3/s$, though free board is less than 1.0 m at some stretch.

The Seyhan River in Adana city is designed with constant width and slope gradient. The river bed slope gradient is designed at 0.07 % (1/1,429). Uniform flow analysis is applied to estimate the water depth for the river in Adana city. Flood flow capacity at the stretch in Adana city is bigger than that at the downstream stretch. The uniform flow depth and free board are summarized as follows.

|  | Discharge ($m^3/s$) | Water depth (m) | Free board (m) |
|---|---|---|---|
| Typical Section-1 | 1,200 | 3.86 | 3.17 |
|  | 2,000 | 5.27 | 1.76 |
| Typical Section-2 | 1,200 | 4.08 | 2.14 (Min.) |
|  | 2,000 | 5.53 | 0.69 (Min.) |

The present capacity of high water channel of the downstream river is carefully checked by the past flood records and the operation records of flood routing activity at the Seyhan Dam.

## 7.2 Flood Flow Operation

### 7.2.1 General

An effective dam-flood-control rule will mitigate flood damage. As well, an effective reservoir operation rule can generate optimum hydro power energy. Dam flood control rule and reservoir operation rule are studied hereunder.

DSİ established flood hydrograph at the place of the Çatalan Dam and Seyhan Dam. The flood hydrograph are listed in Tables 7.2.1 and 7.2.2. Flood flow dam operation is studied on a basis of the hydrograph. The peak discharge is summarized below.

| Probable | Çatalan Dam |  | Seyhan Dam*[1] |  |
|---|---|---|---|---|
| Flood | Peak ($m^3/s$) | Volume (x $10^6$) | Peak ($m^3/s$) | Volume (x $10^6$) |
| 2-year | 1,175 | 538.1 | 280 | 14.1 |
| 5-year | 1,740 | 656.4 | 435 | 53.4 |
| 10-year | 2,130 | 762.5 | 550 | 68.7 |
| 25-year | 2,650 | 870.3 | 705 | 86.0 |
| 50-year | 3,045 | 963.7 | 825 | 100.8 |
| 100-year | 3,455 | 1,063.3 | 955 | 114.0 |
| 200-year | 3,850 | 1,191.5 | 1,075 | 138.0 |
| 500-year | 4,375 | 1,286.4 | 1,235 | 154.9 |
| Catastrophy | 9,376 | 2,310.4 | 6,731 | 617.9 |

Note *[1] : Çakıt River and the Körkün River

DSİ made dam flood control plan against 500-year probable flood.

This report makes flood routing study to the respective probable floods. Dam safety is checked by applying the catastrophy flood estimated by DSİ.

Spill-out discharge through the tenter gate is calculated by applying the following equation.

$$Q = (2g)^{0.5} \times 2/3 \times \mu \times B \times (H_1^{3/2} - H_2^{3/2})$$

Where is,

| | |
|---|---|
| $g$ | Gravity acceleration |
| $\mu$ | Discharge coefficient introduced by U.S.B.R |
| $B$ | Spill-out width |
| $H_1$ | Water head from water surface to spillway crest |
| $H_2$ | Water head from water surface to the bottom of the gate |

The reservoir flood routine is carried out to examine reservoir water level while changing spilling-out discharge. The following formula is applied for the analysis.

$$(I_1 + I_2) \times \Delta t/2 = (S_2 - S_1) + (O_1 + O_2) \times \Delta t/2$$

Where is,

| | |
|---|---|
| Suffix 1 | Each value at the time of $t_1$ |
| Suffix 2 | Each value at the time of $t_2 = t_1 + \Delta t$ |
| $\Delta t$ | Duration time |
| $I$ | Inflow discharge into reservoir |
| $S$ | Storage volume in reservoir |
| $O$ | Outflow discharge from reservoir |

Spill-out discharge is to be minimized so as to decrease flood damages at the downstream, or flood water is to be stored in the reservoirs as much as possible. There are two methods on dam gate operation rule to regulate flood flow. One is called as "constant outflow operation" and the other is as "constant ratio operation". Operation rule is explained below.

"Constant outflow operation"

Flood water shall be spilled out, until flood inflow reaches to a target spill-out discharge ($Q_t$), so that a reservoir water level shall be maintained at the flood season low water level. In other words, no flood water is stored in a reservoir during this operation because flood inflow into a reservoir shall be spilled out at the same time. Flood water shall be spilled out at the rate of $Q_t$ after flood inflow exceeds the discharge of $Q_t$. Flood water is stored in a reservoir during this operation. This operation is applied for Çatalan Dam flood routing by DSİ.

"Constant ratio operation"

Variables are defined as follows.

$Q_i$ : Inflow discharge

$Q_t$ : Target spill-out discharge

$Q_P$ : Inflow peak discharge

$Q_0$ : Initial spill-out

$T_p$ : Time at inflow peak

Spill-out discharge shall be increased up to $T_p$ with the following equation.

$Q = (Q_i - Q_0) \times (Q_t - Q_0)/(Q_p - Q_0) + Q_0$

Spill-out discharge shall be maintained constantly at $Q_t$ after $T_p$. This operation can regulate even small flood flow.

Japanese criteria to design dam height is listed below.

$H = H_n + h_w + h_e + 1.5$ or $H_n + 2$ in case of $(h_w + h_e) < 1.5$

$H = H_s + h_w + h_e/2 + 1.5$ or $H_s + 2$ in case of $(h_w + h_e)/2 < 1.5$

$H = H_d + h_w + 1.5$ or $H_d + 2$ in case of $(h_w + h_e)/2 < 1.5$

Where, $H_n$ : Normal high water level $H_s$ : Surcharge water level

$H_d$ : Design flood water level

$h_w$ : Wave height due to wind

Assuming wind velocity at 30 m/s and reservoir length at 8,000 m (Çatalan Dam and Seyhan Dam), $h_w$ is calculated at 1.6 m by applying S.M.B and Saville method.

$h_e$ : Wave height due to earth quake

Assuming earth quake coefficient at 0.15 and water depth at 32 m (Seyhan Dam) and 63 m (Çatalan Dam), $h_e$ is calculated at 0.42 m (Seyhan Dam) and 0.59 m (Çatalan Dam) by applying Japanese standard.

### 7.2.2 Çatalan Dam

The gated spillway is located at the left bank with 6 nos. radial gates, of which dimension is of 11-m width and 15.1-m height. Weir crest is elevated at 109.9 m.

The reservoir area and volume of the Çatalan Dam is shown in Figure 7.2.1. Reservoir volume curve is assumed with the following equation.

Vol. = $0.886 \times (\text{El.})^2 - 138.648 \times (\text{El.}) + 5625.835$

Where, Vol. : Reservoir volume ( $\times 10^6$ m$^3$)

El. : Elevation (m)

Çatalan Dam has the following capacity of reservoir.

| | Elev. (m) | Volume (x $10^6$ m$^3$) |
|---|---|---|
| Dead Storage | Less than 115.0 | 1,399 |
| Active Storage | 115.0 to 125.0 | 740 |
| Flood Control Storage | 118.6 to 125.0 | 494 |
| Total Storage | Less than 125.0 | 2,139 |

Flood routing is carried out by "constant ratio operation" to examine the optimum spill-out discharge. Flood hydrograph at 500-year probability is adopted in the analysis. Target spill-out discharge ($Q_t$) is changed at 600 m³/s, 800 m³/s, 1,000 m³/s and 1,200 m³/s. The flood season high water level is set up at El. 118.60 m. The initial reservoir water level is assumed at 118.60 m for this simulation study. The calculation results are tabulated in Tables 7.2.3 to 7.2.6, and shown in Figure 7.2.2. The results are summarized as follows.

| Inflow peak | Spill-out dis. | Stored vol. | Max. RWL |
|---|---|---|---|
| 4,375 m³/s | 600 m³/s | 555.9 x $10^6$ m³ | 125.74 m |
| 4,375 m³/s | 800 m³/s | 447.4 x $10^6$ m³ | 124.43 m |
| 4,375 m³/s | 1,000 m³/s | 391.2 x $10^6$ m³ | 123.74 m |
| 4,375 m³/s | 1,200 m³/s | 345.4 x $10^6$ m³ | 123.17 m |

Therefore, assuming that ;

(a) Flood control volume = 628 x $10^6$ (m³)
(b) Safety factor = 1.2
(c) Flood control volume with safety factor = 628 x $10^6$ /1.2 = 523.3 x $10^6$ (m³)

Spillout discharge of 800m³/sec.is selected for Çatalan Dam.

### 7.2.3 Seyhan Dam

The reservoir volume curve is assumed with the following equation.

$$\text{Vol.} = 1.499 \times (\text{El.})^2 - 136.998 \times (\text{El.}) + 3285.871$$

Where, Vol. : Reservoir volume ( x $10^6$ m³)
El. : Elevation (m)

The emergency spillway is located at the right bank with 260-m width. The spillway crest elevation is at 67.5 m, while the dam crest is elevated at 72.7 m. The emergency spillway functions to spill-out flood water above El. 67.5 m automatically when the gated spillway can not spill-out a big flood. The gated spillway is located between the emergency spillway and the dam body. Weir crest is elevated at 61.0 m. Flood season low water level is set up at 61.0 m. Preferably, flood flow shall be controlled not to over-top the emergency spillway because the spillway is not lined and the mountain will be eroded by flood flow.

Seyhan Dam has the following capacity of reservoir. The reservoir volume curves in 1956, 1986, 1991 are shown in Figure 7.2.3.

| | Elev. (m) | Volume (x 10$^6$ m$^3$) |
|---|---|---|
| Dead Storage | Less than 49.0 | 171 |
| Active Storage | 49.0 to 67.5 | 710 |
| Flood Control Storage | 61.0 to 67.5 | 370 |
| Total Storage | Less than 67.5 | 881 |

The spilled-out flood water from Çatalan Dam and flood water from the remaining catchment area inflow into Seyhan Dam reservoir at flood time. The spilled-out flood from Çatalan Dam is changed as calculated in the above. The flood water from the remaining area flows along the Çakıt River and the Körkün River.

A trial study reveals that a gated operation does not make benefit for reservoir operation, it is because reservoir water level reaches to emergency spillway crest shortly after flooding and it is enforced to open the gates. Therefore, non gated operation, or free flow operation, is adopted for the Seyhan Dam.

Comparison at the Seyhan Dam between "constant outflow operation" and "constant ratio operation" operated at the Çatalan Dam is made in Figure 7.2.4 to 7.2.7. The results are summarized as follows.

Constant ratio operation at Çatalan Dam

| | Spill-out from Çatalan | Inflow from subbasin | Inflow peak | Stored vol. | Max. RWL | Outflow |
|---|---|---|---|---|---|---|
| 1/2 | 582 m$^3$/s | 280 m$^3$/s | 861 m$^3$/s | 132.2x10$^6$ m$^3$ | 63.73 m | 591 m$^3$/s |
| 1/5 | 622 m$^3$/s | 435 m$^3$/s | 1,054 m$^3$/s | 148.6x10$^6$ m$^3$ | 64.03 m | 659 m$^3$/s |
| 1/10 | 647 m$^3$/s | 550 m$^3$/s | 1,195 m$^3$/s | 162.9x10$^6$ m$^3$ | 64.29 m | 720 m$^3$/s |
| 1/50 | 715 m$^3$/s | 825 m$^3$/s | 1,534 m$^3$/s | 194.0x10$^6$ m$^3$ | 64.84 m | 856 m$^3$/s |
| 1/100 | 738 m$^3$/s | 955 m$^3$/s | 1,691 m$^3$/s | 206.6x10$^6$ m$^3$ | 65.06 m | 913 m$^3$/s |

Constant outflow operation at Çatalan Dam

| | Spill-out from Çatalan | Inflow from subbasin | Inflow peak | Stored vol. | Max. RWL | Outflow |
|---|---|---|---|---|---|---|
| 1/2 | 1,175 m$^3$/s | 280 m$^3$/s | 1,455 m$^3$/s | 158.1x10$^6$ m$^3$ | 64.20 m | 699 m$^3$/s |
| 1/5 | 1,200 m$^3$/s | 435 m$^3$/s | 1,635 m$^3$/s | 210.6x10$^6$ m$^3$ | 65.13 m | 931 m$^3$/s |
| 1/10 | 1,200 m$^3$/s | 550 m$^3$/s | 1,750 m$^3$/s | 247.7x10$^6$ m$^3$ | 65.76 m | 1,102 m$^3$/s |
| 1/50 | 1,200 m$^3$/s | 825 m$^3$/s | 2,025 m$^3$/s | 287.3x10$^6$ m$^3$ | 66.40 m | 1,288 m$^3$/s |
| 1/100 | 1,200 m$^3$/s | 955 m$^3$/s | 2,155 m$^3$/s | 288.7x10$^6$ m$^3$ | 66.42 m | 1,293 m$^3$/s |

## 7.3 Water Use Operation

### 7.3.1 Alternative reservoir rule curve

The operation rule curve of the Çatalan Dam is studied hereunder. Hydropower is generated by water head and flow discharge. If the reservoir water level is set up at higher level to obtain higher water head for power generation in rainy season, the dam can not regulate flood flow and flood water can not be stored in the reservoir to be utilized for power generation in dry season. If the reservoir water level is set up at lower level on the contrary, less water head generates less power energy and minimum guarantee energy (firm energy) becomes less in drought year because of less stored water in the reservoir. The reservoir operation rule curve shall be optimized.

Monthly average inflow discharge is recorded from 1940 to 1980 for 40 years as follows. Irrigation water and evaporation discharge are assumed as in the below.

| | Inflow into Çatalan Dam ($m^3/s$) | Irrigation Water ($m^3/s$) | Monthly Evaporation (mm/month) | Evaporation ($m^3/s$) | Water for Hydro Power ($m^3/s$) |
|---|---|---|---|---|---|
| Oct. | 79.0 | 6.3 | 87.2 | 2.4 | 70.4 |
| Nov. | 91.7 | 0.0 | 49.6 | 1.4 | 90.3 |
| Dec. | 137.4 | 0.0 | 31.3 | 0.8 | 136.6 |
| Jan. | 165.3 | 0.0 | 31.9 | 0.8 | 164.5 |
| Feb. | 196.7 | 0.0 | 39.8 | 1.1 | 195.6 |
| Mar. | 286.8 | 0.0 | 62.4 | 1.6 | 285.2 |
| Apr. | 359.3 | 3.3 | 84.9 | 2.4 | 353.6 |
| May | 245.3 | 11.7 | 124.4 | 3.6 | 230.0 |
| Jun. | 147.2 | 36.9 | 155.6 | 4.9 | 105.4 |
| Jul. | 102.3 | 70.9 | 175.4 | 5.1 | 26.2 |
| Aug. | 85.3 | 57.6 | 161.8 | 4.6 | 23.1 |
| Sep. | 79.3 | 29.3 | 128.0 | 3.7 | 46.4 |
| Avg. | 164.6 | 18.0 | 94.4 | 2.7 | 143.9 |

Monthly inflow discharge from January to May exceeds the average one. Therefore, the reservoir shall be filled during January to May ("storing period"). The average inflow in the "storing period" is at 246.1 ($m^3/s$). The stored water in the reservoir shall be consumed from June to December ("consuming period"). The average inflow in the "consuming period" is at 71.1 ($m^3/s$). The reservoir active storage volume is $740 \times 10^6$ $m^3$ (El. 115.0 to 125.0 m). Storing discharge and consuming discharge on average are respectively calculated at 56.7 $m^3/s$ ($=740 \times 10^6$ $m^3$/151 days/24 hrs./3,600 sec.) during the "storing period" (151 days) and at 40.0 $m^3/s$ ($=740 \times 10^6$ $m^3$/214 days/24 hrs./3,600 sec.) during the "consuming period" (214 days). Alternative rule curves are established as follows.

Case-1

The consuming discharge is distributed to a month depending on monthly average inflow during the "consuming period". Hydropower is generated by monthly inflow added with the distributed discharge. The storing discharge is distributed to a month depending on monthly average inflow during the "storing period". Hydropower is generated by monthly inflow deducted the distributed discharge. Power discharge is expressed as follows.

"Consuming period : $Q_p = Q_i + 40.0 \times Q_i/71.1$

"Storing period : $Q_p = Q_i - 56.7 \times Q_i/246.1$
Where, $Q_p$ : Monthly power discharge
$Q_i$ : Monthly average inflow

Case-2

The average inflow during the "consuming period" is 71.1 m³/s. Hydropower is generated by the discharge of 111.1 m³/s (=71.1 + 40.0) during the "consuming period". The average inflow during the "storing period" is 246.1 m³/s. Hydropower is generated by the discharge of 189.4 m³/s (=246.1 - 56.7) during the "storing period".

Case-3

The rule curve of Case-2 operates reservoir water level at lower level in the "consuming period". Firm energy may not be dependable. It is because the reservoir water level reaches to minimum operation level in November to February and power generation is enforced to be made by inflow discharge only. In order to increase firm energy, power discharge is set up at 101.1 m³/s (=111.1 - 10) during the "consuming period", decreasing 10 m³/s than that in Case-2. Instead, power discharge is set up at 199.4 m³/s (=189.4 + 10) during the "storing period", increasing 10 m³/s than that in Case-2.

Assuming the reservoir water level at 125.0 m at the beginning of June, the reservoir water level for the above cases are calculated in Table 7.3.1. The operation rule curve (R.C) is summarized below.

| | | Case-1 | | Case-2 | | Case-3 | |
|---|---|---|---|---|---|---|---|
| Avg.Inf. | | Q(m³/s) | R.C(m) | Q(m³/s) | R.C(m) | Q(m³/s) | R.C(m) |
| Jan. | 164.5 | 126.6 | 115.0 | 189.4 | 116.0 | 199.4 | 117.6 |
| Feb. | 195.6 | 150.6 | 116.5 | 189.4 | 115.0 | 199.4 | 116.2 |
| Mar. | 285.2 | 219.5 | 118.1 | 189.4 | 115.3 | 199.4 | 116.1 |
| Apr. | 353.6 | 272.2 | 120.5 | 189.4 | 119.0 | 199.4 | 119.4 |
| May | 230.0 | 177.0 | 123.3 | 189.4 | 124.5 | 199.4 | 124.5 |
| | | Case-1 | | Case-2 | | Case-3 | |
| Avg.Inf. | | Q(m³/s) | R.C(m) | Q(m³/s) | R.C(m) | Q(m³/s) | R.C(m) |
| Jun. | 105.4 | 164.6 | 125.0 | 111.1 | 125.0 | 101.1 | 125.0 |
| Jul. | 26.2 | 41.0 | 123.1 | 111.1 | 124.8 | 101.1 | 125.0 |
| Aug. | 23.1 | 36.1 | 122.6 | 111.1 | 122.0 | 101.1 | 122.5 |
| Sep. | 46.4 | 72.5 | 122.2 | 111.1 | 118.8 | 101.1 | 119.8 |
| Oct. | 70.4 | 110.0 | 121.3 | 111.1 | 116.4 | 101.1 | 117.8 |
| Nov. | 90.3 | 141.1 | 119.9 | 111.1 | 115.0 | 101.1 | 116.6 |
| Dec. | 136.6 | 213.5 | 118.1 | 111.1 | 115.0 | 101.1 | 116.2 |

Monthly maximum operation level is set up as follows.

|  | Max.El.(m) |  | Max.El.(m) |
|---|---|---|---|
| Jan. | 118.6 | Jul. | 125.0 |
| Feb. | 118.6 | Aug. | 125.0 |
| Mar. | 118.6 | Sep. | 125.0 |
| Apr. | 120.7 | Oct. | 125.0 |
| May | 125.0 | Nov. | 120.7 |
| Jun. | 125.0 | Dec. | 118.6 |

The monthly reservoir rule curve and monthly maximum operation level is shown Figure 7.3.1.

In addition to the above rule curves, power energy is estimated in case that maximum operation level (flood control water level) is assumed as a rule curve.

### 7.3.2 Operation rule

Reservoir operation rule is established as follows.

(a) Target discharge shall be maintained at least for power generation except when reservoir water level is below minimum operation level. Reservoir water level reaches to minimum operation level, target discharge shall be decreased to maintain the reservoir water level at the minimum operation level. In other words, power discharge shall be at inflow discharge.

(b) When the reservoir water level is above minimum operation level and below the rule curve level, power is generated with target discharge.

(c) When the reservoir water level is below the maximum operation level and the rule curve level, design discharge of 360 $m^3/s$ shall be discharged for power generation. Therefore, secondary discharge is at (360 $m^3/s$ - target discharge) under this operation.

(d) When reservoir water level reaches to the maximum operation level, excessive water shall be spilled out.

### 7.3.3 Power simulation

Inflow discharge at Çatalan Dam site is available from 1940 to 1980, after deducting irrigation water use by İmamoğlu Project which is under construction. Generating energy is simulated for 20 years from 1960 to 1979 by applying the above operation rule. Power output is calculated with the following equation.

$$P = g \times Q \times H \times \mu$$

Where,

$P$ Power output (kW)
$g$ Gravity acceleration (9.8 m/s²)
$Q$ Power discharge (m³/s)
$H$ Head = Reservoir WL - T.W.L (64.0 m) - Head loss
$\mu$ Generator/Turbine efficiency

Head loss curve and generator/turbine efficiency curve is shown in Figure 7.3.2 and the following regression is adopted.

Head loss $h_l = 0.138 \times P_w^2 + 1.053 \times P_w + 460.513$
Where, $h_l$ : Head loss (mm)
$P_w$ : Power (MW)
Efficiency $\mu = -1.645 \times 10^{-4} \times P_w^2 + 0.019 \times P_w + 0.382$
Where, $\mu$ : Generator/turbine efficiency
$P_w$ : Power (MW)

Target discharge is changed to see energy output. Simulation results are summarized below.

| | Case-1 | | | Case-2 | | | Case-3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Target dis. (m³/s) | 70.0 | 80.0 | 90.0 | 30.0 | 40.0 | 50.0 | 50.0 | 60.0 | 70.0 |
| Average firm dis. (m³/s) | 67.9 | 76.3 | 79.8 | 30.0 | 39.5 | 48.1 | 50.0 | 59.3 | 67.6 |
| Secondary dis. (m³/s) | 61.4 | 52.1 | 54.9 | 92.8 | 85.4 | 80.0 | 81.2 | 71.9 | 62.6 |
| Spill-out dis. (m³/s) | 8.5 | 8.7 | 4.3 | 9.4 | 5.6 | 3.8 | 2.7 | 3.1 | 2.3 |
| Firm energy (GWh/yr) | 285.2 | 322.0 | 337.5 | 117.3 | 157.0 | 192.9 | 133.9 | 243.6 | 278.0 |
| Second. engy (GWh/yr) | 264.6 | 227.4 | 236.7 | 383.6 | 353.8 | 331.2 | 341.1 | 302.2 | 262.7 |
| Total energy (GWh/yr) | 549.8 | 549.4 | 574.2 | 500.9 | 510.9 | 524.2 | 545.0 | 545.8 | 540.6 |

If target discharge is aimed at higher discharge, total energy becomes larger but firm energy dependability becomes less. Through the above simulation, operation rule curve of Case-1 with the target discharge of 80 m³/s is recommendably adopted because it can generate power energy more and firm energy is acceptably dependable.

### 7.3.4 Power simulation without- and with- flood forecasting warning system

Daily power generation is simulated in case of "without system" and "with system". Operation rule is set up as follows.

(a) Maximum power discharge shall be at 360 m³/s.
(b) Reservoir water level shall be followed the reservoir operation rule curve of Case-1.

(c) "Recovery discharge" ($Q_r$) is defined as the discharge to recover the reservoir water level (RWL) on the previous day to the rule curve (RC) on the operation day.

$Q_r = (V_{RWL} - V_{RC})/24$ hrs./3,600 sec.

Where, $Q_r$ : Recover discharge ($m^3/s$)

$V_{RWL}$ : Reservoir volume on the previous day ($m^3$)

$V_{RC}$ : Reservoir volume on the operation day ($m^3$)

Power discharge shall be daily inflow discharge ($Q_i$) added with $Q_r$.

(d) Minimum power discharge shall be at 80 $m^3/s$.

(e) If RWL exceeds flood control level, reservoir water shall be spilled out.

(f) If RWL is less than the minimum operation level (115.0 m), power discharge shall be at $Q_i$.

Daily power simulation is made on a basis of the above operation rule. Daily inflow ($Q_i$) in 1970, 1975 and 1988 are adopted. Daily inflow ($Q_i$) on the operation day is assumed as same as the $Q_i$ on the previous day, in case of "without system" operation. It is assumed that $Q_i$ on the operation day can be forecasted in advance, in case of "with system" operation.

(Unit : MWh)

| Year | Probability | "Without system" | "With system" |
|---|---|---|---|
| 1970 | 1/2 | 715,962 | 717,567 |
| 1975 | 1/5 | 790,301 | 791,919 |
| 1988 | 1/10 | 992,199 | 996,315 |

It can be found that power operation "with system" can generate energy more stably than power operation "without system".

Additional energy production obtained by the difference of operation is calculated and tabulated below. The difference of storage volume which can be obtained by the difference between constant outflow operation and constant ratio operation is considered to be used for energy production. T.W.L and He for Çatalan and Seyhan Dams are assumed below.

(a) Çatalan Dam (T.W.L = 64.0m, he = 3.0m)

| | 2-year | 5-year | 10-year | 50-year | 100-year |
|---|---|---|---|---|---|
| Difference of Storage Volume (x $10^6$ $m^3$)* | 44.1 | 86.9 | 124.3 | 178.5 | 198.4 |
| Ave. Water Level | 118.9 | 119.3 | 119.7 | 120.5 | 120.9 |
| Ave. Head (m) | 51.9 | 52.3 | 52.7 | 53.5 | 53.9 |
| Energy output (MWh) | 5,296 | 10,516 | 15,157 | 22,097 | 24,744 |

(b) Seyhan Dam (T.W.L = 30.3m, he = 3.5m)

| | 2-year | 5-year | 10-year | 50-year | 100-year |
|---|---|---|---|---|---|
| Difference of Storage Volume (x $10^6$ $m^3$)* | 25.9 | 62.0 | 84.4 | 93.3 | 82.1 |
| Ave. Water Level | 62.6 | 63.1 | 63.4 | 63.7 | 63.7 |
| Ave. Head (m) | 28.8 | 29.3 | 29.6 | 29.9 | 29.9 |
| Energy output (MWh) | 1,726 | 4,203 | 5,780 | 6,455 | 5,680 |

* : Storage volume by constant outflow operation - Storage volume by constant ratio operation

# 8. FEASIBILITY GRADE DESIGN FOR THE OPTIMUM SYSTEM

## 8.1 System Configurations

### 8.1.1 Overall system configuration

The overall configuration and functional block diagram of the flood forecasting and warning system should be shown in Figure 8.1.1. The flow chart of data should be shown in Figure 8.1.2.

### 8.1.2 Circuit configuration

The overall circuit configuration of the flood forecasting and warning system should be shown in Figure 8.1.3.

### 8.1.3 Station configuration of facility

The station configuration of the flood forecasting and warning system facility should be shown in the table below.

| Type of station | Number of stations |
|---|---|
| Control center (DSİ 6th regional directorate flood control committee) | 1 |
| Data monitoring stations (DSİ general directorate, Adana EİE and DMİ) | 3 |
| Seyhan Dam office facility | 1 |
| Çatalan Dam office facility | 1 |
| Multiplex radio repeater stations | 3 |
| Multiplex radio repeater stations (Telemetering repeater station also provided) | 4 |
| Telemetering repeater stations (V-V and Cross type) | 7 |
| Water level gauging stations (Seyhan Dam and Çatalan Dam water level included) | 10 |
| Rainfall gauging stations (Çatalan Dam rainfall included) | 9 |
| Rainfall/temperature gauging stations | 7 |
| Adana Provincial Governor | 1 |
| UHF repeater station | 1 |
| ASO UHF radio liaison stations(Doğankent and Yenice) | 2 |
| Town/villages' head UHF radio liaison stations (downstream areas of Seyhan Dam) | 5 |
| Mobile station | 1 |

## 8.2 System Scheme and Function Outline

The flood forecasting and warning system should consist of three sub-systems:

- Data collection system
- Data processing system
- Data transmission system

The functions of the sub-systems are outlined in Sections 8.2.1 to 8.2.3 below.

### 8.2.1 Data collection system

The data collection system should consist of one (1) supervisory station at Seyhan Dam office, eleven (11) telemetering repeater stations, ten (10) water level gauging stations, nine (9) rainfall gauging stations, and seven (7) rainfall and temperature gauging stations. The functions of the data collection system should outlined below.

(1) Data to be collected

The types of data to be collected should be listed in Table 8.2.1

(2) Collection intervals

In principle, the intervals of data collection should be based on the following table:

| Gauging item | Collection conditions | Remarks |
|---|---|---|
| Rainfall | Every hour on the hour | Calculations of hourly rainfall, every hour on the hour, become the minimum unit. |
| Water level | Every hour on the hour | It is preferable that whenever neces-sary, collection of any data should be possible. |
| *Air temperature* | *Every hour on the hour* | *It is preferable that whenever neces-sray, collection of any data should be possible.* |

(3) Data collection circuits

Simplex radio links for data collection should be of the half duplex communications type based on VHF radio links of high circuits design efficiency. Since a VHF radio frequency band of 70 MHz can be used even during the implementation phase of the system, 70 MHz should be used that is high in circuits design efficiency and ideal for mountainous propagation.

(4) Telemetering method

Polling telemetering should be used as the method of telemetering for the data collection system.

(5) Frequency assignment planning for the telemetering radio links

An outline of frequency assignment planning for the telemetering radio links should be given in Figure 8.2.1.

### 8.2.2 Data processing system

The data processing system should use distributed processing configuration. The system configuration is shown in Figure 8.2.2, and its processing functions are outlined below.

(1) Computing items

The following lists computing items required for the flood forecasting and warning system:

- Hourly rainfall processing
- Daily rainfall processing
- Average basin rainfall processing
- Rainfall warning judgment processing
- Water level warning judgment processing
- Water level/discharge processing
- Statistical processing
- Outflow forecast processing

### 8.2.3 Data transmission system

The data transmission system should transmit data and information for flood control activities from the flood control committee of the DSİ 6th regional directorate to related agencies. A total functional block diagram of the data transmission system should be given in Figure 8.2.3, and an outline of its related circuits and operating frequency planning should be given in Figure 8.2.4. The function of the data transmission system are outlined below.

## (1) Data distribution

Data should be transmitted in image service from the control center. The service area and the types of services should be listed below.

### (a) Image service destination stations and service types

The following lists stations to which image services should be provided:

| Image data distribution source | Image data distribution destination | Service image type |
|---|---|---|
| • Control center<br>(Flood control committee of DSİ 6th regional directorate) | • DSİ general directorate<br>• Seyhan Dam office<br>• Çatalan Dam office<br>• Adana EİE regional directorate<br>• Adana DMİ regional directorate | • River basin status chart<br>• Rainfall data table<br>• Water level data table<br>• Discharge data table<br>• Air temperature data table<br>• Rainfall chronological graph<br>• Water level chronological graph<br>• Discharge chronological graph<br>•Air temperature chronological graph |

Distribution of image data to the Seyhan Dam office and the Çatalan Dam office should be performed via multiplex radio links and distribution of image data to the DSİ general directorate, the Adana EİE regional directorate, and the Adana DMİ regional directorate via PTT private lines provided with optical fiber cables.

## (2) Information transmission through direct call lines

Private lines for interconnection between each of the following sections should be provided to allow direct telephone calls to be placed:

| Section | Communications line type |
|---|---|
| • Between Control center and Seyhan Dam office | Multiplex radio links |
| • Between Control center and Çatalan Dam office | Multiplex radio links |
| • Between Control center and Adana Governor | PTT leased lines |

### (3) Voice information transmission

Voice information should be transmitted via the exchange circuits of multiplex radio links. Information transmission circuits systems are classified as follows according to the combination of the multiplex radio links and UHF radio links to be structured:

- Liaison telephone system that uses multiplex radio links
  This system is made up of only multiplex radio links.
- Liaison radio telephone system
  This system is made up of a combination of multiplex radio links and UHF radio links.

Both two types of information transmission systems listed above should allow full duplex communication through the dial telephone. The functions of the two types of information transmission systems should be outlined below.

(a) Liaison telephone system that uses multiplex radio links

This system, which should be made up of only multiplex radio links, should be provided in the three places listed below. While the call channel remains unoccupied, this system can be used to intercommunicate between stations or with a liaison radio telephone system.

- Flood control committee of the DSİ 6th regional directorate
- Seyhan Dam office
- Çatalan Dam office

(b) Liaison radio telephone system

This system should be made up of a combination of multiplex radio links and UHF radio links. A single-channel radio communication should be provided in the two places and one patrol car listed below. This system should allow telephone contact between these two stations, patrol car and multiplex radio communication stations.

- Doğankent Flood Control Center
- Yenice Flood Control Center
- Patrol car (Downstream areas of Seyhan Dam)

#### (4) Voice liaison system

The voice liaison system should transmit in voice dam discharge information through UHF radio links. Voice information transmission should become possible by selective call communication between the control centers and the following stations since group contact is required for information of dam discharge.

- Taşci (Seyhan River Left Bank)
- Kurança (Seyhan River Left Bank)
- Karayusuflu (Seyhan River Left Bank)
- Baharli (Seyhan River Right Bank)
- Tabaklar (Seyhan River Right Bank)

## 8.3 Feasibility Grade Facilities Design

### 8.3.1 Station equipment configurations

Figure 8.3.1 to 8.3.6 should show the schematic configuration of flood forecasting and warning facility for Seyhan River basin.

### 8.3.2 Feasibility grade design for telemetering facility

The feasibility grade design for the telemetering facility that is to collect hydrometeorological data should be described below.

#### (1) Outline of the telemetering scheme

The following should give outline of the telemetering scheme to be used for the flood forecasting and warning system:

(a) Data collection

- Data collection procedures : Polling
- Collection modes : Automatic and manual
  - Automatic : 4-level collection interval setting
  - Manual : General polling and individual polling
- Recall : Automatic recalling possible if code errors are detected

(b) Transmission

- Method of communication : Half-duplex
- Method of modulation : Frequency modulation
- Transmission rate : 200 bps
- Method of error detection : 16-bit cyclic code or equivalent method

### 8.3.3 Feasibility grade design for the multiplex radio communications facility

The feasibility grade design concepts for the multiplex radio communications facility of the flood forecasting and warning system should be described below.

(1) Frequency assignment planning

Considering the three-way route branching circuits and D/U ratio that are characteristic of the multiplex radio communications links configuration, a minimum of three pairs of radio frequency assignment should be required for the multiplex radio communications links. Of all frequencies falling within the range from 2,520 to 2,670 MHz that is shown in the recommendations of the Conference of European Postal and Telecommunications Administration (CEPT), only those which are temporarily licensed by the TGM should be assigned to suit the particular domestic situation of the Republic of Turkey. One example of assigning frequencies is shown in Figure 8.3.7.

(2) Channel plan

The items listed below are considered during study of a channel plan for the multiplex radio communications facility. The results of feasibility grade design for the channel plan should be shown in Figure 8.3.8.

(a) The links required for the data collection system should be reserved. For maintenance purposes, start connection is excellent as the method of using channels. The multi-drop scheme, however, should be used as far as possible, since this method allows the multiplex radio communications links channels to be used very effectively.

(b) To ensure that a direct telephone system is structured, private lines should be provided for the control center and the following related places:

- Between the flood control committee of the DSİ 6th regional directorate and the Seyhan Dam office
- Between the flood control committee of the DSİ 6th regional directorate and the Çatalan Dam office

(c) Considering the operating conditions of the flood forecasting and warning system and the frequency of use of necessary telephone sets, a telephone exchange should be installed in the control center.

(d) Two (2) multiplex-type liaison telephone channel should be assigned to each place and accommodated in the intercommunications system of the telephone exchange.

(e) Two (2) liaison radio telephone channels should be assigned to the section between the telephone exchange to be installed in the control center, and the UHF radio communications base station.

(f) Two (2) channels should be reserved for data distribution between the control center and the Seyhan and Çatalan Dam offices. One of these two channels should for spare use in the future.

### 8.3.4 Feasibility grade design for the power supply facility

The basis for the feasibility grade design of the power supply facility each station is described below.

(1) Control center

Since the power supply facility of the control center forms the core of the flood forecasting and warning system, the facility should be completely uninterruptible. The uninterruptible power supply facility should consist of AC uninterruptible power supply equipment and a standby engine generator, since the control center has a large load capacity.

(2) Dam offices

The power supply facility of the Seyhan Dam and Çatalan Dam offices should be completely uninterruptible to ensure continual display of dam management processing data and execution of dam operating commands through direct telephone calls. The uninterruptible power supply facility should consist of AC uninterruptible power supply equipment, DC power supply equipment, and a standby engine generator.

(3) Data monitoring stations

Since, in the data monitoring stations of the DSİ general directorate, the EİE, or the DMİ, data will not be processed and will only be received, displayed, recorded, etc., the power supply facility of these stations should consist of that uninterruptible type based on AC uninterruptible power supply equipment that permits about 10 minutes of interruption.

(4) Multiplex radio communications stations

Since the power supply facility of the multiplex radio communications stations forms one functionally integral part of the flood forecasting and warning system, the facility should consist of the completely uninterruptible type that consists of DC power supply equipment and a standby engine generator.

(5) Telemetering repeater stations and gauging stations

Considering the power supply situation in the Seyhan River basin areas, the power supply facility of the telemetering repeater stations and gauging stations should consist of the solar battery type as far as possible, even if commercial power can be received.

(6) UHF radio liaison stations

Considering the power consumption and frequency of operation use, the power supply facility of the UHF radio liaison stations should consist of DC power supply equipment.

# 9. IMPLEMENTATION PLAN AND COST ESTIMATION

## 9.1 Implementation Schedule

The implementation schedule for the structuring of the flood forecasting and warning system is shown in Table 9.1.1. During formulation of the implementation schedule, the following items are incorporated into the schedule:

### (1) Entire work period

The entire work, which ranges from detailed designing to civil construction work, equipment procurement, transportation, installation, adjustment, acceptance test and site OJT (On -the-Job Training) will be completed within twenty two (22) months; this period considering the scale of the system and the number of places which require work.

### (2) Detailed design period

The period of detailed design based on the results of feasibility study, including preparation of Tender Documentation, will be set to become five (5) months.

### (3) Supplemental radio wave propagation investigation

The period of supplemental radio wave propagation investigation occurring after completion of detailed designing will be set to become about two (2) months. This period will include the period of the radio wave propagation investigation of the Seyhan River upstream basin and other areas that was not executable because of the limited time and for other reasons during the feasibility study.

### (4) Tender processing period

The period required for Tender processing will be set to become two (2) months.

### (5) Civil construction work period

The civil construction work for towers, station buildings and all other related facilities should be executed by the Government of the Republic of Turkey. The implementation schedule will be formed for the preparation work and necessary work period to become seven point five (7.5) months.

(6) Equipment design and manufacture period

The period of equipment design and manufacture (factory witness inspection included) will be set to become seven (7) months; this period considering the situation of equipment procurement in Japan.

(7) Transportation period

The total period required for export processing from Japan, marine transportation (including the customs clearance in İşkenderum, the Republic of Turkey), and inland transportation in the Republic of Turkey, will be set to become two (2) months.

(8) Equipment installation and adjustment period

Considering the number of about fifty (50) related sites and the geographical conditions of these sites, the equipment installation and site adjustment period will be set to become six (6) months, including the preparation work period.

(9) Final acceptance test period

The final acceptance test period will be set to become one (1) month.

(10) Training period

The maintenance personnel for the flood forecasting and warning system requires prior overseas training and site OJT, and the overseas training period and the site OJT period will be set to become one (1) month and one point five (1.5) months, respectively,

## 9.2 Construction Cost Estimation

### 9.2.1 Basic conditions for construction cost estimation

Direct construction work costs are estimated on the basis of the work quantities and work unit costs during the feasibility study. The major assumptions and conditions for construction cost estimation are listed below.

(a) All prices will be the market prices existing as of February 1994. Commercial power leading-in work expenses and inland transport expenses, however, are estimated by multiplying the market prices existing as of February, 1993, by 1.6.

(b) Construction costs are estimated in both foreign currency (the US. dollar) and domestic currency (the Turkish lira). The exchange rate as of February 1, 1994, is used as that of the dollar and the yen. This exchange rate is shown below.
$1 = ¥109.20

(c) Construction costs consist of the following items:

- Direct construction expenses
- Governmental overhead expenses
- Engineering expenses
- Educational and training expenses
- Provisional expenses

(d) Land compensation expenses are estimated in domestic currency and included in construction costs.

### 9.2.2 Construction cost estimation

Construction costs are estimated for each of the items listed below.

(1) Direct construction cost

The direct construction expenses estimated here consist of direct expenses (such as labor expenses, materials expenses, equipment expenses, etc.) and indirect expenses (such as the indirect expenses, profits, and site expenses of subcontractors). Of all these direct expenses, only the expenses for the work listed below are estimated in Turkish domestic currency that includes a value added tax of 15%. Any equipment and materials that may be imported are handled tax-free in their cost estimates.

- Construction work for towers (Design and materials included)
- Construction work for station buildings and water level gauging wells (Design and materials included)
- Construction work for pressure type water level gauge protective piping facilities (Design and materials included)
- Construction work for water level gauge extension cable ducting
- Construction work for maintenance roads (One part excluded)

- Construction work for commercial power leading-in
- Installation and adjustment work (Experts expenses excluded)
- Initial installation work for termination PTT private lines
- Inland transportation in the Republic of Turkey (Unloading and storage warehouse expenses included)

(2) Governmental overhead expenses

The expenses for administration, operation, and other management jobs by the Turkish Government are estimated at the rate of 1 % of the total direct work expense.

(3) Engineering expenses

Engineering expenses for the detailed design and implementation/management jobs that will be carried out by Engineers are estimated at the rate of 13 % of the equipment expense.

(4) Educational and training expenses

The educational and training expenses for the overseas training and on-the-job training of Turkish engineers are estimated at the rate of 1.7 % of the equipment and expense.

(5) Provisional expenses

The provisional expenses are estimated at the rates of 15% of the total civil construction work expense and 5 % of the total equipment and installation/adjustment expense.

The construction costs based on the above estimates are listed in Table 9.2.1, and an outline of the construction costs is given below. Station-by-station direct work expenses are listed in Table 9.2.2.

| Item | Foreign currency (Unit: $) | Domestic currency (Unit: 1000 TL) |
|---|---:|---:|
| Direct construction expense | 10,096,490 | 19,745,400 |
| Land acquisition expense | 0 | 6,600 |
| Governmental overhead expense | 0 | 197,454 |
| Engineering expense | 1,170,200 | 0 |
| Educational/training expense | 148,580 | 0 |
| Provisional expenses | 554,870 | 2,630,010 |
| Total construction expenses | 11,970,140 | 22,579,464 |

## 9.3 Maintenance and Management Costs

To ensure continued normal operation of the flood forecasting and warning system after completion of this project, appropriate maintenance and management is required. Maintenance expenses for the flood forecasting and warning system should therefore be budged. Annual maintenance and management expenses are estimated below.

### 9.3.1 Estimation conditions

Annual maintenance and management expenses are estimated under the conditions listed below.

(1) Maintenance and management system

The maintenance and management system shown in Figure 11.3.1 is to be established.

(2) Operation of a standby engine generator

A standby engine generator shall be operated for 40.00 hours/month. Its fuel expenses are estimated.

(3) Repair and consumable parts cost

The repair and consumable parts cost per annum is estimated at the rate of 0.1% of an initial equipment cost.

(4) Vehicle cost

The necessary number of vehicles should be purchased to compensate for any insufficiency in quantity, and they will be renewed for every fifteen (15) years. The gas fee of vehicle is estimated on the assumption that one vehicle is to be driven through the distance of 12,000 km a year.

(5) Charges for the PTT private lines

The lease charges for the PTT private lines are estimated. The initial costs for the first fiscal year will be included in the construction cost estimates.

(6) Electricity charges

The electricity charges per annum are estimated.

(7) Management expenses

Management expenses are estimated at the rate of 15% of the annual maintenance expenses.

### 9.3.2 Maintenance expenses

The maintenance expenses per annum are listed in the table below.

| Item | Foreign currency (Unit: $) | Domestic currency (Unit: 1000 TL) |
|---|---|---|
| 1. Personnel expenses | — | 1,968,000 |
| 2. Fuel expenses | — | 137,120 |
| 3. Repair part expenses | — | 208,460 |
| 4. Vehicle gas expenses | — | 19,550 |
| 5. PTT private line charge | — | 755,000 |
| 6. Electricity charge | — | 470,000 |
| 7. Management expenses | — | 533,720 |
| Total | | 4,091,850 |

# 10. EVALUATION OF THE PROJECT

## 10.1 Basic Concepts of Project Evaluation

The project evaluation of this report aims to provide basic information for the project implementation decision making. Information covers the project's social and economic impacts to the society, financial and economic burden and efficiency, and technological appropriateness and importance.

The evaluation consists of the following three component: a) identification of the project impacts, b) financial and economic analyses, c) social and technological evaluations. The expected project impacts are identified from the typical or theoretically possible impacts by the flood forecasting and warning system considering the present and expected future conditions and activities, and past experiences. Among the identified impacts, quantifiable ones in monetary term are utilized for financial and economic analysis and others are elements of the social and technological evaluation.

### 10.1.1 Target beneficial area

The identified main target beneficial area of the project is the High Water Channel (HWC) of the lower reach from the lower regulating structure located in the lower reach of the Seyhan River. The area is not well protected and suffering continual inundation by the flood. This physical condition is expected to be unchanged in near future. Most of the HWC land is used for cultivation. Small residential areas exist within the Adana City boundary.

Adjacent areas to the levees down from the Seyhan Dam which include part of the downtown Adana City are target areas, too. The latter areas' risk of the flood damage, however, is only scarce probability of having damage by the flood since the structure measure consists of the Çatalan Dam, Seyhan Dam, and the levees are designed to protect these areas properly with 500 years' probability.

In addition to the above areas in the lower reaches, Feke and Pozantı areas in the middle reaches are indirect beneficial areas. These areas are connected to the warning system through the Provincial Governor's office and transmission of the warning information is the office's disposal.

### 10.1.2 Affected groups

Since the system intends to provide flood data and information for major parties mostly concerning to the lower reach flood of the Seyhan River, the main affected groups are the residents in the flood risk area in lower reach of the Seyhan River. The other affected parties include the DSİ which is responsible organization for the river management, local governmental organizations related to the flood damages, residents and other potential sufferers of the flood, residents near the river, and the other organizations concerning the flood and its damages such as EİE and DMİ.

### 10.1.3 Typical socio-economic impacts of the flood forecasting and warning system

The project has a considerably vast kind of socio-economic impacts. The evaluation of the project to be taken is comprehensive one which exert to incorporate these various impacts. Since the Project aims to achieve the faster, more accurate, and more reliable flood forecasting and warning for the dam operations, major impacts of the project are derived from speed up, and accuracy and reliability increase in flood forecasting as well as reduction of manpower and facilities directly involved in the forecasting and warning. The project's negative impacts to the society and environment are insignificant by nature.

The possible impacts brought by the project are the following:

- the viewpoint from the replacement of the current system

(a) Substitution effect of the personnel related to the flood forecasting and warning by the system,

- the viewpoint from the speed up partly with accuracy and reliability increase

(b) Time savings of the flood forecasting staff,
(c) Time savings of the flood fighting teams,
(d) Time savings and most appropriate decision making for flood,
(e) Increase in saved movable property value by earlier evacuation information,

- the viewpoint from the accuracy and reliability increase partly with speed up

(f) Decrease in flood areas/damages by proper dam operations,
(g) Maximization of reservoir water use by more flexible and appropriate dam operations,
(h) Increase in social safety feelings by reliable information, decision making, and proper public sector's action, and

(i) Decrease in possibility of potential risk realization and increase in social safety feelings by reduced discharge water volume from the Seyhan Dam during the flood time.

### 10.1.4 Expected project socio-economic impacts

Among the above stated typical socio-economic impact, the project's particular expected socio-economic impacts are determined by consideration of the present operations and the conditions of the expected beneficial areas stated in 10.1.1. The expected project impacts are the followings:

(a) Substitution effect of the personnel related to the flood forecasting and warning by the system,
(b) Time savings of the flood forecasting staff,
(d) Time savings and most appropriate decision making for flood,
(f) Decrease in flood areas/damages by proper dam operations,
(g) Maximization of reservoir water use by more flexible and appropriate dam operations,
(h) Increase in social safety feelings by reliable information, decision making, and proper public sector's action, and
(i) Decrease in possibility of potential risk realization and increase in social safety feelings by reduced discharge water volume from the Seyhan Dam during the flood time.

The river flow runs through the project's main target areas is (is going to be) regulated by the dam(s). The increase of the water volume in the lower reaches from the dams is much more moderate than the bare flood. This condition guarantees enough lead time for the areas to prepare for the flood even without the project implementation. Therefore, (e) increase in saved movable property value by earlier evacuation information is not expected.

Item (c) decrease in waiting time of the flood fighting team may not be significant, too, since the same condition to the above does not necessitate the team to be waited for immediate works. Also they are to be mobilized by actual condition of the river informed by the field personnel. This present operation system is reasonable and not necessarily going to be changed.

The benefit of the project for the middle reach risk areas is expected to happen in (a) substitution effect of the people being engaged in the flood forecasting and warning operations, which is not so area specific and (h) increased safety feeling by the reliability increase. Since the flood type of the expected floods in these areas is the flash flood, forecasting is depend only on the duration and intensity of precipitation. No significant time difference between conventional flood forecasting and the system's is expected. Furthermore there is no flood absorbing structure which could be controlled based on coming water volume information.

Among the expected project impacts, measurable ones in monetary term are the followings:

(a) Substitution effect of the personnel related to the flood forecasting and warning by the system,
(b) Time savings of the flood forecasting staff,
(c) Time savings and most appropriate decision making for flood (marginal),
(d) Decrease in flood areas/damages by proper dam operations, and
(e) Maximization of reservoir water use by more flexible and appropriate dam operations.

These impacts form the base of the project's economic benefit except (b) Time savings of the flood forecasting staff, and (c) Time savings and most appropriate decision making for flood. These two involves other important factors such as political and organizational responsibilities. They may have to be ready for action during flood time regardless of the new system.

## 10.2 Financial and Economic Analysis

Since this project has no actual income by its operations, the financial analysis shows only cash flow of the expenditure. It displays only conceptual financial burden of the project implementation since the analysis is isolated from nominal changes of value such as inflation and foreign exchange rate fluctuation to reveal essential viability of the project. The project life cycle is 17 years after the commencement of the system operation.

The economic analysis using economic cost and benefit is conducted based on the financial analysis. The financial cost shown in the financial analysis is converted to the economic cost considering the distortion of the Turkish economy and/or transfer within the economy. The beneficial impacts of the project to the society which are measurable in monetary term are used as economic benefit. Net present value (NPV) and economic internal rate of return (EIRR) are used to value the project. This analysis is also isolated from the nominal changes of values and employs the same project life cycle.