(b) The effective energy at the receiving end is expressed by the below equation that reduces the station service rate by 0.3% and transmission loss rate by 0.7% from the average energy for the 43 year period.

$$\text{Effective Energy} = (1 - 0.003) \times (1 - 0.007) \times \text{Average annual energy}$$

### Table 9-6 Alternative Thermal Power Plant for Comparative Study

| Item | Unit | Description | |
|---|---|---|---|
| Type | | Coal Fired Power Plant | |
| Installed Capacity | MW | 300 | |
| Annual Plant Factor | % | 70 | |
| Thermal Efficiency | % | 38.3 | |
| Annual Energy Production | GWh | 1,839.6 | |
| Investment Cost | $10^6$ TL | 4,019,400 | |
| Service Life | Years | 25 | |
| Construction Period | Years | 4 | |
| Capital Recovery Factor | | 0.10596 | |
| Coal Calorific Value | kcal/kg | 6,500 | |
| Coal Surface Moisture | % | 7 | |
| Oil Calorific Value | Kcal/kg | 10,500 | |
| Fuel Consumption Rate (Coal 95%) | kg/kWh | 0.353 | |
| Fuel Consumption Rate (Oil 5%) | kg/kWh | 0.011 | |
| O & M Cost, Administration Cost | % | 3.0 | |
| Unit Fuel Cost (Coal) | TL/kg | 417.6 | |
| Unit Fuel Cost (Oil) | TL/kg | 1,113.6 | |
| **Annual Cost** | | **Fixed Cost** | **Variable Cost** |
| Capital Recovery | $10^6$ TL | 425,895.6 | - |
| O & M Cost, Administration Cost | $10^6$ TL | 108,523.8 | 12,058.2 |
| Fuel Cost | $10^6$ TL | - | 293,715.0 |
| Total | $10^6$ TL | 534,419.4 | 305,773.2 |
| Annual Cost at Receiving End | | | |
| kW Cost | TL/kW | 2,326,506[1)] | |
| kWh Cost | TL/kWH | | 184.33[2)] |

1) $$\frac{534,419.4 \times 10^6 TL}{300,000 kW} \times 1.306^{3)} = 2,326,506$$

2) $$\frac{305,773.2 \times 10^6 TL}{1,839.6 \times 10^6 kWh} \times 1.109^{3)} = 184.33$$

3) Adjustment Factor for kW & kWh

| Item | kW | kWh |
|---|---|---|
| Transmission Loss Rate (%) | 1.4 | 1.1 |
| Station Service Rate (%) | 8.1 | 8.8 |
| Forced Outage Rate (%) | 4.0 | - |
| Scheduled Outage Rate (%) | 12.0 | - |

$$\text{kW Adjustment Factor} = \frac{1}{(1-0.014) \times (1-0.081) \times (1-0.04) \times (1-0.12)} = 1.306$$

$$\text{kWh Adjustment Factor} = \frac{1}{(1-0.011) \times (1-0.088)} = 1.109$$

### 9.2.2 Layout

In the Master Plan Report, only the name of the Kesedağ site, 1 km upstream, other than the dam site presently projected was mentioned regarding an alternative to the Köprübaşı Project, while concerning the present plan, comparison studies were carried out only of dam heights and power station scales, no study being made at all about alternative layouts of dam site, waterway route, etc.

Therefore, the studies below were made regarding selection of alternative plans for development based on the results of review of the Master Plan Report and the results of field reconnaissances.

(1) Dam Site

The Master Plan Report, proposes a site 5.8 km downstream of Kesebük village (1.5 km northeast of Kesebük village) as the dam site (referred to as "M/P dam site"), with the high water level at EL. 437 m, the limit topographically, while the effective storage capacity is put as 200 x $10^6$ $m^3$. Besides the Kesedağ site 1 km Upstream, the site 2.5 upstream of M/P Dam has the topographical and geological conditions to become a dam site (referred to as "upstream dam site"). Because of topographic condition it is difficult to secure an effective storage capacity of 200 x $10^6$ $m^3$ at these sites practically. It is thought that these were not made concrete objects of comparison studies in the Master Plan Report because of this.

In the present study, optimization of storage capacity was taken into consideration,and as shown in Figure 9-4, the abovementioned Upstream dam site was selected as the alternative dam site, and upon a comparison study with the M/P dam site, the appropriateness of the M/P dam site was to be confirmed. As for the Kesedağ dam site, it was decided to omit it from consideration since the valley width is large and the left-bank side ridge is thin.

The catchment areas at the dam sites, as a result of measurements by 1/250,000 and 1/25,000 topographic maps, were set as 1,994 $km^2$ for the Master Plan dam site, and 1,959 $km^2$ for the Upper dam site. The storage capacities at the dam sites were measured by 1/5,000 topographic maps. The storage-capacity curve for the Master Plan dam site is shown in Figure 9-5 and that for the Upper dam site in Figure 9-6.

(2) Waterway Route, Powerhouse Site

In the Master Plan Report it is proposed that the waterway route and powerhouse would be such that the intake and outlet would be connected by the shortest route, and there is no mention of comparison studies with alternative waterway routes and powerhouse sites.

With the waterway route and powerhouse site proposed in the Master Plan Report (hereinafter referred to as "M/P Layout") the penstock length will be very long and the tendency will be for construction cost and head loss to be increased. Consequently, with the purpose of shortening the penstock length, alternative layouts of three waterway routes, A, B, and C, with the headrace tunnel, surface-type penstock, semi-underground powerhouse, and open-canal tailrace as shown in Figure 9-4 were selected on the ridge to the west of the M/P Layout.

Further, although with the abovementioned A, B, and C layouts penstock lengths would be respectively shortened, lengths would still be long and the overall waterway routes including headrace tunnels would be longer than for the M/P Layout. Furthermore, since the headrace tunnels of all of the layouts, M/P, A, B, and C, would pass through a zone expected to have weathering reaching deep inside with earth cover comparatively thin as described in 7.3, a D layout with a tunnel type penstock and underground powerhouse arranged immediately downstream of the intake, and with connection to the outlet site made by a tailrace tunnel in a straight line was considered for a total of five alternatives.

(3) Formulation of Alternative Development Plan

For the alternative development plan, combinations of the M/P dam and the Upstream dam with the M/P, A, B, C, and D layouts were made with cases set up according to effective storage capacity. The output of the power station was determined by calculating maximum power discharge with equivalent peak duration as 6 hours.

The annual sediment volume at the dam site will be as described in 6.4.7. It was decided that the design sediment volume of the reservoir would take into account sedimentation for a 50 year period, with the base of intake at the same elevation as the design sediment surface level.

**Table 9-7 Sediment Surface Level and Low Water Level of Köprübaşı Reservoir**

| Dam Site | Catchment Area ($km^2$) | Design Sediment Surface Level (m) | Low Water Level (m) |
|---|---|---|---|
| M/P Dam | 1,994 | EL. 380.40 | EL. 392.00 |
| Upper Dam | 1,959 | EL. 388.40 | EL. 400.00 |

The tail water level was decided at the same elevation as the water level of the Devrek River at the point of tailrace end of the Köprübaşı Project.

The characteristics of the various alternative plans are given in Table 9-8.

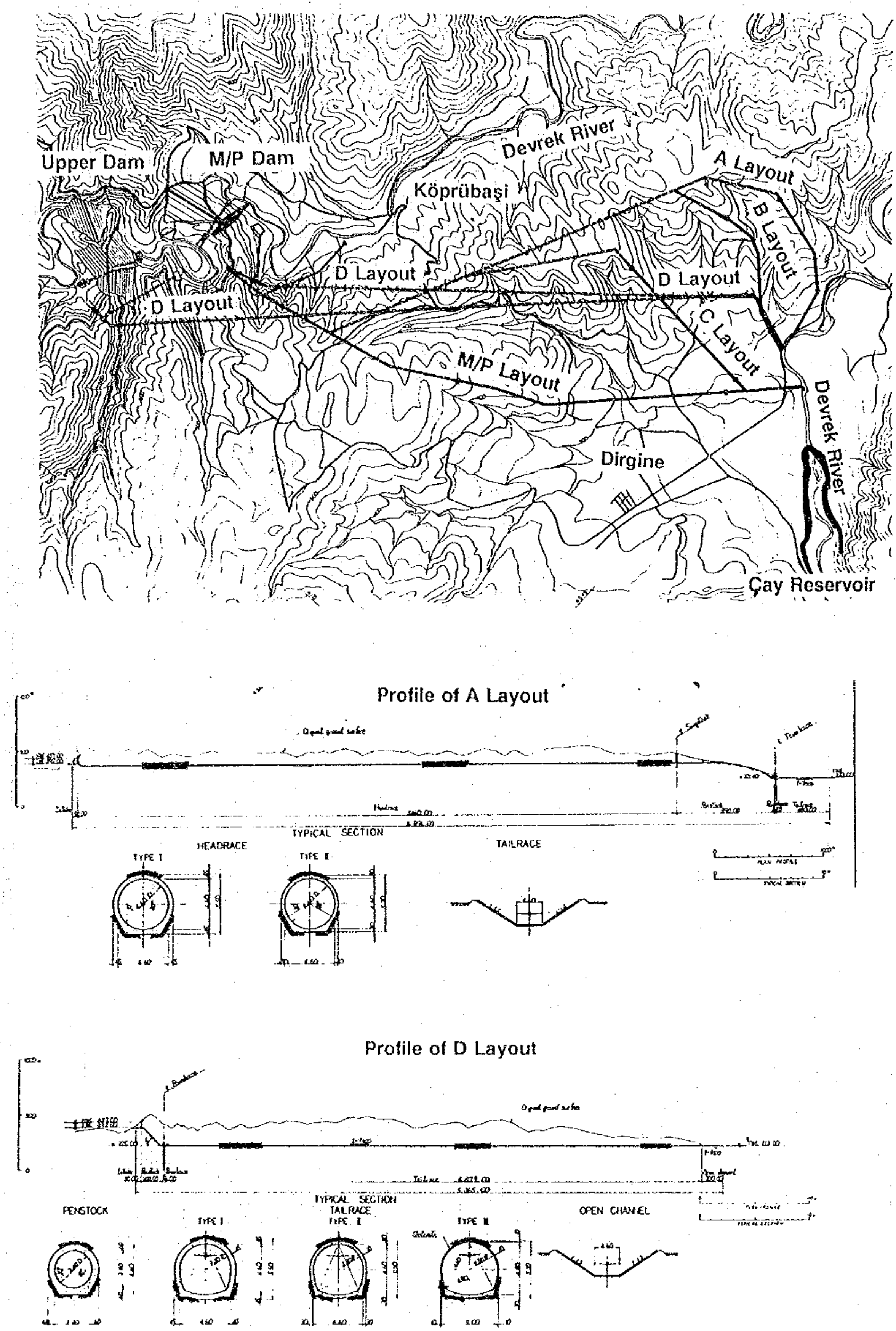



**Figure 9-4 Alternative Development Plan of Köprübaşı Project**

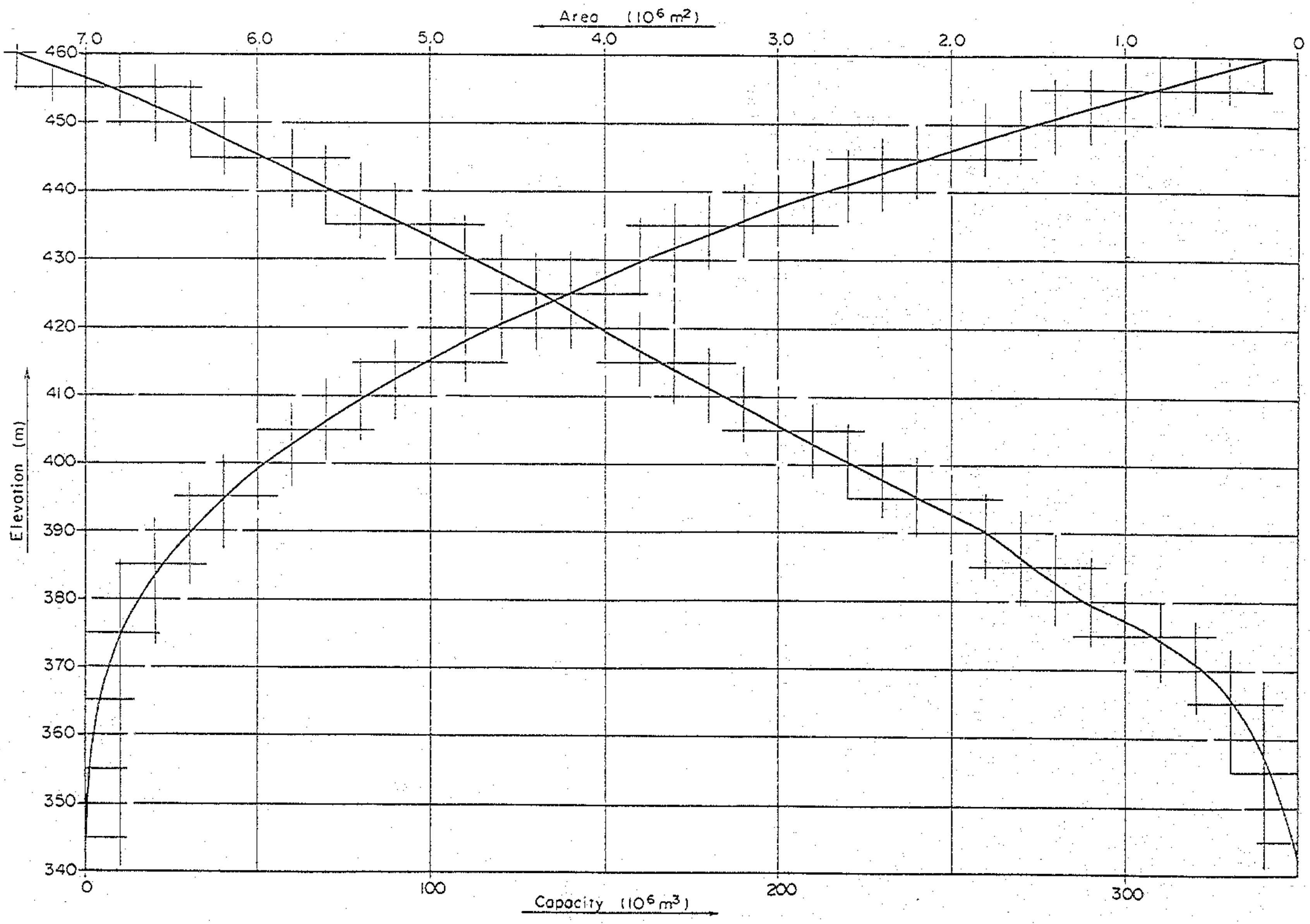



Figure 9-5 Area-Capacity Curve at M/P Dam Site

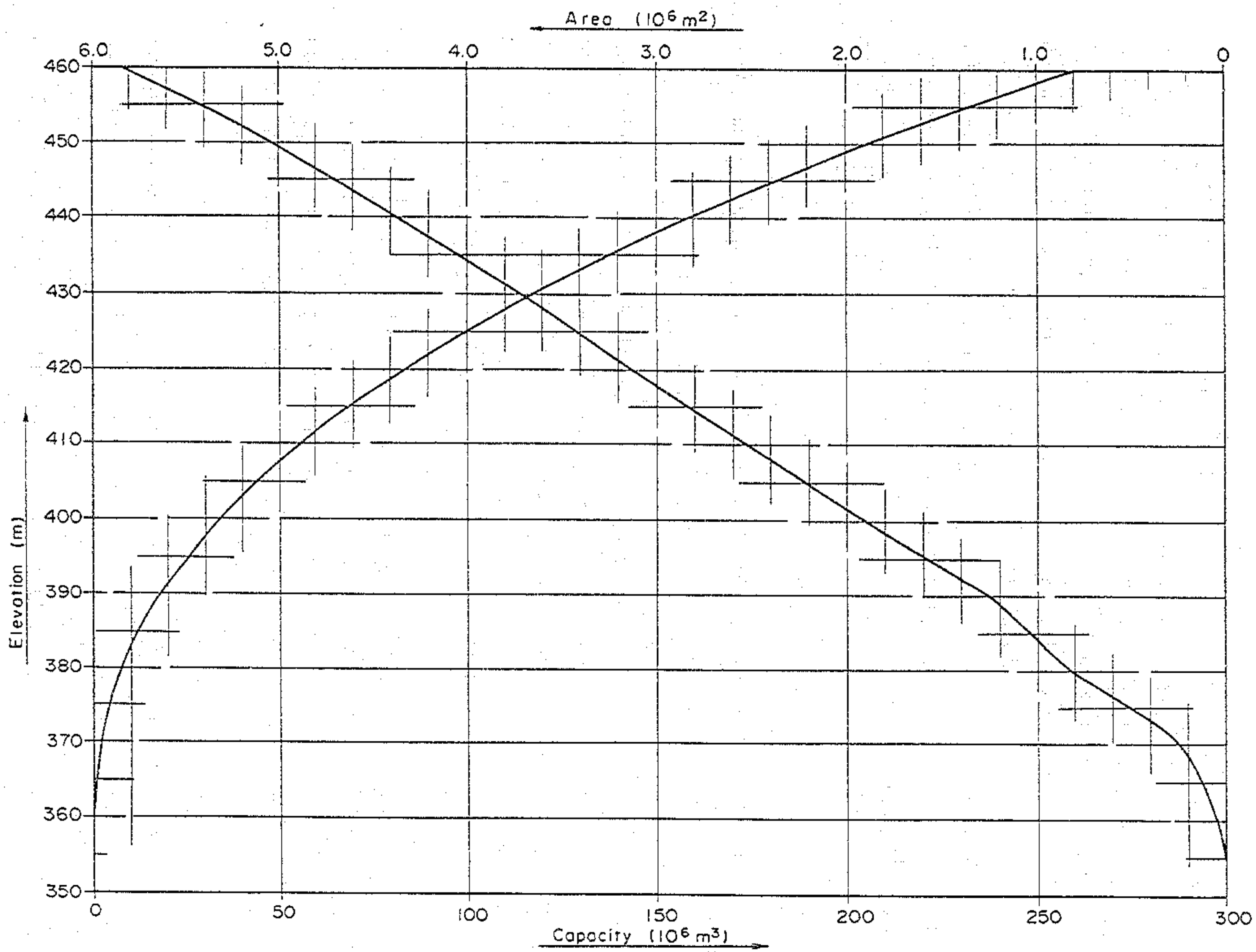



**Figure 9-6 Area-Capacity Curve at Upper Dam Site**

## (4) Results of Comparison Studies of Alternative Development Plans

Comparison studies of the various alternative development plans were carried out combining the M/P Dam and the Upper Dam with the waterway routes of M/P, A, B, C, and D, while for the A and D routes, the effective storage capacities of M/P Dam and Upper Dam were varied at nine levels between $200 \times 10^5$ $m^3$ and $25 \times 10^5$ $m^3$. The outline of alternative development plan concerning layout are given in Table 9-8. The results of the studies are given in Table 9-9 and Figure 9-7.

### a) Dam Sites

Comparison study of M/P dam site and upper dam site with D layout was carried out.

The Upper dam site has a saddle of EL. 435 m existing at the back of the right abutment and a necessity to provide an auxiliary dam at that part will arise if the effective storage capacity is set at more than 100 $\times 10^6$ $m^3$, and the economics would be abruptly worsened.

With the M/P dam site, it is judged that the upper limit of high-water level would be geologically EL. 437 m and the effective water storage of $163 \times 10^6 m^3$ as previously mentioned, and the economics would be of a similar trend.

The M/P dam site is economically superior to the Upper dam site because (i) economics of M/P dam site is superior than that of upper dam site with D layout and (ii) order of economics of waterway route is D, A, B, C and M/P as described in b).

The superiority does not change no matter what combination with waterway route and powerhouse type is made.

b) Waterway Route, Powerhouse Type

In comparisons of the A, B, and C routes, which are headrace tunnel, surface-type penstock, and surface-type powerhouse schemes, Route A with the shortest penstock length will be superior economically to the others.

In the comparison of the route D with underground powerhouses and tailraces and route A, the route D is economically superior.

Route D, compared with Route A, not only will have a lower construction cost, but head loss will be less, and the output and electric energy production will be more than for Route A. Regarding the construction period for Route D, the underground powerhouse will not be the critical path and 4 years will be sufficient, the same as for Route A.

Thus, Route D with an underground powerhouse will be selected for the waterway route and powerhouse type.

Therefore, the dam is to be the M/P dam, a tunnel-type penstock and underground powerhouse are to be located immediately downstream of the intake, and the tailrace is to be a non-pressurized tunnel with the end portion an open canal. This alternative plan is to be taken as the optimum alternative development plan concerning layout. Optimization is to be carried out on reservoir scale, dam height, and power generation scale of this alternative plan.

## Table 9-8 Outline of Alternative Development Plan Concerning Layout (1)

| Name of Case | | UP-D200 | UP-D175 | UP-D150 | UP-D125 | UP-D100 | UP-D75 | UP-D50 | UP-D25 | MP-D200 | MP-D175 | MP-D163 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | Upper | | | | | | | | M/P | | |
| Waterway Route | | D | | | | | | | | D | | |
| **Reservoir** | | | | | | | | | | | | |
| Catchment Area | $Km^2$ | 1,959.00 | 1,959.00 | 1,959.00 | 1,959.00 | 1,959.00 | 1,959.00 | 1,959.00 | 1,959.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 455.40 | 450.60 | 445.50 | 440.00 | 434.10 | 427.40 | 419.90 | 411.10 | 443.60 | 439.20 | 437.00 |
| Low Water Level | m | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 392.00 | 392.00 | 392.00 |
| Available Drawdown | m | 55.40 | 50.60 | 45.50 | 40.00 | 34.10 | 27.40 | 19.90 | 11.10 | 51.60 | 47.20 | 45.00 |
| Gross Storage Capacity | $10^6m^3$ | 233 | 208 | 183 | 158 | 133 | 108 | 83 | 58 | 234 | 209 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 200 | 175 | 150 | 125 | 100 | 75 | 50 | 25 | 200 | 175 | 163 |
| **Dam** | | | | | | | | | | | | |
| Type | | | | | | | | | | | | |
| Height from Foundation | m | 113 | 109 | 104 | 98 | 92 | 85 | 78 | 69 | 117 | 112 | 110 |
| Crest Length | m | 940 | 850 | 750 | 590 | 390 | 300 | 270 | 240 | 600 | 560 | 540 |
| Volume | $10^6m^3$ | 9,189 | 7,603 | 5,942 | 4,179 | 2,803 | 2,021 | 1,372 | 1,210 | 6,152 | 5,334 | 5,025 |
| **Headrace Tunnel** | | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | - | - | - | - | - |
| Diameters | m | - | - | - | - | - | - | - | - | - | - | - |
| Length | m | - | - | - | - | - | - | - | - | - | - | - |
| **Penstock** | | | | | | | | | | | | |
| Type | | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface |
| Diameters | m | 3.5 | 3.4 | 3.3 | 3.2 | 3.2 | 3.0 | 2.7 | 2.3 | 3.5 | 3.4 | 3.4 |
| Length | m | 282.00 | 282.00 | 282.00 | 282.00 | 282.00 | 282.00 | 282.00 | 282.00 | 271.00 | 271.00 | 271.00 |
| **Powerhouse** | | | | | | | | | | | | |
| Type | | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface | Surface |
| **Tailrace Tunnel** | | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure |
| Diameters | m | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 3.9 | 3.5 | 4.7 | 4.6 | 4.6 |
| Length | m | 6,270.00 | 6,270.00 | 6,270.00 | 6,270.00 | 6,270.00 | 6,270.00 | 6,270.00 | 6,270.00 | 4,899.00 | 4,899.00 | 4,899.00 |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| **Development Plan** | | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 45 | 43 | 41 | 39 | 37 | 34 | 27 | 20 | 46 | 44 | 43 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 213.93 | 210.73 | 207.33 | 203.67 | 199.73 | 195.27 | 190.27 | 184.40 | 203.40 | 200.47 | 199.00 |
| Loss of Head | m | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 9.00 | 9.00 | 9.00 |
| Effective Head | m | 203.93 | 200.73 | 197.33 | 193.67 | 189.73 | 185.27 | 180.27 | 174.40 | 194.40 | 191.47 | 190.00 |
| Installed Capacity | MW | 79 | 74 | 70 | 65 | 60 | 54 | 42 | 30 | 76 | 72 | 70 |

## Table 9-8 Outline of Alternative Development Plan Concerning Layout (2)

| Name of Case | | MP-D150 | MP-D125 | MP-D100 | MP-D75 | MP-D50 | MP-D25 | MP-MP163 | MP-A163 | MP-B163 | MP-C163 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | |
| Waterway Route | | D | | | | | | M/P | A | B | C |
| Reservoir | | | | | | | | | | | |
| Catchment Area | $Km^2$ | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 434.50 | 429.40 | 423.90 | 417.80 | 410.90 | 402.60 | 437.00 | 437.00 | 437.00 | 437.00 |
| Low Water Level | m | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 |
| Available Drawdown | m | 42.50 | 37.40 | 31.90 | 25.80 | 18.90 | 10.60 | 45.00 | 45.00 | 45.00 | 45.00 |
| Gross Storage Capacity | $10^6m^3$ | 184 | 159 | 134 | 109 | 84 | 59 | 197 | 197 | 197 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 150 | 125 | 100 | 75 | 50 | 25 | 163 | 163 | 163 | 163 |
| Dam | | | | | | | | | | | |
| Type | | | | | | | | | | | |
| Height from Foundation | m | 108 | 102 | 97 | 91 | 84 | 76 | 110 | 110 | 110 | 110 |
| Crest Length | m | 530 | 520 | 490 | 430 | 400 | 370 | 540 | 540 | 540 | 540 |
| Volume | $10^6m^3$ | 4,689 | 4,052 | 3,436 | 2,844 | 2,284 | 1,654 | 5,025 | 5,025 | 5,025 | 5,025 |
| Headrace Tunnel | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | Pressure | Pressure | Pressure | Pressure |
| Diameters | m | - | - | - | - | - | - | 4.6 | 4.6 | 4.6 | 4.6 |
| Length | m | - | - | - | - | - | - | 2,300.00 | 5,460.00 | 4,970.00 | 3,980.00 |
| Penstock | | | | | | | | | | | |
| Type | | Embedded is tunnel | Embedded is tunnel | Embedded is tunnel | Embedded is tunnel | Embedded is tunnel | Embedded is tunnel | Surface | Surface | Surface | Surface |
| Diameters | m | 3.4 | 3.3 | 3.2 | 3.0 | 2.7 | 2.4 | 3.4 | 3.4 | 3.4 | 3.4 |
| Length | m | 271.00 | 271.00 | 271.00 | 271.00 | 271.00 | 271.00 | 2,500.00 | 890.00 | 1,180.00 | 1,430.00 |
| Powerhouse | | | | | | | | | | | |
| Type | | Underground | Underground | Underground | Underground | Underground | Underground | Surface | Surface | Surface | Surface |
| Tailrace Tunnel | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | - | - | - | - |
| Diameters | m | 4.5 | 4.4 | 4.3 | 4.2 | 3.9 | 3.5 | - | - | - | - |
| Length | m | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | - | - | - | - |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 700.00 | 480.00 | 230.00 | 630.00 |
| Development Plan | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 42 | 40 | 37 | 34 | 27 | 21 | 43 | 43 | 43 | 43 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 222.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 197.33 | 193.93 | 190.27 | 186.20 | 181.60 | 176.07 | 200.00 | 199.00 | 199.00 | 199.00 |
| Loss of Head | m | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 21.00 | 14.00 | 14.00 | 15.00 |
| Effective Head | m | 188.33 | 184.93 | 181.27 | 177.20 | 172.60 | 167.07 | 179.00 | 185.00 | 185.00 | 184.00 |
| Installed Capacity | MW | 67 | 63 | 57 | 51 | 39 | 30 | 66 | 68 | 68 | 67 |

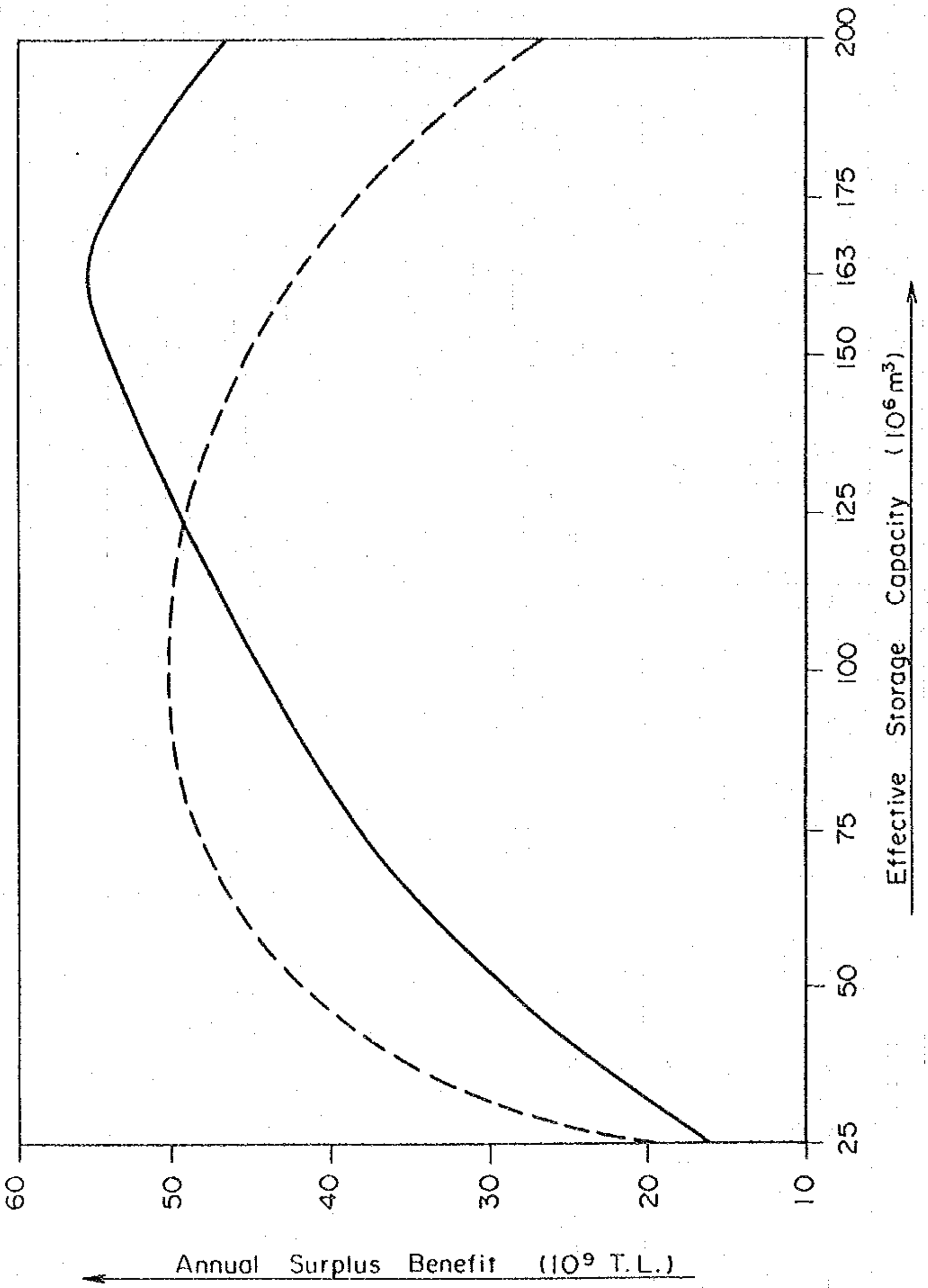



Figure 9-7 Comparative Study on Dam Site

## Table 9-9 Comparative Study on Alternative Development Plan Concerning Layout (1)

| Description | Name of Case | UP-D200 | UP-D175 | UP-D150 | UP-D125 | UP-D100 | UP-D75 | UP-D50 | UP-D25 | MP-D200 | MP-D175 | MP-D163 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | Upper | | | | | | | | M/P | | |
| Waterway Route | | D | | | | | | | | D | | |
| High Water Level | m | 455.40 | 450.60 | 445.50 | 440.00 | 434.10 | 427.40 | 419.90 | 411.10 | 443.60 | 439.20 | 437.00 |
| Low Water Level | m | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 392.00 | 392.00 | 392.00 |
| Available Drawdown | m | 55.40 | 50.60 | 45.50 | 40.00 | 34.10 | 27.40 | 19.90 | 11.10 | 51.60 | 47.20 | 45.00 |
| Gross Storage Capacity | $10^6m^3$ | 233 | 208 | 183 | 158 | 133 | 108 | 83 | 58 | 234 | 209 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 200 | 175 | 150 | 125 | 100 | 75 | 50 | 25 | 200 | 175 | 163 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 203.93 | 200.73 | 197.33 | 193.67 | 189.73 | 185.27 | 174.40 | 194.40 | 194.40 | 191.47 | 190.00 |
| Maximum Discharge | $m^3/s$ | 45 | 43 | 41 | 39 | 37 | 34 | 27 | 20 | 46 | 44 | 43 |
| Installed Capacity | MW | 79 | 74 | 70 | 65 | 60 | 54 | 42 | 30 | 76 | 72 | 70 |
| Firm Peak Power | MW | 71.3 | 69.1 | 66.3 | 60.5 | 55.8 | 50.2 | 41.0 | 29.2 | 68.6 | 67.2 | 66.0 |
| Energy Production | | | | | | | | | | | | |
| Average Energy | GWh | 226.9 | 220.5 | 218.7 | 209.7 | 207.1 | 199.8 | 186.2 | 150.5 | 218.3 | 214.6 | 212.1 |
| Firm Energy | GWh | 172.9 | 160.5 | 153.9 | 140.8 | 131.9 | 118.6 | 93.7 | 65.4 | 166.3 | 156.2 | 151.8 |
| Unit Benefit Value | | | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 158.2 | 153.2 | 147.2 | 134.1 | 123.8 | 111.4 | 91.0 | 64.8 | 153.3 | 150.2 | 147.5 |
| Average Energy | $10^9$T.L. | 41.1 | 40.0 | 39.6 | 38.0 | 37.5 | 36.2 | 33.7 | 27.3 | 39.2 | 39.2 | 38.7 |
| Total | $10^9$T.L. | 199.3 | 193.2 | 186.8 | 172.1 | 161.3 | 147.6 | 124.8 | 92.1 | 193.1 | 189.3 | 186.2 |
| Investment Cost | | | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 1,298.2 | 1,160.2 | 1,015.1 | 873.5 | 753.6 | 653.8 | 527.8 | 462.5 | 1,049.8 | 959.1 | 916.0 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 372.1 | 357.0 | 348.0 | 331.9 | 318.1 | 303.8 | 267.5 | 232.0 | 353.6 | 338.4 | 334.3 |
| Total | $10^9$T.L. | 1,670.3 | 1,517.2 | 1,363.1 | 1,205.4 | 1,071.8 | 957.5 | 795.3 | 694.5 | 1,403.4 | 1,297.5 | 1,250.3 |
| Annual Cost | | | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 131.1 | 117.2 | 102.5 | 88.2 | 76.1 | 66.0 | 53.3 | 46.7 | 106.0 | 96.9 | 92.5 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 42.4 | 40.7 | 39.7 | 37.8 | 36.3 | 34.6 | 30.5 | 26.5 | 40.3 | 38.6 | 38.1 |
| Total | $10^9$T.L. | 173.5 | 157.9 | 142.2 | 126.1 | 112.4 | 100.7 | 83.8 | 73.2 | 146.3 | 135.4 | 130.6 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 27.2 | 36.7 | 46.0 | 47.3 | 50.1 | 48.0 | 41.9 | 19.6 | 46.8 | 53.9 | 55.6 |
| Benefit Cost Ratio (B/C) | | 1.16 | 1.23 | 1.32 | 1.38 | 1.45 | 1.48 | 1.50 | 1.27 | 1.32 | 1.40 | 1.43 |
| Unit Annual Cost | T.L./KWh | 765 | 716 | 650 | 601 | 543 | 504 | 450 | 486 | 670 | 631 | 616 |

## Table 9-9 Comparative Study on Alternative Development Plan Concerning Layout (2)

| Description | Name of Case | MP-D150 | MP-D125 | MP-D100 | MP-D75 | MP-D50 | MP-D25 | MP-MP163 | MP-A163 | MP-B163 | MP-C163 | MP-D163 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | | |
| Waterway Route | | D | | | | | | M/P | A | B | C | D |
| High Water Level | m | 434.50 | 429.40 | 423.90 | 417.80 | 410.90 | 402.60 | 437.00 | 437.00 | 437.00 | 437.00 | 437.00 |
| Low Water Level | m | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 | 329.00 | 392.00 | 392.00 | 392.00 | 392.00 | 392.00 |
| Available Drawdown | m | 42.50 | 37.40 | 31.90 | 25.80 | 18.90 | 10.60 | 45.00 | 45.00 | 45.00 | 45.00 | 45.00 |
| Gross Storage Capacity | $10^6m^3$ | 184 | 159 | 134 | 109 | 84 | 59 | 197 | 197 | 197 | 197 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 150 | 125 | 100 | 75 | 50 | 25 | 163 | 163 | 163 | 163 | 163 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 222.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 188.33 | 184.93 | 181.27 | 177.20 | 172.60 | 167.07 | 179.00 | 185.00 | 185.00 | 184.00 | 190.00 |
| Maximum Discharge | $m^3/s$ | 42 | 40 | 37 | 34 | 27 | 21 | 43 | 43 | 43 | 43 | 43 |
| Installed Capacity | MW | 67 | 63 | 57 | 51 | 39 | 30 | 66 | 68 | 68 | 67 | 70 |
| Firm Peak Power | MW | 63.5 | 58.6 | 53.0 | 47.4 | 38.1 | 29.2 | 62.2 | 64.3 | 64.3 | 63.9 | 66.0 |
| Energy Production | | | | | | | | | | | | |
| Average Energy | GWh | 209.3 | 203.3 | 196.8 | 188.7 | 172.9 | 150.5 | 199.8 | 206.5 | 206.5 | 205.4 | 212.1 |
| Firm Energy | GWh | 147.3 | 136.5 | 125.3 | 112.0 | 87.0 | 65.4 | 143.0 | 147.8 | 147.8 | 147.0 | 151.8 |
| Unit Benefit Value | | | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.3 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 141.9 | 130.9 | 118.4 | 105.9 | 85.1 | 65.3 | 138.9 | 143.6 | 143.6 | 142.8 | 147.5 |
| Average Energy | $10^9$T.L. | 38.2 | 37.1 | 35.9 | 34.4 | 31.5 | 27.5 | 36.5 | 37.7 | 37.7 | 37.5 | 38.7 |
| Total | $10^9$T.L. | 180.1 | 168.0 | 154.3 | 140.4 | 116.7 | 92.7 | 175.4 | 181.3 | 181.3 | 180.3 | 186.2 |
| Investment Cost | | | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 883.3 | 818.8 | 749.2 | 680.5 | 602.1 | 509.9 | 900.0 | 977.1 | 962.2 | 955.2 | 916.0 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 326.6 | 314.1 | 301.9 | 287.2 | 251.9 | 223.1 | 460.2 | 350.8 | 373.4 | 389.1 | 334.3 |
| Total | $10^9$T.L. | 1,210.0 | 1,132.9 | 1,051.1 | 967.6 | 854.0 | 733.0 | 1,360.2 | 1,327.9 | 1,335.6 | 1,344.3 | 1,250.3 |
| Annual Cost | | | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 89.2 | 82.7 | 75.7 | 68.7 | 60.8 | 51.5 | 90.9 | 98.7 | 97.2 | 96.5 | 92.5 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 37.2 | 35.8 | 34.4 | 32.7 | 28.7 | 25.4 | 52.5 | 40.0 | 42.6 | 44.4 | 38.1 |
| Total | $10^9$T.L. | 126.5 | 118.5 | 110.1 | 101.5 | 89.5 | 76.9 | 143.4 | 138.7 | 139.8 | 140.8 | 130.6 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 53.6 | 49.5 | 44.2 | 38.9 | 27.2 | 15.8 | 32.0 | 42.6 | 41.5 | 39.5 | 55.6 |
| Benefit Cost Ratio (B/C) | | 1.42 | 1.42 | 1.40 | 1.38 | 1.30 | 1.21 | 1.22 | 1.31 | 1.30 | 1.28 | 1.43 |
| Unit Annual Cost (Average) | T.L./KWh | 604 | 583 | 560 | 538 | 518 | 511 | 717 | 671 | 677 | 686 | 616 |

### 9.2.3 Reservoir Scale

(1) Reservoir Operation Study

The annual average inflow at the Köprübaşı dam site is 14.39 $m^3/s$, with the snowmelt period of March to May corresponding to the high water season, 60% of the annual inflow occurring during this period. The inflow during December to February corresponding to the low water season has 8% of the annual inflow, and the seasonal variation range of inflow is not narrow. The minimum value of annual inflow is 37% of the average inflow, and the maximum value 164%. The maximum value of annual inflow is 4.5 times the minimum value.

As described above, inflows at the Köprübaşı project site have fairly large seasonal and annual fluctuations, and a certain degree of reservoir capacity is necessary for effective utilization for power generation.

As reservoir capacity for the Köprübaşı Project, it is possible to obtain an effective storage capacity of 163 x $10^6$ $m^3$ at high water level elevation of 437 m. With regulating capacity of this degree it will not be possible to completely average out inflow, but it will be possible for spillover from the reservoir to be held to a minimum.

The reservoir operation rules of Köprübaşı Reservoir have been determined for each study case, based on considerations on the following factors.

(a) The river water in a wet year is to be stored and released in a dry year, to make the firm discharge as large as possible.

(b) During a year, the reservoir is to be operated in such a way that the water in the wet season is to be stored and supplied in the dry season.

(c) The reservoir is to be operated so that the spill is as small as possible.

(d) The reservoir is to be operated so that a stable supply of power is assured for a long period and at the same time the energy generation is large.

The calculations of reservoir operation have been performed by an electronic computer system, and based on the monthly average inflow, for the period of 36 years from October 1956 to September 1991.

The firm discharge is defined as the discharge which can be utilized for power generation at all times during 95% of the 36 year period, and it is obtained by making it the largest with the inflow mass curve considering carry over storage. The inflow mass curve and the effective storage capacity and the firm discharge are shown in Figure 9-8 and 9-9 respectively. In the operation calculations of the reservoir, amount of evaporation has not been counted because it is negligibly small.

In the calculation, the change of turbine and generator efficiency depending on the change of the reservoir water level has been taken into account. The maximum power discharge is limited by the rated output when the water level is higher than the rated intake water level, and the maximum power discharge is reduced by the reduction of head when the water level is below the rated intake water level.

The rated intake water level was set at an elevation which is below the high water level by 1/3 of the available drawdown.

The procedure of electric energy calculations is shown in Figure 9-10 and the reservoir operation rules in Figure 9-11. As an expediency, the operation rules were made according to the single rule curve of $V_s$ for securing firm

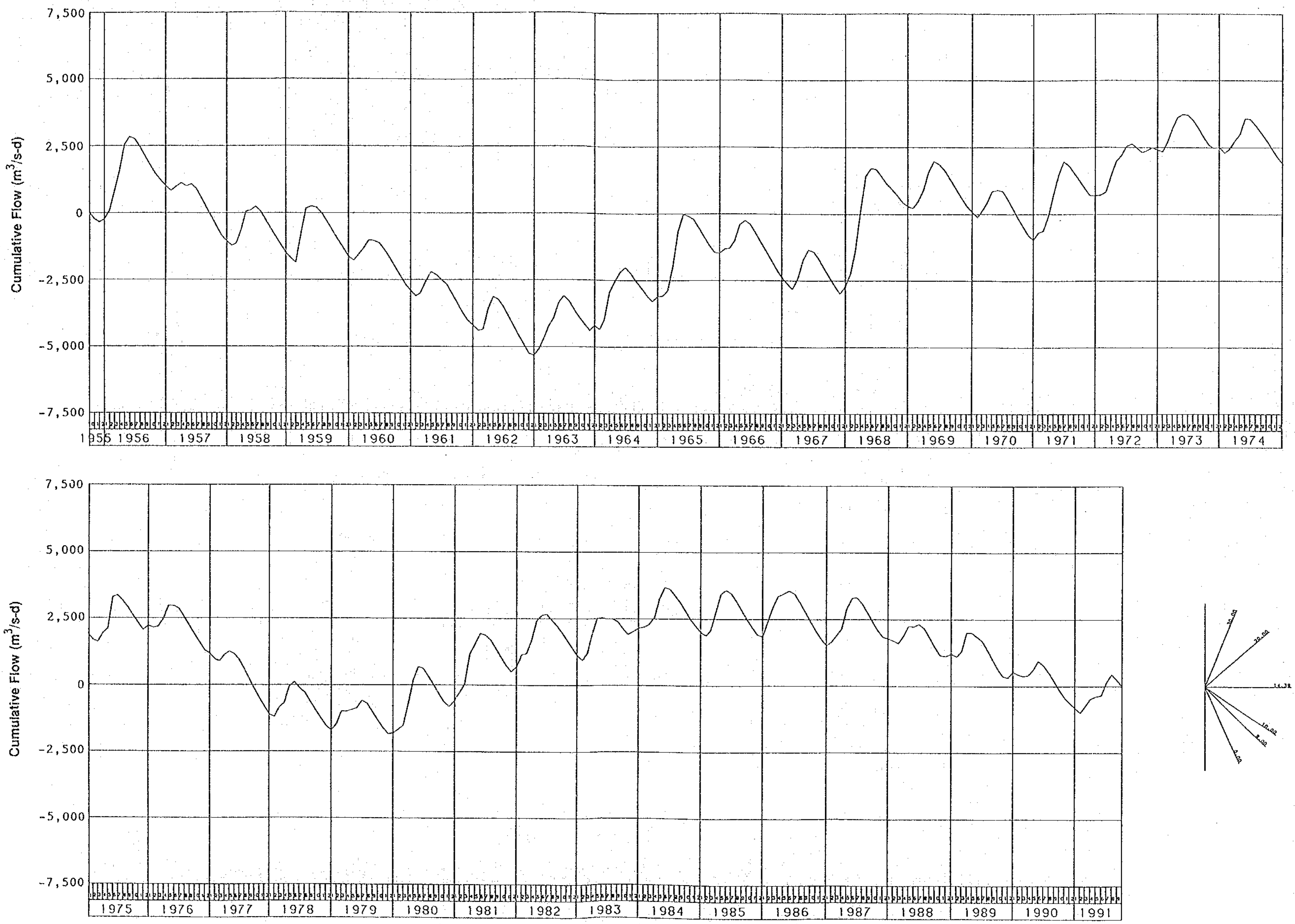



Figure 9-8 Mass Curve at Köprübaşı Dam Site

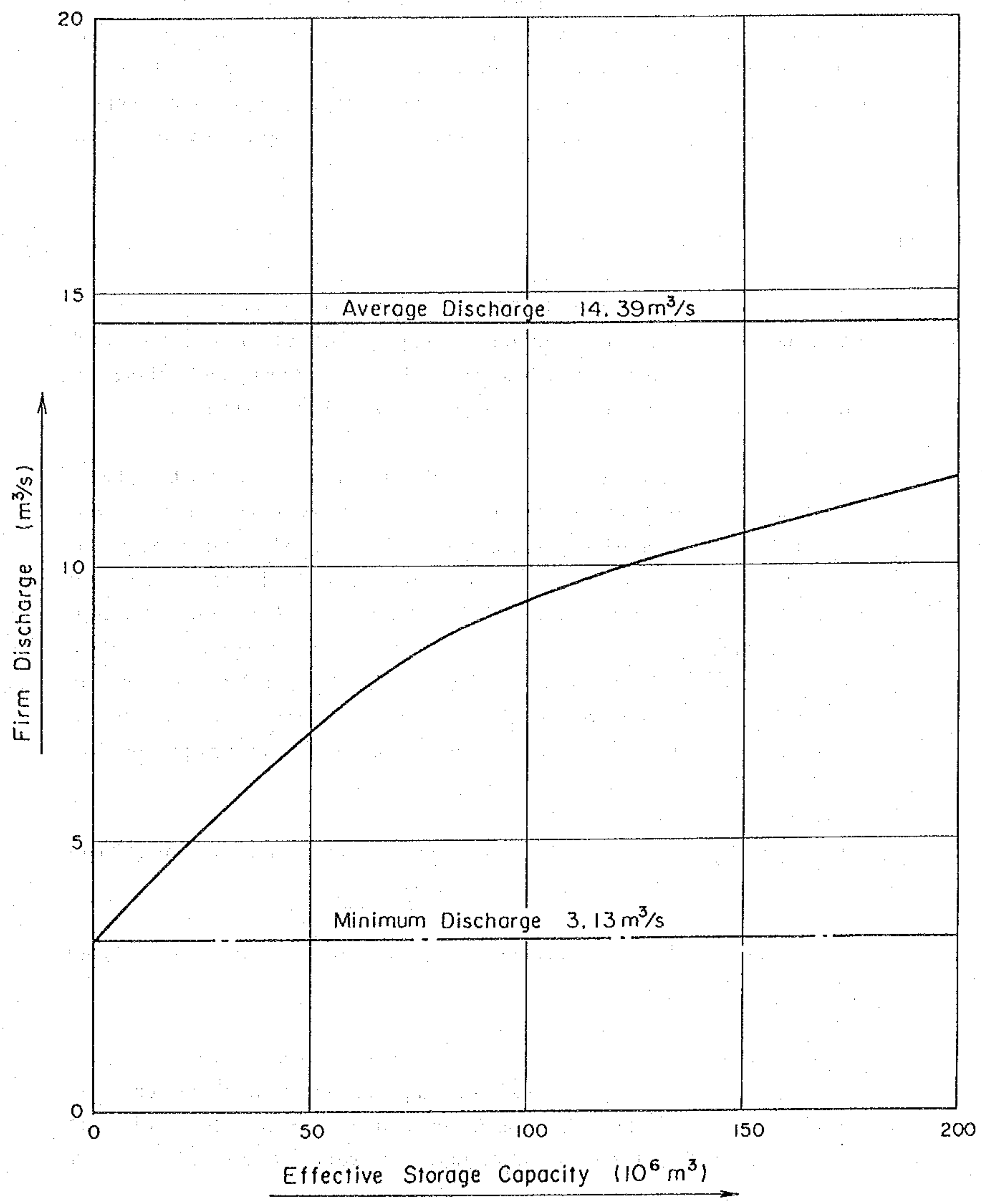



Figure 9-9 Effective Storage Capacity and Firm Discharge at Köprübaşı Dam Site

available water. The $V_s$ was obtained taking inflows for the 36 year period, determining the necessary capacity to be secured for not going under low water level with a probability higher than 95% by discharging firm available water for each case, and the envelope for these points was adopted.

(2) Optimum Reservoir Scale

The high water level and effective storage capacity were to be determined for the economically greatest advantage and various cases were set up for the D layout selected as optimum, upon which comparison studies were made.

In case of optimization of the layout through a combination of dam site and waterway route, the low-water level was fixed at the minimum intake water level according to sedimentation capacity and intake static draft head, by which comparative cases of different effective storage capacities were set up, but in optimization of high water level and effective storage capacity, not only high water level but also low water level was varied so the dam scale according to dam height was made a factor for optimization upon which comparison studies were made.

The outline of alternative development plan concerning reservoir scale are given in Table 9-10.

The results of examinations are given in Table 9-11 and Figure 9-12.

According to the examination results, high water level is low with the same effective storage capacity. That is, the economics is better the smaller the scale of the dam, and there is no merit in raising the low water level aiming for high head.

High-water level at EL. 437.00 m and effective storage capacity of 163 x $10^6$ $m^3$ will be the optimum reservoir scale.

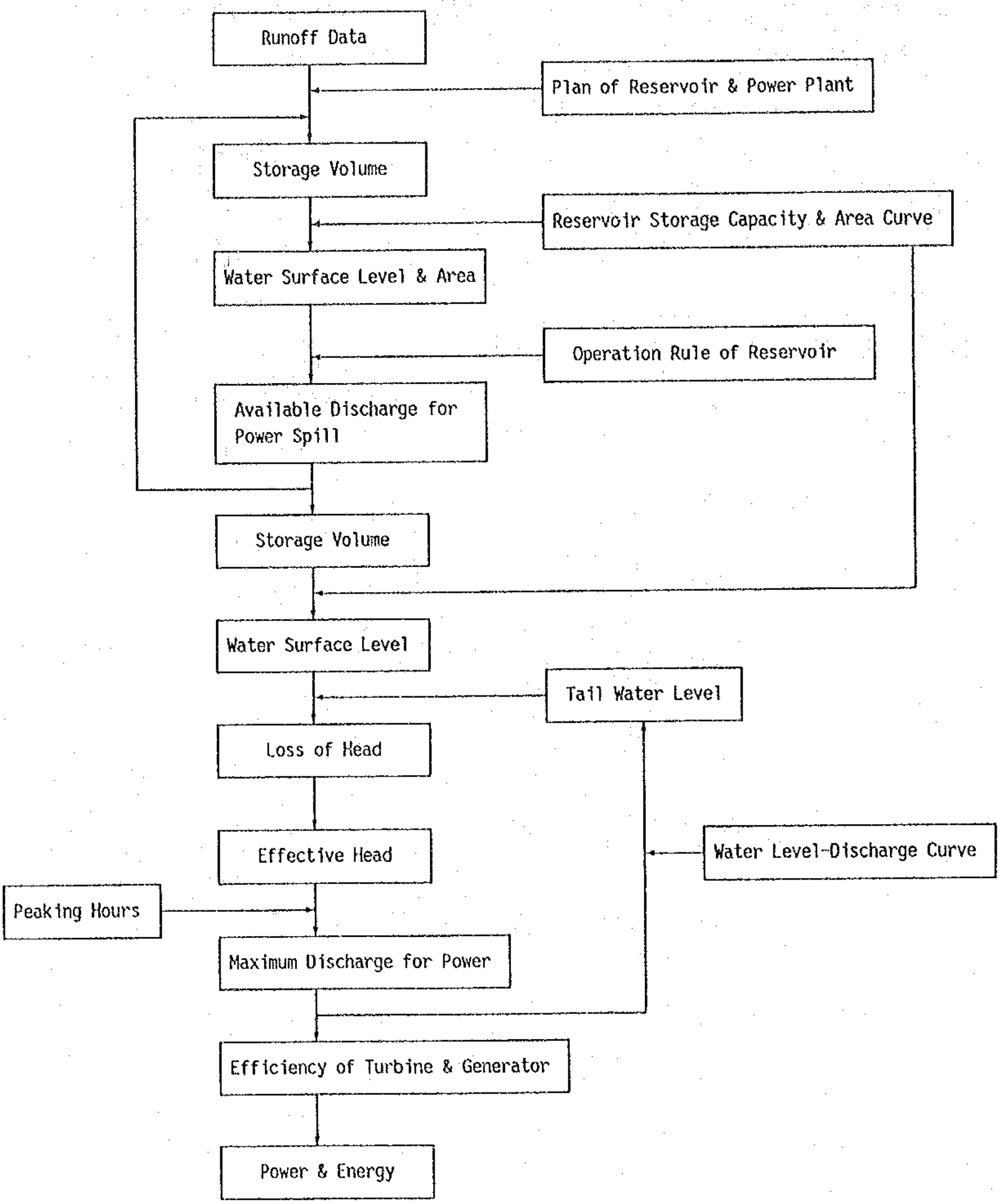
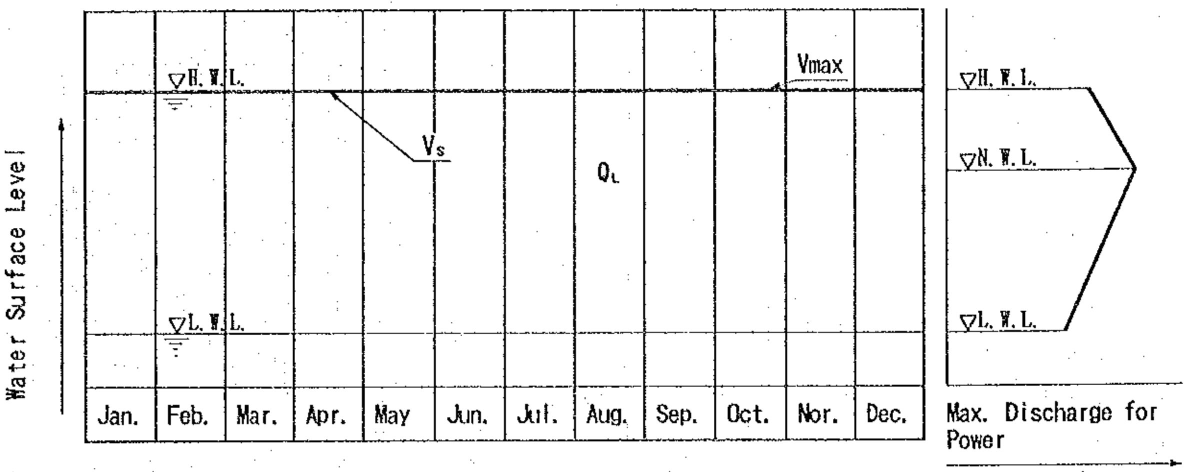



Figure 9-10 Flow Chart of Calculation of Power and Energy




Symbols

| | | |
|---|---|---|
| Vn-1 | : | Storage at the end of previous month |
| Vn | : | Storage at the end of current month |
| Vn' | : | Temporary storage at the end of current month |
| Vmax | : | Maximum storage (Effective storage capacity) |
| Vs | : | Secured storage for firm discharge |
| fn | : | Spill in current month |
| qn | : | Inflow in current month |
| Qn | : | Available discharge for power in current month |
| QL | : | Firm discharge for power |
| QH | : | Maximum discharge for power, variable depending on water level |

Operation Rule

Vń = Vn - 1 + qn

1. Vń ≥ Vmax

   (1) Vń - Vmax ≥ QH → Qn = QH
   (2) QH > Vń - Vmax ≥ QL → Qn = Vń - Vmax
   (3) QL > Vń = Vmax → Qn = QL

2. Vs > Vń

   (1) Vń ≥ QL → QN = QL
   (2) QL > Vń → QN = Vń

Vń = Vmax - Qn ≥ 0.0 → FN = Vń - Vmax - Qn
Vń = Vmax - Qn < 0.0 → fn = 0.0
Vn = Vń - Qn - fn

**Figure 9-11 Operation Rule of Reservoir**

## Table 9-10 Outline of Alternative Development Plan Concerning Reservoir Scale (1)

| Description | Name of Case | MP-D200-1 | MP-D175-1 | MP-D163-1 | MP-D150-1 | MP-D125-1 | MP-D100-1 | MP-D75-1 | MP-D50-1 | MP-D25-1 | MP-D175-2 | MP-D163-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | | |
| Waterway Route | | D | | | | | | | | | | |
| Reservoir | | | | | | | | | | | | |
| Catchment Area | $Km^2$ | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 439.20 | 439.20 |
| Low Water Level | m | 392.00 | 402.60 | 406.80 | 410.90 | 417.80 | 423.90 | 429.40 | 434.50 | 439.20 | 392.00 | 397.40 |
| Available Drawdown | m | 51.60 | 41.00 | 36.80 | 32.70 | 25.80 | 19.70 | 14.20 | 9.10 | 4.40 | 47.20 | 41.80 |
| Gross Storage Capacity | $10^6m^3$ | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 209 | 209 |
| Effective Storage Capacity | $10^6m^3$ | 200 | 175 | 163 | 150 | 125 | 100 | 75 | 50 | 25 | 175 | 163 |
| Dam | | | | | | | | | | | | |
| Type | | | | | | | | | | | | |
| Height from Foundation | m | 117 | 117 | 117 | 117 | 117 | 117 | 117 | 117 | 117 | 112 | 112 |
| Crest Length | m | 590 | 590 | 590 | 590 | 590 | 590 | 590 | 590 | 590 | 560 | 560 |
| Volume | $10^6m^3$ | 6,152 | 6,152 | 6,152 | 6,152 | 6,152 | 6,152 | 6,152 | 6,152 | 6,152 | 5,334 | 5,334 |
| Headrace Tunnel | | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | - | - | - | - | - |
| Diameters | m | - | - | - | - | - | - | - | - | - | - | - |
| Length | m | - | - | - | - | - | - | - | - | - | - | - |
| Penstock | | | | | | | | | | | | |
| Type | | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel |
| Diameters | m | 3.7 | 3.6 | 3.6 | 3.6 | 3.5 | 3.3 | 3.2 | 2.9 | 2.5 | 3.6 | 3.6 |
| Length | m | 271.00 | 285.84 | 291.72 | 297.46 | 307.12 | 315.66 | 323.36 | 330.50 | 337.08 | 271.00 | 278.56 |
| Powerhouse | | | | | | | | | | | | |
| Type | | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground |
| Tailrace Tunnel | | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure |
| Diameters | m | 4.7 | 4.6 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 3.9 | 3.5 | 4.6 | 4.6 |
| Length | m | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| Development Plan | | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 46.00 | 44.00 | 43.00 | 42.00 | 40.00 | 37.00 | 34.00 | 27.00 | 21.00 | 44 | 43 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 203.40 | 206.93 | 208.33 | 209.70 | 212.00 | 214.03 | 215.87 | 217.57 | 219.13 | 200.47 | 202.27 |
| Loss of Head | m | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Effective Head | M | 194.40 | 197.93 | 199.33 | 200.70 | 203.00 | 205.03 | 206.87 | 208.57 | 210.13 | 191.47 | 193.27 |
| Installed Capacity | MW | 76 | 74 | 73 | 72 | 69 | 65 | 60 | 48 | 37 | 72 | 71 |

## Table 9-10 Outline of Alternative Development Plan Concerning Reservoir Scale (2)

| Description | Name of Case | MP-D150-2 | MP-D125-2 | MP-D100-2 | MP-D75-2 | MP-D50-2 | MP-D25-2 | MP-D163-3 | MP-D150-3 | MP-D125-3 | MP-D100-3 | MP-D75-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | | |
| Waterway Route | | D | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | | | |
| Catchment Area | $Km^2$ | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 437.00 | 437.00 | 437.00 | 437.00 | 437.00 |
| Low Water Level | m | 402.60 | 410.90 | 417.80 | 423.90 | 429.40 | 434.50 | 392.00 | 398.00 | 407.20 | 414.60 | 421.10 |
| Available Drawdown | m | 36.60 | 28.30 | 21.40 | 15.30 | 9.80 | 4.70 | 45.00 | 39.00 | 29.80 | 22.40 | 15.90 |
| Gross Storage Capacity | $10^6m^3$ | 209 | 209 | 209 | 209 | 209 | 209 | 197 | 197 | 197 | 197 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 150 | 125 | 100 | 75 | 50 | 25 | 163 | 150 | 125 | 100 | 75 |
| **Dam** | | | | | | | | | | | | |
| Type | | | | | | | | | | | | |
| Height from Foundation | m | 112 | 112 | 112 | 112 | 112 | 112 | 110 | 110 | 110 | 110 | 110 |
| Crest Length | m | 560 | 560 | 560 | 560 | 560 | 560 | 540 | 540 | 540 | 540 | 540 |
| Volume | $10^6m^3$ | 5,334 | 5,334 | 5,334 | 5,334 | 5,334 | 5,334 | 5,025 | 5,025 | 5,025 | 5,025 | 5,025 |
| **Headrace Tunnel** | | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | - | - | - | - | - |
| Diameters | m | - | - | | - | - | - | - | - | - | - | - |
| Length | m | - | - | | - | - | - | - | - | - | - | - |
| **Penstock** | | | | | | | | | | | | |
| Type | | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel |
| Diameters | m | 3.6 | 3.5 | 3.3 | 3.2 | 2.9 | 2.5 | 3.6 | 3.6 | 3.5 | 3.3 | 3.2 |
| Length | m | 285.84 | 297.46 | 307.12 | 315.66 | 323.36 | 330.50 | 271.00 | 279.40 | 292.28 | 302.64 | 311.74 |
| **Powerhouse** | | | | | | | | | | | | |
| Type | | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground |
| **Tailrace Tunnel** | | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure |
| Diameters | m | 4.5 | 4.4 | 4.3 | 4.2 | 3.9 | 3.5 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 |
| Length | m | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| **Development Plan** | | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 42 | 40 | 37 | 34 | 27 | 21 | 43 | 42 | 40 | 37 | 34 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 204.00 | 206.77 | 209.07 | 211.10 | 212.92 | 214.63 | 199.00 | 201.00 | 204.07 | 206.53 | 208.70 |
| Loss of Head | m | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Effective Head | m | 195.00 | 197.77 | 200.07 | 202.10 | 203.93 | 205.63 | 190.00 | 192.00 | 195.07 | 197.53 | 199.70 |
| Installed Capacity | MW | 70 | 67 | 63 | 58 | 47 | 37 | 70 | 69 | 66 | 62 | 58 |

## Table 9-10 Outline of Alternative Development Plan Concerning Reservoir Scale (3)

| Description | Name of Case | MP-D50-3 | MP-D25-3 | MP-D150-4 | MP-D125-4 | MP-D100-4 | MP-D75-4 | MP-D50-4 | MP-D25-4 | MP-D125-5 | MP-D100-5 | MP-D75-5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | | |
| Waterway Route | | D | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | | | |
| Catchment Area | $Km^2$ | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 437.00 | 437.00 | 434.50 | 434.50 | 434.50 | 434.50 | 434.50 | 434.50 | 429.40 | 429.40 | 429.40 |
| Low Water Level | m | 426.90 | 432.20 | 392.00 | 402.60 | 410.90 | 417.80 | 423.90 | 429.40 | 392.00 | 402.60 | 410.90 |
| Available Drawdown | m | 10.10 | 4.80 | 42.50 | 31.90 | 23.60 | 16.70 | 10.60 | 5.10 | 37.40 | 26.80 | 18.50 |
| Gross Storage Capacity | $10^6m^3$ | 197 | 197 | 184 | 184 | 184 | 184 | 184 | 184 | 159 | 159 | 159 |
| Effective Storage Capacity | $10^4m^3$ | 50 | 25 | 150 | 125 | 100 | 75 | 50 | 25 | 125 | 100 | 75 |
| **Dam** | | | | | | | | | | | | |
| Type | | | | | | | | | | | | |
| Height from Foundation | m | 110 | 110 | 108 | 108 | 108 | 108 | 108 | 108 | 102 | 102 | 102 |
| Crest Length | m | 540 | 540 | 430 | 430 | 430 | 430 | 430 | 430 | 520 | 520 | 520 |
| Volume | $10^6m^3$ | 5,025 | 5,025 | 4,689 | 4,689 | 4,689 | 4,689 | 4,689 | 4,689 | 4,052 | 4,052 | 4,052 |
| **Headrace Tunnel** | | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | - | - | - | - | - |
| Diameters | m | - | - | - | - | - | - | - | - | - | - | - |
| Length | m | - | - | - | - | - | - | - | - | - | - | - |
| **Penstock** | | | | | | | | | | | | |
| Type | | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel |
| Diameters | m | 2.9 | 2.5 | 3.6 | 3.5 | 3.3 | 3.2 | 2.9 | 2.5 | 3.5 | 3.3 | 3.2 |
| Length | m | 319.86 | 327.28 | 271.00 | 285.84 | 297.46 | 307.12 | 315.66 | 323.36 | 271.00 | 285.84 | 297.46 |
| **Powerhouse** | | | | | | | | | | | | |
| Type | | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground |
| **Tailrace Tunnel** | | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure |
| Diameters | m | 3.9 | 3.5 | 4.5 | 4.4 | 4.3 | 4.2 | 3.9 | 3.5 | 4.4 | 4.3 | 4.2 |
| Length | m | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| **Development Plan** | | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 27.00 | 21.00 | 42.00 | 40.00 | 37.00 | 34.00 | 27.00 | 21.00 | 40 | 37 | 34 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 210.63 | 212.40 | 197.33 | 200.87 | 203.63 | 205.93 | 207.97 | 209.80 | 193.93 | 197.47 | 200.23 |
| Loss of Head | m | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Effective Head | m | 201.63 | 203.40 | 188.33 | 191.87 | 194.62 | 196.93 | 198.97 | 200.80 | 184.93 | 188.47 | 191.23 |
| Installed Capacity | MW | 46 | 36 | 67 | 65 | 61 | 57 | 46 | 36 | 63 | 59 | 55 |

## Table 9-10 Outline of Alternative Development Plan Concerning Reservoir Scale (4)

| Description | Name of Case | MP-D50-5 | MP-D25-5 | MP-D100-6 | MP-D75-6 | MP-D50-6 | MP-D25-6 | MP-D75-7 | MP-D50-7 | MP-D25-7 | MP-D50-8 | MP-D25-8 | MP-D25-9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | | | | |
| Waterway Route | | D | | | | | | | | | | | |
| Reservoir | | | | | | | | | | | | | |
| Catchment Area | Km² | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 | 1,994.00 |
| Annual Inflow | $m^3/S$ | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 | 14.39 |
| High Water Level | m | 429.40 | 429.40 | 423.90 | 423.90 | 423.90 | 423.90 | 417.80 | 417.80 | 417.80 | 410.90 | 410.90 | 402.60 |
| Low Water Level | m | 417.80 | 423.90 | 392.00 | 402.60 | 410.90 | 417.80 | 392.00 | 402.60 | 410.90 | 392.00 | 402.60 | 392.00 |
| Available Drawdown | m | 11.60 | 5.50 | 31.90 | 21.30 | 13.00 | 6.10 | 25.80 | 15.20 | 6.90 | 18.90 | 8.30 | 10.60 |
| Gross Storage Capacity | $10^6m^3$ | 159 | 159 | 134 | 134 | 134 | 134 | 109 | 109 | 109 | 84 | 84 | 59 |
| Effective Storage Capacity | $10^6m^3$ | 50 | 25 | 100 | 75 | 50 | 25 | 75 | 50 | 25 | 50 | 25 | 25 |
| Dam | | | | | | | | | | | | | |
| Type | | | | | | | | | | | | | |
| Height from Foundation | m | 102 | 102 | 97 | 97 | 97 | 97 | 91 | 91 | 91 | 84 | 84 | 76 |
| Crest Length | m | 520 | 520 | 490 | 490 | 490 | 490 | 430 | 430 | 430 | 400 | 400 | 370 |
| Volume | $10^6m^3$ | 4,052 | 4,052 | 3,436 | 3,436 | 3,436 | 3,436 | 2,844 | 2,844 | 2,844 | 2,284 | 2,284 | 1,654 |
| Headrace Tunnel | | | | | | | | | | | | | |
| Type | | - | - | - | - | - | - | - | - | - | - | - | - |
| Diameters | m | - | - | - | - | - | - | - | - | - | - | - | - |
| Length | m | - | - | - | - | - | - | - | - | - | - | - | - |
| Penstock | | | | | | | | | | | | | |
| Type | | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel | Embedded in Tunnel |
| Diameters | m | 2.9 | 2.5 | 3.3 | 3.2 | 2.9 | 2.5 | 3.2 | 2.9 | 2.5 | 2.9 | 2.5 | 2.4 |
| Length | m | 307.12 | 315.66 | 271.00 | 285.84 | 297.46 | 307.12 | 271.00 | 285.84 | 297.46 | 271.00 | 264.84 | 271.00 |
| Powerhouse | | | | | | | | | | | | | |
| Type | | Underground | Underground | Underground | Undergra. | Underground | Underground | Underground | Underground | Underground | Underground | Underground | Underground |
| Tailrace Tunnel | | | | | | | | | | | | | |
| Type | | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure | Nonpressure |
| Diameters | m | 3.9 | 3.5 | 4.3 | 4.2 | 3.9 | 3.5 | 4.2 | 3.9 | 3.5 | 3.9 | 3.5 | 3.5 |
| Length | m | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 | 4,899.00 |
| Channel Length | m | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 | 200.00 |
| Development Plan | | | | | | | | | | | | | |
| Maximum Discharge | $m^3/S$ | 27 | 21 | 37 | 34 | 27 | 21 | 34 | 27 | 21 | 27 | 21 | 21 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Gross Head | m | 202.53 | 204.57 | 190.27 | 193.80 | 196.57 | 198.87 | 186.20 | 189.73 | 192.50 | 181.60 | 185.13 | 176.07 |
| Loss of Head | m | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Effective Head | m | 193.53 | 195.57 | 181.27 | 184.80 | 187.57 | 189.87 | 177.20 | 180.73 | 183.50 | 172.60 | 176.13 | 167.07 |
| Installed Capacity | MW | 44 | 35 | 57 | 53 | 43 | 34 | 51 | 41 | 33 | 39 | 31 | 30 |

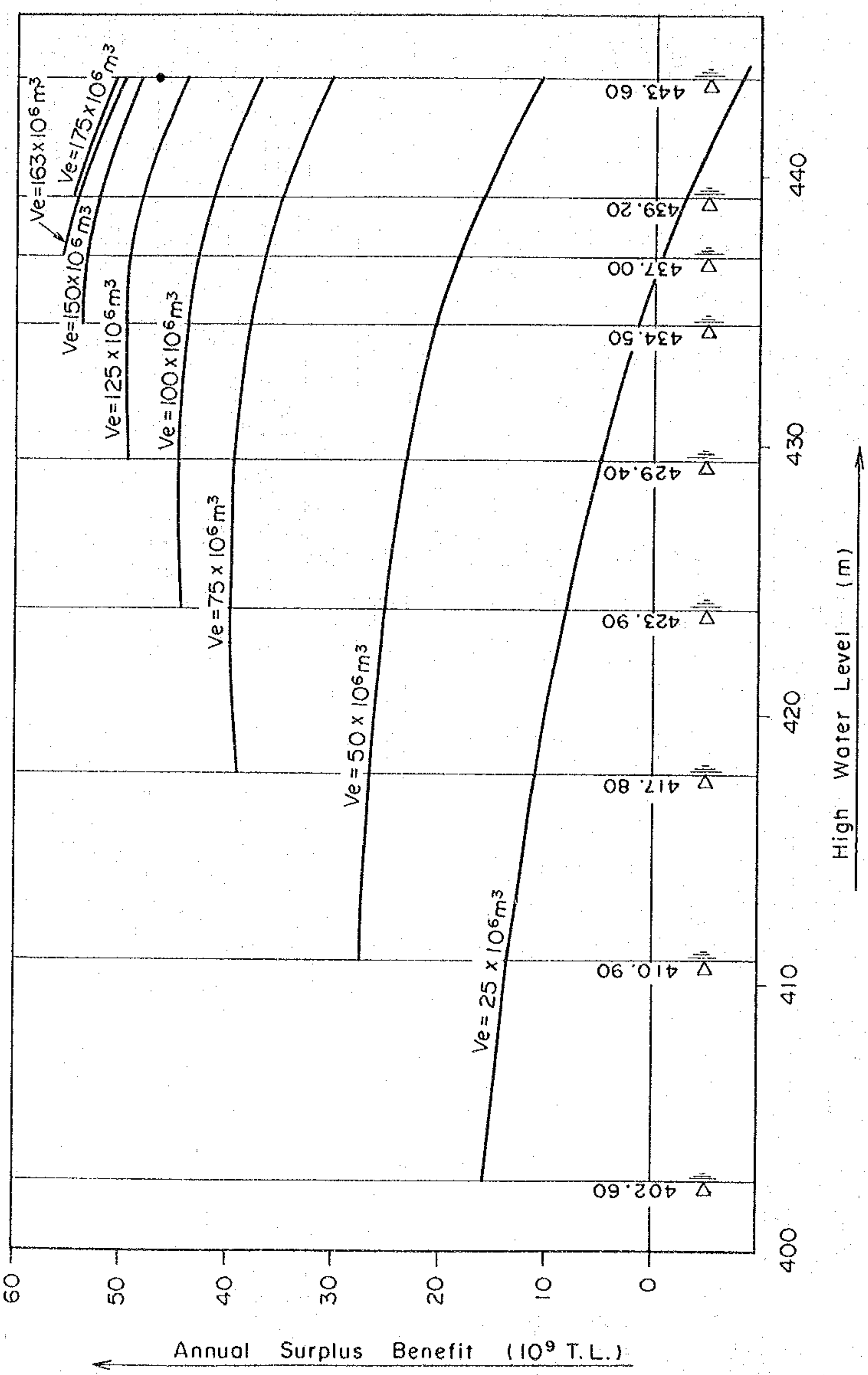



Figure 9-12 Comparative Study on Development Alternative Concerning Reservoir Scale

## Table 9-11 Comparative Study on Development Alternative Concerning Reservoir Scale (1)

| Description | Name of Case | MP-D200-1 | MP-D175-1 | MP-D163-1 | MP-D150-1 | MP-D125-1 | MP-D100-1 | MP-D75-1 | MP-D50-1 | MP-D25-1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | |
| Waterway Route | | Alta.-D | | | | | | | | |
| High Water Level | m | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 | 443.60 |
| Low Water Level | m | 392.00 | 402.60 | 406.80 | 410.90 | 417.80 | 423.90 | 429.40 | 434.50 | 439.20 |
| Available Drawdown | m | 51.60 | 41.00 | 36.80 | 32.70 | 25.80 | 19.70 | 14.20 | 9.10 | 4.40 |
| Gross Storage Capacity | $10^6m^3$ | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 234 |
| Effective Storage Capacity | $10^6m^3$ | 200 | 175 | 163 | 150 | 125 | 100 | 75 | 50 | 25 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 194.40 | 197.93 | 199.33 | 200.70 | 203.00 | 205.03 | 206.87 | 208.57 | 210.13 |
| Maximum Discharge | $m^3/s$ | 46 | 44 | 43 | 42 | 40 | 37 | 34 | 27 | 21 |
| Installed Capacity | MW | 76 | 74 | 73 | 72 | 69 | 65 | 60 | 48 | 37 |
| Firm Peak Power | MW | 68.6 | 69.6 | 69.1 | 68.1 | 65.4 | 61.5 | 57.4 | 47.0 | 37.3 |
| Energy Production | | | | | | | | | | |
| Average Energy | GWh | 218.3 | 219.9 | 219.9 | 220.0 | 219.9 | 218.9 | 217.0 | 206.1 | 188.6 |
| Firm Energy | GWh | 166.3 | 162.4 | 158.5 | 156.3 | 151.5 | 141.2 | 130.3 | 104.8 | 82.9 |
| Unit Benefit Value | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 153.3 | 155.5 | 154.4 | 152.2 | 146.1 | 137.4 | 128.3 | 105.0 | 83.4 |
| Average Energy | $10^9$T.L. | 39.8 | 40.1 | 40.1 | 40.1 | 40.1 | 40.0 | 39.6 | 37.6 | 34.4 |
| Total | $10^9$T.L. | 193.1 | 195.7 | 194.5 | 192.3 | 186.3 | 177.4 | 167.9 | 142.6 | 117.8 |
| Investment Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 1,049.8 | 1,042.4 | 1,039.1 | 1,036.1 | 1,028.7 | 1,021.5 | 1,012.3 | 991.6 | 967.8 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 353.6 | 347.3 | 343.9 | 343.6 | 335.9 | 324.6 | 308.3 | 278.1 | 248.4 |
| Total | $10^9$T.L. | 1,043.4 | 1,389.7 | 1,383.1 | 1,379.6 | 1,364.6 | 1,346.1 | 1,320.7 | 1,269.7 | 1,216.1 |
| Annual Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 106.0 | 105.3 | 105.0 | 104.6 | 103.9 | 103.2 | 102.2 | 100.2 | 97.7 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 40.3 | 39.6 | 39.2 | 39.2 | 38.3 | 37.0 | 35.1 | 31.7 | 28.3 |
| Total | $10^9$T.L. | 146.3 | 144.9 | 144.2 | 143.8 | 142.2 | 140.2 | 137.4 | 131.9 | 126.1 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 46.8 | 50.8 | 50.4 | 48.5 | 44.1 | 37.2 | 30.5 | 10.8 | -8.3 |
| Benefit Cost Ratio (B/C) | | 1.32 | 1.35 | 1.35 | 1.34 | 1.31 | 1.27 | 1.22 | 1.08 | 0.93 |
| Unit Annual Cost | T.L./KWh | 670 | 659 | 655 | 654 | 647 | 640 | 633 | 640 | 668 |

## Table 9-11 Comparative Study on Development Alternative Concerning Reservoir Scale (2)

| Description | Name of Case | MP-D175-2 | MP-D163-2 | MP-D150-2 | MP-D125-2 | MP-D100-2 | MP-D75-2 | MP-D50-2 | MP-D25-2 | MP-D163-3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | |
| Waterway Route | | Alta.-D | | | | | | | | |
| High Water Level | m | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 439.20 | 437.00 |
| Low Water Level | m | 392.00 | 397.40 | 402.60 | 410.90 | 417.80 | 423.90 | 429.40 | 434.50 | 392.00 |
| Available Drawdown | m | 47.20 | 41.80 | 36.60 | 28.30 | 21.40 | 15.30 | 9.80 | 4.70 | 45.00 |
| Gross Storage Capacity | $10^6m^3$ | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 197 |
| Effective Storage Capacity | $10^6m^3$ | 175 | 163 | 150 | 125 | 100 | 75 | 50 | 25 | 163 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 191.47 | 193.27 | 195.00 | 197.77 | 200.07 | 202.10 | 203.93 | 205.63 | 190.00 |
| Maximum Discharge | $m^3/s$ | 44 | 43 | 42 | 40 | 37 | 34 | 27 | 21 | 43 |
| Installed Capacity | MW | 72 | 71 | 70 | 67 | 63 | 58 | 47 | 37 | 70 |
| Firm Peak Power | MW | 67.2 | 66.9 | 65.9 | 63.4 | 59.7 | 55.9 | 45.9 | 36.5 | 66.0 |
| Energy Production | | | | | | | | | | |
| Average Energy | GWh | 214.6 | 214.8 | 214.8 | 214.9 | 213.9 | 212.4 | 201.8 | 184.3 | 212.1 |
| Firm Energy | GWh | 156.2 | 154.1 | 151.8 | 147.2 | 136.9 | 127.8 | 102.6 | 80.8 | 151.8 |
| Unit Benefit Value | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 150.2 | 149.5 | 147.3 | 141.7 | 133.4 | 124.9 | 102.6 | 81.6 | 147.5 |
| Average Energy | $10^9$T.L. | 39.2 | 39.2 | 39.2 | 39.2 | 39.0 | 38.8 | 36.8 | 33.6 | 38.7 |
| Total | $10^9$T.L. | 189.3 | 188.7 | 186.5 | 180.9 | 172.4 | 163.7 | 139.4 | 115.2 | 186.2 |
| Investment Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 959.1 | 956.5 | 953.3 | 945.5 | 938.4 | 929.6 | 909.0 | 885.1 | 916.0 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 338.4 | 339.6 | 339.6 | 334.0 | 322.8 | 307.4 | 279.8 | 250.7 | 334.3 |
| Total | $10^9$T.L. | 1,297.5 | 1,296.1 | 1,293.0 | 1,279.6 | 1,261.2 | 1,237.0 | 1,188.8 | 1,135.8 | 1,250.3 |
| Annual Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 96.9 | 96.6 | 96.3 | 95.5 | 94.8 | 93.9 | 91.8 | 89.4 | 92.5 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 38.6 | 38.7 | 38.7 | 38.1 | 36.8 | 35.0 | 31.9 | 28.6 | 38.1 |
| Total | $10^9$T.L. | 135.4 | 135.3 | 135.0 | 133.6 | 131.6 | 128.9 | 123.7 | 118.0 | 130.6 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 53.9 | 53.4 | 51.5 | 47.3 | 40.9 | 34.7 | 15.7 | -2.8 | 55.6 |
| Benefit Cost Ratio (B/C) | | 1.40 | 1.39 | 1.38 | 1.35 | 1.31 | 1.27 | 1.13 | 0.98 | 1.43 |
| Unit Annual Cost | T.L./KWh | 631 | 630 | 628 | 622 | 615 | 607 | 613 | 640 | 616 |

## Table 9-11 Comparative Study on Development Alternative Concerning Reservoir Scale (3)

| Description | Name of Case | MP-D150-3 | MP-D125-3 | MP-D100-3 | MP-D75-3 | MP-D50-3 | MP-D25-3 | MP-D150-4 | MP-D125-4 | MP-D100-4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | |
| Waterway Route | | Alta.-D | | | | | | | | |
| High Water Level | m | 437.00 | 437.00 | 437.00 | 437.00 | 437.00 | 437.00 | 434.50 | 434.50 | 434.50 |
| Low Water Level | m | 398.00 | 407.20 | 414.60 | 421.10 | 426.90 | 432.20 | 392.00 | 402.60 | 410.90 |
| Available Drawdown | m | 39.00 | 29.80 | 22.40 | 15.90 | 10.10 | 4.80 | 42.50 | 31.90 | 23.60 |
| Gross Storage Capacity | $10^6m^3$ | 197 | 197 | 197 | 197 | 197 | 197 | 184 | 184 | 184 |
| Effective Storage Capacity | $10^6m^3$ | 150 | 125 | 100 | 75 | 50 | 25 | 150 | 125 | 100 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 192.00 | 195.07 | 197.53 | 199.70 | 201.63 | 203.40 | 188.33 | 191.87 | 194.63 |
| Maximum Discharge | $m^3/s$ | 42 | 40 | 37 | 34 | 27 | 21 | 42 | 40 | 37 |
| Installed Capacity | MW | 69 | 66 | 62 | 58 | 46 | 36 | 67 | 65 | 61 |
| Firm Peak Power | MW | 64.8 | 62.4 | 58.8 | 55.1 | 45.3 | 36.0 | 63.5 | 61.2 | 57.8 |
| Energy Production | | | | | | | | | | |
| Average Energy | GWh | 212.3 | 212.3 | 211.7 | 209.9 | 200.1 | 182.9 | 209.3 | 209.4 | 208.8 |
| Firm Energy | GWh | 149.6 | 145.0 | 136.4 | 125.7 | 102.3 | 80.4 | 147.3 | 142.7 | 134.3 |
| Unit Benefit Value | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.83 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 144.8 | 139.4 | 131.4 | 123.1 | 101.2 | 80.4 | 141.9 | 136.8 | 129.2 |
| Average Energy | $10^9$T.L. | 38.7 | 38.7 | 38.6 | 38.3 | 36.5 | 33.4 | 38.2 | 38.2 | 38.1 |
| Total | $10^9$T.L. | 183.5 | 178.2 | 170.0 | 161.4 | 137.8 | 113.8 | 180.1 | 175.0 | 167.3 |
| Investment Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 912.9 | 905.7 | 899.0 | 889.6 | 869.1 | 845.5 | 883.3 | 875.8 | 869.5 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 334.7 | 327.3 | 315.7 | 305.4 | 273.7 | 243.9 | 326.6 | 322.9 | 314.1 |
| Total | $10^9$T.L. | 1,247.6 | 1,233.0 | 1,214.7 | 1,195.0 | 1,142.7 | 1,089.4 | 1,210.0 | 1,198.7 | 1,183.5 |
| Annual Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 92.2 | 91.5 | 90.8 | 89.8 | 87.8 | 85.4 | 89.2 | 88.5 | 87.8 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 38.2 | 37.3 | 36.0 | 34.8 | 31.2 | 27.8 | 37.2 | 36.8 | 35.8 |
| Total | $10^9$T.L. | 130.4 | 128.8 | 126.8 | 124.7 | 119.0 | 113.2 | 126.5 | 125.3 | 123.6 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 53.2 | 49.4 | 43.2 | 36.8 | 18.8 | 0.6 | 53.6 | 49.7 | 43.7 |
| Benefit Cost Ratio (B/C) | | 1.41 | 1.38 | 1.34 | 1.29 | 1.16 | 1.01 | 1.42 | 1.40 | 1.35 |
| Unit Annual Cost | T.L./KWh | 614 | 607 | 599 | 594 | 594 | 619 | 604 | 598 | 592 |

## Table 9-11 Comparative Study on Development Alternative Concerning Reservoir Scale (4)

| Description | Name of Case | MP-D75-4 | MP-D50-4 | MP-D25-4 | MP-D125-5 | MP-D100-5 | MP-D75-5 | MP-D50-5 | MP-D25-5 | MP-D100-6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | | | | | M/P | | | | |
| Waterway Route | | | | | | Alta.-D | | | | |
| High Water Level | m | 434.50 | 434.50 | 434.50 | 429.40 | 429.40 | 429.40 | 429.40 | 429.40 | 423.90 |
| Low Water Level | m | 417.80 | 423.90 | 429.40 | 392.00 | 402.60 | 410.90 | 417.80 | 423.90 | 392.00 |
| Available Drawdown | m | 16.70 | 10.60 | 5.10 | 37.40 | 26.80 | 18.50 | 11.60 | 5.50 | 31.90 |
| Gross Storage Capacity | $10^6m^3$ | 184 | 184 | 184 | 159 | 159 | 159 | 159 | 159 | 134 |
| Effective Storage Capacity | $10^6m^3$ | 75 | 50 | 25 | 125 | 100 | 75 | 50 | 25 | 100 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 196.93 | 198.97 | 200.80 | 184.93 | 188.47 | 191.23 | 193.53 | 195.57 | 181.27 |
| Maximum Discharge | $m^3/s$ | 34 | 27 | 21 | 40 | 37 | 34 | 27 | 21 | 37 |
| Installed Capacity | MW | 57 | 46 | 36 | 63 | 59 | 55 | 44 | 35 | 57 |
| Firm Peak Power | MW | 54.1 | 44.7 | 35.6 | 58.6 | 55.6 | 52.2 | 43.3 | 34.6 | 53.0 |
| Energy Production | | | | | | | | | | |
| Average Energy | GWh | 207.1 | 197.2 | 179.8 | 203.3 | 203.1 | 201.8 | 192.3 | 175.0 | 196.8 |
| Firm Energy | GWh | 123.6 | 100.3 | 78.6 | 136.5 | 129.9 | 120.9 | 97.9 | 76.4 | 125.3 |
| Unit Benefit Value | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 120.9 | 99.9 | 79.6 | 130.9 | 124.2 | 116.6 | 96.8 | 77.3 | 118.4 |
| Average Energy | $10^9$T.L. | 37.8 | 36.0 | 32.8 | 37.1 | 37.1 | 36.8 | 35.1 | 31.9 | 35.9 |
| Total | $10^9$T.L. | 158.7 | 135.9 | 112.4 | 168.0 | 161.3 | 153.5 | 131.8 | 109.3 | 154.3 |
| Investment Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 860.0 | 839.8 | 816.4 | 818.8 | 811.6 | 803.3 | 782.8 | 759.8 | 749.2 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 301.2 | 275.4 | 245.5 | 314.1 | 305.7 | 298.0 | 268.4 | 241.5 | 301.9 |
| Total | $10^9$T.L. | 1,161.2 | 1,115.2 | 1,061.9 | 1,132.9 | 1,117.3 | 1,101.2 | 1,051.2 | 1,001.3 | 1,051.1 |
| Annual Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 86.9 | 84.8 | 82.5 | 82.7 | 82.0 | 81.1 | 79.1 | 76.7 | 75.7 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 34.3 | 31.4 | 28.0 | 35.8 | 34.9 | 34.0 | 30.6 | 27.5 | 34.4 |
| Total | $10^9$T.L. | 121.2 | 116.2 | 110.4 | 118.5 | 116.8 | 115.1 | 109.7 | 104.3 | 110.1 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 37.5 | 19.7 | 1.9 | 49.5 | 44.5 | 38.4 | 22.2 | 5.0 | 44.2 |
| Benefit Cost Ratio (B/C) | | 1.31 | 1.17 | 1.02 | 1.42 | 1.38 | 1.33 | 1.20 | 1.05 | 1.40 |
| Unit Annual Cost | T.L./KWh | 585 | 589 | 614 | 583 | 575 | 570 | 570 | 596 | 560 |

## Table 9-11 Comparative Study on Development Alternative Concerning Reservoir Scale (5)

| Description | Name of Case | MP-D75-6 | MP-D50-6 | MP-D25-6 | MP-D75-7 | MP-D50-7 | MP-D25-7 | MP-D50-8 | MP-D25-8 | MP-D25-9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dam Site | | M/P | | | | | | | | |
| Waterway Route | | Alta.-D | | | | | | | | |
| High Water Level | m | 423.90 | 423.90 | 423.90 | 417.80 | 417.80 | 417.80 | 410.90 | 410.90 | 402.60 |
| Low Water Level | m | 402.60 | 410.90 | 417.80 | 392.00 | 402.60 | 410.90 | 392.00 | 402.60 | 392.00 |
| Available Drawdown | m | 21.30 | 13.00 | 6.10 | 25.80 | 15.20 | 6.90 | 18.90 | 8.30 | 10.60 |
| Gross Storage Capacity | $10^6m^3$ | 134 | 134 | 134 | 109 | 109 | 109 | 84 | 84 | 59 |
| Effective Storage Capacity | $10^6m^3$ | 75 | 50 | 25 | 75 | 50 | 25 | 50 | 25 | 25 |
| Tail Water Level | m | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 | 223.00 |
| Effective Head | m | 184.80 | 187.57 | 189.87 | 177.20 | 180.73 | 183.50 | 172.60 | 176.13 | 167.07 |
| Maximum Discharge | $m^3/s$ | 34 | 27 | 21 | 34 | 27 | 21 | 27 | 21 | 21 |
| Installed Capacity | MW | 53 | 43 | 34 | 51 | 41 | 33 | 39 | 31 | 30 |
| Firm Peak Power | MW | 50.1 | 41.8 | 33.5 | 47.4 | 40.1 | 32.3 | 38.1 | 31.0 | 29.2 |
| Energy Production | | | | | | | | | | |
| Average Energy | GWh | 195.6 | 186.0 | 170.1 | 188.7 | 180.3 | 164.8 | 172.9 | 159.0 | 150.5 |
| Firm Energy | GWh | 116.6 | 93.8 | 74.2 | 112.0 | 91.4 | 72.0 | 87.0 | 69.7 | 65.4 |
| Unit Benefit Value | | | | | | | | | | |
| Firm Peak Power | T.L./KW | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 | 2,326,506 |
| Average Energy | T.L./KWh | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 | 184.33 |
| Benefit | | | | | | | | | | |
| Firm Peak Power | $10^9$T.L. | 112.0 | 93.4 | 74.9 | 105.9 | 89.6 | 72.2 | 85.1 | 69.3 | 65.3 |
| Average Energy | $10^9$T.L. | 35.7 | 33.9 | 31.0 | 34.4 | 32.9 | 30.1 | 31.5 | 29.0 | 27.5 |
| Total | $10^9$T.L. | 147.6 | 127.3 | 105.9 | 140.4 | 122.5 | 102.3 | 116.7 | 98.3 | 92.7 |
| Investment Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 740.8 | 721.1 | 697.8 | 680.5 | 660.7 | 638.0 | 602.1 | 579.3 | 509.9 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 289.1 | 263.6 | 238.5 | 287.2 | 256.4 | 233.2 | 251.6 | 226.9 | 223.1 |
| Total | $10^9$T.L. | 1,029.9 | 984.6 | 936.3 | 967.6 | 917.0 | 871.3 | 854.0 | 806.2 | 733.0 |
| Annual Cost | | | | | | | | | | |
| Civil Facilities | $10^9$T.L. | 74.8 | 72.8 | 70.5 | 68.7 | 66.7 | 64.4 | 60.8 | 58.5 | 51.5 |
| Hydro & Ele.-Mech. Eq. | $10^9$T.L. | 33.0 | 30.0 | 27.2 | 32.7 | 29.2 | 26.6 | 28.7 | 25.9 | 25.4 |
| Total | $10^9$T.L. | 107.8 | 102.9 | 97.7 | 101.5 | 96.0 | 91.0 | 89.5 | 84.4 | 76.9 |
| Annual Surplus Benefit (B-C) | $10^9$T.L. | 39.9 | 24.5 | 8.2 | 38.9 | 26.6 | 11.2 | 27.2 | 13.9 | 15.8 |
| Benefit Cost Ratio (B/C) | | 1.37 | 1.24 | 1.08 | 1.38 | 1.28 | 1.12 | 1.30 | 1.16 | 1.21 |
| Unit Annual Cost | T.L./KWh | 551 | 553 | 574 | 538 | 532 | 552 | 518 | 531 | 511 |

### 9.2.4 Power Station Scale

Factors determining the installed capacity of a hydroelectric power station are effective head and maximum available discharge as indicated in the equation below, while maximum available discharge is generally determined by firm discharge and equivalent peak duration hours.

Installed Capacity (kW) = 9.8 x Turbine-Generator Efficiency x Effective Head (m) x Maximum Discharge ($m^3/s$)

$$\text{Maximum Available Discharge} = \text{Firm Discharge } (m^3/s) \times \frac{24 \text{ hr}}{\text{Equivalent Peak Duration Hours (hr)}}$$

Of the abovementioned factors, effective head and firm discharge are determined by physical conditions such as effective storage capacity and intake and tail water levels, but equivalent peak duration hours are determined by conditions different from the above.

According to the electric power demand and supply plan, the situations of the electric power system in the year 2001 when the Köprübaşı Project is scheduled to be commissioned, and 2010, the last year of the demand and supply plan, will be as indicated in Table 9-12.

Table 9-12 Demand and Supply Balance

| Year | | 2001 | 2010 |
|---|---|---|---|
| Demand | | | |
| a. Peak Power | (MW) | 22,610 | 43,590 |
| b. Annual Energy Consumption | (GWh) | 140,850 | 271,450 |
| Supply | | | |
| c. Thermal | (MW) | 18,070 | 36,970 |
| d. Hydro | (MW) | 13,841 | 23,086 |
| e. Total | (MW) | 31,911 | 60,056 |
| Annual Energy Production | | | |
| f. Thermal | (GWh) | 113,208 | 236,558 |
| g. Hydro (Dependable) | (GWh) | 35,619 | 52,219 |
| Supply Margin (e-a) | (MW) | 9,301 | 16,466 |
| Supply Margin Rate ((e-a)/a) | (%) | 41 | 38 |
| Equivalent Peak Duration Hours for Hydro (g/d)/365) | (Hour) | 7.1 | 6.2 |

According to the above table, the average equivalent peak duration times of all hydroelectric power generation in 2001 and 2010 will be 7.1 hours and 6.2 hours, but since these have been calculated with daily energy production of the maximum load day as the annual average electric energy, the actual peak duration times are thought to be somewhat longer than these. However, since the trend is for the proportion of hydroelectric power generation in the entire electric power system to decrease year by year, it is thought equivalent peak duration time will also be shortened year by year.

In the Köprübaşı Project, similarly to most other hydroelectric power generation projects, since storage capacity is large enough that roughly the entire quantity of inflow can be used for power generation, a large increase in electric energy production cannot be expected even when equivalent peak duration time is made shorter and installed capacity larger.

Therefore, for the equivalent peak duration time of the Köprübaşı Project, it is judged reasonable for about 6 hours, the average for all hydroelectric power generation, to be made the limit.

Examination of the optimum scale of installed capacity for the Köprübaşı Project was made by comparisons on setting up maximum available discharges for the cases of 8 hours, 10 hours, and 12 hours, with 6 hours the limit for equivalent peak duration times for dependable discharge of 10.75 $m^3/s$.

The result of the comparison studies, as shown in Table 9-13 and Figure 9-13, is that equivalent peak duration time of 6 hours is optimum. Therefore, maximum available discharge of 43 $m^3/s$ and installed capacity of 70 MW will be the optimum scale.

**Table 9-13 Optimization Study on Installed Capacity of Köprübaşı Project**

| Description | Unit | Case | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| Peak Hours | Hours | 6 | 8 | 10 | 12 |
| Maximum Discharge | $m^3/s$ | 43 | 32 | 26 | 22 |
| Installed Capacity | MW | 70 | 53 | 42 | 35 |
| Firm Peak Power | MW | 66.0 | 49.3 | 39.4 | 32.9 |
| Energy Production | | | | | |
| Average Energy | GWh | 212.1 | 204.4 | 195.5 | 187.4 |
| Firm Energy | GWh | 151.8 | 151.8 | 151.8 | 151.8 |
| Benefit (B) | $10^9$ TL | 186.2 | 147.7 | 123.7 | 107.7 |
| Investment Cost | $10^9$ TL | 1,250.3 | 1,187.1 | 1,144.4 | 1,118.4 |
| Annual Cost | $10^9$ TL | 130.6 | 123.6 | 118.8 | 115.9 |
| Annual Surplus Benefit (B-C) | $10^9$ TL | 55.6 | 23.8 | 4.8 | -8.3 |
| Benefit Cost Ratio (B/C) | | 1.43 | 1.19 | 1.04 | 0.93 |
| Unit Annual Cost | TL/KWh | 616 | 605 | 608 | 619 |

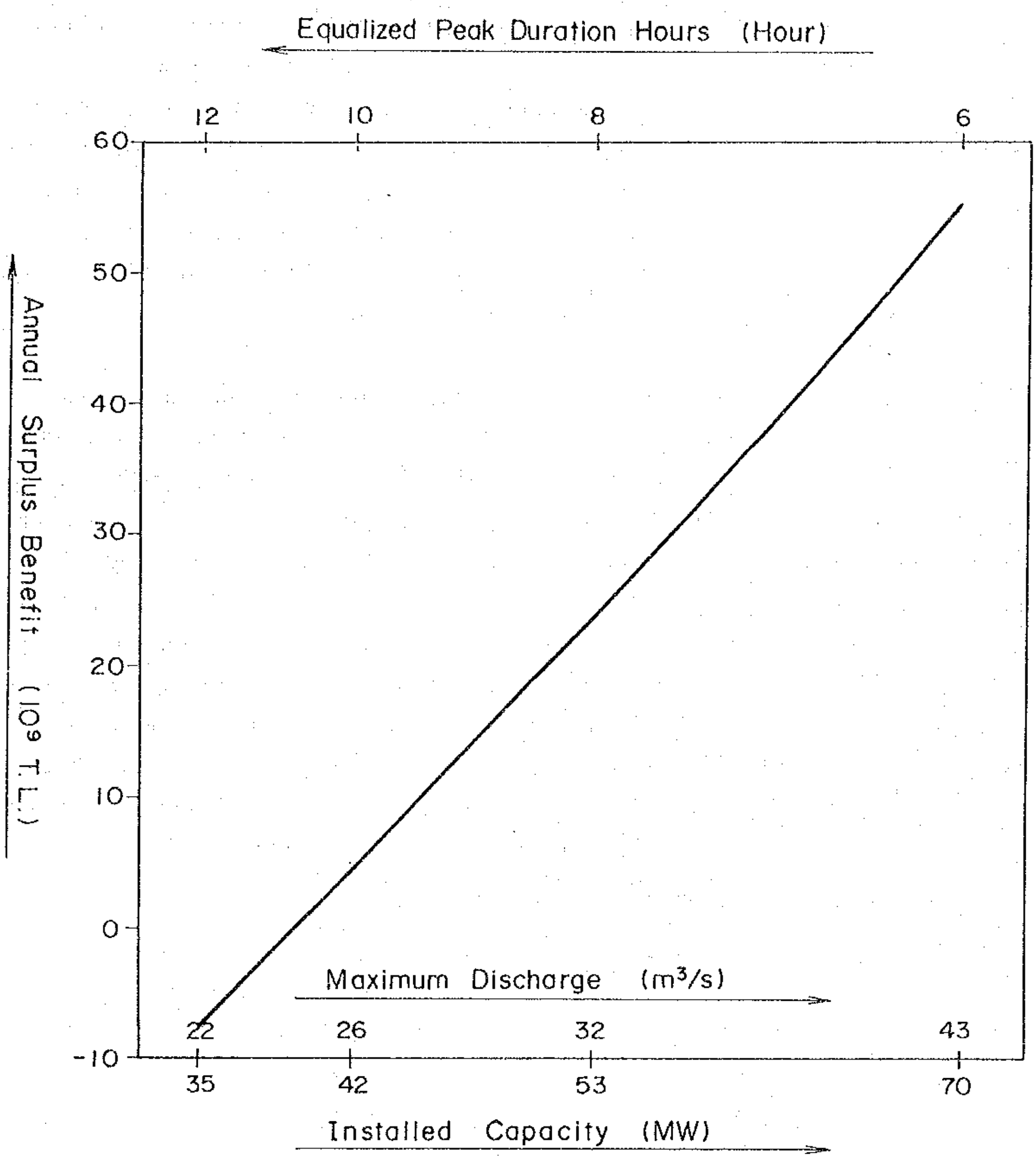



Figure 9-13 Optimization Study on Installed Capacity

### 9.2.5 Optimum Development Plan

As a result of studies of development plan up to this point, the optimum development plan of Köprübaşı Project is to construct a 110 m high dam at the site of 3 km upstream from Köprübaşı village; provide 163 x $10^6$ $m^3$ of effective storage capacity with high water level of EL 437 m, take 43 $m^3/s$ of discharge by intake located at right bank of dam; discharge the water to underground powerhouse through embedded penstock in inclined shaft tunnel; generate maximum output of 70 MW by utilizing 190 m head; and after generation discharge water through tailrace tunnel to the Devrek River at the site of Dirgene village.

Table 9-14 shows the characteristics of the optimum development plan of the Köprübaşı Project. Table 9-15 shows the preliminary estimated construction cost of the Köprübaşı Project. Table 9-16 and Figure 9-14 shows the reservoir water level, inflow, discharge for power and spilled water quantity in the Köprübaşı Project according to the results of reservoir operation respectively. Table 9-17 and 9-18 shows the monthly energy production and firm energy production of the Köprübaşı Project respectively. Table 9-19 and 9-20 shows the monthly peak power and peak power durations of the Köprübaşı Project respectively. Figure 9-15 shows the monthly peak power, monthly energy production and firm energy production of the Köprübaşı Project.

Table 9-14 Outline of Optimum Development Plan of Köprübaşı Project

| Description | | | Unit | |
|---|---|---|---|---|
| Reservoir | | | | |
| Catchment Area | | | Km$^2$ | 1,994.00 |
| Annual Inflow | | | m$^3$/S | 14.39 |
| High Water Level | | | m | 437.00 |
| Low Water Level | | | m | 392.00 |
| Available Drawdown | | | m | 45.00 |
| Gross Storage Capacity | | | 10$^6$m$^3$ | 197.70 |
| Effective Storage Capacity | | | 10$^6$m$^3$ | 163.00 |
| Dam | Type | | | |
| | Height from Foundation | | m | 110 |
| | Crest Length | | m | 540 |
| | Volume | | 10$^3$m$^3$ | 5,025 |
| Penstock | Type | | | Embedded in Tunnel |
| | Diameter | | m | 3.40 |
| | Length | | m | 271.00 |
| Powerhouse | Type | | | Underground |
| Tailrace Tunnel | Type | | | Nonpressure |
| | Diameters | | m | 4.60 |
| | Length | | m | 4,899.00 |
| | Channel Length | | m | 200.00 |
| Development Plan | Firm Discharge | | m$^3$/S | 10.75 |
| | Maximum Discharge | | m$^3$/S | 43.00 |
| | Tail Water Level | | m | 223.00 |
| | Gross Head | Maximum | m | 214.00 |
| | | Normal | m | 199.00 |
| | | Minimum | m | 169.00 |
| | Loss of Head | | m | 9.00 |
| | Effective Head | Maximum | m | 205.00 |
| | | Normal | m | 190.00 |
| | | Minimum | m | 160.00 |
| | Installed Capacity | | MW | 70 |
| | Numbered of Unit | | | 2 |
| | Firm Peak Power | | MW | 66.0 |
| | Annual Energy | Average | GWh | 212.1 |
| | | Firm | GWh | 151.8 |
| | | Secondary | GWh | 60.3 |

Table 9-15 Preliminary Estimated Cost of Optimum Development Plan of Köprübaşı Project

Unit: $10^9$ T.L.

| Item | |
|---|---|
| Civil Work | |
| Relocation Road | 41.0 |
| Clamp Facilities | 10.0 |
| Care of River | 22.4 |
| Dam | 248.0 |
| Spillway | 44.9 |
| Outlet works | 2.7 |
| Intake | 3.9 |
| Penstock | 5.0 |
| Powerhouse | 48.8 |
| Tailrace | 100.6 |
| Switchyard | 3.4 |
| Sub-total | 479.7 |
| Hydraulic Equipment | 39.7 |
| Electro-Mechanical Equipment | 182.7 |
| Transmission Line | 43.1 |
| Total Cost | 878.1 |
| Contingency | 94.9 |
| Engineering and Administration Cost | 119.6 |
| Land Aquisition | 81.9 |
| Interest during Construction | 157.7 |
| Grand Total | 1,250.3 |

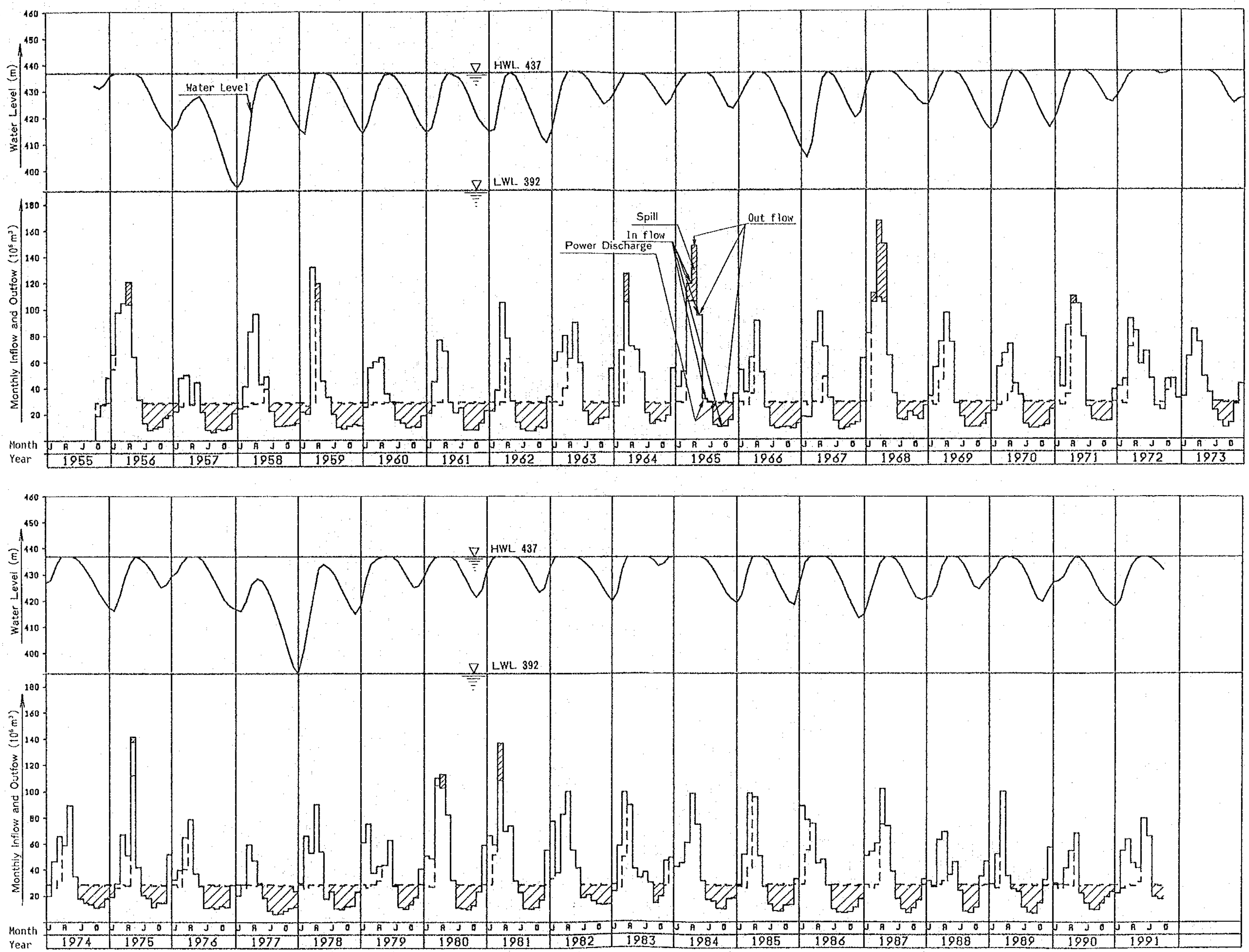
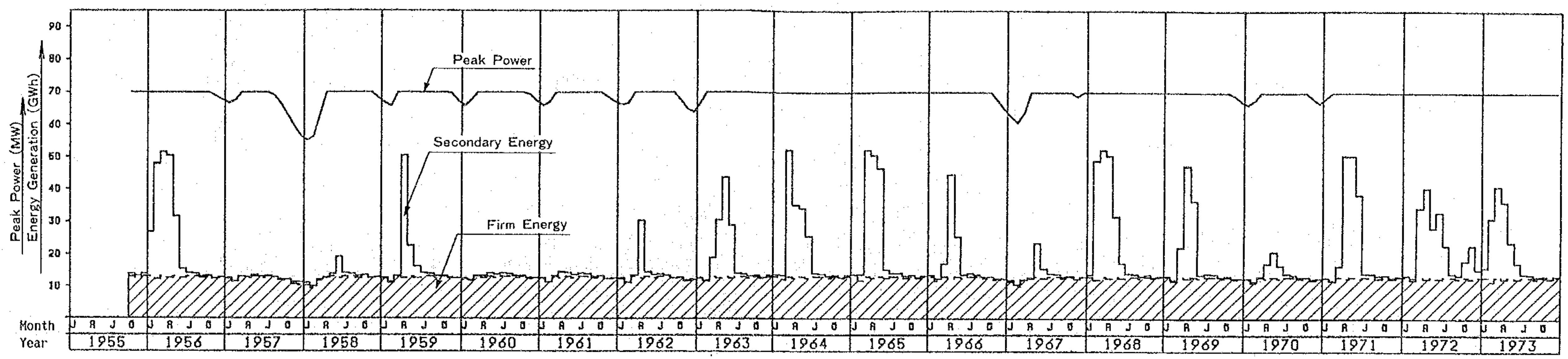



**Figure 9-14 Köprübaşı Reservoir Operation**



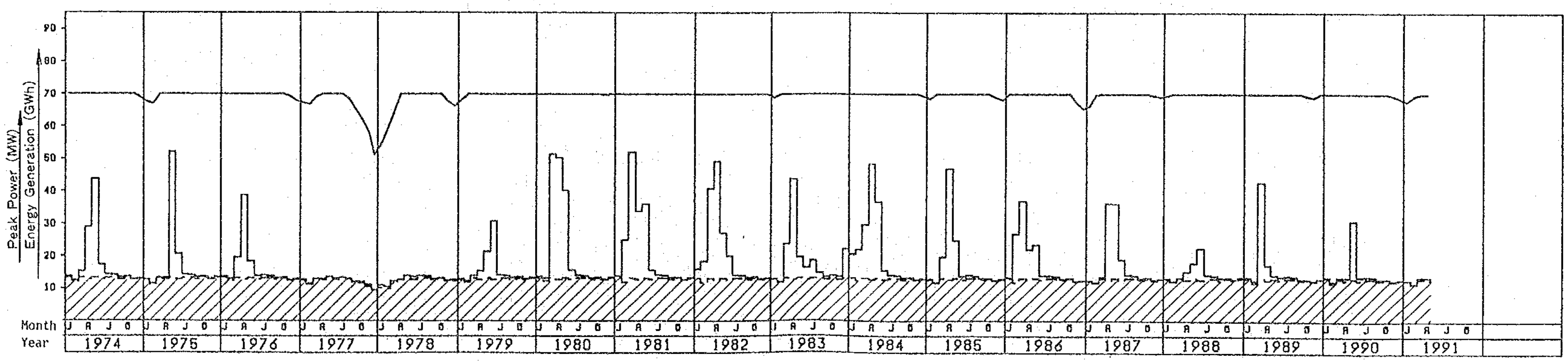




Figure 9-15 Energy Generation of Köprübaşı Project

## Table 9-16 Summary of Operation Study on Köprübaşı Reservoir

Unit: $10^6 m^3$

| Month Year | INFLOW | POWER DISCHARGE | SPILL |
|---|---|---|---|
| 1956 | 7046.87 | 7243.75 | 215.66 |
| 1957 | 3299.88 | 3923.75 | 0.0 |
| 1958 | 4835.30 | 4053.68 | 0.0 |
| 1959 | 5140.16 | 5043.31 | 165.26 |
| 1960 | 3923.84 | 3934.50 | 0.0 |
| 1961 | 3897.34 | 3951.31 | 0.0 |
| 1962 | 4032.06 | 4329.28 | 0.0 |
| 1963 | 5944.79 | 5494.05 | 0.0 |
| 1964 | 6364.23 | 6096.12 | 244.85 |
| 1965 | 7190.62 | 6499.91 | 678.22 |
| 1966 | 4701.27 | 4985.11 | 0.0 |
| 1967 | 4255.32 | 4189.19 | 0.0 |
| 1968 | 8596.53 | 7022.68 | 1334.61 |
| 1969 | 5254.86 | 5436.27 | 0.0 |
| 1970 | 4163.31 | 4243.24 | 0.0 |
| 1971 | 6657.41 | 6287.70 | 71.10 |
| 1972 | 6305.09 | 6041.63 | 0.0 |
| 1973 | 5840.28 | 6215.66 | 0.0 |
| 1974 | 5114.35 | 5095.25 | 0.0 |
| 1975 | 5092.13 | 4997.85 | 49.95 |
| 1976 | 4557.29 | 4757.34 | 0.0 |
| 1977 | 3217.48 | 3923.75 | 0.0 |
| 1978 | 4463.89 | 3862.56 | 0.0 |
| 1979 | 4839.81 | 4542.57 | 0.0 |
| 1980 | 6252.20 | 6337.12 | 119.01 |
| 1981 | 6648.61 | 6153.53 | 356.54 |
| 1982 | 6175.92 | 6040.04 | 0.0 |
| 1983 | 5397.45 | 5201.44 | 0.0 |
| 1984 | 5935.53 | 6261.87 | 0.0 |
| 1985 | 4939.58 | 5108.03 | 0.0 |
| 1986 | 5183.22 | 5235.25 | 0.0 |
| 1987 | 5232.98 | 5111.34 | 0.0 |
| 1988 | 4327.08 | 4275.23 | 0.0 |
| 1989 | 4431.25 | 4691.40 | 0.0 |
| 1990 | 4456.94 | 4322.88 | 0.0 |
| 1991 | 5395.14 | 4966.24 | 0.0 |
| TOTAL | 189110.03 | 185874.84 | 3235.19 |

## Table 9-17 Total Energy Generation of Köprübaşı Project

Unit: GWh

| Month / Year | < OCT > | < NOV > | < DEC > | < JAN > | < FEB > | < MAR > | < APR > | < MAY > | < JUN > | < JUL > | < AUG > | < SEP > | <TOTAL> |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | 13796. | 13266. | 13849. | 26687. | 48039. | 51470. | 50402. | 31556. | 15353. | 14043. | 13773. | 13030. | 305260. |
| 1957 | 13148. | 12479. | 12716. | 12574. | 11490. | 13105. | 12859. | 13416. | 13063. | 13276. | 12894. | 12113. | 153134. |
| 1958 | 12113. | 11268. | 11266. | 11065. | 10154. | 12116. | 12828. | 13911. | 19123. | 14110. | 13937. | 13228. | 155119. |
| 1959 | 13385. | 12666. | 12804. | 12592. | 11256. | 13330. | 50402. | 22525. | 16115. | 14091. | 13890. | 13153. | 206211. |
| 1960 | 13279. | 12558. | 12678. | 12477. | 11890. | 13234. | 13329. | 14083. | 13683. | 14053. | 13839. | 13134. | 158236. |
| 1961 | 13263. | 12522. | 12686. | 12513. | 11391. | 13199. | 14559. | 14178. | 13650. | 14024. | 13834. | 13074. | 158891. |
| 1962 | 13160. | 12427. | 12649. | 12525. | 11352. | 13342. | 30271. | 14571. | 13597. | 13790. | 13452. | 12659. | 173796. |
| 1963 | 12729. | 11971. | 12218. | 12568. | 11934. | 18901. | 30489. | 43782. | 28837. | 14106. | 13933. | 13243. | 224711. |
| 1964 | 13456. | 12830. | 13382. | 13569. | 13460. | 52082. | 35306. | 34161. | 25465. | 14098. | 13915. | 13250. | 254974. |
| 1965 | 13470. | 12842. | 13410. | 13717. | 13635. | 52082. | 50402. | 46485. | 15136. | 14151. | 14021. | 13308. | 272660. |
| 1966 | 13458. | 12765. | 13132. | 13395. | 12350. | 17039. | 44465. | 25342. | 13675. | 13973. | 13679. | 12934. | 206207. |
| 1967 | 13020. | 12281. | 12346. | 12049. | 10671. | 12215. | 12840. | 23383. | 15471. | 14051. | 13781. | 13028. | 165137. |
| 1968 | 13144. | 12439. | 13012. | 13725. | 48722. | 52082. | 50402. | 31605. | 17221. | 14060. | 13856. | 13250. | 293516. |
| 1969 | 13552. | 12928. | 13226. | 13231. | 12202. | 22151. | 47351. | 36422. | 13696. | 14069. | 13839. | 13104. | 225770. |
| 1970 | 13218. | 12485. | 12674. | 12518. | 11492. | 13305. | 17332. | 20883. | 16577. | 14030. | 13749. | 12998. | 171260. |
| 1971 | 13104. | 12373. | 12574. | 12824. | 11958. | 16409. | 50402. | 50507. | 38340. | 14128. | 14004. | 13351. | 259974. |
| 1972 | 13568. | 12896. | 13285. | 13462. | 12822. | 34346. | 40537. | 28272. | 33089. | 22746. | 14128. | 13612. | 252763. |
| 1973 | 18105. | 22761. | 15279. | 15898. | 31221. | 41220. | 36290. | 23769. | 17373. | 14107. | 13945. | 13245. | 263212. |
| 1974 | 13401. | 12827. | 13359. | 13395. | 12184. | 15201. | 28930. | 43836. | 17230. | 14077. | 13896. | 13236. | 211573. |
| 1975 | 13418. | 12705. | 12888. | 12702. | 11423. | 13012. | 13101. | 52082. | 20603. | 14093. | 13955. | 13309. | 203290. |
| 1976 | 13510. | 12852. | 13361. | 13578. | 12821. | 19617. | 38733. | 18366. | 13696. | 14022. | 13759. | 13051. | 197366. |
| 1977 | 13199. | 12491. | 12759. | 12674. | 11397. | 12919. | 12926. | 13527. | 13028. | 13218. | 12847. | 12040. | 153025. |
| 1978 | 12013. | 11192. | 9534. | 10974. | 10463. | 12314. | 12683. | 13822. | 13486. | 13820. | 13639. | 12911. | 146850. |
| 1979 | 13036. | 12336. | 12544. | 12783. | 12179. | 13933. | 15498. | 21443. | 30808. | 14146. | 14013. | 13307. | 186025. |
| 1980 | 13492. | 12858. | 13311. | 13586. | 13024. | 51292. | 50402. | 40247. | 15672. | 14030. | 13765. | 13040. | 264719. |
| 1981 | 13187. | 12581. | 13223. | 13769. | 25173. | 52082. | 34112. | 36152. | 15579. | 14112. | 13938. | 13225. | 257132. |
| 1982 | 13379. | 12709. | 13269. | 15988. | 18681. | 40743. | 49228. | 27264. | 20259. | 14081. | 13949. | 13355. | 252905. |
| 1983 | 13590. | 12913. | 13079. | 12897. | 11860. | 23963. | 43782. | 19880. | 16513. | 18749. | 14777. | 13605. | 215608. |
| 1984 | 13893. | 13516. | 22487. | 20731. | 22264. | 29904. | 48388. | 36786. | 15510. | 14074. | 13898. | 13227. | 264678. |
| 1985 | 13378. | 12704. | 12943. | 12840. | 11788. | 19830. | 47006. | 24875. | 13691. | 14034. | 13772. | 13020. | 209880. |
| 1986 | 13150. | 12467. | 12790. | 13347. | 26940. | 37052. | 22230. | 23769. | 13892. | 14024. | 13726. | 12958. | 216345. |
| 1987 | 13023. | 12289. | 12435. | 12541. | 11740. | 13513. | 36379. | 36118. | 18995. | 14077. | 13863. | 13122. | 208096. |
| 1988 | 13240. | 12563. | 12921. | 12983. | 12175. | 13323. | 15241. | 17860. | 22628. | 14122. | 13945. | 13193. | 174192. |
| 1989 | 13320. | 12802. | 13437. | 13580. | 12453. | 42786. | 17407. | 14130. | 13620. | 13914. | 13617. | 12838. | 193903. |
| 1990 | 12957. | 12461. | 13172. | 13425. | 12157. | 13590. | 13445. | 31036. | 13660. | 13974. | 13728. | 13001. | 176605. |
| 1991 | 13159. | 12542. | 12839. | 12732. | 11680. | 13476. | 13434. | 15117. | 38979. | 32111. | 14088. | 13498. | 203655. |
| TOTAL | 481311. | 462567. | 473536. | 491911. | 566443. | 900180. | 1113389. | 975155. | 667309. | 535586. | 497643. | 471650. | 7636671. |
| AVERAGE | 13370. | 12849. | 13154. | 13664. | 15735. | 25005. | 30927. | 27088. | 18536. | 14877. | 13823. | 13101. | 212130. |
| MAXIMUM | 18105. | 22761. | 22487. | 26687. | 48722. | 52082. | 50402. | 52082. | 38979. | 32111. | 14777. | 13612. | 305260. |
| MINIMUM | 12013. | 11192. | 9534. | 10974. | 10154. | 12116. | 12683. | 13416. | 13028. | 13218. | 12847. | 12040. | 146850. |

## Table 9-18 Firm Energy Generation of Köprübaşı Project

Unit: GWh

| Month / Year | < OCT > | < NOV > | < DEC > | < JAN > | < FEB > | < MAR > | < APR > | < MAY > | < JUN > | < JUL > | < AUG > | < SEP > | <TOTAL> |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1957 | 13020. | 12418. | 12572. | 12365. | 11361. | 13020. | 12600. | 13020. | 12600. | 13020. | 12831. | 11887. | 150714. |
| 1958 | 11704. | 10688. | 10521. | 10246. | 9473. | 11709. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 141202. |
| 1959 | 13020. | 12600. | 12699. | 12392. | 11025. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151616. |
| 1960 | 13020. | 12534. | 12516. | 12226. | 11752. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151928. |
| 1961 | 13020. | 12481. | 12528. | 12278. | 11218. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151404. |
| 1962 | 13020. | 12342. | 12474. | 12295. | 11162. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151172. |
| 1963 | 12590. | 11683. | 11855. | 12358. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 150124. |
| 1964 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1965 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1966 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1967 | 13020. | 12130. | 12037. | 11615. | 10191. | 11851. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 147703. |
| 1968 | 13020. | 12360. | 13003. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153463. |
| 1969 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1970 | 13020. | 12428. | 12510. | 12284. | 11365. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151486. |
| 1971 | 13020. | 12264. | 12366. | 12728. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152018. |
| 1972 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1973 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1974 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1975 | 13020. | 12600. | 12822. | 12551. | 11264. | 13004. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152120. |
| 1976 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1977 | 13020. | 12436. | 12633. | 12510. | 11227. | 12868. | 12600. | 13020. | 12600. | 13020. | 12762. | 11782. | 150476. |
| 1978 | 11563. | 10582. | 9534. | 10122. | 9901. | 11991. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 140553. |
| 1979 | 13020. | 12210. | 12322. | 12670. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151861. |
| 1980 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1981 | 13020. | 12567. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153267. |
| 1982 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1983 | 13020. | 12600. | 13020. | 12835. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153114. |
| 1984 | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| 1985 | 13020. | 12600. | 12903. | 12751. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152913. |
| 1986 | 13020. | 12401. | 12678. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152758. |
| 1987 | 13020. | 12141. | 12166. | 12319. | 11726. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 151251. |
| 1988 | 13020. | 12540. | 12871. | 12960. | 12168. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153438. |
| 1989 | 13020. | 12600. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153300. |
| 1990 | 12923. | 12392. | 13020. | 13020. | 11760. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152994. |
| 1991 | 13020. | 12509. | 12750. | 12594. | 11638. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 152391. |
| TOTAL | 465418. | 445305. | 454078. | 453435. | 417128. | 465041. | 453598. | 468718. | 453598. | 468718. | 468271. | 452067. | 5465363. |
| AVERAGE | 12928. | 12370. | 12613. | 12595. | 11587. | 12918. | 12600. | 13020. | 12600. | 13020. | 13008. | 12557. | 151816. |
| MAXIMUM | 13020. | 12600. | 13020. | 13020. | 12180. | 13020. | 12600. | 13020. | 12600. | 13020. | 13020. | 12600. | 153720. |
| MINIMUM | 11563. | 10582. | 9534. | 10122. | 9473. | 11709. | 12600. | 13020. | 12600. | 13020. | 12762. | 11782. | 140553. |

## Table 9-19 Monthly Peak Power of Köprübaşı Project

Unit: MW

| Month / Year | < OCT > | < NOV > | < DEC > | < JAN > | < FEB > | < MAR > | < APR > | < MAY > | < JUN > | < JUL > | < AUG > | < SEP > | <TOTAL> |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1957 | 70.0 | 69.0 | 67.6 | 66.5 | 67.6 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 69.0 | 66.0 | 825.7 |
| 1958 | 62.9 | 59.4 | 56.6 | 55.1 | 56.4 | 63.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 773.3 |
| 1959 | 70.0 | 70.0 | 68.3 | 66.6 | 65.6 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 830.5 |
| 1960 | 70.0 | 69.6 | 67.3 | 65.7 | 67.5 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 830.2 |
| 1961 | 70.0 | 69.3 | 67.4 | 66.0 | 66.8 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 829.5 |
| 1962 | 70.0 | 68.6 | 67.1 | 66.1 | 66.4 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 828.2 |
| 1963 | 67.7 | 64.9 | 63.7 | 66.4 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 822.8 |
| 1964 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1965 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1966 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1967 | 70.0 | 67.4 | 64.7 | 62.4 | 60.7 | 63.7 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 808.9 |
| 1968 | 70.0 | 68.7 | 69.9 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 838.6 |
| 1969 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1970 | 70.0 | 69.0 | 67.3 | 66.0 | 67.6 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 830.0 |
| 1971 | 70.0 | 68.1 | 66.5 | 68.4 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 833.0 |
| 1972 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1973 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1974 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1975 | 70.0 | 70.0 | 68.9 | 67.5 | 67.0 | 69.9 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 833.4 |
| 1976 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1977 | 70.0 | 69.1 | 67.9 | 67.3 | 66.8 | 69.2 | 70.0 | 70.0 | 70.0 | 70.0 | 68.6 | 65.5 | 824.3 |
| 1978 | 62.2 | 58.8 | 51.3 | 54.4 | 58.9 | 64.5 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 770.0 |
| 1979 | 70.0 | 67.8 | 66.2 | 68.1 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 832.2 |
| 1980 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1981 | 70.0 | 69.8 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 839.8 |
| 1982 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1983 | 70.0 | 70.0 | 70.0 | 69.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 839.0 |
| 1984 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1985 | 70.0 | 70.0 | 69.4 | 68.6 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 837.9 |
| 1986 | 70.0 | 68.9 | 68.2 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 837.1 |
| 1987 | 70.0 | 67.5 | 65.4 | 66.2 | 69.8 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 828.9 |
| 1988 | 70.0 | 69.7 | 69.2 | 69.7 | 69.9 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 838.5 |
| 1989 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| 1990 | 69.5 | 68.8 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 838.3 |
| 1991 | 70.0 | 69.5 | 68.5 | 67.7 | 69.3 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 835.0 |
| TOTAL | 2502.2 | 2473.9 | 2441.3 | 2437.8 | 2460.5 | 2500.2 | 2520.0 | 2520.0 | 2520.0 | 2520.0 | 2517.6 | 2511.5 | 29925.0 |
| AVERAGE | 69.5 | 68.7 | 67.8 | 67.7 | 68.3 | 69.5 | 70.0 | 70.0 | 70.0 | 70.0 | 69.9 | 69.8 | 831.2 |
| MAXIMUM | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 70.0 | 840.0 |
| MINIMUM | 62.2 | 58.8 | 51.3 | 54.4 | 56.4 | 63.0 | 70.0 | 70.0 | 70.0 | 70.0 | 68.6 | 65.5 | 770.0 |

# Table 9-20 Peak Power Duration of Köprübaşi Project

PEAK POWER DURATION OF KOPRUBASI PROJECT (5510 - 9109)
90% --- 67.5( 7404 )
95% --- 65.7( 5904 )

Unit: MW

| NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P | NO. | DATE | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5801 | 70.0 | 51 | 6011 | 70.0 | 101 | 6701 | 70.0 | 151 | 7208 | 70.0 | 201 | 7904 | 70.0 | 251 | 8406 | 70.0 | 301 | 9009 | 70.0 | 351 | 8002 | 69.8 | 401 | 7003 | 66.5 |
| 2 | 6206 | 70.0 | 52 | 6012 | 70.0 | 102 | 6704 | 70.0 | 152 | 7209 | 70.0 | 202 | 7906 | 70.0 | 252 | 8407 | 70.0 | 302 | 9010 | 70.0 | 352 | 8605 | 69.8 | 402 | 5604 | 66.5 |
| 3 | 6401 | 70.0 | 53 | 6101 | 70.0 | 103 | 6705 | 70.0 | 153 | 7212 | 70.0 | 203 | 7907 | 70.0 | 253 | 8408 | 70.0 | 303 | 9011 | 70.0 | 353 | 8704 | 69.7 | 403 | 6105 | 66.4 |
| 4 | 6601 | 70.0 | 54 | 6107 | 70.0 | 104 | 6706 | 70.0 | 154 | 7301 | 70.0 | 204 | 7908 | 70.0 | 254 | 8409 | 70.0 | 304 | 9012 | 70.0 | 354 | 8702 | 69.7 | 404 | 6204 | 66.4 |
| 5 | 6804 | 70.0 | 55 | 6108 | 70.0 | 105 | 6707 | 70.0 | 155 | 7302 | 70.0 | 205 | 7909 | 70.0 | 255 | 8410 | 70.0 | 305 | 5501 | 70.0 | 355 | 5902 | 69.6 | 405 | 7803 | 66.2 |
| 6 | 7211 | 70.0 | 56 | 6109 | 70.0 | 106 | 6708 | 70.0 | 156 | 7304 | 70.0 | 206 | 7910 | 70.0 | 256 | 8411 | 70.0 | 306 | 5504 | 70.0 | 356 | 9002 | 69.5 | 406 | 8604 | 66.2 |
| 7 | 7401 | 70.0 | 57 | 6110 | 70.0 | 107 | 6709 | 70.0 | 157 | 7305 | 70.0 | 207 | 7911 | 70.0 | 257 | 8412 | 70.0 | 307 | 5610 | 70.0 | 357 | 8901 | 69.5 | 407 | 6104 | 66.1 |
| 8 | 8311 | 70.0 | 58 | 6205 | 70.0 | 108 | 6710 | 70.0 | 158 | 7306 | 70.0 | 208 | 7912 | 70.0 | 258 | 8501 | 70.0 | 308 | 5802 | 70.0 | 358 | 8403 | 69.4 | 408 | 6904 | 66.0 |
| 9 | 8504 | 70.0 | 59 | 6207 | 70.0 | 109 | 6711 | 70.0 | 159 | 7307 | 70.0 | 209 | 8001 | 70.0 | 259 | 8505 | 70.0 | 309 | 5806 | 70.0 | 359 | 6002 | 69.3 | 409 | 5612 | 66.0 |
| 10 | 8601 | 70.0 | 60 | 6208 | 70.0 | 110 | 6712 | 70.0 | 160 | 7308 | 70.0 | 210 | 8003 | 70.0 | 260 | 8506 | 70.0 | 310 | 5912 | 70.0 | 360 | 9005 | 69.3 | 410 | 6004 | 66.0 |
| 11 | 8811 | 70.0 | 61 | 6209 | 70.0 | 111 | 6805 | 70.0 | 161 | 7309 | 70.0 | 211 | 8005 | 70.0 | 261 | 8507 | 70.0 | 311 | 6009 | 70.0 | 361 | 8703 | 69.2 | 411 | 5904 | 65.7 |
| 12 | 5502 | 70.0 | 62 | 6210 | 70.0 | 112 | 6806 | 70.0 | 162 | 7310 | 70.0 | 212 | 8006 | 70.0 | 262 | 8508 | 70.0 | 312 | 6106 | 70.0 | 362 | 7606 | 69.2 | 412 | 5805 | 65.6 |
| 13 | 5503 | 70.0 | 63 | 6212 | 70.0 | 113 | 6807 | 70.0 | 163 | 7311 | 70.0 | 213 | 8007 | 70.0 | 263 | 8509 | 70.0 | 313 | 6111 | 70.0 | 363 | 7602 | 69.1 | 413 | 7612 | 65.5 |
| 14 | 5505 | 70.0 | 64 | 6301 | 70.0 | 114 | 6808 | 70.0 | 164 | 7312 | 70.0 | 214 | 8008 | 70.0 | 264 | 8510 | 70.0 | 314 | 6112 | 70.0 | 364 | 6902 | 69.0 | 414 | 8603 | 65.4 |
| 15 | 5506 | 70.0 | 65 | 6302 | 70.0 | 115 | 6809 | 70.0 | 165 | 7402 | 70.0 | 215 | 8009 | 70.0 | 265 | 8511 | 70.0 | 315 | 6211 | 70.0 | 365 | 8204 | 69.0 | 415 | 6202 | 64.9 |
| 16 | 5507 | 70.0 | 66 | 6303 | 70.0 | 116 | 6811 | 70.0 | 166 | 7409 | 70.0 | 216 | 8010 | 70.0 | 266 | 8512 | 70.0 | 316 | 6304 | 70.0 | 366 | 5602 | 69.0 | 416 | 6603 | 64.7 |
| 17 | 5508 | 70.0 | 67 | 6305 | 70.0 | 117 | 6901 | 70.0 | 167 | 7410 | 70.0 | 217 | 8011 | 70.0 | 267 | 8606 | 70.0 | 317 | 6310 | 70.0 | 367 | 5611 | 69.0 | 417 | 7706 | 64.5 |
| 18 | 5509 | 70.0 | 68 | 6306 | 70.0 | 118 | 6906 | 70.0 | 168 | 7411 | 70.0 | 218 | 8012 | 70.0 | 268 | 8607 | 70.0 | 318 | 6503 | 70.0 | 368 | 7403 | 68.9 | 418 | 6203 | 63.7 |
| 19 | 5510 | 70.0 | 69 | 6307 | 70.0 | 119 | 6908 | 70.0 | 169 | 7412 | 70.0 | 219 | 8101 | 70.0 | 269 | 8608 | 70.0 | 319 | 6610 | 70.0 | 369 | 8502 | 68.9 | 419 | 6606 | 63.7 |
| 20 | 5511 | 70.0 | 70 | 6308 | 70.0 | 120 | 6909 | 70.0 | 170 | 7501 | 70.0 | 220 | 8102 | 70.0 | 270 | 8609 | 70.0 | 320 | 6801 | 70.0 | 370 | 8902 | 68.8 | 420 | 5706 | 63.0 |
| 21 | 5512 | 70.0 | 71 | 6309 | 70.0 | 121 | 6910 | 70.0 | 171 | 7503 | 70.0 | 221 | 8103 | 70.0 | 271 | 8610 | 70.0 | 321 | 6802 | 70.0 | 371 | 6702 | 68.7 | 421 | 5701 | 62.9 |
| 22 | 5601 | 70.0 | 72 | 6311 | 70.0 | 122 | 6911 | 70.0 | 172 | 7504 | 70.0 | 222 | 8104 | 70.0 | 272 | 8701 | 70.0 | 322 | 6803 | 70.0 | 372 | 7611 | 68.6 | 422 | 6604 | 62.4 |
| 23 | 5606 | 70.0 | 73 | 6312 | 70.0 | 123 | 6912 | 70.0 | 173 | 7505 | 70.0 | 223 | 8105 | 70.0 | 273 | 8707 | 70.0 | 323 | 6810 | 70.0 | 373 | 6102 | 68.6 | 423 | 7701 | 62.2 |
| 24 | 5607 | 70.0 | 74 | 6402 | 70.0 | 124 | 7001 | 70.0 | 174 | 7506 | 70.0 | 224 | 8106 | 70.0 | 274 | 8708 | 70.0 | 324 | 6812 | 70.0 | 374 | 8404 | 68.6 | 424 | 6605 | 60.7 |
| 25 | 5608 | 70.0 | 75 | 6403 | 70.0 | 125 | 7005 | 70.0 | 175 | 7507 | 70.0 | 225 | 8107 | 70.0 | 275 | 8709 | 70.0 | 325 | 6907 | 70.0 | 375 | 9003 | 68.5 | 425 | 5702 | 59.4 |
| 26 | 5609 | 70.0 | 76 | 6404 | 70.0 | 126 | 7006 | 70.0 | 176 | 7508 | 70.0 | 226 | 8108 | 70.0 | 276 | 8710 | 70.0 | 326 | 7102 | 70.0 | 376 | 7004 | 68.4 | 426 | 7705 | 58.9 |
| 27 | 5707 | 70.0 | 77 | 6405 | 70.0 | 127 | 7007 | 70.0 | 177 | 7509 | 70.0 | 227 | 8109 | 70.0 | 277 | 8711 | 70.0 | 327 | 7210 | 70.0 | 377 | 5803 | 68.3 | 427 | 7702 | 58.8 |
| 28 | 5708 | 70.0 | 78 | 6406 | 70.0 | 128 | 7008 | 70.0 | 178 | 7510 | 70.0 | 228 | 8110 | 70.0 | 278 | 8712 | 70.0 | 328 | 7303 | 70.0 | 378 | 8503 | 68.2 | 428 | 5703 | 56.6 |
| 29 | 5709 | 70.0 | 79 | 6407 | 70.0 | 129 | 7009 | 70.0 | 179 | 7511 | 70.0 | 229 | 8112 | 70.0 | 279 | 8801 | 70.0 | 329 | 7407 | 70.0 | 379 | 7002 | 68.1 | 429 | 5705 | 56.4 |
| 30 | 5710 | 70.0 | 80 | 6408 | 70.0 | 130 | 7010 | 70.0 | 180 | 7512 | 70.0 | 230 | 8203 | 70.0 | 280 | 8803 | 70.0 | 330 | 7408 | 70.0 | 380 | 7804 | 68.1 | 430 | 5704 | 55.1 |
| 31 | 5711 | 70.0 | 81 | 6409 | 70.0 | 131 | 7011 | 70.0 | 181 | 7601 | 70.0 | 231 | 8206 | 70.0 | 281 | 8804 | 70.0 | 331 | 7502 | 70.0 | 381 | 7603 | 67.9 | 431 | 7704 | 54.4 |
| 32 | 5712 | 70.0 | 82 | 6410 | 70.0 | 132 | 7012 | 70.0 | 182 | 7607 | 70.0 | 232 | 8207 | 70.0 | 282 | 8805 | 70.0 | 332 | 7711 | 70.0 | 382 | 7802 | 67.8 | 432 | 7703 | 51.3 |
| 33 | 5807 | 70.0 | 83 | 6411 | 70.0 | 133 | 7101 | 70.0 | 183 | 7608 | 70.0 | 233 | 8208 | 70.0 | 283 | 8806 | 70.0 | 333 | 7806 | 70.0 | 383 | 9004 | 67.7 | | | |
| 34 | 5808 | 70.0 | 84 | 6412 | 70.0 | 134 | 7103 | 70.0 | 184 | 7609 | 70.0 | 234 | 8209 | 70.0 | 284 | 8807 | 70.0 | 334 | 7812 | 70.0 | 384 | 6201 | 67.7 | | | |
| 35 | 5809 | 70.0 | 85 | 6501 | 70.0 | 135 | 7104 | 70.0 | 185 | 7610 | 70.0 | 235 | 8210 | 70.0 | 285 | 8808 | 70.0 | 335 | 7905 | 70.0 | 385 | 6905 | 67.6 | | | |
| 36 | 5810 | 70.0 | 86 | 6502 | 70.0 | 136 | 7105 | 70.0 | 186 | 7707 | 70.0 | 236 | 8211 | 70.0 | 286 | 8809 | 70.0 | 336 | 8004 | 70.0 | 386 | 5605 | 67.6 | | | |
| 37 | 5811 | 70.0 | 87 | 6504 | 70.0 | 137 | 7106 | 70.0 | 187 | 7708 | 70.0 | 237 | 8212 | 70.0 | 287 | 8810 | 70.0 | 337 | 8111 | 70.0 | 387 | 5603 | 67.6 | | | |
| 38 | 5812 | 70.0 | 88 | 6505 | 70.0 | 138 | 7107 | 70.0 | 188 | 7709 | 70.0 | 238 | 8301 | 70.0 | 288 | 8812 | 70.0 | 338 | 8201 | 70.0 | 388 | 5905 | 67.5 | | | |
| 39 | 5901 | 70.0 | 89 | 6506 | 70.0 | 139 | 7108 | 70.0 | 189 | 7710 | 70.0 | 239 | 8303 | 70.0 | 289 | 8903 | 70.0 | 339 | 8202 | 70.0 | 389 | 7404 | 67.5 | | | |
| 40 | 5906 | 70.0 | 90 | 6507 | 70.0 | 140 | 7109 | 70.0 | 190 | 7712 | 70.0 | 240 | 8304 | 70.0 | 290 | 8904 | 70.0 | 340 | 8205 | 70.0 | 390 | 8602 | 67.5 | | | |
| 41 | 5907 | 70.0 | 91 | 6508 | 70.0 | 141 | 7110 | 70.0 | 191 | 7801 | 70.0 | 241 | 8305 | 70.0 | 291 | 8905 | 70.0 | 341 | 8302 | 70.0 | 391 | 6602 | 67.4 | | | |
| 42 | 5908 | 70.0 | 92 | 6509 | 70.0 | 142 | 7111 | 70.0 | 192 | 7805 | 70.0 | 242 | 8306 | 70.0 | 292 | 8907 | 70.0 | 342 | 8611 | 70.0 | 392 | 6003 | 67.4 | | | |
| 43 | 5909 | 70.0 | 93 | 6510 | 70.0 | 143 | 7112 | 70.0 | 193 | 7807 | 70.0 | 243 | 8307 | 70.0 | 293 | 8908 | 70.0 | 343 | 8612 | 70.0 | 393 | 5903 | 67.3 | | | |
| 44 | 5910 | 70.0 | 94 | 6511 | 70.0 | 144 | 7201 | 70.0 | 194 | 7808 | 70.0 | 244 | 8308 | 70.0 | 294 | 8909 | 70.0 | 344 | 8706 | 70.0 | 394 | 6903 | 67.3 | | | |
| 45 | 5911 | 70.0 | 95 | 6512 | 70.0 | 145 | 7202 | 70.0 | 195 | 7809 | 70.0 | 245 | 8309 | 70.0 | 295 | 8911 | 70.0 | 345 | 8802 | 70.0 | 395 | 7604 | 67.3 | | | |
| 46 | 6001 | 70.0 | 96 | 6607 | 70.0 | 146 | 7203 | 70.0 | 196 | 7810 | 70.0 | 246 | 8310 | 70.0 | 296 | 8912 | 70.0 | 346 | 8906 | 70.0 | 396 | 6103 | 67.1 | | | |
| 47 | 6006 | 70.0 | 97 | 6608 | 70.0 | 147 | 7204 | 70.0 | 197 | 7811 | 70.0 | 247 | 8312 | 70.0 | 297 | 9001 | 70.0 | 347 | 8910 | 70.0 | 397 | 7405 | 67.0 | | | |
| 48 | 6007 | 70.0 | 98 | 6609 | 70.0 | 148 | 7205 | 70.0 | 198 | 7901 | 70.0 | 248 | 8401 | 70.0 | 298 | 9006 | 70.0 | 348 | 8705 | 69.9 | 398 | 7605 | 66.8 | | | |
| 49 | 6008 | 70.0 | 99 | 6611 | 70.0 | 149 | 7206 | 70.0 | 199 | 7902 | 70.0 | 249 | 8402 | 70.0 | 299 | 9007 | 70.0 | 349 | 7406 | 69.9 | 399 | 6005 | 66.8 | | | |
| 50 | 6010 | 70.0 | 100 | 6612 | 70.0 | 150 | 7207 | 70.0 | 200 | 7903 | 70.0 | 250 | 8405 | 70.0 | 300 | 9008 | 70.0 | 350 | 6703 | 69.9 | 400 | 5804 | 66.6 | | | |

## 9.3 Downstream Çay Project

The Çay Project is planned on the Devrek River in the Master Plan as a development project downstream of the Köprübaşı Project.

A review was made of the Çay Project proposed in the Master Plan in connection with the development plan of the Köprübaşı Project just decided in 9.2. Results of the review are described below.

### 9.3.1 Reservoir Scale

(1) Reservoir High Water Level

In the Master Plan, the reservoir high water level of the Çay Project is given as EL 219 m and the end of the tailrace of the Köprübaşı Project is located inside the Çay Project reservoir approximately 1.5 km downstream of the planned end of the Çay Project reservoir backwater.

However, according to the 1/1,000 topographical map prepared newly by the DSI in 1993 and used for the present study, the river bed elevation of the Devrek River at the end of the Köprübaşı Project tailrace is EL 221 m, while the tailrace water level at that point will be at EL 223 m, and when the reservoir high water level of the Çay Project is made EL 219 m as in the Master Plan, the location of the backwater end will be approximately 0.6 km downstream of the tailrace end. As a result, there would be an idle head of 4 m between the Köprübaşı Project and the Çay Project.

As stated in 9.2, it will not be economical for the location of the Köprübaşı Project tailrace end site to be moved downstream from the present location, and to utilize this idle head for power generation, it will be necessary for the reservoir high water level in the Çay Project to be raised 4 m above the EL 219 m proposed in the Master Plan to make it EL 223 m.

For the dam site of the Çay Project, unlike that of the Köprübaşı Project, there are no topographical or geological restrictions to be seen in particular about raising the high water level above EL 219 m, and it is judged there is a good possibility that it will be feasible for the high water level to be raised to EL 223 m.

Accordingly, it will be appropriate for an examination to be made concerning this point in the feasibility study of the Çay Project.

(2) Effective Storage Capacity

In the Master Plan the available drawdown of the reservoir in the Çay Project is put as 39 m for an effective storage capacity of 144 x $10^6$ $m^3$. In the upstream Köprübaşı Project, approximately 99% of the inflow is utilized for power generation through regulation of runoff by the Köprübaşı reservoir, while the annual inflow to the Çay Project from the remaining catchment area between the Köprübaşı Project and the Çay Project will be 129 x $10^6$ $m^3$, which is 28% of the inflow for the Köprübaşı Project. Hence, if there were to be an effective storage capacity of about 46 x $10^6$ $m^3$ for the Çay Project, it would be possible for inflow from the remaining catchment area to be regulated for power generation as to be done in the Köprübaşı Project.

When the reservoir high water level of the Çay Project is made EL 223 m, if there were to be an available depth of 8 m, an effective storage capacity of 46 x $10^6$ $m^3$ would be secured. It will become possible for operation at a higher water level than in the scheme proposed in the Master Plan, and output and energy production will be increased.

Therefore, optimization of the effective storage capacity of the Çay Project will be necessary upon considering the runoff regulating effect of the Köprübaşı Project in the feasibility study of the Çay Project.

### 9.3.2 Power Station Scale

The Çay Project would be the downstreammost power generation project on the Devrek River and there is no reservoir plan downstream of the Çay Project even to the mouth of the mainstream Filyos River after merging of the Devrek River with the Filyos River. In the Master Plan the maximum available discharge of the Çay Project is given as 46 $m^3/s$, approximately 10% more than the Köprübaşı Project, with the plan being for the Çay Project to be used as a peaking power station.

However, the river channel length from the powerhouse site of the Çay Project to the confluence with the Filyos River is 40 km, and that from the confluence to the mouth of the Filyos River is 50 km. Although there is no necessity for consideration regarding this point at the present time, since there is no facility for water utilization on the downstream stretch, it will be necessary for thorough consideration to be given to fluctuation in the downstream river water level due to power generation operation.

With the Çay Project, if equalizing operation were to be done similarly to the Suat Uğurlu Project and the Derbent Project which are downstreammost power generation projects on other rivers, and if the equivalent peak duration time were to be made about 12 hours, the maximum available discharge would be 28 $m^3/s$, and in this case also about 89% of the reservoir inflow can be utilized for power generation.

Therefore, it will be appropriate for examinations to be made concerning equalizing operation in the feasibility study of the Çay Project.

### 9.3.3 Alternative Development Plan for Çay Project

As a result of above mentioned the review high water, it is considered that the development plan indicated in Table 9-21 would serve as a basic alternative development plan in the feasibility study of the Çay Project.

In this case incremental annual average energy production, annual firm energy production and firm peak power by the Köprübaşı Project at the Çay Project are 12 GWh, 28 GWh and 6.6 MW respectively.

**Table 9-21 Alternative Development Plan of Çay Project**

| Item | Unit | Description |
|---|---|---|
| Catchment Area | $km^2$ | 2,422 |
| Annual Inflow | $10^6$ $m^3$ | 582.54 |
| High Water Level | m | 223.00 |
| Normal Water Level | m | 219.00 |
| Low Water Level | m | 215.00 (188.00) |
| Total Storage Capacity | $10^6$ $m^3$ | 185 |
| Effective Storage Capacity | $10^6$ $m^3$ | 46 (145) |
| Tail Water Level | m | 125.00 |
| Effective Head | m | 90.50 (82.80) |
| Maximum Discharge | $m^3/s$ | 28 (25) |
| Installed Capacity | MW | 22 (18) |
| Firm Peak Power | MW | 21.4 (14.8) |
| Annual Energy Projection | GWh | 116 (104) |
| Firm Energy Projection | GWh | 94 (66) |

Note: Figures in the ( ) are the figures in case of without Köprübaşı Project

In the above alternative plan, since the output is held low considering equalizing operation, when evaluation is done by the benefit cost method, it is judged that the economics of the Çay Project by itself is that it will be barely feasible. But when an evaluation is made combined with the Köprübaşı Project, it would be amply economical, and the judgment is that it is a project which should be developed at an early time in succession to the Köprübaşı Project from the standpoint of operation of the Köprübaşı Project.

# Chapter 10 TRANSMISSION LINE AND POWER SYSTEM ANALYSIS

## Chapter 10

# TRANSMISSION LINE AND POWER SYSTEM ANALYSIS

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# Chapter 10 TRANSMISSION LINE AND POWER SYSTEM ANALYSIS

## 10.1 Summary of Power System

The transmission system in Turkey comprises 380 kV of primary system and 154 kV of secondary system. In addition, 66 kV and 34.5 kV form the lower voltage systems. The total distance of transmission lines at the end of 1992 is 9,500 km for 380 kV and 22,000 km for 154 kV. Since Turkey has the borders on the east and west, its power systems are linked with those of the adjacent foreign countries thus allowing the power interchange.

The voltage of linked transmission lines widely differs among the countries such as 400 kV, 200 kV, 154 kV, etc. depending upon the adopted system voltage of these countries. Presently, this international linkage of power systems tends to be extended more and more and thus a number of projects are under planning now.

## 10.2 Transmission Line for Köprübaşı Power Station

### 10.2.1 Route Survey

The route survey for the planned transmission line was conducted as to the following two routes based on the master plan prepared by DSI and the long-term plan by TEK. During the local site survey that was conducted using the topographic maps, the condition of main roads and those of roads located in mountainous areas, as well as actual state of the transmission line routes were fully investigated.

- Master plan route by DSI:

  Köprübaşı - Bolu (Existing 154 kV substation)

  Distance: 40 km

- Planned route by TEK:

Köprübaşı - Devrek (Planned substation)

Distance: 30 km

As a result of the survey, it was found that there are no technical restrictions which may obstruct construction of these two routes and thus it is possible to implement the plan for these two routes. However, after further discussion with TEK, it was notified that the power should be sent to Ereğli and Karabük substations from the Köprübaşı power station in order to cater for the nearby power demand first.

Accordingly, the following two additional routes are further reviewed:

Köprübaşı - Karabük (Existing 154 kV substation)

Distance: 80 km

Köprübaşı - Ereğli (Existing 154 kV substation)

Distance: 50 km

Since these routes were already surveyed by TEK for itself, and moreover in consideration of the geographical features of these routes, it must be possible to construct the transmission lines these routes. Nonetheless, as a result of the review performed by our survey team, it is still conceivable that the construction costs might be rising if these direct routes from Köprübaşı to Karabük and Ereğli are chosen.

For that reason, the transmission line routes shown in the transmission plan prepared by TEK and the master plan by DSI which have fully taken into account the location of the Çay power station should be considered in the study of the route.

As for the design, it is most suitable to extend the two-circuit outgoing transmission lines with two-circuit steel towers from the Köprübaşı power station to the Çıplak district which closes to the Çay power station, where these lines are separated into two independent lines with one- circuit steel towers to reach Karabük and Ereğli substations respectively.

### 10.2.2 Transmission Line Plan

(1) Lead-in substation

It is presumed that power demand (in 2001 or so) for 154 kV system near the Köprübaşı power station is 540 MW and thus the generated power from this station is consumed by the near 154 kV system. In view of the demand distribution, it may be concluded that the 154 kV transmission lines from the Köprübaşı power station should be lead in to Karabük and Ereğli substations (See Figure 10-1).

(2) Summary of transmission line facilities

Table 10-1 shows the summary of transmission line facilities.

**Table 10-1 Summary of Transmission Lines**

| Section | Voltage (kV) | Conductor size (MCM) | Length (km) | No. of circuit (cct) |
|---|---|---|---|---|
| Köprübaşı-Karabük | 154 | ACSR1272 | 80 | 1 |
| Köprübaşı-Ereğli | 154 | ACSR1272 | 50 | 1 |

a) Transmission line voltage

The transmission line voltage is taken for 154 kV in order to match the bus voltage of lead-in substations.

b) Conductor size

Conductor size is taken for ACSR127MCM out of the standard sizes currently used by TEK.

c) Number of circuits and routes

The number of circuits is taken for one. The number of transmission line routes is taken for two though one route is still acceptable due to the output of the Köprübaşı power station itself and its percentage to the integrated power system are very small. This is because to enhance the system reliability by constructing it in a loop form and moreover is in consideration of the future plan for the Çay power station.

## 10.3 Power System Analysis

### 10.3.1 Conditions for System Calculation

(1) Purpose of calculation and contents

A power system analysis was conducted to verify the characteristics of the power system near the Köprübaşı power station.

The contents of the calculation are as follows:

- Power flow calculation
- Stability calculation
- Short-circuit current calculation

(2) Target year of calculation and range of simulation

The target year of calculation is presumed to be around 2001 when the operation of the Köprübaşı power station is commissioned. The peak power demand at that time for the integrated power system is estimated to be 22,610 MW.

Since the planned output of 70 MW of the Köprübaşı power station is consumed in the nearby 154 kV system, the range of calculation is only limited to the 154 kV system. In addition, the 380 kV system from far side of the Osmanca substation was simplified as one-generator system because the nearby 154 kV system is connected to 380 kV system at Osmanca substation.

To simplify as the one-generator system as mentioned above, the short-circuit current flown from the integrated 380 kV system into 380 kV bus of the Osmanca substation is taken for 15 kA (equivalent to 9,870 MVA of short-circuit capacity). Figure 10-2 shows the range of the system and the line impedance used for the calculation.

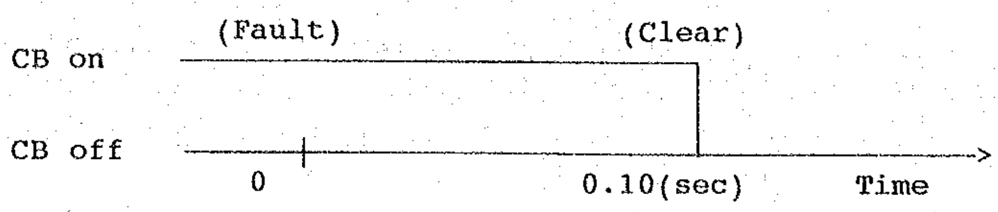
(3) Power flow calculation

Power flow and voltage calculation was conducted by presuming the operational conditions of the power system as follows:

| | |
|---|---|
| System voltage being maintained: | 95 to 105% |
| Operating voltage of generator: | 100 ±5% |
| Operation power factor of generator: | Above 0.85 |
| Tap ratio of transformer: | 1.00 ±0.10 P.U |

(4) Stability calculation

In power system stability study after commissioning the Köprübaşı power station, a three-phase-ground- fault is applied as the system disturbance on the 154 kV transmission lines: Köprübaşı - Ereğli line and Köprübaşı - Karabük line, and then the fluctuations of generators were checked. In this study, the fault resistance is taken for zero, and the high-speed reclosing of the faulty transmission line is not assumed. The fault sequence to apply to these transmission lines is illustrated below. The fault clearing time is taken for 0.10 seconds assuming that the protective relays operate normally.




(5) Short-circuit current calculation

Three phase short-circuit current was calculated for the Köprübaşı power station and its nearby 154 kV system presuming, as previously mentioned in Section (2), that the short-circuit current to be flown into the 380 kV bus of the Osmanca substation is 15 kA. Regarding a generator constant, the transient reactance (Xd') is used.

### 10.3.2 Results of System Calculation

(1) Power flow calculation

Power flow calculation was performed in two cases: when the Köprübaşı power station is in operation case and is not in operation case, and then the effect of operating the power station was checked and verified.

a) Köprübaşı Power Station in operation

Figure 10-3 shows the power flow when the Köprübaşı power station is in operation in 2001. The power demand of the 154 kV system near the Köprübaşı power station is about 540 MW and that the loads are comparatively large for Erdemir, Çatalağzi and Karabük substations among the related substations. On the other hand, the main supply is obtainable only from the Çatalağzi thermal power station, which is about 300 MW. Accordingly, about 240 MW of power lacking in the 154 kV system should be balanced by receiving from the 380 kV system and by generation of the Köprübaşı power station.

However, once the Köprübaşı power station (70 MW) has commissioned, the power receiving from other systems will be reduced to about 170 MW. As a result, the voltage drop at nearby substations will be reduced and the secondary voltages of all 154 kV substations are easily maintained at 100% or over.

b) Köprübaşı Power Station in non-operation

Figure 10-4 shows the power flow when the Köprübaşı power station is not in operation. In this case, it is known that the voltage drop becomes larger at 154 kV substations that are located distant from the 380 kV system and from the Çatalağzi power station. In particular, at Karabük and Ismetpaşa substations, it may be very difficult to maintain the secondary voltage at 100%. In addition, because the power receiving from the 380 kV system increases, the transmission loss increases.

It is also known that the transmission loss of the 154 kV system increases by 4.0 MW when the Köprübaşı power station is not in operation. This transmission loss amounts to 5.7% of 70 MW of the rated output from the Köprübaşı power station.

c) Priority of construction of new transmission lines

According to the transmission line plan prepared by TEK, one each of new lines is to be constructed starting from the Köprübaşı power station to Ereğli and Karabük substations. From the power flow calculation, however, it was found that the power flow from Köprübaşı to Karabük is 55 MW while that of Köprübaşı to Ereğli is only 15 MW which is very light(Figure 10-3).

In view of it, it may be concluded that the line from Köprübaşı to Ereğli is not necessarily be completed as the Köprübaşı power station commissions. Instead, it is surely possible to postpone the construction of that line until the downstream development, the Çay project, is completed. For this reason, the priority should be given to the construction of the line between Köprübaşı to Karabük.

(2) Stability calculation

Figure 10-5 and 10-6 show the results of the stability calculation in generator swing curves. Figure 10-5 is the case that the Köprübaşı - Karabük line is opened after the fault, while Figure 10-6 is the same fault case for Köprübaşı - Ereğli line. In both cases, the generator of the Köprübaşı power station can maintain its operation stably.

Figure 10-7 and 10-8 show the voltage fluctuation curves of the 154 kV busses of Köprübaşı, Karabük and Ereğli substations. Figure 10-7 is the case that the Köprübaşı - Karabük line is opened after the fault, and Figure 10-8 is the same condition for the Köprübaşı - Ereğli line.

The range of voltage drop of Karabük illustrated in Figure 10-7 is larger compared with that in Figure 10-8. These characteristics show that the operation of the Köprübaşı - Karabük line is taken an important function for maintaining the 154 kV local system.

(3) Short-circuit current calculation

Figure 10-9 shows the short-circuit currents of the 380 kV and the 154 kV buses, which are obtained on the assumption that the short-circuit current flown from the integrated 380 kV system into the 380 kV bus of the Osmanca substation is 15 kA and which differ from the actual values but nonetheless still are conceivable to be more or less the same in general.

The top-six 154 kV bus short-circuit currents are selected from the substations (or power stations) and listed below.

| | |
|---|---|
| Osmanca: | 8.7 kA (2312 MVA) |
| Ereğli : | 8.0 kA (2140 MVA) |
| Erdemir: | 7.6 kA (2026 MVA) |
| Çatalağzi: | 6.9 kA (1833 MVA) |
| Akçakoca: | 6.3 kA (1679 MVA) |
| Köprübaşı: | 4.5 kA (1213 MVA) |

(4) Development effect of Köprübaşı power station

The development of the Köprübaşı power station brings such advantageous effect as to improve characteristics of the power system in the vicinity of this power station. The effecting points are as shown below:

a) As for the demand and supply balance in this region, 55% of the demand is supplied from the Çatalağzi thermal power station, while the balance is supplied from the 380 kV and 154 kV systems. After commissioning of the Köprübaşı power station, it is possible to supply as much as almost 70% of the total power demand regionally.

b) Receiving power from the 380 kV system decreased, the transmission line loss in the 154 kV system is reduced and the system voltage level is improved.

c) Likewise, receiving power from the 380 kV system decreased, addition of 380/154 kV transformers at Osmanca and Ereğli substations may favorably be postponed.

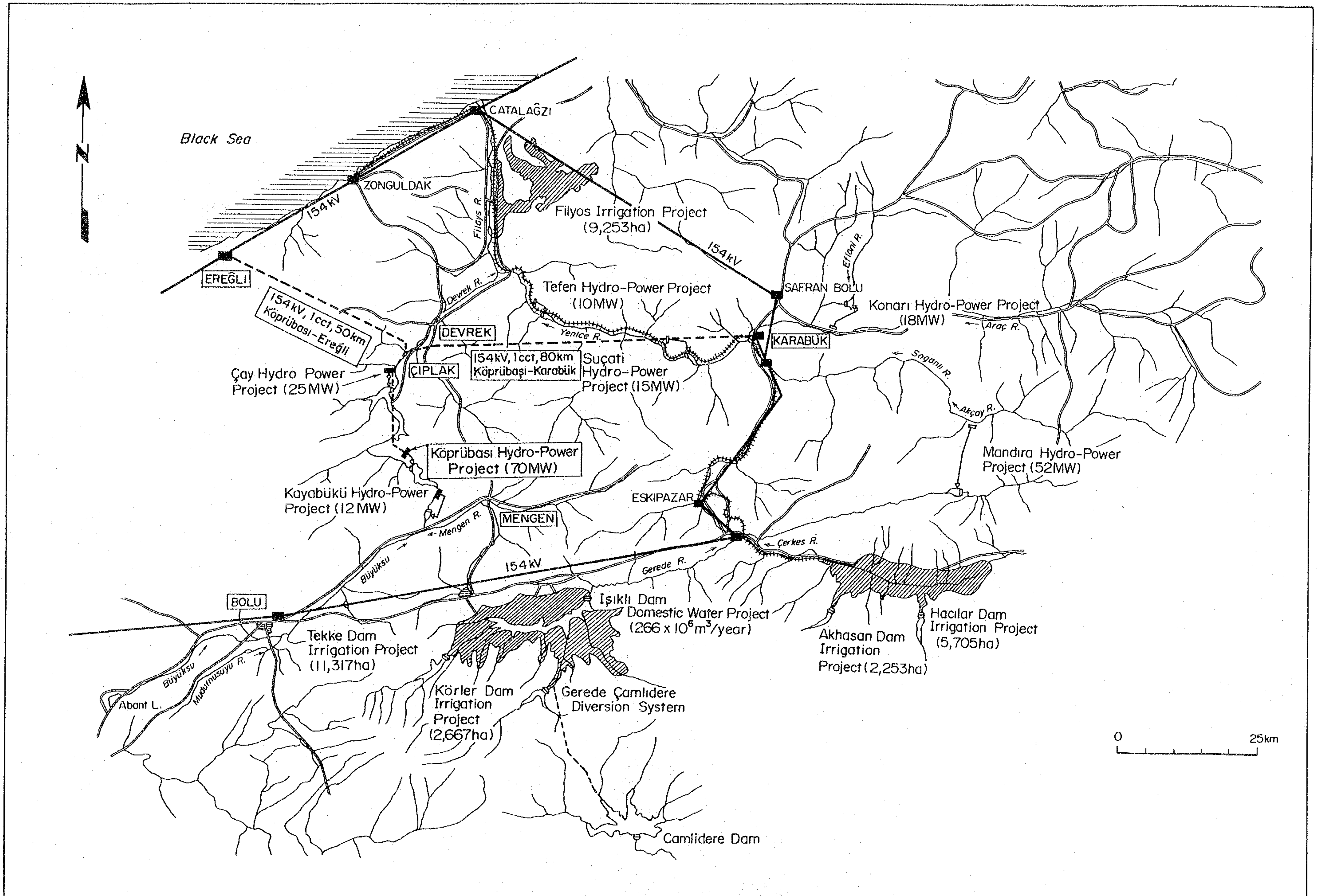
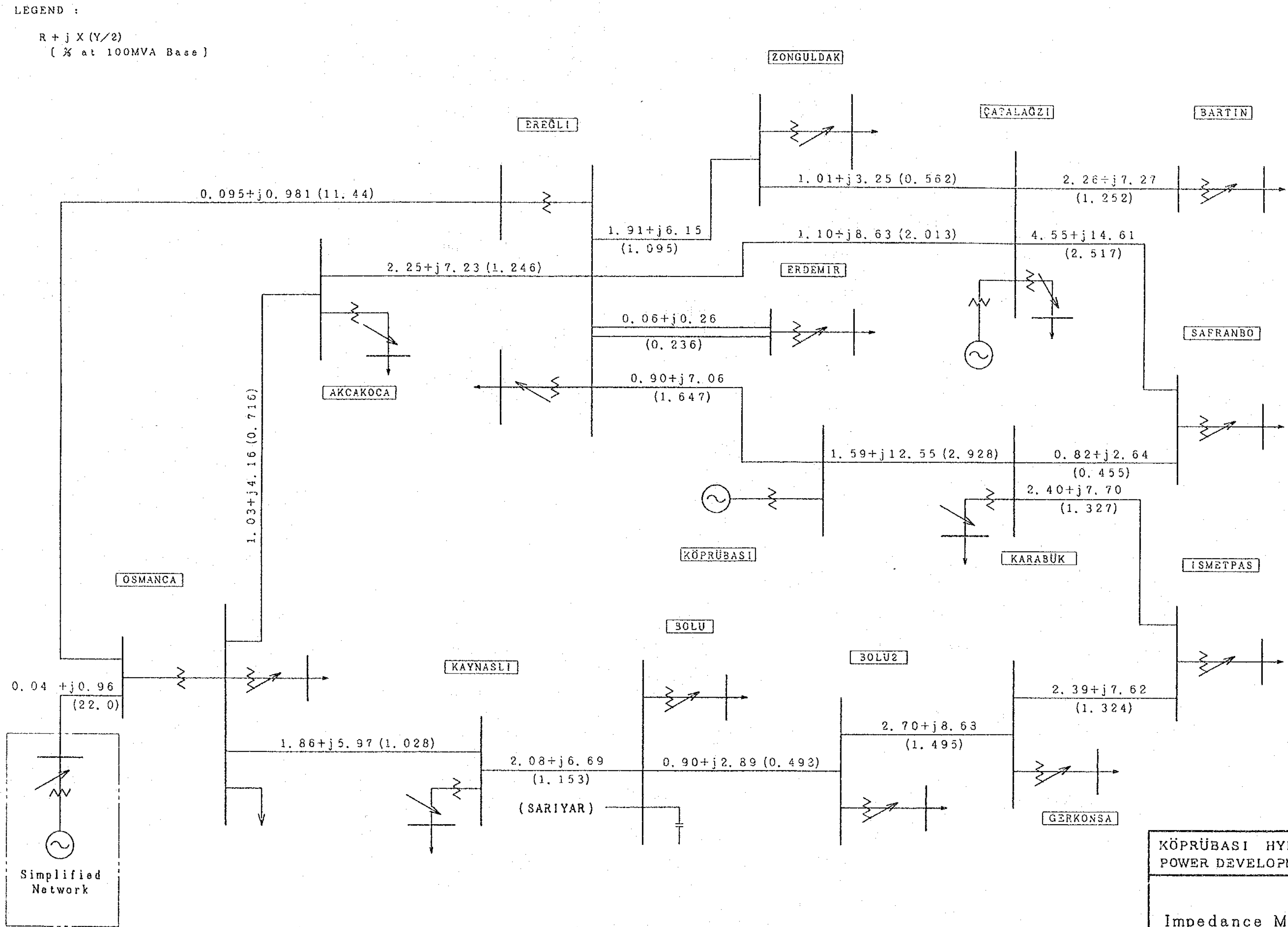


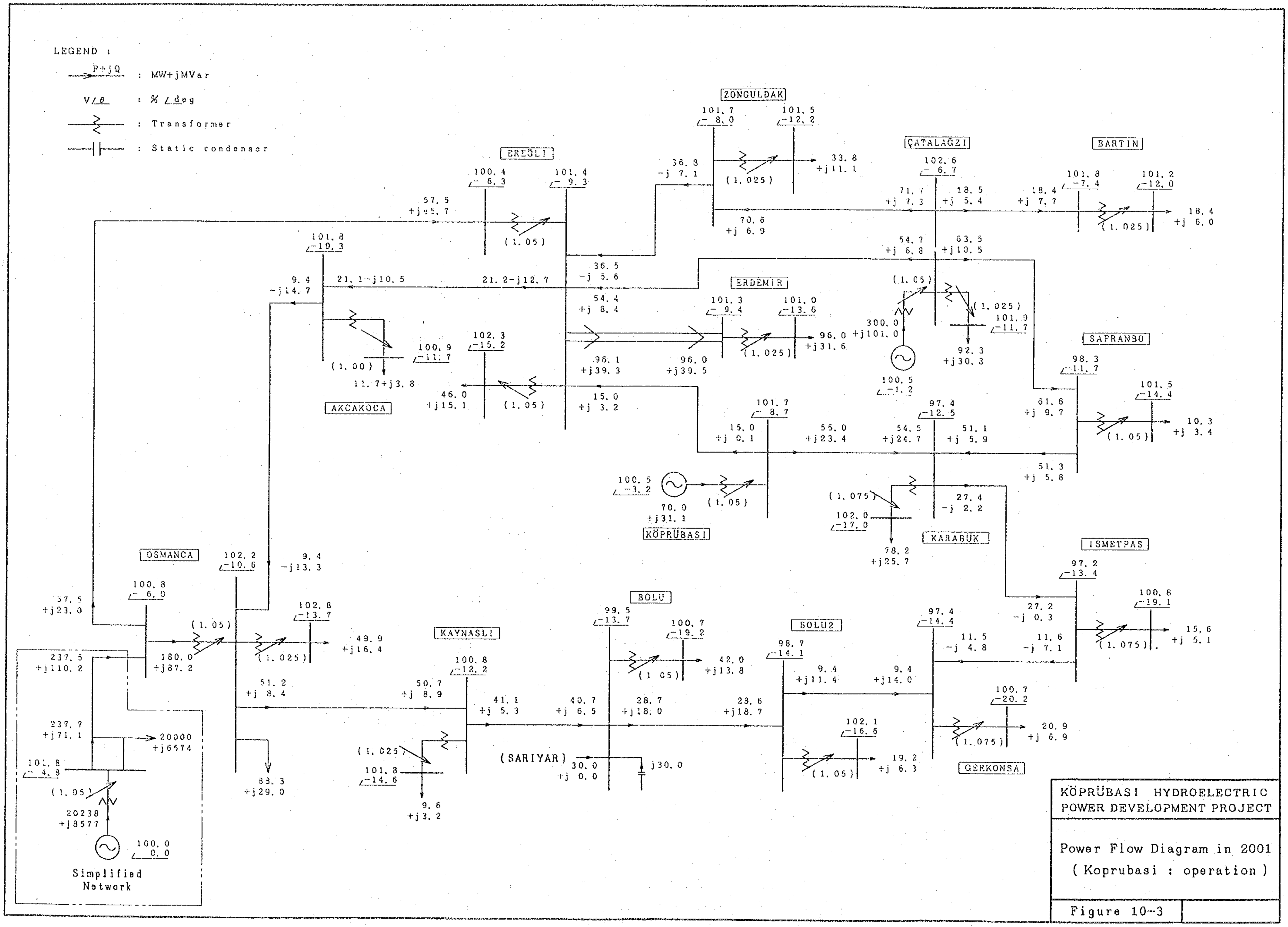

**Figure 10-1 154 kV Transmission Line in Köprübaşı Project**




KÖPRÜBASI HYDROELECTRIC POWER DEVELOPMENT PROJECT

Impedance Map in 2001

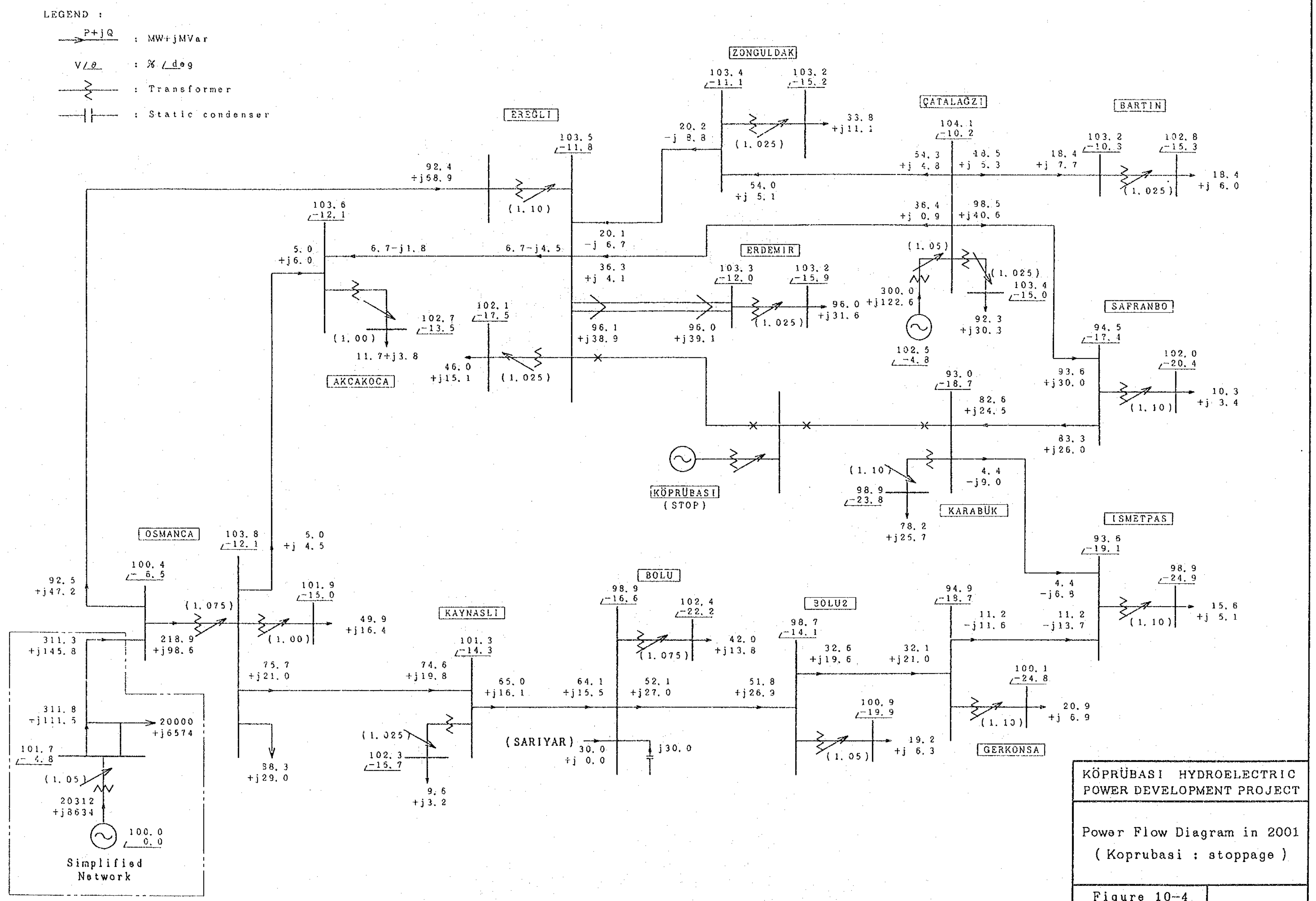
Figure 10-2




KÖPRÜBASI HYDROELECTRIC POWER DEVELOPMENT PROJECT

Power Flow Diagram in 2001
( Koprubasi : operation )

Figure 10-3




KÖPRÜBASI HYDROELECTRIC POWER DEVELOPMENT PROJECT

Power Flow Diagram in 2001
( Koprubasi : stoppage )

Figure 10-4

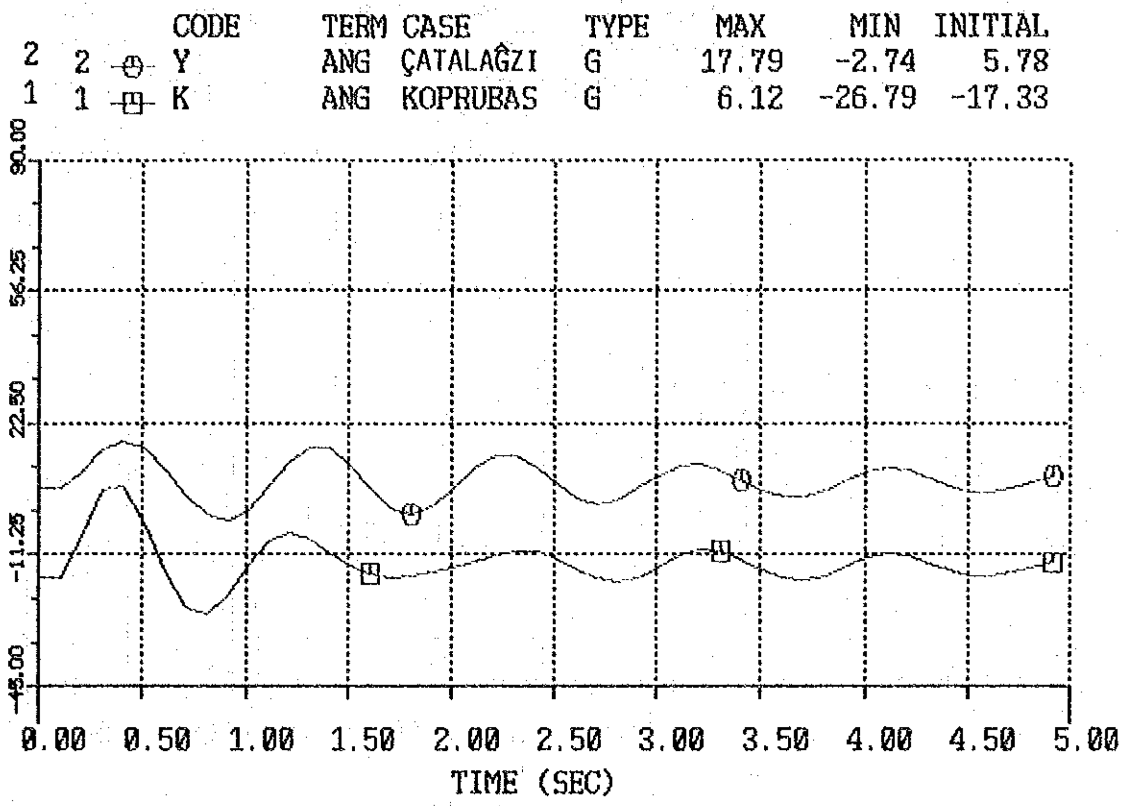



**Figure 10-5 Dynamic Stability Swing Curve**

Köprübaşı-Karabük Line opened after 3ϕG-fault at Köprübaşı P.S

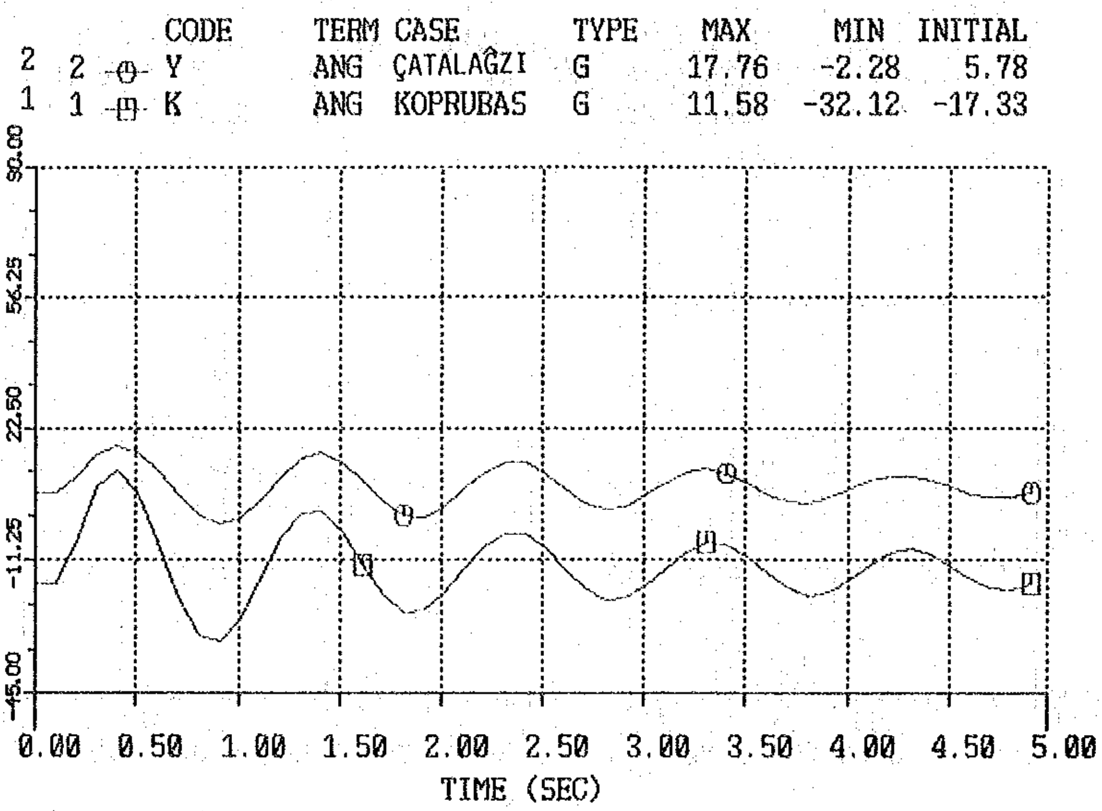



**Figure 10-6 Dynamic Stability Swing Curve**

Köprübaşı-Ereğli Line opened after 3ϕG-fault
at Köprübaşı P.S

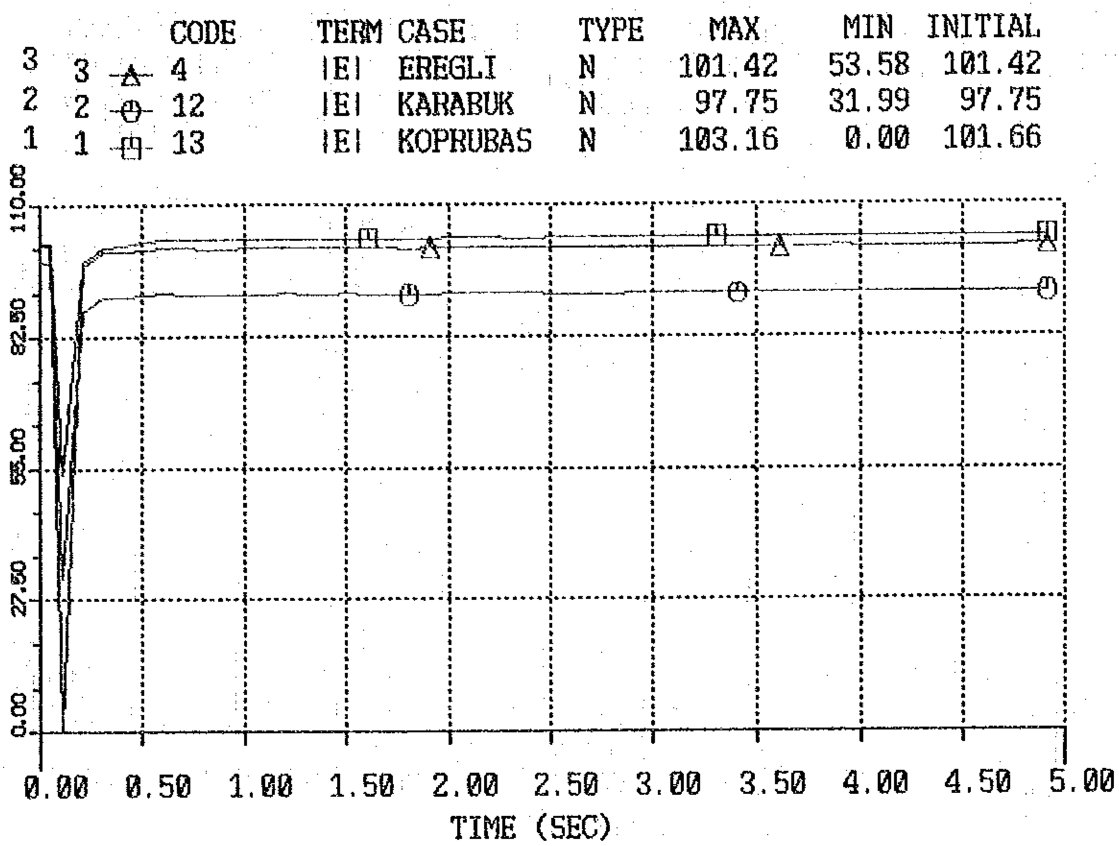



**Figure 10-7 Bus Voltage Fluctuation Curve**

Köprübaşı-Karabük Line opened after 3$\phi$G-fault at Köprübaşı P.S

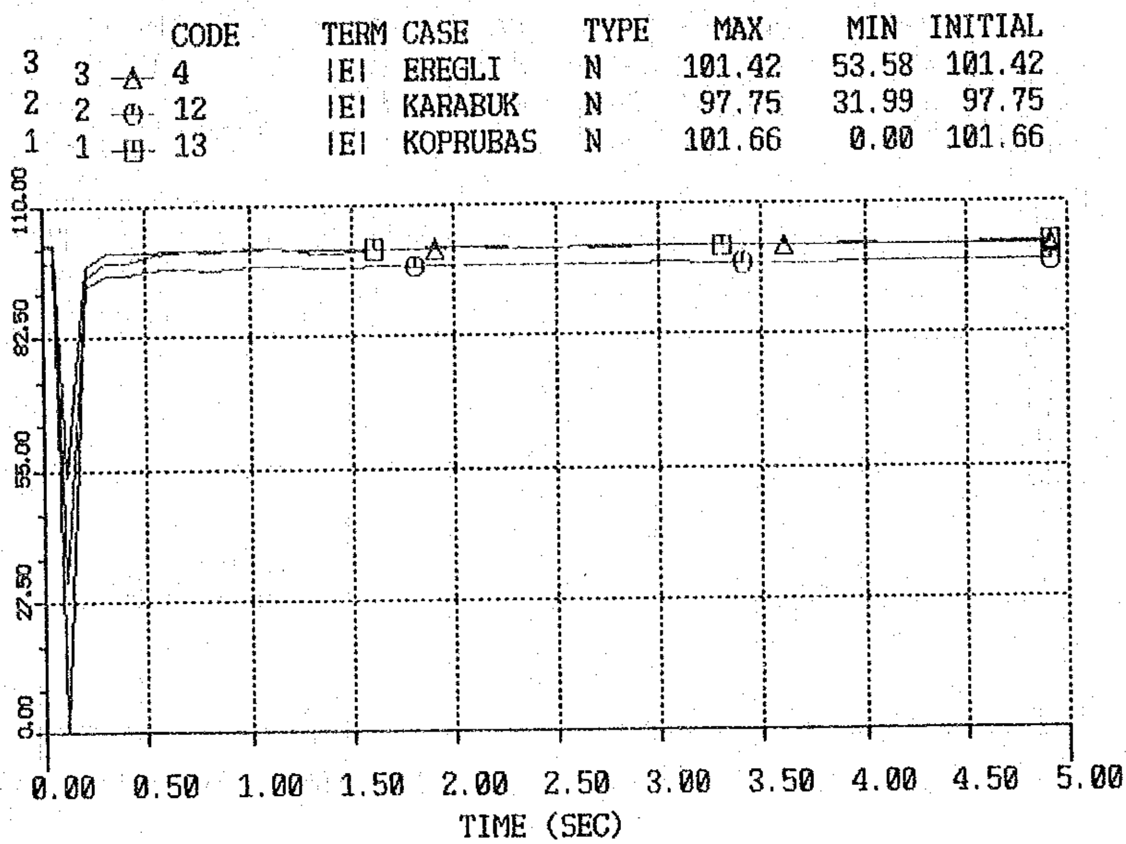
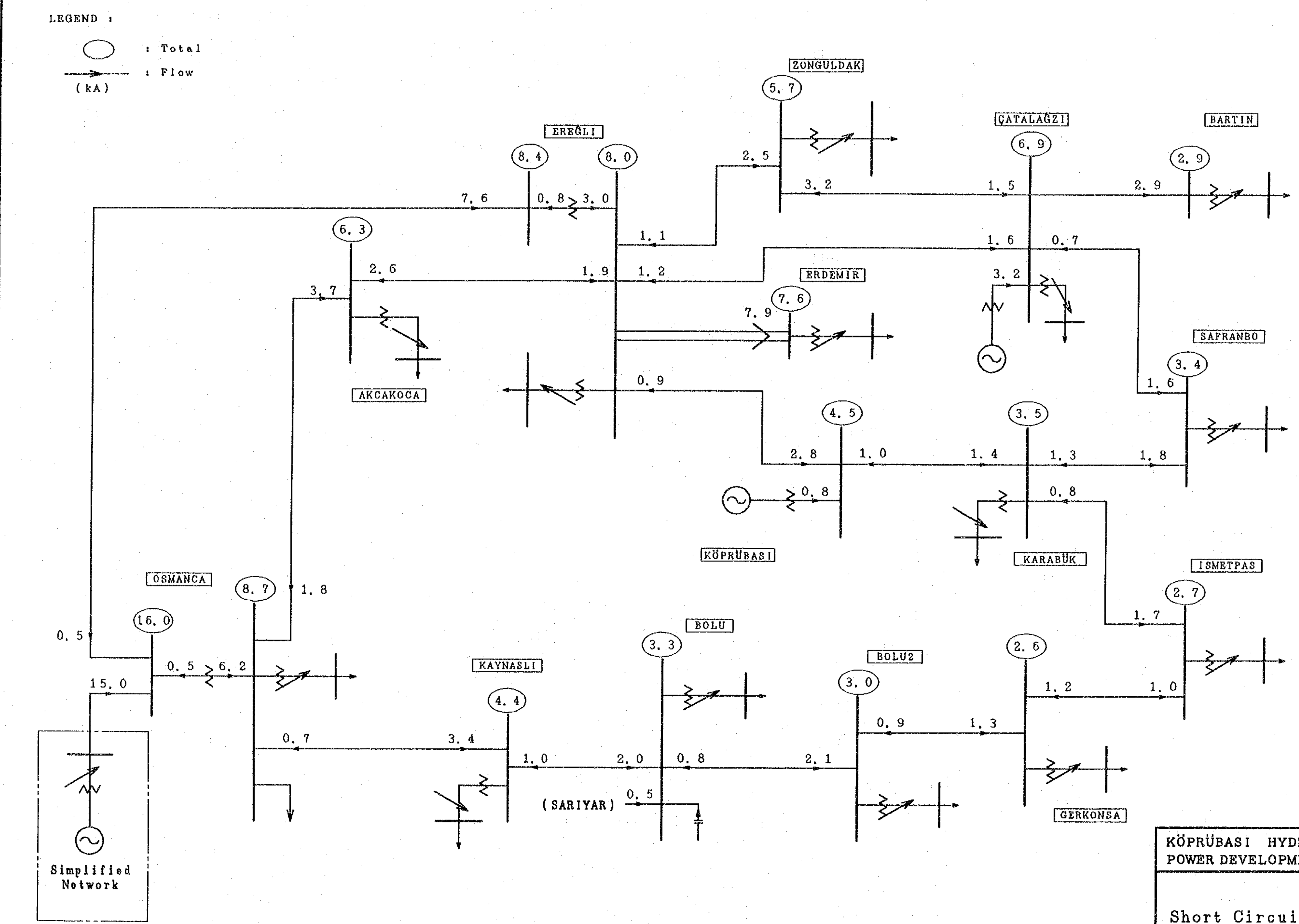



**Figure 10-8 Bus Voltage Fluctuation Curve**

Köprübaşı-Karabük Line opened after 3φG-fault at Köprübaşı P.S




KÖPRÜBASI HYDROELECTRIC POWER DEVELOPMENT PROJECT

Short Circuit Current

Figure 10–9

# Chapter 11 FEASIBILITY DESIGN

## Chapter 11

## FEASIBILITY DESIGN

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# Chapter 11 FEASIBILITY DESIGN

## 11.1 Civil Work

### 11.1.1 Dam

(1) Locations and Outlines

The Devrek river, in the Project area including the dam site, repeatedly meanders due to the geologic structure. It flows north as a whole and joins the Yenice River, then reaches the Black Sea. In a area of 2 to 3 km where includes the dam site, the Devrek River has hairpin turns at two places where it changes course to the south and then to the north, providing a topography advantageous for a rockfill dam site.

The dam site proposed for the Project is located on the downstream hairpin curve, and is roughly the same site as proposed in the Master Plan.

The left-bank side of the dam site provides a comparatively massive abutment of a uniform slope of approximately 30°, but the valley is wider to the downstream direction. On the other hand, the right-bank side is of a comparatively scraggy ridge topography, with the slope of approximately 40° near the river bed and with gentle slope at higher abutment than the low water level. As a whole an asymmetric cross-sectional shape is presented at the dam site.

The valley width at the dam site is approximately 50 m at the river bed, while it is approximately 540 m at the dam crest.

The thickness of river-bed deposits at the dam site is around 15 m, and the deposits are comprised of a comparatively thinly deposited sand layer underlain by a gravel deposit. Granodiorite is distributed underlying the river-bed deposits. Rock properties in terms of RQD and permeability and others suggests that the abutment will satisfy the requirements for the high dam foundation.

(2) Selection of Dam Type

Topographical features and geological conditions of the dam site tells us that it is possible to construct the rockfill dam and concrete gravity dam. Advantages and disadvantages of both type dams are indicates as follows:

Rockfill Dam

- Since the rockfill dam allows the foundation with low shear strength, foundation excavation can be planned economically.

- Since the dam site is located at a hairpin curve, an economical layout is possible for the spillway and diversion tunnel which generally increase rockfill dam construction costs.

- Dam embankment materials such as impervious core material, filter material, and rock material can be collected and hauled from within a range of several kilometers upstream of the dam site. This will be economical.

- Excavated material at the dam and spillway can be utilized for embankment materials.

Concrete Gravity Dam

- The concrete gravity dam foundation should have higher shear strength. Consequently, the foundation excavation line will be deeper compared with a rockfill dam, and both dam volume and excavation quantities will increase.

- The spillway of the concrete dam can be constructed in the dam body. This is an advantage compared with the rockfill-dam.

- Care-of-river during construction can be economically done by the river diversion method, method of temporary diversion conduit in the dam, or a combination of these methods.

Construction costs on dam, spillway, diversion tunnel, and cofferdams for both dams are summarized as follows:

Construction cost for rockfill dam : $315 \times 10^9$ TL
Construction cost for concrete gravity dam: $403 \times 10^9$ TL

Because of less construction cost, the rockfill dam is selected.

(3) Selection of Dam Axis

An upstream dam axis, midstream dam axis proposed in the Master Plan, and downstream dam axis are prepared within a range of 70 m for the purpose of contemplating the dam axis. It is not reasonable to make another alternatives beyond the range because of the topography.

The downstream dam axis is selected because it has minimum volume among three alternatives.

(4) Dam Body

The rockfill dam consists of an impervious core zone at dam center, two fine coarse filter zones and rockfill zones at both upstream and downstream side. Slope gradients are 1:2.5 for the upstream slope and 1:2.0 for the downstream slope. The impervious core zone has 8 m in thickness at the crest and the thickness corresponding to roughly 50% of the acting water pressure at the foundation. Stability of the dam is analyzed by a circular arc method. the analyses concluds that the dam is stable against the maximum earthquake expected at the site.

The embankment quantity is to be approximately 5 x $10^6$ $m^3$. Rock material of 3,067,000 $m^3$ will be mainly conveyed from a quarry located at the right-bank, 1.5 km upstream of the dam, while coarse-particled rock included in excavation muck is also used. Filter materials of 735,000 $m^3$ will be conveyed from river-bed deposits at the upstream side of the dam and excavation muck in their natural site or upon adjustments of gradation. Impervious core material of 757,000 $m^3$ is collected from a borrow areas upstream or downstream of the dam. Selection of the borrow area should be subject to additional investigations carried out after the F/S.

#### 11.1.2 Spillway

The spillway is placed at the right-bank side to shortcut a bend taking advantage of the topographical feature of the dam site.

The spillway has total width of 29 m at the portal and two radial gates of 13.00 m in width and 14.50 m in height. The spillway has a capacity to discharge the 2,500 $m^3$/sec of the probable maximum flood at the high water level 437 m.

The spillway has a chute of 26 m in width and a flip bucket at the end of the chute. Water energy is expected to be dissipated at a plunge pool.

### 11.1.3 Care-of-River

Prior to dam foundation excavation at the river bed, cofferdams are provided at upstream and downstream of the dam, and a diversion tunnel will be constructed for the river diversion.

The design flood discharge during construction is to be 350 $m^3$/sec corresponding to a 25-year return period flood, and the cofferdams and diversion tunnel have a capacity to safely discharge the flood. Study on the care-of-river is made varying the height of the upstream cofferdam at a number of levels for the optimum combination with the diversion tunnel. As the results, the elevation of upstream cofferdam crest is EL. 365 m and the diameter of the diversion tunnel is 6.00 m. The height of the coffer dam will be approximately 20 m, and the total length of the tunnel of standard horseshoe shape will be 390 m.

The upstream cofferdam is located apart from the dam in consideration of the topographical conditions, arrangement of the hauling road, and the conditions for executing dam foundation excavation. The area between the main dam and the cofferdam is utilized for a spoil bank.

The downstream cofferdam is located at the downstream end of the dam.

### 11.1.4 Outlet

Outlet is installed at the diversion tunnel, and is available for controlling reservoir water level at initial water impoundment and for emergency discharge.

The outlet works has a new intake, a connecting vertical shaft, a conduit on auxiliary gate, and on outlet valve. The capacity of the outlet works is determined generally upon comparison studies on reservoir capacity, inflow, number of days allowable for lowering water level, construction cost. In this case, taking into account data in similar projects in Turkey, the mode of initial water impoundment, and others, the diameter of the outlet valve is temporally designed to be 1.50 m with a capacity of 33.1 $m^3$/sec at full open.

#### 11.1.5 Intake

The intake is located at approximately 500 m upstream of the right-bank side of the dam (spillway) taking into consideration the followings:

- Topographical condition for easy installation of the intake structure,
- Shortening length of the access road

In order to minimize the excavated slope at steep ground the intake is separated from the vertical shaft for the intake gate.

The elevation of the intake bottom is EL. 380 m, 12 m deeper than the low water level in order to prevent air from entering into penstock.

#### 11.1.6 Penstock

A tunnel type steel penstock is installed between the intake gate shaft and inlet valve at the turbine. One line penstock has a gradient of 1:1 at the inclined portion with internal diameter of 3.40 m, through Y type branch, it becomes two lines of 2.20 m in internal diameter at the bottom horizontal portion.

The penstock is designed under the condition that the steel penstock bears the maximum design head of 275.90 m at the turbine center taking into account a pressure rise of 30% at load shut-down.

In case that properties of the surrounding rock are rationally determine in a future, it will be possible by having the surrounding rock shared some part of the design head to reduce the thickness of the steel penstock.

### 11.1.7 Underground Powerhouse

As stated in the Chapter 9, the underground powerhouse is selected from technical and economic reasons concerning the entire waterway system.

The powerhouse cavern consists of a generator hall installing two turbine-generator units, a main transformer hall, a control room, and others. The size of the excavated cavern is 16 m in width, 62 m in length, and 35.30 m in height.

The underground powerhouse is associated with a ventilation tunnel and drainage gallery. An access tunnel and the cable tunnel connect the powerhouse to the ground surface.

The powerhouse is located at approximately 150 m under the north slope of the ridge providing the right-bank abutment of the dam.

It is estimated from topographical survey, field reconnaissances and an exploratory drilling that the projected powerhouse site will satisfy the following requirements for the underground powerhouse.

- A massive rock body with sound rock and no remarkable faults and fracture zones for making it possible to construct the powerhouse cavern and drainage gallery.

- Ease in location of the access tunnel and cable tunnel.

The powerhouse cavern has a mushroom type cross-section. The ceiling arch and side wall of the cavern are lined with concrete. As a few properties of the rock around the cavern are known, a standard design such as pre-stressed steel cable anchors, rock bolts, and a drainage tunnel is adopted for securing stabilization of excavated rock.

An inclined shaft of 424 m in length and 1:3.2 in gradient is constructed between the main transformer hall and the projected switchyard. The shaft is initially used as a work adit for excavation of the powerhouse, then used as the cable tunnel after being lined with concrete.

A tunnel of 126 m in length is constructed toward the arch portion of the cavern from part way along the cable tunnel. This tunnel is initially utilized for excavation of the powerhouse, then used for the ventilation at the powerhouse after being lined with concrete.

The access tunnel of 1,100 m in length with an internal diameter of 5.00 m and gradient of 1:8.8 connects the powerhouse erection bay (EL 233 m) to its portal located at an EL. 358 m in the vicinity of an existing road, approximately 1 km downstream of the powerhouse.

### 11.1.8 Tailrace

The tailrace will release a maximum discharge of 43.0 $m^3$/sec to the Devrek River. It consists of a non-pressure tunnel and a trapezoidal open canal.

After power generation with the two turbine-generator units, two draft tunnels of 3.3 m in inner diameter and approximately 20 m in length will merge at the surge chamber. Then they will become single standard horseshoe shape tunnel of 4.6 m in inner diameter and 4,899 m in length. This is a non-pressure tunnel with gradient of 1:1,200.

The trapezoidal open canal of 200 m in length connects the tunnel to the Devrek River because it goes across river terraces having specific heights of 4 to 5 m from the Devrek River.

Above results is shown Figure 11-15 and 16.

Two draft gates are equipped at the ends of the draft tunnels. One outlet gate is equipped at the end of the tailrace tunnel.

## 11.2 Electro-mechanical Equipment

### 11.2.1 Selection of Number of Units

The installed capacity of Köprübaşı project is 70,000 kW.

There are several conceivable combinations of the number of units and unit capacity, but in general the fewer the number of units is, the lower the construction cost becomes.

It is possible that the number of units for Köprübaşı power station will be "one" just from the technical and economical point of view and also considering the scale of unit. However, "two" units alternative has been selected finally as a result of taking the actual problems on the operation of hydro power plants in Turkey into consideration, such as an accident stop and spare parts procurement, etc. And also the basic policy of the DSI is to select the plural number of units for hydropower projects.

### 11.2.2 Type and Ratings of Major Equipment

From the maximum discharge and the effective head, a vertical shaft Francis type is judged as appropriate for this project.

The generator is directly coupled to the turbine shaft and is a vertical shaft, three phases, alternating current, synchronous generator.

Generator voltage is stepped up to the transmission voltage by a main transformer.

The type of main transformer will be of three phases, oil-immersed.

Two circuits of 154 kV transmission line will be provided at the outdoor switchyard to send power. The type of switchyard is that of Aluminum pipe bus in accordance with TEK's standard for the time being.

The ratings of major electro-mechanical equipment are as follows:

| | |
|---|---|
| **Water Turbine** | |
| Type | Vertical shaft, Francis |
| Number of units | 2 |
| Normal effective head | 190.0 m |
| Maximum discharge | 43 $m^3/s$ |
| Turbine output | 36,200 kW |
| Revolving speed | 429 rpm |
| **Generator** | |
| Type | Three phases, alternating current, synchronous |
| Number of units | 2 |
| Output | 38,900 kVA |
| Power factor | 0.9 lagging |
| Voltage | 11.0 kV |
| Frequency | 50 Hz |
| Revolving speed | 429 rpm |
| **Main Transformer** | |
| Type | Indoor, three phases |
| Number of units | 2 |
| Capacity | 38,900 kVA |
| Voltage primary: | 11.0 kV |
| secondary: | 154 kV |
| **Outdoor Switchyard** | |
| Bus system | Single bus + transfer bus |
| Bus | Aluminum pipe |
| Number of transmission lines connected | 154 kV x 2 cct |

### 11.2.3 Main Circuit Equipment

As the underground powerhouse is relatively far from outdoor switchyard, the main transformer is installed in the powerhouse to reduce the cost of power cables connecting between the underground powerhouse and the outdoor switchyard.

A parallel-in circuit breaker is equipped at the low voltage side of the main transformer and is used for synchronizing generator to the power system.

The type of the parallel-in circuit breaker will be of load breaking which is not capable of interrupting the current exceeding the full load current for economical reason.

For interruption of fault current of the generator feeder, the circuit breaker at high voltage side of the main transformer will serve.

For connection between the main transformer and the outdoor switchyard, 154 kV XLPE power cable will be adopted.

Two circuits of 154 kV transmission lines will be connected to the single bus plus transfer bus system in the outdoor switchyard. It is the TEK's standard to provide a transfer bus to enable an inspection of the circuit breaker for the transmission line keeping the line alive through the transfer bus.

To secure station service power in any failures on the transmission line or the switchyard equipment, 2 diesel engine-generator sets will be installed in this power station.

Fig. 11-14 and 11-15 indicate the single line diagram of the power station and the switchyard plan, respectively.