7.13 Juam Dam

The Juam damsite is located in the north running course of the Boseong river about 28 km upstream of the confluence of the Seomjin river and Boseong river.

There are two dams upstream of the proposed damsite. The Boseong dam with a catchment area of 275 km^2 diverts water to the southern coast and its annual spillout to the Boseong river is estimated to be 185 x 10^6 m^3. The Dongbog dam with a catchment area of 187 km^2 supplying M&I water to Gwangju will divert its entire inflow after the reconstruction in the near future. Taking into account these diversions to the outside of the catchment area, the annual inflow into the Juam dam was estimated to be 701 x 10^6 m^3. The hydrological data estimated in the present study are:

Catchment area	:	1,010 km^2
Annual rainfall	:	1,382 mm
Annual inflow	:	701 x 10^6 m^3
Experienced maximum flood	:	4,000 m^3/s
2-year flood	:	1,800 m^3/s
50-year flood	:	4,900 m^3/s
200-year flood	:	6,200 m^3/s

A geological map of the Juam damsite is shown in DRAWING No. 019. The riverbed is at El. 61 m. The rock is granite gneiss. The left abutment is a gentle slope of talus deposit of 5 m in thickness underlain by cracky zone of granite gneiss of which the thickness was estimated to be 5 m at the foot and 15 m at El. 125 m. The riverbed is 130 m wide and is covered with gravel. The right abutment is a steep slope of granite gneiss covered with decomposed material of 5 to 10 m in thickness.

A hill slope of granite gneiss 800 m upstream of the left tributary joining the Boseong river at 350 m upstream of the damsite will provide quarry material. Impervious material of 1.8 x 10^6 m^3 will be obtained from deposits scattered within 4 km reach from the damsite. Sand and gravel material of 240 x 10^3 m^3 located 2 km downstream of the damsite will not be sufficient for the production of necessary concrete even for a rockfill dam.

The main stream plan of the proposed Juam dam was worked out to release total regulated flow immediately downstream of the dam for the intake from the Seomjin river. This plan was studied under both the constant draft operation and variable draft operation.

A pre-feasibility design of the Juam dam main stream plan under the constant draft operation is shown in DRAWING No. 118 of ADDENDUM. The active storage capacity in the reservoir will be 780 x 10^6 m^3 between HWS El. 120 m and LWS El. 85 m. A flood control space of 48 x 10^6 m^3 will be provided in the 1 m height above HWS. A multiple stage diversion method will be applied by means of temporary diversion conduit in the dam and a 30 m-wide diversion channel excavated on the left bank. A 69 m-high concrete gravity dam of 610 x 10^3 m^3 in volume will be constructed on the fresh rock and partly in the cracky zone. A gated ogee crest spillway will be located in the center section of the dam. A power station will be constructed on the right side of the spillway. The installed capacity will be 1 x 8 MW with a maximum discharge of 23.6 m^3/s and a rated water head of 39.4 m. The tailwater surface will be at El. 61.4 m. The total construction cost is estimated to be $ 152 x 10^6.

A pre-feasibility design of the Juam dam main stream plan under the variable draft operation is shown in DRAWING No. 114. The active storage capacity in the reservoir will be 448 x 10^6 m^3 between HWS El. 11 m and LWS El. 85 m. A flood control space of 30 x 10^6 m^3 will be provided in the 1 m height above HWS. The dam will be 60 m in height and 460 x 10^3 m^3 in volume. The basic layout of structure is the same as in the case under the constant draft operation except that a value house of 27 m^3/s in discharge capacity will be constructed instead of a power station. The total construction cost will be $ 126 x 10^6.

The major purpose of the Juam dam will be the M&I water supply to the industrial centers along the Gwangyang bay coast. The intake for the M&I water supply will be located at or near the present intake of the Yeocheon/Gwangyan Industrial Water Supply System near Hadong.

The outline of the future pipeline system associated with the Juam dam (main stream plan) was assumed as shown in Fig. 22 and Table 45.

One of the alternative plans studied for the proposed Juam dam was a diversion plan in which most water in the Juam reservoir would be diverted through a tunnel to the southern coast and would be conveyed to the M&I water demand centers by a pipeline system. This plan, though a little less economical than the main stream plan so far studied, was taken up as one of the proposed schemes, because it can guarantee pollution-free water and may be more economical than the main stream plan if utilized for the M&I and irrigation water supply to the west of the Gwangyang bay coast.

Three alternative routes of M&I conveyance system were studied as shown in Fig. 23. Route A has the shortest diversion tunnel among others and it consists of an 11 km-long diversion tunnel between the Juam reservoir and Isa river, regulating reservoir in the Isa river with water surface El. 70 m, four lines of 33 km-long pipelines between the regulating reservoir and Gwangyang bay coast and primary treatment plants at the Gwangyang bay coast. Route B includes the development of the Isa river and it comprises a 13.5 km-long diversion tunnel between the Juam reservoir and Isa river, the Yeonggye dam with HWS El. 89 m in the Isa river, four lines of 26 km long pipelines between the Yeonggye dam and the Gwangyang bay coast and a primary treatment plants at the Gwangyang bay coast. Route B can gain 173 x 10^3 m^3/d of M&I water supply by the Yeonggye dam. Route C is a 14 km-long diversion tunnel between the Juam reservoir and Beolgyo, a regulating pond at Beolgyo with the water surface at El. 67 m, four lines of 45 km-long pipelines including a booster pumps between the regulating pond and the Gwangyang bay coast and primary treatment plants at the Gwangyang bay coast. Route C is probably most convenient to divert irrigation water in the southern coast if required.

In the diversion plan, majority of regulated flow is diverted to the southern coast at a constant rate but the water head developed between the Juam reservoir and the demand center is totally utilized to convey the diverted water. The outflow into the main stream is minor. Under these conditions, no power generation is envisaged and the variable draft into the main stream is studied for the diversion plan.

A study in ANNEX Q showed that the optimum HWS of the Juam dam diversion plan is at El. 120 m for Route A and Route C, and at El. 114 m for Route B. The pre-feasibility design of the Juam dam for the diversion plan in DRAWING No. 115 is applicable if Route A or Route C is selected. The dimensions of the reservoir and dam are the same as those for the main stream plan under the constant draft operation. The discharge capacity of the value house is 9.4 m^3/s. The construction cost of the dam is estimated to be \$ 146 x 10^6 (The construction cost of the dam with HWS El. 114 m will be \$ 133 x 10^6 if Route B is selected).

8 AGRICULTURAL BENEFIT

8.1 Prospective Crop Yield

According to the regional cooperative yield trials carried out in 1976 and 1977 over the country (Refs. 3 & 4), the yield of high-yielding rice varieties was 5.1 to 5.9 tons/ha, though there were certain differences among the varieties. The high-productive paddies recorded the yield of 6.2 to 8.4 tons/ha. The yield in experiemental farms was 5.8 to 7.2 tons/ha under the standard cultivation. ORD has set the target yield of 6 tons/ha in the irrigated and consolidated paddy. As the national average, the high-yielding varieties have shown a yield of 5.5 tons/ha at the maximum as shown in Table 47. It was assumed that the yield of the high-yielding rice varieties would be 5.6 tons/ha under the most favorable condition.

A relative crop productivity index was calculated based on the soils in each agricultural zone and ORD criteria (Table 15) as shown in Table 48. The index was applied in estimating the regional difference in the crop yield.

It was assumed that the yield in the reservoir depending paddy would be 5 % higher than that in the river depending paddy, because the construction cost of the irrigation is becoming so high as can be economically justified only on highly productive soils.

The tributary depending paddies would be subject to water shortage which could not be met by the proposed dams. A yield reduction of 10 % was assumed for the tributary depending paddy against the main stream depending paddy.

The yield of traditional rice varieties was assumed to be 75 % of the high-yielding rice varieties, because it often lowered to this level as indicated in Table 46.

The rice yield in the supplementarily irrigated paddy was assumed to be 80 % of that in the tributary depending paddy, referring to Table 49.

The effect of land consolidation will be in the cost saving and yield increase as indicated in the example in Table 50. It was assumed that the yield increase would be 10 % in rice only.

Table 51 shows the anticipated yield of paddy rice derived from the above-mentioned consolidations.

Typical cropping patterns on rainfed and irrigated uplands were assumed as shown in Table 52 and the crop yield was estimated as shown in Table 53.

8.2 Gross and Net Production Values

The economic farmgate prices of crops were estimated at 1978 price level as shown in Table 54. The price of rice and soybean was estimated based on IBRD international price projection to 1990 at 1978 price level. Other prices were 1976 domestic market price escalated to 1978.

The economic farmgate prices of major farm inputs were estimated as shown in Table 55. Fertilizer element prices were estimated based on the prices of urea for N, triple super phosphate for P and potassium chloride for K of IBRD international price projection to 1990 at 1978 price level. Agrochemical prices were 1976 import price escalated to 1978. Other prices were based on the domestic market prices. The labor cost was assumed to be ₩ 2,500/day ($ 5.15) for family labor and ₩ 3,600/day ($ 7.42) for hired labor.

The gross production value and production cost were estimated by use of the above-mentioned economic prices. The requirement for the farm input was based on ORD standard (Ref. 17) and labor and animal requirement was based on a survey by MAF. Breakdown of production costs is shown in Table 56 for paddy rice, in Table 57 for irrigated upland crops and in Table 58 for rainfed upland crops, respectively.

The gross value, production cost and net value are summarized in Table 59 for rice and in Table 60 for upland crops by agricultural zone and irrigation condition.

8.3 Cost of Irrigation Facilities

The unit construction costs of reservoir irrigation and pump irrigation were estimated based on the actual construction costs of the projects completed by ADC in 1977. The construction cost of five reservoir irrigation systems was ₩ 2,627 x 10^6 for 641 ha, being disbursed in 1976 and 1977. The escalated cost to 1978 was estimated to be ₩ 3,124 x 10^6 or ₩ 4,870 x 10^3/ha. Adding 20 % of physical contingency, the unit price was assumed to be ₩ 5,800 x 10^3/ha. The construction cost of four pump irrigation systems was ₩ 764 x 10^6 for 404 ha being also disbursed in 1976 and 1977. The unit price at 1978 price level was estimated to be ₩ 2,240 x 10^3/ha. The pump irrigation system is becoming costly, because it is going to be constructed under rather difficult topographic condition. The unit price of pump irrigation system was assumed to be ₩ 3,400 x 10^3/ha, with a contingency of 44 %.

The unit construction cost of land consolidation was estimated from the data provided by union of FLIA, who carried out the detailed design for 16 land reclamation projects. The estimated construction cost was ₩ 5,020 x 10^6 for 2,872 ha at 1978 price level, or ₩ 1,750 x 10^3/ha. It was assumed that the unit construction cost is ₩ 2,100 x 10^3/ha including a physical contingency of 20 %.

The estimated land reclamation cost in ADB/ADC Namgang Development Project and KOR 75 was 5 % to 7 % higher than the land consolidation cost. The unit construction cost of land reclamation was assumed to be ₩ 2,300 x 10^3/ha.

ADC estimated the construction cost of upland irrigation of 260 ha in the Namgang Area Development Project to be ₩ 551 x 10^6 in 1976. It will be ₩ 705 x 10^6, or ₩ 2,700 x 10^3/ha at 1978 price level. Adding 20 % of physical contingency, the upland irrigation cost was assumed to be ₩ 3,200 x 10^3/ha.

The economic construction cost was estimated from the above-mentioned unit cost deducting the estimated, transfer payment. O&M cost was estimated including the fixed annual cost and energy cost, based on the water charges of FLIA.

The estimated costs are summarized in Table 61. In this table the annual equivalent of capital cost was calculated assuming a discount rate of 8 %.

More details are described in ANNEX G.

8.4 Net Incremental Benefit

Irrigation facilities will be provided for more reliable irrigation on the presently supplementarily irrigated paddy. Some upland will be reclaimed for paddy cultivation. Upland irrigation will develop on the present upland and supplementarily irrigated paddy. Land consolidation will be provided on the presently unconsolidated paddy. The net incremental benefit per ha expected from irrigation, land consolidation, reclamation and upland irrigation were estimated for all the possible cases as shown in Tables 62 to 64.

The change of the cultivated area from an irrigation condition to another was analyzed based on the results of the agricultural land development projection, which was described in Section 4.1. The results of the analysis is presented as the increase in the benefited area in intervals of five years as shown in Tables 65 to 67. Each case of the change in the irrigation condition in Tables 65 to 67 corresponds to one in Tables 62 to 64.

The increase in the irrigation benefit in each basin in the intervals of five years is therefore obtained by multiplying the unit benefit in Tables 62 to 64 to the incremental area in Tables 65 to 67. It is summarized in Tables 68 to 70. It is noted that Tables 65 to 70 were prepared for the areas considered in the water budget (see Section 5.3).

The agricultural benefit was estimated assuming that a proposed dam would supply sufficient water in the main stream in which natural flow would be even reduced by the irrigation depending on reservoirs and tributaries.

8.5 Production Foregone

The agricultural production in the proposed reservoir area will be permanently lost if a dam will be constructed. The production foregone was estimated for the cultivated areas to be flooded by the proposed dams. The net production values on paddy, upland and orchard to be lost were estimated based on 1966-1976 average crop production in related Guns as shown in Table 71.

The total production foregone for varying reservoir water surface at each proposed reservoir was estimated as descrived in ANNEX O.

9 FLOOD CONTROL BY THE PROPOSED DAMS

9.1 Flood Inflow into Damsites

The flood inflow into the proposed damsites was estimated based on 3-day storm rainfall, because a study on the annual maximum continuous rainfall records at MOC raingauges in the catchment areas of proposed dams revealed that the majority of story rainfall continued for three days.

The storm rainfall in the catchment areas of each proposed dam was estimated as a weighted average of 3-day rainfall at one to four MOC raingauges in and near the catchment area. The selected raingauges had at least 19-year record. The interruptions were supplemented by a correlation of rainfall records among nearby stations. The rainfalls corresponding to the annual maximum flood was regarded as the annual maximum storm rainfall from 1965-1977. For the years before 1965, in which daily rainfall record was unavailable, the weighted average of the annual maximum 3-day point rainfall was assumed as the annual maximum basin rainfall. The probability distribution of storm rainfall in the catchment area of each proposed damsite was determined assuming a log-normal distribution of the annual maxima. The hyetograph of the storm rainfall of a probability of exceedence was constructed applying a typical non-dimensional storm hyetograph which was derived from hourly rainfall records of several floods for each of the three basins.

The probable flood hydrograph at a proposed damsite was estimated from the probable storm hyetograph by means of storage function method, of which the storage coefficients and other constants were taken from Refs. 18 and 19 with some modifications. The estimated maximum discharge of probable flood at the proposed damsites is as shown in Table 72 (for hydrographs, see ANNEX N). The estimated 100-year flood discharges at the proposed damsites are compared with the design floods in previous reports as shown in Fig. 24.

More details are described in ANNEX C.

9.2 Flood Control Effect by the Proposed Dams

The flood vulnerable areas downstream the proposed damsites were divided into 18 river stretches each represented by a water level gauge as shown in Fig. 25 (The lowest two stretches of the Han river were represented by the Indogyo gauge). Discharge rating curves were available for 12 gauges among the 17. Rating curves were newly estimated for two gauges and, for the remaining three gauges, the 3-day basin rainfall instead of water level and discharge was taken as the parameter indicating the flood control effect.

The ratio of the maximum outflow from a dam to the maximum inflow into the dam (hereafter called the flood reduction ratio at the damsite) was determined assuming a constant ratio and constant rate operation. In this study the flood control space in the reservoir was equal to the volume of water to be retained from the beginning of flood control operation to the time that the inflow equals to outflow if a 100-year flood occurs.

The ratio of the flood peak discharge affected by a dam operation to the flood peak discharge with no dam operation at a representing gauge (herein called the flood reduction ratio at the gauge) was estimated by the following equation, which was proposed by KOR 16 assuming the Myers-Garris formula between the catchment area and flood peak discharge:

$$K = \sqrt{1 - \Sigma a\ (1 - m^2)/A}$$

where,

K	:	Flood reduction ratio at a gauge
a	:	Catchment area of a dam
m	:	Flood reduction ratio at the damsite
A	:	Catchment area of the gauge
Σ	:	Summation for all the dam upstream the gauge

It was assumed that the 3-day storm rainfall in the catchment area of a gauge where no rating curve is available would be reduced in the same volume of the part of storage space which would be utilized for the flood reduction at the damsite.

As an indication of flood control effect by the proposed dams, the estimated reduction in 100-year flood water levels at the representing gauges are shown in Table 73.

More details are described in ANNEX D.

9.3 Flood Control Benefit

The flood control benefit was estimated in terms of the direct flood damage reduction and land enhancement benefit. The reduction in the indirect flood damage such as the loss due to interruption of business, transportation, communication, etc. was not counted.

A stage-damage curve at each representing gauge was constructed based on MOC flood damage statistics (Ref. 20) in the recent 10-year period of 1967-1976. For the gauges having no discharge rating curve, 3-day storm rainfall-damage curves were prepared. The damage items in the statistics are the buildings, ships, agricultural land, crops, public facilities and others. Ships and some items in the public facilities were eliminated in this study because these items will not be affected by the proposed dams. A river stretch is a part of several cities/Guns. The ratio of damage in the river stretch to that in the cities/Guns was estimated as the ratio of flat land on 1/50,000 map for the agricultural land, crops and irrigation facilities and based on the density of houses and facilities for the other items.

The damage having an arbitrary probability of exceedence, either affected by dam or not, is obtained from the probable water level by use of the stage damage curve. The most probable flood damage reduction was calculated as the integral by the probability of exceedence of the difference in the flood damages between with- and without-the-proposed-dam conditions.

The land enhancement benefit was estimated as the increase in the net agricultural income from a more beneficial cropping which would be made possible by less frequent inundation, owing to the flood control.

A stage-inundated area (paddy and upland) curve was prepared for each river stretch in the same procedure as for the stage-damage curve. The curve related with the probably flood water level resulted the estimate of increased area of less frequent inundation and decreased area of more frequent inundation as an effect of the proposed dams. The increase in the area was regarded as the increase in the net agricultural production value less, if necessary, irrigation cost and the decreased area was regarded as the loss in the net agricultural production value. The balance between the increased value and decreased value was, consequently, estimated as the land enhancement benefit. In estimating the unit value the following land use was assumed taking into account the production loss due to the inundation and soils which are generally sandy in the flood vulnerable area:

(1) For the frequency of flooding less than 1/10, high-yielding rice varieties will be grown on paddy, on which irrigation and land consolidation will be provided. Rice yield will be 96 % of that in Table 51. Upland will be rainfed with yield as shown in Table 53.

(2) For the frequency of flooding 1/10 to 1/5, traditional rice varieties will be grown on paddy which will have been supplementarily irrigated. Rice yield will be 80 % of that in Table 51. Upland will be rainfed with yield 85 % of that in Table 53.

(3) For the frequency of flooding 1/5 to 1/3, traditional rice growing on supplementarily irrigated paddy will yield 75 % of the yield in Table 51. Upland will be rainfed with yield 75 % of that in Table 53.

(4) For the frequency of flooding 1/3 to 1/2, traditional rice growing on supplementarily irrigated paddy will yield 50 % of the yield in Table 51. Rainfed upland crop yield will be 50 % of that in Table 53.

(5) For the frequency of flooding more than 1/2, land will not be cultivated.

The unit values applied for the estimate of land enhancement benefit are as shown in Table 74.

The estimated flood control benefits by varying flood control space of proposed dams are summarized in Tables 75 and 76.

More details are described in ANNEX N.

10 COSTS OF ALTERNATIVE M&I WATER SUPPLY DAMS

10.1 M&I Water Supply Alternative Dams

A study on the storage possibilities other than the existing and proposed dams was carried out by use of 1/25,000 maps. Among 19 storage possibilities investigated, nine least-costly M&I water supply alternative dams of which capacities comparable with those of the proposed dams was selected as shown in Table 77.

The active storage capacity of M&I water supply alternative dam was set at approximately 80 % of the available inflow or smaller if there was any constraint. The net supply capacity was estimated assuming a variable draft operation in accordance with the water deficit in each river basin. It ranged from 7.4 to 44.4 m^3/s for the Han river and 4.3 to 19.2 m^3/s for the Nagdong river. The Yeonggye dam of 6.2 m^3/s in the net supply capacity only was the alternative identified for the Seomjin river.

10.2 M&I Water Supply Benefit

For reference, the cost of water for each alternative dam is shown in Table 77. It was calculated as the annual equivalent of cost of alternative dam divided by the net supply capacity for the year assuming an 8 % of discount rate for 50 years of evaluation period.

M&I water supply benefit was calculated as the cost of the alternative dam and its associated facilities such as intake, pipeline and treatment facilities less the cost of the facilities associated with the proposed dam, because the benefit was measured at the outlet of the proposed dam. It is identical with the cost of alternative dam except for the Yeonggye dam, because associated facilities are the same for the proposed dam and M&I water supply alternative dam both of which will release all regulated flow into the river for the intake by the demand centers.

The target M&I water supply capacity of a proposed dam was assumed to be the net M&I water withdrawal building up between the year of commission and the target year, while the target supply of the Juam dam included the net withdrawal between 1977 and the year of commission (see Section 6.2). The net water withdrawal in the tributary area was discounted into a half, because all the deficit in the tributary area may not be met by the proposed dam. The target M&I water supply capacity by a proposed dam was not always equal to the net supply capacity of a M&I water supply alternative dam. An alternative dam of the least cost was selected among those which had a net supply capacity close to the target supply capacity of the proposed dam. The cost of M&I water supply alternative dam was then adjusted by the ratio of the target supply capacity to the net supply capacity. If the target supply capacity of a proposed dam was very large compared with that of any alternative dam, a stage development of several alternative dams was assumed in accordance with the build-up of the net M&I water withdrawal.

The Yeonggye dam in the Isa river, adjacent to the Seomjin river basin, was proposed as the M&I water supply alternative dam for the Seomjin river. The M&I conveyance system will be different from that associated with the proposed dam. In this connection two operation methods of the Yeonggye dam were studied. One was a constant draft operation to supply the demand all the year. The other was a variable draft operation to supply the demand only in the deficit periods, the supply during the non-deficit periods being carried out from the Seomjin river. In the constant draft operation, only a single conveyance system between the Yeonggye dam and the demand center is necessary but the net supply capacity of the dam is only 2.1 m^3/s. In the variable operation, on the other hand, conveyance systems are needed between the Yeonggye dam and the demand center and between the Seomjin river and the demand center but the net supply capacity is 6.2 m^3/s. The variable draft operation was taken up, because a comparative study showed that the variable draft operation method would be more economical than the constant draft operation as indicated in Table 78. The Yeonggye dam only was found as the realistic alternative source for M&I water supply of the Seomjin river, but its net supply capacity was only 1/5 to 1/2 of the assumed target supply capacity by the proposed Juam dam. A stage construction of necessary number of hypothetical M&I water supply dams each having the same capacity and cost as the Yeonggye dam was assumed in estimating M&I water supply benefit of the Juam dam. Hydrological data indicated that only 156 x 10^3 m^3/d, or 1.8 m^3/s of water could be sustained from the Seomjin river to the existing Yeocheon/Gwangyang water supply system in the dry period if no storage dam would be constructed. Therefore, the demand to be supplied by the M&I water supply alternative dams was calculated as the difference between the target demand and 1.8 m^3/s. The outline of the M&I supply system associated with the Yeonggye dam was assumed as shown in Fig. 26.

11 COST OF ALTERNATIVE POWER FACILITIES

The power generation benefit of the proposed dam schemes was estimated as the cost of alternative thermal power plant. The oil-fired thermal, coal-fired thermal or the nuclear power plant may be the least-costly alternative. The oil-fired thermal plant was selected among them, because it was estimated that the oil-fired thermal power plant would be slightly lower in the cost of power than the coal-fired thermal power plant for the discount rate of 10 % to 20 % and the cost of nuclear power would be quite uncertain in the future.

According to the long-term power facilities expansion program (revised in August 1, 1978) by KECO, the unit capacity of thermal power plant to be constructed from now on will be 500 MW. Data provided by KECO shows the unit financial construction cost of 500 MW oil-fired thermal power plant is $ 422/kW at the 1978 price level. Adding the cost of fuel gas desulfurization equipment and deducting the interest during construction and taxes, the unit economic investment cost was estimated to be $ 481/kW as broken down in Table 79. The capacity adjustment factor was estimated to be 1.225 taking into account the relative power losses of hydropower to thermal power. Accordingly, the cost of alternative thermal power of equivalent capacity of the hydropower was calculated to be $ 589.23/kW. The annual cost of alternative thermal power consists of the annual fixed cost including the insurance and fixed O & M cost, and the variable cost which is the cost of fuel. The annual fixed cost was estimated to be $ 11.79/kW based on the percentage to the investment cost. The annual variable cost was estimated to be 21.53 mills/kWh based on the ex-factory price of Bunker C fuel oil of 95 mills/lit in June, 1978. This cost was adjusted to 22.87 mills/kWh of the annual variable cost of thermal power equivalent to hydropower based on an estimated energy adjustment factor of 1.039. The replacement cost less salvage value at every 30-year interval was estimated to be $ 530.30/kW which is 90 % of the investment cost. The composition of estimated alternative power cost is summarized in Table 80. Herein the capital costs and annual fixed cost of alternative thermal power plant is called the capacity value and the annual variable cost is named the energy value. It is calculated based on the data in Table 80 that the capacity value is $ 68.73/kW and energy value is 22.87 mills/kWh at a discount rate of 8%.

More details are described in ANNEX J.

12 ECONOMIC ANALYSIS

12.1 Benefits

M&I water supply benefit was estimated based on the costs of least-costly alternative dams as explained in Chapter 10. The agricultural benefit was estimated as the net incremental benefit (see Section 8.4) building up between the year of commission and the target year. It was assumed that the agricultural benefit in a particular area accrues at its full value a year after the completion of irrigation facilities in the area, approximately equivalent to the benefit stream building up in three years after the completion of the facilities. The flood control benefit was obtained from the flood control space-flood control benefit curve in Fig. N 5 of ANNEX N. The power benefit was estimated as the composition of the capital cost, annual fixed cost and energy cost of an alternative thermal power plant. The effective power was assumed to be an arithmetic mean of the installed capacity and the minimum peaking capacity. The energy benefit was claimed for both the project's output and the increased output in the existing power stations. The production foregone in the reservoir was obtained from Fig. O 2 of ANNEX O. Neither intangible nor secondary benefit was taken into account.

12.2 Costs

The economic investment cost was derived by deducting the transfer payment from the estimated financial construction cost. The transfer payments were assumed to be the compensation on land and 5 % of other costs which was regarded as taxes and local contractors' profit. The disbursement of the investment cost was assumed to be 12.5 % in the first year, 25 % each in the second year to fourth year and 12.5 % in the fifth year of the construction period.

The metalwork, generating equipment, transmission and substation equipment were assumed to be replaceable with a life of 30 years. A salvage value of 10 % was taken into account.

The ratio of O & M cost to the investment cost was set to be 0.5 % for dam and 2.5 % for power facilities.

12.3 Optimization Criteria

The optimum size of the project facilities was so determined that the annual equivalent of benefit less the annual equivalent of cost (B - C) would be maximum. The annual equivalents were calculated for an evaluation period of 50 years with the zero point at the year of commission. The discount rate assumed was 8 % which was taken as the minimum acceptable in the multipurpose water resources development in Korea.

The above-mentioned optimization criteria were taken into account for the studies of the year of commission, optimization of flood control space, justification of power generation purpose and the scale of dam of the proposed projects.

12.4 Year of Commission

The full benefit will be expected for the flood control and power generation purposes of the proposed project immediately after the completion of construction, but the M&I and irrigation benefits will grow starting at the time beyond which the existing dams can no longer meet all the water deficit. The year of commission of the proposed project was therefore assumed to be the time from which an additional dam is needed for the water supply purposes. There may be a case that a proposed dam will be constructed earlier than assumed. In such case, the dam will be operated for only the purposes of flood control and power generation in the initial years, but it will also serve for the M&I and agricultural water supply later on.

12.5 Optimization of Flood Control Space

The optimum flood control space was determined for the Ganhyeon and Imha dams on a comparison of the increments of flood control benefit, production foregone and cost in ANNEX Q. The flood water surface for the other dams was fixed to be 1 m above HWS because the estimated flood control benefit was rather small.

12.6 Justification of Power Purpose

The power generation purpose was assumed for all the proposed dams under the constant draft operation.

The hydropower should be developed for the peaking power generation as far as possible under the condition of Korean power system in which the base load is met by the thermal power. The annual equivalent of power generation benefit was compared with the annual equivalent of the exclusive facilities cost for power generation assuming a 5-hour daily peaking operation as shown in Table 81. As shown in the second column from the right in Table 81, the 5-hour daily peaking power generation is justified for the proposed dams except the Dalcheon, Ganhyeon, Hamyang and Juam dams, which show the benefit less cost to be negative.

The oil prices are rising high in Korea reflecting the recent world market condition. It was informed by the Government of Republic of Korea that the price of Bunker C oil rose from ₩ 51/lit (105 mills/lit) to ₩ 84/lit (173 mills/lit) in July 1979. The economic study in this report is based on the 1978 constant prices in which the price of Bunker C oil is 95 mills/lit. In order to see an effect of increase in the oil price, the column at the right end in Table 81 is presented assuming that the price of Bunker C oil is doubled (190 mills/lit) but other prices remain at the 1978 price level. It is indicative that the 5-hour peaking power generation will be justified for all the proposed dams, if the oil price substantially rises relative to other prices.

For the proposed Dalcheon, Ganhyeon, Hamyang and Juam dams, under the constant draft operation, 18-hour daily power generation is justified as shown in Table 82, though 5-hour daily power generation was unjustified for these proposed dams.

The power generation purpose was not assumed for the variable draft operation in the present preliminary feasibility study but that will be one of the subject in the future study.

12.7 Optimization of Size of Dam

The high water surface (HWS) elevation was taken as the parameter showing the alternative size of each proposed dam. The flood control space and size of power generation facilities were predetermined for each alternative HWS of dam based on the optimization criteria as explained in Sections 12.5 and 12.6.

The annual equivalents of benefit and cost for varying HWS elevation are illustrated for all the proposed dam schemes in Fig. 27. Under the constant draft operation, the Bamseonggol, Hongcheon, Imha and Juam (Main Stream) dams are justified. The Gujeol and Ganhyeon dam will be also justified, if the energy value is doubled. The Inje, Bonghwa and Hamyang dams are found to be unjustified for the range of normally conceivable size, so far as the discount rate of 8 % is assumed. All the studied schemes are justified under the variable draft operation; the Hongcheon, Dalcheon, Ganhyeon, Imha, Juam (Main Stream) and Juam (Diversion Routes A, B and C).

The optimum size of each proposed dam was determined to be the size that makes the value of B - C maximum among the alternative sizes. Such optimum size was found to be limited by the social or physical constraint for most of the proposed dams as shown in Table 83. The size showing the smallest negative value of benefit less cost is tentatively called the optimum size for the unjustified dams in the table.

The salient features of the proposed dam schemes at the optimum size are summarized in Tables 84 to 87. It is noted that the optimum size of the proposed dams does not change even if the energy value is doubled, except that the optimum size of the Inje dam becomes larger with the increase in the energy value.

12.8 Internal Rate of Return

In preparing the cash flow of the benefits which were estimated based on the costs of the least-costly alternative facilities, the following assumptions were introduced:

(1) The project output has a certain unit value, which is constant throughout the evaluation period.

(2) The alternative facilities have an internal rate of return of 8 %.

The unit value of water for M&I water supply as shown in Table 88 was determined as that with which the total present worth of the net M&I water withdrawal to be met by a particular proposed dam was equal to the total present worth of the cost of the M&I water supply alternative dams including their associated facilities cost less the cost of the M&I water supply facilities associated with the proposed dam at a discount rate of 8 %.

Comparatively high value of water for the Juam dam schemes resulted from the high costs of the pipeline facilities associated with the alternative dams compared with those of the pipeline facilities associated with the proposed dam.

The unit value of power under the above-mentioned assumption is equal to the annual equivalent of the unit cost of an alternative thermal power plant at a discount rate of 8 % and it is a composition of the capacity value of $ 68.73/kW and the energy value of 22.87 mills/kWh (see Chapter 11).

An economic cash flow analysis was made for the justified dams under the above-mentioned assumptions and the internal rate of return (EIRR) was calculated for the following cases:

A : Normal
B : Benefit reduction by 10 %
C : Cost increase by 20 %
D : Delayed benefit by 1 year
E : Energy benefit doubled
F : B + C
G : B + C + D

The results presented in Table 89 show that all the justified 12 dam schemes derived from six proposed dams have appropriately high values of EIRR. The schemes based on the variable draft operation generally present higher values of EIRR compared with those based on the constant draft operation.

12.9 Remarks on the Assumptions made in Estimating EIRR Values

In estimating the values of EIRR, the cost stream of alternative facilities for a purpose is often regarded as the benefit stream of the purpose. The values of EIRR of five dam schemes estimated under this assumption is shown in Table 90. Compared with Table 89, the values of

EIRR in Table 90 reveal themselves to be larger under a normal condition (column A) and more sensitive under varied conditions.

Let's assume that a single-purpose dam for M&I water supply is proposed and its benefit is estimated based on the cost of an alternative dam. The net M&I water supply benefit of the planned dam in a particular year can be obtained as the cost of the alternative dam deducted by the cost of the planned dam in the same year, if, as mentioned above, the cost stream of the alternative dam is regarded as the benefit stream of the planned dam. For both the planned and alternative dams, their cost streams are characterized by a large investment in the initial period and a comparatively small annual cost in the later period. If the cost streams of both the dams are analogous with each other, the net benefit stream of the planned dam is positive every year through the evaluation period. Then, the value of EIRR of the planned dam would be calculated to be infinitive. Even though the cost streams of both the dams are not perfectly analogous but they are analogous to a certain extent with each other, the EIRR of the planned dam can have an extremely large value. Actually, in Table 90 the EIRR under the normal condition (column A) shows considerably large values for the Juam Main Stream Plan and Juam Diversion Plan with Route A.

The economic benefits of M&I water supply and power generation are estimated based on the costs of alternative facilities, because there is no other appropriate method to measure them. If there is a true benefit of M&I water supply or power generation and if it should be measured by the utility of the project output, the benefit stream will be largely different from the cost stream of alternative facilities. The project output which is effectively utilized, usually grows with the passing of time, starting from a small amount in the initial period and growing until the target year of the project, at which time it keeps constant thereafter. The output of the proposed project was assumed to have a certain unit price in this study; this is based on the recognition that the utility of output is closely related to the volume of the output. The abovementioned type of analysis yielded assumption (1) stated in Section 12.8.

If the procedure stated at the beginning of this chapter was applied to obtain the value of EIRR of a proposed dam, it means that the total present value of the cost of alternative facilities, discounted by the rate equal to the above-mentioned value of EIRR, was regarded as the total present value of the true benefit under this discount rate. In order words, it means that under this discount rate, the total present value of the alternative facilities is regarded to be equal to that of the true benefit. It also means that, if an alternative facility were to be built, its value of EIRR would be equal to that of the proposed dam itself.

If there are a number of proposed dams with a certain utility of output, i.e. with a particular benefit stream, but with different cost streams, there must be the same number of EIRR of alternative facilities for the true benefit as the number of the proposed dams. This means that the true benefit stream, and accordingly the unit price of output of the proposed project, varies depending on the EIRR of the proposed project. To explain in more detail, if a large value of EIRR of the proposed project was obtained, that implies a large unit price of output was assumed for the estimation of the value of EIRR. To solve this discrepancy, a particular value of EIRR for alternative facilities was introduced in order to determine a fixed unit price of output, and by applying this unit price, the benefit stream was produced. This assumption corresponds to assumption (2) in Section 12.8.

Attention should be paid sufficiently to the fact that, in making a decision of project selection, the EIRR for the proposed projects in this study varies depending on the EIRR assumed for the alternative facilities, and that, consequently, its values cannot be compared directly with the values of EIRR derived under different assumptions. It is noted that the value of EIRR presented in Table 89 were estimated most conservatively, because the value of EIRR of the alternative facilities were assumed at 8 % and this is the minimum rate that can be considered acceptable. In a case when the value of EIRR of alternative facilities is possibly larger than 8 %, the values of EIRR of the proposed projects will be larger than presented in Table 89. In this connection, a trial sample study of Juam Diversion Plan Route A shows in Table 91 that if the value of EIRR of alternative facilities varies from 8 % to 10 %, the value of EIRR of the total project increases from 12.8 % to 14.5 % in the normal condition (column A) and by 1.3 % to 1.8 % in other assumed conditions.

12.10 Semi-Variable Draft Operation

A continuous power generation is made possible and accordingly the capacity value can be claimed even under the variable draft operation, if the outflow from the proposed dam is increased in the non-deficit periods by reducing the outflow to some extent in the deficit periods. By this way, the hydroelectric potential can be developed even under the variable draft operation, though the net water supply capacity will be reduced to some extent. This method when observed from the opposite side, means the augment of outflow in the deficit periods for more water supply by reducing outflow in the non-deficit periods in the constant draft operation. The method is herein called the semi-variable draft operation method.

A scheme based on the semi-variable draft operation was investigated for the Juam dam main stream plan and the results are compared with the schemes based on the constant draft operation and variable draft operation in Table 92. It is noted that the net water supply capacities in the table are estimated based on the water deficit assuming that there is no outflow from the proposed damsite. If the constant rate of draft in the non-deficit period is set to be 2/3 of the net water supply capacity, the optimum HWS is found at El. 120 m. This is the same as that for the constant draft operation but the optimum HWS for the variable draft operation is found at El. 111 m. The semi-variable draft operation compared with the constant draft operation increases the net water supply capacity from 17.7 m^3/s to 24.6 m^3/s, or from 7 years to 19 years in terms of the build up period which is measured between the year of commission and target year. It reduces the installed capacity from 8 MW to 7 MW while the energy output is little reduced. The semi-variable draft operation compared with the variable draft operation reduces the net water supply capacity from 27.2 m^3/s to 24.6 m^3/s, or from 23 years to 19 years in terms of the build up period. The values of benefit less cost and EIRR under the semi-variable draft operation falls between those under the constant draft operation and variable draft operation.

The semi-variable draft operation should be taken into account in the detailed study in order to develop both the water supply capacity and potential energy to the utmost.

13 CONSIDERATION ON THE PRIORITY OF THE PROPOSED PROJECTS

According to the water budget for the Han river, the water deficit expected to occur will be characterized to be of a short duration, after the time when supply capacity of existing dams including Chungju dam has reached its maximum. Under such condition, a variable draft operation will be effective. In this connection, the proposed Hongcheon, Dalcheon or Ganhyeon dam should be taken up, relying upon their large water supply capacity and high economic viability. The Hongcheon dam can develop a hydroelectric potential of 150 GWh which is the largest among those possible by the proposed dams except the unjustified Inje dam, if it constructed based on the constant draft operation. It is expected that the Hongcheon dam will be able to develop a large hydroelectric potential little losing the water supply capacity and economic viability, if the semi-variable draft operation or some other measure is introduced in favor of power generation. The Hongcheon dam among others will be probably taken up as the next multipurpose dam to the Chungju dam in the Han river basin, in view of importance of water supply as well as hydropower generation which is going to be more important as the energy conservation policy directs. Once a dam is constructed based on the variable or semi-variable draft operation in the Han river basin, subsequent dam of constant draft operation can claim more water supply benefits than herein estimated, because the regulated outflow is more effectively utilized to meet the water deficit in elongated periods.

The net water supply capacity and economic viability of the Imha dam in the Nagdong river basin do not differ so much between the constant draft operation and variable draft operation, because the water deficit building up will be already flat owing to the variable draft operation of the Andong dam. This dam should be constructed with power facilities allowing to be flexible enough to respond to both the water deficit and power demand.

As for the proposed Juam dam in the Seomjin river basin, all the studied plans were justified. The main stream plan under the variable draft operation should be taken up so far as the major water demand center is located on the Gwangyang bay coast as assumed herein, because it showed the highest value of EIRR among others. The power generation will be minor, but its development by applying the semi-variable draft operation should be considered, if the main stream plan is taken up. The present study did not go into the details of the future pollution problem near the estuary of the Seomjin river, irrigation water demand in the southern coast and the possibility of new M&I water demand centers in the southern coast. The diversion plan should be taken into account, if these problems so dictate.

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Table 1 LIST OF JICA FIELD TEAM (SECOND STAGE)

Name	Title
Ichiro KUNO	Team Leader
Hideo SATO	Vice Team Leader
Yasuo IWASAKI	Planning Engineer
Kimihiko YANAGISAWA	Economist
Mitsuishi AOSHIMA	Hydrologist
Shuichi KAIEDA	Flood Hydrologist
Minoru NAKAHARA	Flood Control Engineer
Suenao HAYASHI	River Engineer
Yutaka MATSUMOTO	Agronomist
Shun-ichi MURAMOTO	Irrigation Engineer
Mitsuo TANOUE	Soil Scientist
Hiroshi KAGAMI	Electrical Engineer
Taketoshi FUJITA	Geologist
Hiroshi SUETOMI	Geologist
Noboru MIYAMOTO	Geologist
Ichiro NAKAZATO	Construction Material Specialist
Minoru KIYOURA	Construction Material Specialist
Takeshi SUZUKI	Geophysicist
Hiroshi IBARAGI	Geophysicist
Eijiro KOHCHI	Geophysicist
Takahiro NISHIBORI	Geophysicist
Fumio KABATA	Geophysicist
Toshihiro TSUBOI	Geophysicist
Akira OGAWA	Administrative Staff

Table 2 OUTLINE OF DAM SCHEMES PRESENTED IN THE INTERIM REPORT (1/2)

Name of Dam	Bamseonggol	Inje	Hongcheon	Gujeol	Dalcheon
River System	North Han	North Han	North Han	South Han	South Han
Catchment Area (km^2)	583	1,043	1,473	101	1,348
High Water Surface (El. m)	305	315	120	747	117
Flood Control Space (10^6 m^3)	14	20	50	7	50
Active Storage Capacity (10^6 m^3)	368	376	954	67	555
Dam Type	R	CG	CG	R	CG
Dam Height (m)	105	97	88	66	55
Installed Capacity (MW)	48	72	82	47	-
Investment Cost (\$ 10^6)	123	153	167	70	144
Net Water Output (m^3/s)	10.3	1.6	26.1	-	21.7
Energy Output (GWh)	101	168	147	99	-
Annual Benefits					
-M&I water supply (\$ 10^6)	7.50	1.47	19.11	-	14.62
-Agricultural water supply (\$ 10^6)	0.03	0	0.06	-	0.41
-Flood control (\$ 10^6)	0.08	0.08	0.32	0.05	0.70
-Power (\$ 10^6)	6.05	8.23	8.62	5.49	0.18
-Production foregone (\$ 10^6)	-0.68	-0.73	-1.82	-0.01	-3.49
-Total (\$ 10^6)	12.98	9.05	26.29	5.53	12.42
Annual Cost (\$ 10^6)	11.20	15.58	12.31	7.15	4.81
Benefit - Cost (\$ 10^6)	1.78	-6.53	13.98	-1.62	7.61
Benefit/Cost	1.2	0.6	2.1	0.8	2.6

Remarks; R: Rockfill type
CG: Concrete gravity type
A discount rate of 8 % was assumed.

Table 3 OUTLINE OF DAM SCHEMES PRESENTED IN THE INTERIM REPORT (2/2)

Name of Dam	Ganhyeon	Bonghwa	Imha	Hamyang	Juam
River System	South Han	Nagdong	Nagdong	Nagdong	Seomjin
Catchment Area (km^2)	1,180	1,135	1,230	264	1,010
High Water Surface (El. m)	111.4	267	185	376	123.5
Flood Control Space (10^6 m^3)	80	15	214	6	60
Active Storage Capacity (10^6 m^3)	525	269	583	151	1,007
Dam Type	CG	CG	CG	R	CG
Dam Height (m)	46	97	82	80	76
Installed Capacity (MW)	-	38	48	-	-
Investment Cost ($ 10^6)	106	106	140	69	161
Net Water Output (m^3/s)	19.9	0.6	15.3	3.6	18.4
Energy Output (GWh)	-	97	86	-	-
Annual Benefits					
-M&I water supply ($ 10^6)	13.91	0.51	6.26	2.03	10.30
-Agricultural water supply ($ 10^6)	0.38	0.21	1.75	0.54	0.72
-Flood control ($ 10^6)	0.85	0.95	2.28	0.04	0.26
-Power ($ 10^6)	0.17	4.51	4.29	0.06	-
-Production foregone ($ 10^6)	-2.77	-0.26	-0.96	-0.27	-2.00
-Total ($ 10^6)	12.54	5.92	13.62	2.40	9.28
Annual Cost ($ 10^6)	3.64	10.41	11.20	4.75	8.76
Benefit - Cost ($ 10^6)	8.90	-4.49	2.60	-2.35	0.52
Benefit/Cost	3.4	0.6	1.2	0.5	1.1

Remarks; R: Rockfill type
CG: Concrete gravity type
A discount rate of 8 % was assumed.

Table 4 CENSUS POPULATION

Unit: 10^6 persons

	1966	1970	1975
Seoul Special City	3.80	5.53	6.89
Busan Special City	1.43	1.88	2.45
Gyeonggi Do	3.11	3.35	4.04
Gangweon Do	1.83	1.86	1.86
Chungcheong-bug Do	1.55	1.48	1.52
Chungcheong-nam Do	2.91	2.86	2.95
Jeonla-bug Do	2.52	2.43	2.46
Jeonla-nam Do	4.05	4.00	3.99
Gyeongsang-bug Do	4.47	4.56	4.86
Gyeongsang-nam Do	3.18	3.12	3.28
Jeju Do	0.34	0.37	0.41
Total	29.19	31.44	34.71

Table 5 ECONOMIC DATA

	1961	1966	1971	1976	1977	1978/1
Population						
National population (10^3 persons)	25,766	29,160	32,883	35,860	36,436	37,030
Average annual growth (%)	-	2.63	2.43	1.75	1.61	1.63
Gross National Products						
GNP at current price (₩ 10^9)	297	1,032	3,152	12,143	15,240	22,256
GNP at 1978 price (₩ 10^9)	4,244	6,146	10,101	17,031	18,792	22,256
Average annual growth at 1978 price (%)	5.1	7.7	10.4	11.0	10.3	18.4
Per capita GNP at current price ($)	87/2	130	266	692	864	1,242
Composition on GNP by Industrial Group						
Agriculture, forestry & fisheries (%)	40.2	35.4	28.9	24.8	23.7	21.2
Mining & manufacturing (%)	15.3	20.1	22.8	31.0	30.0	28.2
Social overhead & others (%)	44.5	44.5	48.3	44.2	46.3	50.6
Price Indices						
Wholesale (1978 = 100)	10.8	23.0	33.5	82.2	89.8	100.0
Consumer in Seoul (1978 = 100)	10.5	22.1	38.1	79.3	87.4	100.0
International Trade						
Export (at current price $ 10^6 F.O.B)	39	251	1,067	7,715	10,046	12,722
Import (at current price $ 10^6 C.I.F.)	316	716	2,344	8,774	10,811	14,607
Foreign reserve (at current price $ 10^6)	207	245	568	2,961	4,306	
Exchange Rate						
₩/$ at end of year (Basic exchange rate by the Bank of Korea)	130.00	271.46	373.30	484.00	484.00	484.00
Labor Force Employment						
Total employed (10^3 persons)	9,788	8,423	10,066	12,556	12,929	14,080/3
Agriculture, forestry & fisheries (%)	79.8	57.9	48.4	44.6	41.8	40.7
Mining & manufacturing (%)	4.9	10.8	14.2	21.9	22.4	22.2
Social overhead & others (%)	12.3	31.3	37.4	33.5	35.8	37.1
Unemployed (10^3 persons)		648	476	505	511	430
Unemployed rate (%)		7.1	4.5	3.9	3.8	2.9

Remarks; /1: Tentative figures presented by Bank of Korea on Jan. 5, 1979
/2: Data as of 1962
/3: Data as of Sept., 1978, EPB

Table 6 AGRICULTURAL DATA

	1972	1973	1974	1975	1976	1977
Farm Household and Population (10^6)						
Farm household	2.45	2.45	2.38	2.38	2.34	2.34
Farm population	14.7	14.6	13.5	13.2	12.8	12.3
Cultivated Area (10^6 ha)						
Fully irrigated paddy	1.03	1.04	1.05	1.07	1.08	1.09
Partially irrigated paddy	0.23	0.22	0.22	0.21	0.21	0.20
Upland	0.98	0.98	0.97	0.96	0.95	0.94
Total	2.24	2.24	2.24	2.24	2.24	2.24
Land Consolidated	0.15	0.17	0.24	0.26	0.29	0.29
Crop Area (10^6 ha)						
Rice	1.19	1.18	1.20	1.22	1.22	1.23
Barley & wheat	0.78	0.71	0.75	0.76	0.75	
Pulse	0.34	0.37	0.35	0.34	0.32	
Potatoes	0.15	0.14	0.12	0.15	0.14	
Vegetable	0.25	0.25	0.27	0.28	0.27	
Other annual crops	0.24	0.25	0.26	0.24	0.23	
Mulberry	0.08	0.08	0.09	0.09	0.08	
Orchard	0.06	0.07	0.08	0.09	0.10	0.10
Multiple Crop Index	1.37	1.36	1.40	1.41	1.38	1.40
Food Crop Production (10^6 ton)						
Rice	3.96	4.21	4.45	4.67	5.22	5.97
Barley & wheat	1.76	1.55	1.47	1.81	1.85	0.86
Pulses	0.26	0.28	0.37	0.36	0.35	0.38
Potatoes	0.67	0.61	0.54	0.74	0.67	0.60
Miscellaneous grain	0.09	0.10	0.10	0.09	0.12	0.19
Vegetables	2.72	2.61	2.98	2.91	3.22	3.06
Fruits	0.49	0.55	0.58	0.64	0.62	0.74

Table 7 OUTLINE OF POWER GENERATION DAMS IN KOREA

	Hwacheon	Chuncheon	Uiam
River System	North Han	North Han	North Han
Catchment Area (km^2)	4,145	4,736	7,666
High Water Surface (El. m)	181	103	71.5
Drawdown (m)	24.2	5	5.2
Active Storage Capacity (10^6 m^3)	658	61	39
Dam Height (m)	77.5	40	17.5
Maximum Discharge (m^3/s)	185	228.4	340
Rated Water Head (m)	62.5	26.3	14.6
Installed Capacity (MW)	108	57.6	45
Year of Completion	1944/1968	1965	1967

	Cheongpyeong	Goesan	Paldang
River System	North Han	South Han	Lower Han
Catchment Area (km^2)	10,138	671	23,608
High Water Surface (El. m)	51	135.7	25.5
Drawdown (m)	5	4	0.5
Active Storage Capacity (10^6 m^3)	83	5.7	18
Dam Height (m)	31	28	21.5
Maximum Discharge (m^3/s)	372.6	11.6	800
Rated Water Head (m)	23.5	21.8	11.5
Installed Capacity (MW)	79.6	2.6	80
Year of Completion	1943/1967	1957	1974

Table 8 OUTLINE OF MULTIPURPOSE DAMS IN KOREA

	Soyanggang	Chungju	Daecheong	Andong	Yeongcheon
River System	North Han	South Han	Geum	Nagdong	Nagdong
Catchment Area (km^2)	2,703	6,648	4,134	1,588	235
High Water Surface (El. m)	192	414	76.5	160	138
Drawdown (m)	42	31	16.5	30	18.8
Active Storage Capacity (10^6 m^3)	1,772	1,781	790	1,000	81.4
Reservoir Area (km^2)	70	85	73	52	
Dam Type	R	CG	CG + R	R	R
Dam Height (m)	125	93	72	83	40
Dam Volume (10^3 m^3)	9,600	810	490+880	4,046	747
Maximum Discharge (m^3/s)	251		270	170	-
Rated Water Head (m)	96	57.5	48	57	-
Installed Capacity (MW)	200	400	90	80	-
Year of Completion	1973	1984	1980	1976	1978

	Habcheon	Namgang	Seomjingang	Boseong
River System	Nagdong	Nagdong	Seomjin	Seomjin
Catchment Area (km^2)	925	2,285	763	275
High Water Surface (El. m)	176	37.5	196.5	127.3
Drawdown (m)	36	6.5	21.5	6.8
Active Storage Capacity (10^6 m^3)	543	109	350	4.7
Reservoir Area (km^2)		24	27	2
Dam Type	R	CG	CG	CG
Dam Height (m)	93	21	64	11.9
Dam Volume (10^3 m^3)	4,000		410	42
Maximum Discharge (m^3/s)	87	100		5
Rated Water Head (m)	102	10.1		83.6
Installed Capacity (MW)	72.5	11	31.4	3.12
Year of Completion		1970	1965	1937

Remarks; Power generation facilities of the Seomjingang dam comprises the Chilbo (28.8 MW) and Unam (2.6 MW) power stations.
The Habcheon dam is under planning by the Government.

Table 9 METEOROLOGICAL DATA

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Average Air Temperature (°C)					
Jan.	-4	-3	-1	2	0
Apr.	11	11	13	13	12
Aug.	25	25	26	26	26
Annual	11	11	13	14	13
Relative Humidity (%)					
Oct. - Mar.	67	67	63	57	72
Apr. - Sept.	73	73	71	77	76
Annual	70	70	67	67	74
Pan Evaporation (mm)					
Oct. - Mar.	347	443	453	550	413
Apr. - Sept.	762	874	908	754	866
Annual	1,109	1,317	1,361	1,304	1,279
Rainfall (mm)					
Oct. - May	409	437	356	630	513
June - Sept.	983	756	658	847	806
Annual	1,392	1,193	1,014	1,477	1,319
Sunshine Hours (h/d)					
Jan. - Mar.	5.9	6.2	6.4	6.2	5.9
Apr. - June	6.7	7.3	6.8	6.3	6.9
July - Sept.	4.9	5.7	5.7	5.6	6.2
Oct. - Dec.	5.5	6.0	6.1	6.2	5.9
Annual	5.8	6.3	6.2	6.1	6.2
Wind Velocity (m/s)					
Oct. - Mar.	2.5	3.5	3.2	4.5	2.2
Apr. - Sept.	2.4	2.5	3.1	4.4	2.2
Annual	2.4	3.0	3.2	4.4	2.2
First Frost	Oct. 18	Oct. 14	Oct. 20	Nov. 21	Oct. 28
Last Frost	Apr. 14	Apr. 12	Apr. 11	Mar. 8	Apr. 24

Remarks; Han: Seoul (1954-1976)
Nagdong North: Chupungryeong (1953-1976)
Nagdong Central: Daegu (1952-1976)
Nagdong South: Busan (1952-1976)
Seomjin: Gwangju (1952-1976) out of basin.
Rainfall at Gurye raingauge (1966-1976) in the basin is 1,371 mm.

Table 10 FLOW RECORDS INCORPORATED IN THE STUDY

Dam/Gauge Site	Basis for Flow Rating
North Han River	
Hwacheon dam	Monthly operation record in KECO Yearbook
South Han River	
Jeongseon gauge	Daily WL record & measurement in MOC Yearbook
Chungju gauge	ECI F/S + Supplement by ECI rating curve & MOC Yearbook
Goesan dam	Monthly operation record in KECO Yearbook
Yeoju gauge	ECI F/S + Supplement by daily WL record & measurement in MOC Yearbook
Lower Han River	
Goan gauge	Daily WL record & measurement in MOC Yearbook
Nagdong River	
Imha gauge	Daily WL record in MOC Yearbook & ISWACO measurement
Waegwan gauge	ISWACO daily flow record + ISWACO measurement
Changri gauge	ISWACO daily flow record + ISWACO measurement
Jindong gauge	ISWACO daily flow record + ISWACO measurement
Seomjin River	
Seomjingang dam	Monthly operation record in KECO Yearbook
Abrog gauge	Daily WL record & measurement in MOC Yearbook
Boseong dam	Monthly operation record in KECO Yearbook

Remarks; ECI F/S: ISWACO Chungju Multipurpose Project Feasibility Report, 1976, Engineering Consultants, Inc.

Table 11. DATA FOR ESTIMATE OF INFLOW INTO DAM SITES

Name of Dam Site	Catchment Area (km^2)	Nos. of Raingauge	Discharge Record Transmitted
North Han River			
Bamseonggol	583	3	Hwacheon dam
Hwacheon	4,063		Hwacheon dam
Inje	1,043	5	Hwacheon dam
Soyanggang	2,703		Hwacheon dam
Hongcheon	1,473	5	Hwacheon dam
South Han River			
Gujeol	101	4	Jeongseon gauge
Chungju	6,648		Chungju gauge
Dalcheon	1,348	5	(Yeoju - Chungju - Goesan) + Goesan
Ganhyeon	1,180	4	(Yeoju - Chungju - Goesan)
Nagdong River			
Bonghwa	1,135	6	Imha gauge
Andong	1,588		Imha gauge
Imha	1,230	5	Imha gauge
Habcheon	925		Changri gauge
Hamyang	264	4	Changri gauge
Seomjin River			
Juam	1,010	4	Abrog + Boseong

Table 12 SUMMARY OF ESTIMATED AVERAGE ANNUAL RAINFALL AND RUN-OFF

Dam/Gauge	Catchment Area (km^2)	Annual Rainfall (mm)	Annual Run-off (10^6 m^3)
North Han River			
Bamseonggol dam	583	1,276	509
Hwacheon dam inflow	4,145	1,276	3,618
Inje dam	1,043	1,200	857
Soyanggang dam inflow	2,703	1,150	2,127
Hongcheon dam	1,473	1,340	1,351
South & Lower Han Rivers			
Gujeol dam	101	1,186	79
Jeongseon gauge	1,425	1,133	1,065
Chungju dam inflow	6,648	1,140	5,453
Chungju gauge	6,657	1,140	5,461
Goesan dam outflow	671	1,072	475
Dalcheon dam	1,348	1,106	932
Ganhyeon dam	1,180	1,349	945
Yeoju gauge	11,036	1,161	8,600
Goan gauge	23,613	1,241	19,117
Nagdong River			
Bonghwa dam	1,135	1,033	695
Andong dam inflow	1,588	1,028	968
Imha dam	1,230	995	725
Imha gauge	1,361	995	802
Waegwan gauge	11,074	1,025	4,865
Changri gauge	925	1,270	863
Habcheon dam inflow	925	1,270	863
Hamyang dam	264	1,422	276
Namgang dam inflow	2,285	1,499	1,826
Jindong gauge	20,311	1,139	11,206
Seomjin River			
Seomjingang dam outflow	763	1,440	0
Abrog gauge	2,448	1,389	1,595
Boseong dam outflow	275	1,387	185
Juam dam	1,010	1,382	701

Remarks; Juam dam: The catchment area of 187 km^2 with rainfall of 1,277 mm of Dongbog dam is included in the catchment area but no outflow into the Seomjin river basin is assumed.

Table 13 SUMMARY OF ORD RECONNAISSANCE SOIL MAP LEGEND

Mapping Unit	Legend & Mapping Subunits
F :	Soils of Fluvio-marine Plains, Coastal Plains & Dunes
Ft	Tidal flats; Fta
Fb	Sand & gravels, Coastal beaches & dunes; Fba
Fm	Low-humic gley and alluvial soils, Fluvio-marine plains; Fma, Fmb, Fmc, Fmd, Fmg and Fmk
A :	Soils of Flood Plains, Alluvial Plains & Narrow Valleys
Af	Alluvial soils and riverwash, Flood plains; Afa, Afb, Afc and Afd
Ap	Low-humic gley & alluvial soils, Alluvial plains; Apa, Apb, Apc, Apd and Apg
An	Complex of soils, Narrow valleys; Ana, Anb, Anc and And
R :	Soils of Dilluvial Terrace
Ra	Red-yellow podzolic soils, Siliceous crystalline materials; Raa, Rab, Rac and Rad
Re	Lithosols, Severely eroded, Siliceous materials; Rea
Rs	Lithosols & red-yellow podzolic soils, Sedimentary materials; Rsa, Rsb and Rsc
Rv	Red-yellow podzolic & reddish brown lateritic soils, siliceomafic materials; Rva, Rvb, Rvc and Rvd
Rl	Reddish brown lateritic soils & lithosols, Calcareous materials; Rla, Rlb
Rx	Alluvial & low-humic gley soils, Narrow valleys between rolling lands, Undifferential materials; Rxa
M :	Soils of Strongly Dissected Hilly & Mountainous Lands
Ma, Ms, Mv, Ml, Mm, Mu	Maa, Mab, Mac, Msa, Msb, Mva, Mvb, Mla, Mlb, Mma, Mmb, Mua and Mub

Table 14 EXTENTS OF SOILS

Unit: 10^3 ha

Association		Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
F	Ft & Fb	14.8	0.1	0.1	0.2	0.0
	Fm	15.1	0.3	0.3	14.2	5.4
	Sub-total	29.9	0.4	0.4	14.4	5.4
A	Af	83.2	32.9	57.7	39.2	12.5
	Ap	59.3	17.7	51.5	43.1	19.2
	An	160.3	62.9	91.6	75.7	60.6
	Sub-total	302.8	113.5	200.8	158.1	92.3
R	Ra	196.7	37.8	29.8	16.9	27.2
	Re	76.1	27.9	1.2	1.5	2.2
	Rs	1.3	17.4	36.8	16.3	4.5
	Rv	5.3	1.2	2.1	7.5	4.0
	Rl	22.4	1.7	0.0	-	-
	Rx	66.6	18.8	15.0	6.6	10.1
	Sub-total	368.4	104.8	84.9	48.8	48.0
M	Sub-total	1,335.3	519.6	541.7	359.5	313.1
Rocky Land		238.3	57.2	54.2	94.8	33.7
Water Resources		6.1	1.6	1.5	0.9	0.7
Village road, etc.		9.6	-	3.9	4.6	0.2
	Total	2,290.4	797.1	887.4	681.1	493.4

Remarks; Han river basin excluding north Korea.

Table 15 SUITABILITY/PRODUCTIVITY GRADE OF PADDY SOIL FOR THE HIGH-YIELDING RICE VARIETIES

Grade	Suitability	Productivity (Yield Index)	Environment of Paddy Field	Soil Association
1	Most suitable	100	Ordinary paddy field in fluvio-marine and alluvial plains	Fma, Apa
			Two thirds of ordinary paddy field in narrow valleys	Rxa (2/3)
2	Suitable	95-100	One third of ordinary paddy field in narrow valleys	Rxa (1/3)
3	Suitable	95	Sandy paddy field in fluvio-marine, flood and alluvial plains and in narrow valleys	Fmb, Afb, Apc, Ana, Anc
4	Suitable	84	Half of unripe paddy field in narrow valleys	Anb (1/2)
5	Less suitable	75-80	Poorly drained paddy field in fluvio-marine and alluvial plains	Fmd, Apd
6	Less suitable	70-75	Half of unripe paddy field in narrow valleys	Anb (1/2)
7	Less suitable	63	Saline and acid sulphate paddy field in fluvio-marine plains	Fmc, Fmg, Fmk

Source; Refs. 3 & 4

Table 16 PROPORTIONAL EXTENT OF HIGH-YIELDING RICE SUITABILITY GROUPS OF PADDY SOIL

Unit: %

Grade	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
1	28.8	19.1	25.2	28.6	20.1
2	7.2	5.9	3.1	1.5	3.6
3	32.9	37.4	47.9	51.6	44.6
4	15.2	18.6	11.6	8.2	14.0
Sub-total	84.1	81.0	87.8	89.9	82.3
5	0.5	0.4	0.6	0.4	3.5
6	15.2	18.6	11.6	8.2	14.0
7	0.2	0	-	1.5	0.2
Sub-total	15.9	19.0	12.2	10.1	17.7
Total	100.0	100.0	100.0	100.0	100.0

Table 17 POTENTIAL LAND USE PATTERN

Unit: 10^3 ha

Land Use	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Paddy	161.1	67.9	123.9	104.2	64.1
Upland	190.3	75.4	63.0	38.3	36.0
Paddy/Upland	8.2	0.2	2.4	1.5	1.4
Orchard	71.0	21.0	35.1	20.3	10.0
Intensive Grassland	2.6	2.9	3.5	4.3	1.7
Extensive Grassland	39.5	94.0	36.1	30.0	9.8
Forest	1,564.6	466.7	553.3	413.8	348.8
Erosion control	123.0	57.5	34.5	47.4	16.8
Water, villages, etc.	130.1	11.5	35.6	21.3	4.8
Total	2,290.4	797.1	887.4	681.1	493.4

Table 18 AGRICULTURAL SITUATION IN THE THREE RIVER BASINS

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Farm Population (10^3)	1,608	772	1,122	940	643
Nos. of Farm Household (10^3)	289	139	211	177	115
Household by Holding Size (%)					
Less than 0.5 ha	27.4	24.1	34.6	38.4	36.7
0.5 ha - 1.0 ha	32.4	37.8	37.9	37.2	38.6
1.0 ha - 1.5 ha	21.5	23.9	17.2	15.5	16.2
1.5 ha - 2.0 ha	10.3	9.0	6.2	5.3	5.6
More than 2.0 ha	8.4	5.2	4.1	3.6	2.9
Cultivated Area (10^3 ha)					
Paddy	156	65	117	103	64
Annual crop field	161	60	54	37	29
Perennial crop field	21	13	19	10	5
Total	338	138	190	150	98
Crop Area (10^3 ha)					
Paddy rice	141	61	110	95	60
Barley & wheat	30	34	94	85	47
Pulses	64	27	25	16	12
Potatoes	15	8	7	10	6
Miscellaneous grains	35	7	3	2	2
Vegetables	49	13	23	21	11
Special crops	20	8	11	7	7
Fruits	11	6	12	4	1
Mulberry	10	7	7	6	4
Total	375	171	292	246	150
Multiple Crop Index					
Paddy	1.17	1.32	1.66	1.66	1.65
Upland	1.06	1.17	1.33	1.58	1.30
Whole cultivated area	1.11	1.24	1.54	1.64	1.53

Remarks; 1976 figures

Table 19 PROPORTION OF HIGH-YIELDING RICE VARIETIES ON PADDY

Unit: %

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
1972	7.3	22.1	14.7	8.7	10.0
1973	7.1	14.4	10.3	3.8	6.9
1974	7.9	21.4	14.3	8.0	10.2
1975	11.3	32.3	20.7	12.0	15.4
1976	23.0	58.6	41.5	25.1	31.9

Table 20 AVERAGE CROP PRODUCTION

Unit: 10^3 tons

Crop	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Rice	531	233	403	330	221
Barley & wheat	78	84	214	188	129
Pulses	66	25	27	15	14
Potatoes	197	80	83	143	115
Miscellaneous grains	68	8	2	2	2
Vegetables	462	139	244	313	110
Special crops	5	3	4	4	5
Fruits	65	81	103	44	9
Total	1,472	653	1,080	1,039	605

Remarks; 1972-1976 average figures

Table 21 OUTLINE OF EXISTING YEOCHEON/GWANGYANG INDUSTRIAL WATER SUPPLY SYSTEM

1. Intake	
1.1 Location	Seomjin river 6.5 km upstream of Hadong
1.2 Intake water surface	El. 3.5 m
1.3 Intake pump	6,000 PS, H = 68 m
2. Intake Tunnel	
2.1 Location	Intake - Sueo dam
2.2 Discharge capacity	550,000 m^3/d
2.3 Dimensions	2.5 m dia. x 1,500 m
3. Sueo dam	
3.1 Location	Sueo river
3.2 Catchment area	49 km^2
3.3 HWS	El. 64 m
3.4 Drawdown	20 m
3.5 Active storage capacity	22.5×10^6 m^3
3.6 Dam type	Rockfill
3.7 Dam height	60 m
4. Conveyance and Distribution System	
4.1 Discharge capacity	250,000 m^3/d (300,000 m^3/d at maximum)
4.2 Trunk main	1,650 mm dia. x 40.24 km
	1,500 mm dia. x 4.87 km
4.3 Distribution main	900 mm to 1,000 mm dia. x 10.44 km
4.4 Booster pump	3,600 PS, H = 39 m
4.5 Primary treatment plant	265,000 m^3/d
5. Estimated O & M Cost (Financial)	
5.1 Fixed cost	$ 0.75×10^6
5.2 Material	$ 0.14×10^6
5.3 Energy	$ 2.14×10^6
Total	$ 3.03×10^6

Table 22 CLASSIFICATION OF CULTIVATED AREA BY IRRIGATION CONDITION

Category	Classification in Ref. 6
1. Paddy Depending on Reservoir/Groundwater	Reservoirs, tubewells & infiltration galleries: FLIA + non-FLIA
2. Paddy Depending on River	Pumps, feed canals, weirs & others: FLIA + non-FLIA
3. Paddy Supplementarily Irrigated	Replacement required, movable pumps & partially irrigated: FLIA + non-FLIA
4. Irrigated Upland	
5. Rainfed Upland	

Table 23 PROJECTED AGRICULTURAL LAND DEVELOPMENT IN THE HAN RIVER BASIN

Unit: 10^3 ha

	1968	1976	1981	1986	1991	1996	2001
Tributary							
Reservoir, consolidated	0.86	3.79	7.85	11.37	15.45	19.46	23.62
Reservoir, unconsolidated	14.75	20.40	18.34	15.52	13.55	11.24	8.93
Sub-total	15.61	24.19	26.19	26.89	29.00	30.70	32.55
River, consolidated	2.37	7.75	16.66	23.81	31.71	39.80	47.42
River, unconsolidated	48.63	52.30	45.10	36.95	31.69	26.33	21.19
Sub-total	51.00	60.05	61.76	60.76	63.40	66.13	68.61
Supplementary	76.60	56.86	51.56	43.24	37.52	31.87	26.45
Irrigated upland	-	-	2.32	4.70	7.02	9.45	11.82
Total	143.21	141.10	141.83	135.59	136.94	138.15	139.43
Main Stream							
River, consolidated	2.07	6.63	10.69	16.99	20.13	23.44	26.96
River, unconsolidated	14.02	11.29	9.54	12.72	10.85	9.01	6.98
Sub-total	16.09	17.92	20.23	29.71	30.98	32.45	33.94
Irrigated upland	-	-	0.76	1.51	2.27	3.02	3.73
Total	16.09	17.92	20.99	31.22	33.25	35.47	37.67
Rainfed Upland	207.75	185.34	180.67	176.64	172.71	168.48	164.20
Grand Total	367.05	344.36	343.49	343.45	342.90	342.10	341.30

Table 24 PROJECTED AGRICULTURAL LAND DEVELOPMENT IN THE NORTHERN NAGDONG RIVER BASIN

Unit: 10^3 ha

	1968	1976	1981	1986	1991	1996	2001
Tributary							
Reservoir, consolidated	1.20	4.51	6.46	8.42	10.54	12.70	14.92
Reservoir, unconsolidated	9.47	10.77	10.37	9.76	9.11	8.30	7.58
Sub-total	10.67	15.28	16.83	18.18	19.65	21.00	22.50
River, consolidated	2.10	6.09	8.81	11.48	14.08	16.85	19.66
River, unconsolidated	18.39	14.65	13.20	12.22	11.00	9.83	8.72
Sub-total	20.49	20.74	22.01	23.70	25.08	26.68	28.38
Supplementary	30.99	23.28	20.30	16.95	13.95	10.85	7.60
Irrigated upland	2.43	5.31	6.60	8.86	10.16	11.42	12.71
Total	64.58	64.61	65.74	67.69	68.84	69.95	71.19
Main Stream							
River, consolidated	0.25	1.73	2.23	2.85	3.43	4.00	4.52
River, unconsolidated	1.70	4.35	4.23	3.97	3.74	3.47	3.20
Sub-total	1.95	6.08	6.46	6.82	7.17	7.47	7.72
Irrigated upland	0.27	0.50	0.72	0.95	1.14	1.31	1.49
Total	2.22	6.58	7.18	7.77	8.31	8.78	9.21
Rainfed Upland	72.40	66.97	65.08	62.19	60.40	58.52	56.70
Grand Total	139.20	138.16	138.00	137.65	137.55	137.25	137.10

Table 25 PROJECTED AGRICULTURAL LAND DEVELOPMENT IN THE CENTRAL NAGDONG RIVER BASIN

Unit: 10^3 ha

	1968	1976	1981	1986	1991	1996	2001
Tributary							
Reservoir, consolidated	5.77	18.77	23.27	27.53	32.36	37.06	42.06
Reservoir, unconsolidated	31.81	27.61	25.53	23.52	21.04	18.64	15.99
Sub-total	37.58	46.38	48.80	51.05	53.40	55.70	58.05
River, consolidated	3.90	9.98	12.50	15.34	17.93	20.56	23.06
River, unconsolidated	23.99	18.03	16.07	14.36	12.67	10.93	9.53
Sub-total	27.89	28.01	28.57	29.70	30.60	31.49	32.59
Supplementary	48.14	29.95	26.67	22.85	19.40	15.85	12.10
Irrigated upland	3.57	7.73	9.82	13.20	15.43	17.70	20.15
Total	117.18	112.07	113.86	116.80	118.83	120.74	122.89
Main Stream							
River, consolidated	0.87	4.15	5.23	6.53	7.76	9.13	10.38
River, unconsolidated	3.50	8.32	7.73	6.97	6.14	5.23	4.38
Sub-total	4.37	12.47	12.96	13.50	13.90	14.36	14.76
Irrigated upland	0.62	1.25	1.63	2.20	2.72	3.20	3.75
Total	4.99	13.72	14.59	15.70	16.62	17.56	18.51
Rainfed Upland	76.03	64.31	61.20	56.60	53.10	49.65	46.05
Grand Total	198.20	190.10	189.65	189.10	188.55	187.95	187.45

Table 26 PROJECTED AGRICULTURAL LAND DEVELOPMENT IN THE SOUTHERN NAGDONG RIVER BASIN

Unit: 10^3 ha

	1968	1976	1981	1986	1991	1996	2001
Tributary							
Reservoir, consolidated	3.65	11.72	14.68	17.42	21.69	25.23	29.13
Reservoir, unconsolidated	20.95	18.77	17.57	16.28	13.86	11.92	9.77
Sub-total	24.60	30.49	32.25	33.70	35.55	37.15	38.90
River, consolidated	3.41	9.50	11.91	14.54	17.82	20.45	22.81
River, unconsolidated	22.25	18.14	16.30	14.93	12.20	10.55	8.64
Sub-total	25.66	27.64	28.21	29.47	30.02	31.00	31.45
Supplementary	38.33	25.80	22.40	18.90	15.60	12.35	9.50
Irrigated upland	1.34	2.70	3.48	4.53	5.56	6.55	7.38
Total	89.93	86.63	86.34	85.60	86.73	87.05	87.23
Main Stream							
River, consolidated	2.79	9.53	11.31	12.94	14.99	16.59	18.41
River, unconsolidated	11.61	9.76	9.03	8.19	7.04	6.11	4.94
Sub-total	14.40	19.29	20.34	21.13	22.03	22.70	23.35
Irrigated upland	0.22	0.40	0.61	0.79	1.00	1.18	1.32
Total	14.62	19.69	20.95	21.92	23.03	23.88	24.67
Rainfed Upland	48.92	44.11	42.76	41.18	39.64	38.17	36.90
Grand Total	153.47	150.43	150.05	148.70	149.40	149.10	148.80

Table 27 PROJECTED AGRICULTURAL LAND DEVELOPMENT IN THE SEOMJIN RIVER BASIN

Unit: 10^3 ha

	1968	1976	1981	1986	1991	1996	2001
Tributary							
Reservoir, consolidated	0.28	3.22	6.34	9.18	11.66	14.44	16.75
Reservoir, unconsolidated	16.69	16.01	14.01	12.47	11.29	9.76	8.75
Sub-total	16.97	19.23	20.35	21.65	22.95	24.20	25.50
River, consolidated	0.31	3.44	6.50	9.14	11.79	14.42	16.85
River, unconsolidated	15.21	15.32	13.40	11.94	10.53	9.11	7.90
Sub-total	15.52	18.76	19.90	21.08	22.32	23.53	24.75
Supplementary	30.39	25.27	23.12	20.62	18.15	15.65	13.20
Irrigated upland	-	-	0.24	0.48	0.81	1.16	1.60
Total	62.88	63.26	63.61	63.83	64.23	64.54	65.05
Main Stream							
River, consolidated	0.06	0.23	0.36	0.48	0.55	0.64	0.80
River, unconsolidated	0.67	0.67	0.64	0.64	0.63	0.58	0.45
Sub-total	0.73	0.90	1.00	1.12	1.18	1.22	1.25
Irrigated upland	-	-	0.06	0.12	0.19	0.29	0.40
Total	0.73	0.90	1.06	1.24	1.37	1.51	1.65
Rainfed Upland	36.47	33.48	33.38	33.33	33.15	33.05	32.80
Grand Total	100.08	97.64	98.05	98.40	98.75	99.10	99.50

Table 28 ESTIMATED DIVERSION REQUIREMENT IN THE FUTURE CROPPING PATTERN

Unit: mm

Item	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
1. Pan Evaporation	915	1,043	1,039	882	955
2. High-yielding New Rice					
2.1 Single cropping					
- Effective rainfall	571	399	397	574	452
- Percolation loss	559	559	559	559	559
- Consumptive use	673	761	784	649	708
- Farm irrigation requirement	811	1,071	1,096	784	965
- Diversion requirement	1,246	1,650	1,684	1,206	1,485
2.2 Two cropping					
- Effective rainfall	523	356	377	522	387
- Percolation loss	483	483	483	483	483
- Consumptive use	585	658	669	573	611
- Farm irrigation requirement	695	935	925	684	857
- Diversion requirement	1,070	1,432	1,419	1,054	1,317
3. Traditional Rice					
3.1 Single cropping					
- Effective rainfall	-	401	424	558	445
- Percolation loss	-	524	524	524	524
- Consumptive use	-	746	762	653	697
- Farm irrigation requirement	-	1,019	1,012	769	926
- Diversion requirement	-	1,569	1,555	1,180	1,423
3.2 Two cropping					
- Effective rainfall	508	361	-	-	375
- Percolation loss	505	485	-	-	485
- Consumptive use	602	682	-	-	639
- Farm irrigation requirement	749	956	-	-	899
- Diversion requirement	1,153	1,471	-	-	1,381
4. Upland					
- Effective rainfall	277	281	276	332	303
- Consumptive use	773	800	858	867	745
- Farm irrigation requirement	496	519	582	535	442
- Diversion requirement	901	942	1,058	972	805

Remarks; Unconsolidated farm was assumed and hydrological period was October, 1967 and from April to September, 1968.

Table 29 PROJECTED POPULATION OF PIPE-SERVED MUNICIPALITIES IN THE HAN RIVER BASIN

Unit: 10^3 persons

	1976	1981	1986	1991	1996	2001
A. Inside Basin						
(1) More than 3,000,000						
Seoul	7,255	7,970	8,630	9,250	9,910	10,510
(2) 3,000,000 - 500,000						
Incheon	830	1,000	1,190	1,380	1,465	1,550
(3) 500,000 - 100,000						
Seongnam	285	333	387	440	480	520
Chuncheon	142	162	181	200	215	230
Weonju	124	130	140	150	157	164
Chungju	107	112	116	120	125	130
Anyang	146	202	261	320	350	380
Euijeongbu	113	165	213	260	293	325
(4) Less than 100,000	407	483	753	799	830	864
Inside basin total	9,529	10,691	12,026	13,095	14,013	14,873
B. Outside Basin						
(1) 500,000 - 100,000						
Suweon	235	310	380	450	500	550
Banweol	-	88	146	200	228	250
(2) Less than 100,000	58	85	90	95	97	100
Outside basin total	293	483	616	745	825	900
C. Inside & Outside Basin Total	9,822	11,174	12,642	13,840	14,838	15,773

Table 30 PROJECTED POPULATION OF PIPE-SERVED MUNICIPALITIES IN THE NAGDONG RIVER BASIN

Unit: 10^3 persons

	1976	1981	1986	1991	1996	2001
A. Inside Basin						
(1) 3,000,000 - 500,000						
Daegu	1,359	1,500	1,650	1,800	1,900	2,000
(2) 500,000 - 100,000						
Gumi	100	160	230	300	335	370
Jinju	161	210	238	266	283	300
Andong	98	104	112	120	125	130
(3) Less than 100,000	876	1,069	1,228	1,262	1,288	1,317
Inside basin total	2,594	3,043	3,458	3,748	3,931	4,117
B. Outside Basin						
(1) More than 3,000,000						
Busan	2,574	2,840	3,180	3,520	3,760	4,000
(2) 3,000,000 - 500,000						
Masan	425	620	835	1,050	1,150	1,250
(3) 500,000 - 100,000						
Ulsan	270	350	435	520	560	600
Pohang	152	208	274	340	370	400
Jinhae	104	114	122	130	135	140
Samcheonpo	60	90	115	140	155	170
(4) Less than 100,000	112	140	148	155	158	161
Outside basin total	3,697	4,362	5,109	5,855	6,288	6,721
C. Inside & Outside Basin Total	6,291	7,405	8,567	9,603	10,219	10,838

Table 31 PROJECTED POPULATION OF PIPE-SERVED MUNICIPALITIES IN THE SEOMJIN RIVER BASIN

Unit: 10^3 persons

	1976	1981	1986	1991	1996	2001
A. Inside Basin						
(1) Less than 100,000	89	191	193	195	198	200
B. Outside Basin						
(1) 500,000 - 100,000						
Yeosu	135	180	240	300	325	350
Suncheon	110	205	265	325	363	400
Outside basin total	245	385	505	625	688	750
C. Inside & Outside Basin Total	334	576	698	820	886	950

Table 32 PER CAPITA DAILY USE AND SERVICE FACTOR OF MUNICIPAL WATER SUPPLY

Municipality Size Group	Historical		Projected				
	1971	1976	1981	1986	1991	1996	2001
Per Capita Use (lit/capita/day)							
More than 3,000,000	210	300	320	350	380	410	450
3,000,000 - 500,000	180	210	250	300	320	350	380
500,000 - 100,000	120	140	170	210	230	250	270
100,000 - 50,000	70	110	140	180	190	210	220
Less than 50,000	70	110	130	150	160	180	190
Service Factor (%)							
More than 3,000,000	87.5	94.0	95.0	95.0	95.0	98.0	98.0
3,000,000 - 500,000	74.0	92.4	93.0	93.0	95.0	95.0	98.0
500,000 - 100,000	70.0	82.1	85.0	85.0	90.0	90.0	95.0
Less than 100,000	39.7	55.2	60.0	60.0	65.0	65.0	70.0

Remarks; For non-served population 30 lit/capita/day is assumed.

Table 33 PROJECTED M&I WATER REQUIREMENT DEPENDING ON THE THREE RIVER BASINS

Unit: 10^6 m^3/yr

		1976	1981	1986	1991	1996	2001
Han River Basin							
Inside	M	769	1,117	1,355	1,590	1,860	2,158
	I	200	257	325	443	627	920
	M&I	969	1,374	1,680	2,033	2,487	3,078
Outside	M	8	24	38	53	64	80
	I	9	27	66	131	268	554
	M&I	17	51	104	184	332	634
Total	M	777	1,141	1,393	1,643	1,924	2,238
	I	209	284	391	574	894	1,474
	M&I	986	1,425	1,784	2,217	2,818	3,712
Nagdong River Basin							
Inside	M	150	236	308	356	405	457
	I	33	97	133	178	211	244
	M&I	183	333	441	534	616	701
Outside	M	184	395	531	654	815	972
	I	168	420	580	702	772	841
	M&I	352	815	1,111	1,356	1,587	1,813
Total	M	333	631	839	1,010	1,220	1,429
	I	201	516	713	880	983	1,085
	M&I	534	1,147	1,552	1,890	2,203	2,514
Seomjin River Basin							
Inside	M	10	13	14	15	15	16
	I	-	-	-	-	-	-
	M&I	10	13	14	15	15	16
Outside	M	8	21	35	48	58	70
	I	5	104	207	295	371	444
	M&I	13	125	242	343	429	514
Total	M	18	34	49	63	73	86
	I	5	104	207	295	371	444
	M&I	23	138	256	358	444	530

Table 34 PRELIMINARY ESTIMATE OF NET WATER LOSS IN THE LOWER HAN RIVER BASIN

Unit: m^3/s

		1968	1981	2001
(1)	Irrigated paddy (ha)	23,600	28,200	38,540
(2)	Irrigation intake; (1) x 2.5 lit./s · ha	59	71	96
(3)	M&I intake in the lower Han river basin	9	21	22
(4)	Total intake in the lower Han river basin	68	92	118
(5)	M&I intake from the Paldang dam	-	20	72
(6)	Total supply in the lower Han river basin; (4) + (5)	68	112	190
(7)	Return flow	25	50	87
(8)	Net water loss in the lower Han river basin; (4) - (7)	43	42	31

Source; ANNEX G for (1), ANNEX H for (3) & (5)

Remarks; (2): Unit maximum diversion requirement assumed to be 2.5 lit./s · ha

(7): Estimated in ANNEX H for M&I and assumed to be 1/3 of (2) for irrigation

Table 35 WATER REQUIREMENT FOR POLLUTION CONTROL IN THE NAGDONG RIVER

Unit: m^3/s

	Dec.-Mar.	Apr.	May	June	July-Aug.	Sept.	Oct.	Nov.
1981								
Waegwan	5	6	8	14	19	14	10	6
Goryeong	9	11	14	21	26	21	17	11
Jindong	9	11	13	18	22	18	15	11
Weolchon	8	9	10	13	15	13	12	9
1986								
Waegwan	6	8	11	17	20	17	14	8
Goryeong	10	14	18	30	37	30	23	14
Jindong	10	13	16	24	26	24	20	13
Weolchon	9	10	12	15	16	15	14	10
2001								
Waegwan	7	10	14	24	31	24	18	10
Goryeong	14	21	28	45	56	45	36	21
Jindong	14	19	25	34	37	34	31	19
Weolchon	12	14	16	20	21	20	18	14

Source; Ref. 11

Table 36 LONG-TERM POWER DEVELOPMENT SCHEME

Unit: MW

	1977	1981	1986	1991	1996	2001
Hydro	711	801	1,764	1,764	1,764	1,764
Pumped-storage	-	400	1,400	3,000	5,800	9,600
Oil-fired	4,378	7,236	7,504	8,904	8,904	8,904
Coal-fired	700	1,800	3,200	7,400	8,050	8,050
Nuclear	-	595	6,424	14,824	31,624	50,824
Total	5,790	10,832	20,292	35,892	56,142	80,142

Table 37 ANNUAL NET WATER WITHDRAWAL

Unit: 10^6 m^3

	1968	1986	1991	1996	2001
Han River					
Tributary M&I	7	8	9	10	11
Tributary agricultural	522	550	577	602	629
Sub-total	529	558	586	612	640
Main stream M&I	-	1,019	1,438	2,021	2,895
Main stream agricultural	-	106	114	122	131
Sub-total	-	1,125	1,552	2,143	3,026
River maintenance flow	-	1,027	1,027	1,027	1,027
Total	529	2,710	3,165	3,782	4,693
Nagdong River					
Tributary M&I	71	46	47	49	50
Tributary agricultural	1,751	1,859	1,994	2,011	2,089
Sub-total	1,822	1,905	2,041	2,060	2,139
Main stream M&I	-	995	1,232	1,477	1,720
Main stream agricultural	-	394	438	467	477
Sub-total	-	1,389	1,670	1,944	2,197
River maintenance flow	-	1,507	1,554	1,588	1,617
Total	1,822	4,801	5,265	5,592	5,953
Seomjin River					
Tributary M&I	3	4	4	4	4
Tributary agricultural	308	381	397	413	428
Sub-total	311	385	401	417	432
Main stream M&I	-	222	324	409	495
Main stream agricultural	-	11	12	13	14
Sub-total	-	233	336	422	509
River maintenance flow	-	126	126	126	126
Total	311	744	863	965	1,067

Remarks: Figures for 1968 not divided into main stream and tributary and all included in the lines of tributary. Excluded catchment areas: Soyanggang dam, Chungju dam and lower Han for Han. Andong dam and Yeongcheon dam for Nagdong. Seomjingang dam, Donbog dam and Boseong dam for Seomjin.

Table 38 ESTIMATED WATER DEFICIT

			1986	1991	1996	2001
Han River	Annual Volume	(10^6 m^3)	262	415	716	1,241
	Peak	(m^3/s)	71	85	104	132
Nagdong River	Annual Volume	(10^6 m^3)	894	1,101	1,307	1,505
	Peak	(m^3/s)	143	159	169	179
Seomjin River	Annual Volume	(10^6 m^3)	72	127	181	238
	Peak	(m^3/s)	13	17	19	22

Remarks; See Remarks in Table 37 for the excluded catchment areas.

Table 39 OUTFLOW FROM THE CHUNGJU DAM

Unit: m^3/s

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
88.9	90.6	88.9	109.2	132.9	133.5	119.5	129.2	106.1	104.5	90.3	88.9

Table 40 ASSUMED OPERATION METHOD OF PROPOSED DAMS

Name of Dam	Operation Method
Bamseonggol	Constant draft
Inje	Constant draft
Hongcheon	Constant draft and variable draft
Gujeol	Constant draft
Dalcheon	Constant draft and variable draft
Ganhyeon	Constant draft and variable draft
Bonghwa	Constant draft
Imha	Constant draft and variable draft
Hamyang	Constant draft
Juam	Constant draft and variable draft

Table 41 RESULTS OF RESERVOIR OPERATION STUDY (CONSTANT DRAFT OPERATION)

Name of Dam	Bamseonggol			Inje			Hongcheon		
HWS (El. m)	292.5	300	305	315	324.5	332.6	110	115	120
Active Storage (10^6 m^3)	210	303	368	376	565	753	513	720	954
Regulated Outflow (10^6 m^3)	324	387	403	558	665	715	832	951	1065
Regulated Outflow (m^3/s)	10.3	12.3	12.8	17.7	21.1	22.7	26.4	30.2	33.8
Net Supply Capacity (m^3/s)	7.7	9.5	10.0	1.6	2.8	3.8	10.7	14.5	18.1
Year of Commission	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6
Target Year	2010.0	2010.3	2010.4	2008.9	2009.1	2009.3	2010.5	2011.2	2011.8

Name of Dam	Gujeol			Dalcheon			Ganhyeon		
HWS (El. m)	743.5	747	748	109	114	117	103.5	108.5	111.4
Active Storage (10^6 m^3)	50.3	67.1	73.2	200	390	540	265	425	540
Regulated Outflow (10^6 m^3)	52.3	59.9	62.7	454	662	737	545	639	702
Regulated Outflow (m^3/s)	1.66	1.90	1.99	14.4	21.0	23.4	17.3	20.3	22.3
Net Supply Capacity (m^3/s)	-	-	-	5.4	12.0	14.4	7.9	10.9	12.9
Year of Commission	1986.0	1986.0	1986.0	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6
Target Year	1986.0	1986.0	1986.0	2009.6	2010.7	2011.1	2010.0	2010.5	2010.9

Name of Dam	Bonghwa			Imha			Hamyang Constant draft		
HWS (El. m)	267	276	285	180	185	192	376	384	392
Active Storage (10^6 m^3)	269	406	573	438	583	920	151	201	251
Regulated Outflow (10^6 m^3)	410	473	529	491	548	608	170	199	220
Regulated Outflow (m^3/s)	13.0	15.0	16.8	15.6	17.4	19.3	5.39	6.31	6.98
Net Supply Capacity (m^3/s)	1.4	3.0	4.0	11.9	13.7	15.6	2.8	3.7	4.6
Year of Commission	1990.1	1990.1	1990.1	1990.1	1990.1	1990.1	1990.1	1990.1	1990.1
Target Year	1990.5	1991.1	1991.6	1995.5	1996.5	1997.4	1991.0	1991.4	1991.9

Name of Dam	Juam (Main Stream)		
HWS (El. m)	114	117	120
Active Storage (10^6 m^3)	530	630	780
Regulated Outflow (10^6 m^3)	452	494	559
Regulated Outflow (m^3/s)	14.3	15.7	17.7
Net Supply Capacity (m^3/s)	14.3	15.7	17.7
Year of Commission	1986.0	1986.0	1986.0
Target Year	1987.8	1989.9	1993.2

Remarks; The year of commission and target for the Gujeol dam is assumed to be 1986, because water deficit is zero.
The net supply capacity of Juam dam was estimated based on the water deficit which was calculated assuming shut down at the damsite.

Table 42 RESULTS OF RESERVOIR OPERATION STUDY (VARIABLE DRAFT OPERATION)

Name of dam	Hongcheon			Dalcheon			Ganhyeon		
HWS (El. m)	110	115	120	109	114	117	103.5	108.5	111.4
Active Storage (10^6 m^3)	513	720	954	200	390	540	265	425	540
Regulated Outflow (10^6 m^3)	794	909	1064	415	618	696	432	597	666
Net Supply Capacity (m^3/s)	79.4	86.3	93.0	61.5	76.5	81.3	64.5	75.5	79.7
Year of Commission	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6	2008.6
Target Year	2022.6	2023.9	2025.0	2019.5	2022.1	2023.0	2020.0	2022.0	2022.7

Name of dam	Imha			Juam (Main Stream)				
HWS (El. m)	180	185	192	108	111	114	117	120
Active Storage (10^6 m^3)	438	583	920	355	448	530	630	780
Regulated Outflow (10^6 m^3)	475	542	593	377	417	454	495	554
Net Supply Capacity (m^3/s)	19.2	22.0	24.2	25.5	27.2	28.7	30.3	32.7
Year of Commission	1990.1	1990.1	1990.1	1986.0	1986.0	1986.0	1986.0	1986.0
Target Year	1999.3	2000.7	2001.9	2006.8	2009.7	2012.3	2015.2	2019.3

Name of dam	Juam (Diversion) Route A			Juam (Diversion) Route B			Juam (Diversion) Route C		
HWS (El. m)	114	117	120	114	117	120	114	117	120
Active Storage (10^6 m^3)	530	630	780	530	630	780	530	630	780
Regulated Outflow (10^6 m^3)	372	413	473	372	413	473	372	413	473
Net Supply Capacity (m^3/s)	21.2	22.5	24.4	23.2	24.7	26.8	21.2	22.5	24.4
Year of Commission	1986.0	1986.0	1986.0	1986.0	1986.0	1986.0	1986.0	1986.0	1986.0
Target Year	1999.2	2001.6	2005.1	2002.9	2005.7	2009.5	1999.2	2001.6	2005.1

Remarks; The net supply capacity of Juam dam was estimated based on the water deficit which was calculated assuming shut down at the damsite.

Net supply capacity for Route B of Juam dam (Diversion) includes increment output from Yeonggye dam.

Table 43 PRINCIPAL FEATURE OF PROPOSED DAMS ASSUMED IN SAMPLE DESIGN

		Inje	Gujeol	Bonghwa	Hamyang
1. Reservoir					
Catchment area	(km^2)	1,043	101	1,135	264
Flood water surface	(El. m)	347	750	300	393
High water surface	(El. m)	344	748	297	392
Low water surface	(El. m)	300.6	723	259	339
Active storage	(10^6 m^3)	970	73.2	681	252
Flood control space	(10^6 m^3)	105	13	100	8
Reservoir area	(km^2)	31	5.8	28	7
2. Dam					
Type		CG	R	CG	R
Crest	(El. m)	349	753	302	396
Height	(m)	128	68	129	94
Volume	(10^3 m^3)	1,688	1,107	1,723	4,380
3. Power Facilities					
Maximum discharge	(m^3/s)	114.7	11.5	83.5	9.3
Rated water head	(m)	127.1	603.5	102.6	161.1
Installed capacity	(MW)	122	59	72	12.6
4. Construction Cost					
Dam	(\$ 10^6)	98.0	16.6	101.6	63.1
Power facilities	(\$ 10^6)	61.6	37.5	28.8	10.9
Relocation of road & other ground facilities	(\$ 10^6)	13.6	4.8	5.7	2.9
Land compensation	(\$ 10^6)	15.6	5.1	17.6	7.5
Engineering & administration	(\$ 10^6)	16.0	5.4	13.0	7.4
Physical contingency	(\$ 10^6)	41.0	13.9	33.3	18.3
Total	(\$ 10^6)	245.8	83.2	200.0	110.1

Table 44 MAJOR UNIT PRICES ASSUMED IN CONSTRUCTION COST ESTIMATE

Unit: $

Item	Unit	Unit Price
Open Cut Excavation	m^3	3 - 4
Tunnel Excavation	m^3	25 - 30
Dam Concrete	m^3	40
Concrete in Open Structure	m^3	45 - 55
Concrete in Tunnel Lining	m^3	60 - 74
Reinforcement	ton	450 - 500
Dam Embankment	m^3	5.5 - 7
Gate	ton	4,000 - 5,500
Penstock	ton	2,000

Table 45 OUTLINE OF M&I PIPELINE SYSTEM ASSOCIATED WITH THE JUAM DAM SCHEME (MAIN STREAM PLAN)

Order of Construction	1	2	3
1. Scope	Extension of existing system	New pipeline	Extension of new pipeline
2. Discharge capacity (10^3 m^3/d)	300	320	320
3. Intake pump			
3.1 Capacity PS	8,100	7,000	7,000
3.2 Water head m	68	56	56
4. Tunnel			
4.1 Discharge capacity (10^3 m^3/d)	-	640	-
4.2 Dimensions (D m x L km)	-	2.5 x 1.5	-
5. Pipeline			
5.1 Route	Sueo dam - Gwangyang	Tunnel - Gwangyang	Tunnel - Gwangyang
5.2 Trunk main (D mm x L km)	1,750 x 15.4	1,800 x 17.5	1,800 x 17.5
5.3 Distribution main (D mm x L km)	1,200 x 10	1,200 x 10	1,200 x 10
6. Primary Treatment Plant (10^3 m^3)	360	384	384
7. Financial Cost			
7.1 Investment cost ($ 10^6)	27.5	29.5	27.3
7.2 Replacement cost ($ 10^6)	17.6	19.2	18.5
7.3 O & M cost			
- Fixed cost ($ 10^6)	0.48	0.48	0.44
- Material ($ 10^6)	0.17	0.19	0.19
- Energy cost ($ 10^6)	1.04	0.91	0.91
Total: ($ 10^6)	1.69	1.58	1.54

Remarks; The outline of the pipeline system beyond the third stage are assumed to be the same as that in the second stage for the even stage and that in the third stage for the odd stage. The existing Yeocheon/Gwangyang Industrial Water Supply System is assumed to be operated at the full capacity of 250 x 10^3 m^3/d (see Table 21).

Table 46 OUTLINE OF M&I PIPELINE SYSTEM ASSOCIATED WITH THE JUAM DAM SCHEME (DIVERSION PLAN)

Alternative Plan HWS of Juam Dam	(El. m)	Route A 120	Route B 114	Route C 120
1. Nominal Supply Capacity	(m^3/s)	15.0	13.8	15.0
2. Diversion Tunnel				
2.1 Discharge capacity	(m^3/s)	15.0	11.8	15.0
2.2 Dimensions	(D m x L km)	3.1 x 11	2.7 x 13.5	3.1 x 14
2.3 Energy dissipator		Intake value		Intake valve
3. Regulating Reservoir				
3.1 HWS	(El. m)	70	89	67
3.2 LWS	(El. m)	68	60	64
3.3 Active storage	(10^3 m^3)	120	89,600	270
3.4 Increase discharge	(m^3/s)	-	2.0	-
4. Pipeline				
4.1 Trunk main	(D mm x L km)	1,870 x 33	1,870 x 26	1,870 x 45
4.2 Nominal capacity	(10^3 m^3/d)	320	320	320
4.3 Booster pump		-	-	16 m x 2,000 SP
4.4 Primary treatment plant	(10^3 m^3/d)	384	384	384
4.5 Regulating pond	(10^3 m^3)	75	75	75
4.6 Distribution main	(D mm x L km)	1,200 x 10	1,200 x 10	1,200 x 10
4.7 Number of lines		4	4	4
5. Financial Cost				
5.1 Investment cost				
- Intake & tunnel	($ 10^6)	12.6	13.9	15.9
- Regulating reservoir	($ 10^6)	6.0	45.3	7.9
- Pipeline system	($ 10^6)	134.7	106.0	178.6
Total	($ 10^6)	153.3	165.2	202.4
5.2 Replacement cost	($ 10^6)	106.6	85.0	141.8
5.3 O & M Cost				
- Fixed cost	($ 10^6)	1.31	1.43	1.92
- Material cost	($ 10^6)	0.75	0.70	0.75
- Energy cost	($ 10^6)	-	-	1.04
Total	($ 10^6)	2.06	2.13	3.71
6. Annual Equivalent of Economic Cost				
Capital cost	($ 10^6)	10.65	13.12	13.99
O & M cost				
Proposed pipeline	($ 10^6)	1.59	1.98	2.80
Existing pipeline	($ 10^6)	3.03	3.03	3.03
Total	($ 10^6)	15.27	18.14	19.82

Remarks; HWS elevation of Juam dam is optimized one for each alternative Route. The annual equivalent is calculated assuming a stage construction of pipeline system in accordance with demand growth.

Table 47 HISTORICAL YIELD OF HIGH-YIELDING AND TRADITIONAL RICE VARIETIES

Unit: ton/ha

	1972	1973	1974	1975	1976	1977	1978
1. High-yielding Varieties	3.86	4.81	4.73	5.03	4.79	5.53	4.81
2. Traditional Varieties	3.34	3.58	3.53	3.51	3.96	4.23	4.35

Source; Ref. 15

Table 48 RELATIVE CROP PRODUCTIVITY INDEX OF PADDY SOILS

Unit: %

		Nagdong			
	Han	North	Central	South	Seomjin
Crop Index	99	98	100	100	99

Remarks; Relative index along main stream in the central Nagdong river basin: 100

Table 49 RICE YIELD BY IRRIGATION CONDITION

Unit: ton/ha

	1966	1967	1968	1969	1970	1971	1972	1973	1974
1. Irrigated, FLIA	3.49	3.44	3.48	3.80	3.75	3.72	3.69	3.82	4.24
2. Irrigated, Non-FLIA	3.44	3.42	3.36	3.74	3.52	3.66	3.70	4.04	4.10
3. Partially Irrigated	3.10	2.92	2.81	3.49	3.49	3.54	3.48	3.73	3.94

Source; Ref. 16

Table 50 LAND CONSOLIDATION EFFECT

	(1) Unconsolidated	(2) Consolidated	(3) Ratio (2)/(1)
Rice Yield (ton/ha)	3.12	3.89	1.25
Barley Yield (ton/ha)	1.99	2.04	1.03
Multiple Crop Index (%)	136	162	1.19
Production Cost Index (%)	100	84	0.84

Source; Ref. 16

Table 51 ANTICIPATED YIELD OF PADDY RICE

Unit: ton/ha

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
High-Yielding Rice					
Reservoir					
Consolidated	5.5	5.4	5.6	5.6	5.5
Unconsolidated	5.0	4.9	5.1	5.1	5.0
River, Main Stream					
Consolidated	5.2	5.1	5.3	5.3	5.2
Unconsolidated	4.7	4.6	4.8	4.8	4.7
River, Tributary					
Consolidated	4.7	4.6	4.8	4.8	4.7
Unconsolidated	4.2	4.1	4.3	4.3	4.2
Traditional Rice					
River, Tributary					
Unconsolidated	3.1	3.0	3.2	3.2	3.1
Supplementary					
Unconsolidated	2.5	2.4	2.6	2.6	2.5

Table 52 TYPICAL CROPPING PATTERN ON UPLAND

Unit: %

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Rainfed					
Soybean	50	50	40	50	50
Sweet potato	13	8	5	10	20
Chinese cabbage	15	10	11	10	6
Red pepper	2	2	4	10	4
Apple	20	30	40	20	20
Total	100	100	100	100	100
Irrigated Upland					
Cucumber	50	40	40	38	50
Chinese cabbage	45	40	40	40	43
Garlic	10	10	10	20	20
Red pepper	20	16	4	10	12
Apple	20	30	50	20	20
Total	145	136	144	128	145

Table 53 ANTICIPATED YIELD OF UPLAND CROPS

Unit: ton/ha

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Rainfed Upland					
Soybean	1.1	1.1	1.1	1.2	1.2
Sweet potato	11.0	10.6	12.2	11.0	10.9
Chinese cabbage	11.6	11.3	11.9	12.2	11.5
Red pepper	0.9	0.8	0.7	0.7	0.8
Apple	8.0	7.9	8.2	8.0	8.0
Irrigated Upland, Main Stream					
Cucumber	20.0	19.0	20.0	19.0	19.0
Chinese cabbage	16.0	16.0	16.0	18.0	17.0
Garlic	5.0	5.5	5.0	6.0	5.6
Red pepper	1.6	1.5	1.6	1.4	1.6
Apple	13.0	14.0	14.0	13.0	13.0
Irrigated Upland, Tributary					
Cucumber	19.8	19.4	19.3	19.4	18.9
Chinese cabbage	7.0	7.0	7.7	8.5	7.8
Garlic	5.2	5.6	5.5	6.1	5.4
Red pepper	1.5	1.4	1.4	1.3	1.5
Apple	12.8	13.8	18.7	12.9	13.3

Table 54 ESTIMATED ECONOMIC PRICES OF FARM PRODUCTS

Unit: $/ton

Crop	Price	Crop	Price
Rice	474	Cucumber	0.41
Soybean	412	Red pepper (dried)	4.12
Sweet potato	0.25	Garlic (fresh)	1.64
Chinese cabbage	0.16	Apple	0.52

Remarks; See ANNEX F for details.

Table 55 ESTIMATED ECONOMIC PRICES OF FARM INPUTS

Unit: $/ton

Material	Price	Material	Price
Fertilizer		Seeds	
N	480	Rice	577
P	408	Sweet potato	2,164
K	171	Soybean	165
Silicic lime	25	Chinese cabbage	51,550
Farm manure	12	Cucumber	57,730
Fungicides	6,000	Red pepper	18,550
Insecticides	5,900	Garlic	341,200
Herbicides	5,300	Apple	866
Other chemicals	51,000		

Remarks; See ANNEX F for details.

Table 56 ECONOMIC PRODUCTION COST OF PADDY RICE

Unit: $/ha

Symbol	TSU	TIU	NIU	NIC
Seed	23	23	23	23
Fertilizers	134	167	219	249
Chemicals	33	33	33	33
Labor	769	705	744	567
Others	134	124	197	180
	1,093	1,052	1,216	1,052

Remarks; T: Traditional rice variety
N: High-yielding new rice variety
S: Supplementarily irrigated paddy field
I: Irrigated paddy field
U: Unconsolidated paddy field
C: Consolidated paddy field

Table 57 ECONOMIC PRODUCTION COST OF IRRIGATED UPLAND CROPS

Unit: $/ha

	Cucumber	Chinese Cabbage	Garlic	Red pepper	Apple
Seed	404	289	3,412	93	43
Fertilizers	379	373	412	412	252
Chemicals	27	14	8	41	443
Labor	6,307	1,254	1,019	2,087	3,635
Others	368	214	360	563	617
Total	7,485	2,144	5,211	3,196	4,990

Table 58 ECONOMIC PRODUCTION COST OF RAINFED UPLAND CROPS

Unit: $/ha

	Soybean	Sweet potato	Chinese cabbage	Red pepper	Apple
Seed	10	1,082	289	93	43
Fertilizer	78	134	338	351	219
Chemical	6	10	14	35	381
Labor	280	926	973	1,431	2,759
Other	59	405	138	462	577
Total	433	2,557	1,752	2,372	3,979

Table 59 GROSS & NET PRODUCTION VALUES OF RICE

Unit: $/ha

		Han	Nagdong		Seomjin
			North	Central & South	
High-Yielding Rice					
Reservoir, Consolidated	Gross value	2,721	2,660	2,763	2,721
	Production cost	1,052	1,052	1,052	1,052
	Net value	1,669	1,608	1,711	1,669
Reservoir, Unconsolidated	Gross value	2,474	2,412	2,515	2,474
	Production cost	1,216	1,216	1,216	1,216
	Net value	1,258	1,196	1,299	1,258
River, Main Stream, Consolidated	Gross value	2,557	2,516	2,619	2,557
	Production cost	1,052	1,052	1,052	1,052
	Net value	1,505	1,464	1,567	1,505
River, Main Stream, Unconsolidated	Gross value	2,309	2,268	2,371	2,309
	Production cost	1,216	1,216	1,216	1,216
	Net value	1,093	1,052	1,155	1,093
River, Tributary, Consolidated	Gross value	2,330	2,268	2,371	2,330
	Production cost	1,052	1,052	1,052	1,052
	Net value	1,278	1,216	1,319	1,278
River, Tributary, Unconsolidated	Gross value	2,082	2,020	2,123	2,082
	Production cost	1,216	1,216	1,216	1,216
	Net value	866	804	907	866
Traditional Rice					
River, Tributary Unconsolidated	Gross value	1,609	1,547	1,630	1,609
	Production cost	1,052	1,052	1,052	1,052
	Net value	557	495	578	557
Supplementary, Unconsolidated	Gross value	1,279	1,217	1,320	1,279
	Production cost	1,093	1,093	1,093	1,093
	Net value	186	124	227	186

Table 60 GROSS & NET PRODUCTION VALUE OF UPLAND CROP

Unit: $/ha

	Han	Nagdong North	Nagdong Central	Nagdong South	Seomjin
Irrigated Upland, Main Stream					
Gross value	8,796	8,251	9,054	8,062	9,103
Production cost	6,893	6,408	7,025	6,120	7,146
Net value	1,903	1,843	2,029	1,942	1,957
Irrigated Upland, Tributaries					
Gross value	8,563	8,031	8,769	7,829	8,884
Production cost	6,893	6,408	7,025	6,120	7,146
Net value	1,670	1,623	1,744	1,709	1,738
Rainfed Upland					
Gross value	1,660	1,903	2,872	1,833	1,740
Production cost	1,549	1,833	2,699	1,680	1,608
Net value	111	70	173	153	132

Remarks; Water shortage assumed for irrigated upland in tributaries.

Table 61 ECONOMIC COST OF IRRIGATION FACILITIES

Unit: /ha

	Reservoir Irrigation	Pump Irrigation	Consolidation	Reclamation	Upland Irrigation
Financial Investment Cost (W 10^3)	5,800	3,400	2,100	2,300	3,200
Economic Cost ($)					
Investment cost	10,230	6,000	3,710	4,060	6,270
Replacement cost	19	25	10	19	16
O & M cost	128	179	37	41	179
Annual Equivalent					
Capital cost ($)	957	575	351	392	592
O & M cost ($)	127	179	36	42	179
Total ($)	1,084	754	387	434	771

Remarks; Annual O & M cost for supplemental irrigation was estimated to be 123 $/ha.

Table 62 NET INCREMENTAL BENEFIT, RESERVOIR IRRIGATION

Unit: $/ha

	Han	Nagdong Northern	Nagdong Central	Nagdong Southern	Seomjin
Irrigation					
Net value irrigated	1,258	1,196	1,299	1,299	1,258
Net value supplementarily	186	124	227	227	186
Net incremental value	1,072	1,072	1,072	1,072	1,072
Irrigation cost increased	961	961	961	961	961
Net incremental benefit	111	111	111	111	111
Consolidation					
Net value consolidated	1,670	1,608	1,711	1,711	1,670
Net value unconsolidated	1,258	1,196	1,299	1,299	1,258
Net incremental value	412	412	412	412	412
Consolidation cost increase	387	387	387	387	387
Net incremental benefit	25	25	25	25	25
Reclamation					
Net value reclaimed	1,670	1,608	1,711	1,711	1,670
Net value rainfed upland	111	70	173	153	132
Net incremental value	1,559	1,538	1,538	1,558	1,538
Reclamation & irrigation costs increased	1,518	1,518	1,518	1,518	1,518
Net incremental benefit	41	21	21	40	21

Table 63 NET INCREMENTAL BENEFIT, MAIN STREAM PUMP IRRIGATION

Unit: $/ha

	Han	Nagdong Northern	Nagdong Central	Nagdong Southern	Seomjin
Irrigation					
Net value, irrigated	1,093	1,052	1,155	1,155	1,093
Net value, supplementarily	186	124	227	227	186
Net incremental value	907	928	928	928	907
Irrigation cost increased	631	631	631	631	631
Net incremental benefit	276	297	297	297	276
Consolidation					
Net value, consolidated	1,505	1,464	1,567	1,567	1,505
Net value, unconsolidated	1,093	1,052	1,155	1,155	1,093
Net incremental value	412	412	412	412	412
Consolidation cost increased	387	387	387	387	387
Net incremental benefit	25	25	25	25	25
Reclamation					
Net value, reclaimed	1,505	1,464	1,567	1,567	1,505
Net value, rainfed upland	111	70	173	153	132
Net incremental value	1,394	1,394	1,394	1,414	1,373
Reclamation & irrigation costs increased	1,188	1,188	1,188	1,188	1,188
Net incremental benefit	206	206	206	226	185
Upland Irrigation					
Net value, irrigated	1,903	1,843	2,029	1,942	1,957
Net value, rainfed upland	111	70	173	153	132
Net incremental value	1,792	1,773	1,856	1,789	1,825
Irrigation cost increased	1,526	1,526	1,526	1,526	1,526
Net incremental benefit	266	247	330	263	299

Table 64 NET INCREMENTAL BENEFIT, TRIBUTARY PUMP IRRIGATION

Unit: $/ha

	Han	Nagdong Northern	Nagdong Central	Nagdong Southern	Seomjin
Irrigation (Traditional to High-yielding)					
Net value, irrigated	866	804	907	907	866
Net value, supplementarily	186	124	227	227	186
Net incremental value	680	680	680	680	680
Irrigation cost increased	631	631	631	631	631
Net incremental benefit	49	49	49	49	49
Irrigation (Traditional to Traditional)					
Net value, irrigated	557	495	578	578	557
Net value, supplementarily	186	124	227	227	186
Net incremental value	371	371	351	351	371
Irrigation cost increased	631	631	631	631	631
Net incremental benefit	-260	-260	-280	-280	-260
Consolidation					
Net value, consolidated	1,278	1,216	1,319	1,319	1,278
Net value, unconsolidated	866	804	907	907	866
Net incremental value	412	412	412	412	412
Consolidation cost	387	387	387	387	387
Net incremental benefit	25	25	25	25	25
Upland Irrigation (Rainfed to Irrigated)					
Net value, irrigated	1,670	1,623	1,744	1,709	1,738
Net value, rainfed upland	111	70	173	153	132
Net incremental value	1,559	1,553	1,571	1,556	1,606
Irrigation cost	1,526	1,526	1,526	1,526	1,526
Net incremental benefit	33	27	45	30	80

Table 65 INCREASE IN BENEFITED AREA, RESERVOIR IRRIGATION

Unit: ha

Item & Basin		1977/81	1982/86	1987/91	1992/96	1997/01
1. Paddy Field						
1.1 Irrigation (Supplementarily to irrigated)						
Han	Whole	1,080	160	1,550	1,000	1,250
	North	120	110	200	150	150
	South	810	0	1,050	750	800
Nagdong	Whole	4,960	4,490	4,960	4,700	4,950
	Northern	1,280	1,190	1,260	1,150	1,300
	Central	1,920	1,850	1,850	1,950	1,900
	Southern	1,760	1,450	1,850	1,600	1,750
Seomjin		740	990	920	940	990
1.2 Consolidation (Unconsolidated to consolidated)						
Han	Whole	3,120	2,860	3,360	3,130	3,310
	North	410	410	440	450	460
	South	2,650	2,150	2,570	2,560	2,640
Nagdong	Whole	8,600	8,330	10,170	9,620	10,250
	Northern	1,670	1,870	1,760	1,920	1,980
	Central	3,970	3,720	4,140	4,160	4,370
	Southern	2,960	2,740	4,270	3,540	3,900
Seomjin		2,390	2,230	1,890	2,210	1,770
1.3 Reclamation (Rainfed upland to irrigated)						
Han	Whole	590	250	250	350	400
	North	270	100	100	100	150
	South	320	100	150	250	250
Nagdong	Whole	400	150	500	250	300
	Northern	220	50	300	150	200
	Central	180	100	200	100	100
	Southern	-	-	-	-	-
Seomjin		130	60	90	20	40

Table 66 INCREASE IN BENEFITED AREA, MAIN STREAM PUMP IRRIGATION

Unit: ha

Item & Basin		1977/81	1982/86	1987/91	1992/96	1997/01
1. Paddy Field						
1.1 Irrigation (Supplementarily to irrigated)						
Han	Whole	2,190	7,180	1,160	1,350	1,350
	North	80	20	70	70	30
	South	1,530	5,050	490	500	720
Nagdong	Whole	1,380	1,210	1,150	960	850
	Northern	380	360	350	300	250
	Central	490	540	400	460	400
	Southern	510	310	400	200	200
Seomjin		-	-	-	-	-
1.2 Consolidation (Unconsolidated to consolidated)						
Han	Whole	4,010	6,210	3,060	3,240	3,390
	North	20	50	30	40	20
	South	900	3,030	1,890	1,980	2,110
Nagdong	Whole	2,650	2,980	3,080	2,820	2,760
	Northern	500	620	580	570	520
	Central	1,080	1,300	1,230	1,370	1,250
	Southern	1,070	1,060	1,270	880	990
Seomjin		-	-	-	-	-
1.3 Reclamation (Rainfed upland to reclaimed and irrigated)						
Han	Whole	-	750	-	-	-
	North	-	-	-	-	-
	South	-	750	-	-	-
Nagdong	Whole	-	-	-	-	-
	Northern	-	-	-	-	-
	Central	-	-	-	-	-
	Southern	-	-	-	-	-
Seomjin		-	-	-	-	-
2. Upland Field						
2.1 Irrigation (Rainfed upland to reclaimed and irrigated)						
Han	Whole	690	650	740	690	650
	North	10	20	10	10	20
	South	330	330	330	330	330
Nagdong	Whole	810	980	930	840	860
	Northern	220	230	190	170	180
	Central	380	570	530	490	540
	Southern	210	180	210	180	140
Seomjin		50	60	80	90	110

Table 67 INCREASE IN BENEFITED AREA, TRIBUTARY PUMP IRRIGATION

Unit: ha

Item & Basin		1977/81	1982/86	1987/91	1992/96	1997/01
1. Paddy Field						
1.1 Irrigation (Supplementarily to irrigated)						
Han	Whole	1,390	1,510	2,390	2,480	2,150
				(70)	(100)	(130)
	North	360	810	780	580	720
				(70)	(100)	(130)
	South	300	0	910	1,000	930
Nagdong	Whole	2,710	4,260	3,050	3,740	3,450
	Northern	1,180	1,590	1,300	1,550	1,600
	Central	400	930	700	740	950
	Southern	1,130	1,740	1,050	1,450	900
Seomjin		900	930	1,000	980	850
		(0)	(40)	(90)	(70)	(100)
1.2 Consolidation (Unconsolidated to consolidated)						
Han	Whole	7,680	5,890	6,520	6,830	6,450
	North	1,080	1,240	1,130	1,210	1,220
	South	4,850	2,830	3,830	3,810	3,800
Nagdong	Whole	7,570	7,940	8,500	7,930	7,820
	Northern	2,540	2,560	2,510	2,510	2,650
	Central	1,890	2,180	1,930	2,070	1,980
	Southern	3,140	3,200	4,060	3,350	3,190
Seomjin		2,480	2,460	2,270	2,310	2,090
2. Upland Field						
2.1 Irrigation (Rainfed upland to irrigated)						
Han	Whole	1,760	1,850	1,710	1,860	1,800
	North	330	320	330	330	310
	South	1,130	1,130	1,130	1,130	1,130
Nagdong	Whole	3,610	5,270	4,490	3,810	3,660
	Northern	1,060	1,410	1,280	870	860
	Central	1,770	2,810	2,180	1,950	1,970
	Southern	780	1,050	1,030	990	830
Seomjin		190	190	250	280	300

Remarks; Figures in parentheses show the area where no change in rice varieties occurs.

Table 68 IRRIGATION BENEFIT BUILD-UP IN EACH 5-YEAR PERIOD, HAN RIVER BASIN

Unit: $ 10^3

	1977-81	1982-86	1987-91	1992-96	1997-02
1. North Han & South Han					
Reservoir Depending					
Irrigation	103	12	139	100	105
Consolidation	77	64	75	75	78
Reclamation	24	8	10	14	16
Sub-total	204	84	224	189	199
Main Stream Depending					
Irrigation	444	1,399	155	157	207
Consolidation	23	77	48	51	53
Reclamation	0	155	0	0	0
Upland irrigation	90	93	90	90	93
Sub-total	557	1,724	293	298	353
Tributary Depending					
Irrigation	32	40	61	47	39
Consolidation	148	102	124	126	126
Upland irrigation	48	48	48	48	48
Sub-total	228	190	233	221	213
Total	989	1,998	750	708	765
2. Lower Han	439	849	425	456	389
3. Grand Total	1,428	2,847	1,175	1,164	1,154

Table 69 IRRIGATION BENEFIT BUILD-UP IN EACH 5-YEAR PERIOD, NAGDONG RIVER BASIN

Unit: $ 10^3

	1977-81	1982-86	1987-91	1992-96	1997-02
Reservoir Depending					
Irrigation	551	498	551	522	549
Consolidation	215	208	254	241	256
Reclamation	8	3	11	5	6
Sub-total	774	709	816	768	811
Main Stream Depending					
Irrigation	410	359	342	285	252
Consolidation	66	74	77	71	69
Reclamation	-	-	-	-	-
Upland irrigation	239	292	277	251	259
Sub-total	715	726	696	607	580
Tributary Depending					
Irrigation	133	209	149	183	169
Consolidation	189	199	213	198	196
Upland irrigation	132	196	164	141	137
Sub-total	454	604	526	522	502
Total	1,943	2,039	2,038	1,897	1,893

Table 70 IRRIGATION BENEFIT BUILD-UP IN EACH 5-YEAR PERIOD, SEOMJIN RIVER BASIN

Unit: $ 10^3

	1977-81	1982-86	1987-91	1992-96	1997-02
Reservoir Depending					
Irrigation	82	110	101	104	109
Consolidation	60	56	46	55	43
Reclamation	3	1	2	1	1
Sub-total	145	167	149	160	153
Main Stream Depending					
Irrigation	-	-	-	-	-
Consolidation	-	-	-	-	-
Reclamation	-	-	-	-	-
Upland irrigation	15	18	23	27	32
Sub-total	15	18	23	27	32
Tributary Depending					
Irrigation	44	32	21	25	10
Consolidation	62	61	56	57	52
Reclamation	-	-	-	-	-
Upland irrigation	15	15	20	22	24
Sub-total	121	108	97	104	86
Total	281	293	269	291	271

Table 71 PRODUCTION FOREGONE IN THE PROPOSED RESERVOIR AREAS

Unit: $/ha

Name of Dam	Paddy Crop			Upland Crop			Orchard Crop		
	GPVL	PCS	NPVL	GPVL	PCS	NPVL	GPVL	PCS	NPVL
Bamseonggol	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Inje	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Hongcheon	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Gujeol	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Dalcheon	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Ganhyeon	1,238	1,052	186	2,257	2,010	247	5,578	4,392	1,186
Bonghwa	1,176	1,052	124	2,124	1,918	206	5,454	4,392	2,062
Imha	1,176	1,052	124	2,124	1,918	206	5,454	4,392	2,062
Hamyang	1,279	1,052	227	2,340	2,010	330	5,268	4,392	876
Juam	1,238	1,052	186	2,288	2,041	247	5,504	4,392	412

Remarks; GPVL: Gross production value to be lost.
PCS: Production cost to be saved.
NPVL: Net production value to be lost.

Table 72 ESTIMATED FLOOD PEAK DISCHARGE AT PROPOSED DAMSITES

Unit: m^3/s

	20-yr	50-yr	100-yr	200-yr	Past Max.
Han River Basin					
Bamseonggol	2,000	2,500	2,900	3,400	3,000
Inje	4,100	5,400	6,400	7,500	5,000
Hongcheon	5,400	6,800	7,900	9,000	7,100
Gujeol	400	600	700	900	450
Dalcheon	3,950	4,900	5,600	6,400	3,700
Ganhyeon	4,500	5,800	6,750	7,800	5,400
Nagdong River Basin					
Banghwa	3,450	4,400	5,100	5,900	3,800
Imha	2,900	3,500	4,000	4,500	2,700
Hamyang	1,600	2,050	2,400	2,800	1,850
Seomjin River Basin					
Juam	4,100	4,900	5,550	6,200	4,000

Table 73 100-YEAR FLOOD WATER LEVEL REDUCTION BY PROPOSED DAMS

Unit: m

Name of Dam	Bamseonggol			Inje			Hongcheon		
Storage (10^6 m^3)	110	60	20	245	130	45	310	165	60
Indogyo	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.15	0.05
Goan	0.05	0.00	0.00	0.05	0.00	0.00	0.55	0.40	0.15
Cheongypeong	0.15	0.05	0.00	0.20	0.05	0.00	1.10	0.85	0.40
Chuncheon	(11)	(6)	(2)	(25)	(13)	(5)	-	-	-

Name of Dam	Gujeol			Dalcheon			Ganhyeon		
Storage (10^6 m^3)	30	15	5	225	120	40	245	130	45
Indogyo	-	-	-	0.20	0.10	0.05	0.15	0.10	0.05
Goan	-	-	-	0.50	0.35	0.15	0.45	0.35	0.15
Yeoju	-	-	-	0.55	0.40	0.20	0.45	0.35	0.20
Moggye	-	-	-	1.00	0.80	0.35	-	-	-
Yeongweol	0.10	0.10	0.05	-	-	-	-	-	-
Jeongseon	0.35	0.30	0.15	-	-	-	-	-	-
Ganhyeon	-	-	-	-	-	-	(165)	(88)	(30)

Name of Dam	Bonghwa			Imha			Hamyang		
Storage (10^6 m^3)	145	80	30	115	60	20	65	35	10
Jindong	0.00	0.00	0.00	0.25	0.25	0.10	-	-	-
Hyeonpung	0.00	0.00	0.00	0.15	0.10	0.05	-	-	-
Waegwan	0.05	0.00	0.00	0.50	0.40	0.20	-	-	-
Nagdong	0.00	0.00	0.00	0.20	0.15	0.05	-	-	-
Andong	0.15	0.10	0.05	1.75	1.30	0.55	-	-	-
Imha	-	-	-	2.80	1.60	0.55	-	-	-
Sancheong	-	-	-	-	-	-	(50)	(27)	(10)

Name of Dam	Juam		
Storage (10^6 m^3)	200	105	35
Songjeong	1.15	0.80	0.35

Remarks; ( ): Reduction in basin storm rainfall in mm.

Table 74 NET AGRICULTURAL BENEFIT FOR ESTIMATE OF LAND ENHANCEMENT BENEFIT

Unit: $/ha

Frequency	Less than 1/10	1/10-1/5	1/5-1/3	1/3-1/2	More than 1/2
Paddy Field					
Han	371	285	249	167	0
Nagdong, North	268	256	225	151	0
Nagdong, Central	412	326	289	192	0
Nagdong, South	412	326	289	192	0
Seomjin	371	285	249	167	0
Upland Field					
Han	227	192	169	113	0
Nagdong, North	186	159	138	93	0
Nagdong, Central	289	245	216	144	0
Nagdong, South	268	227	200	134	0
Seomjin	247	210	186	124	0

Table 75 ESTIMATED FLOOD CONTROL BENEFIT (1/2)

Flood Reduction Ratio		m = 0.2	m = 0.5	m = 0.8
Bamseonggol				
Flood control space	(10^6 m^3)	110	60	20
Damage reduction	(\$ 10^3)	238	149	95
Enhancement	(\$ 10^3)	19	12	9
Total benefit	(\$ 10^3)	257	161	104
Inje				
Flood control space	(10^6 m^3)	245	130	45
Damage reduction	(\$ 10^3)	331	190	110
Enhancement	(\$ 10^3)	18	16	9
Total benefit	(\$ 10^3)	349	206	119
Hongcheon				
Flood control space	(10^6 m^3)	310	165	55
Damage reduction	(\$ 10^3)	446	395	289
Enhancement	(\$ 10^3)	145	75	42
Total benefit	(\$ 10^3)	591	470	331
Gujeol				
Flood control space	(10^6 m^3)	30	15	5
Damage reduction	(\$ 10^3)	66	60	40
Enhancement	(\$ 10^3)	23	17	7
Total benefit	(\$ 10^3)	89	77	47
Dalcheon				
Flood control space	(10^6 m^3)	225	120	40
Damage reduction	(\$ 10^3)	877	790	581
Enhancement	(\$ 10^3)	125	101	72
Total benefit	(\$ 10^3)	1,002	891	653
Ganhyeon				
Flood control space	(10^6 m^3)	245	130	45
Damage reduction	(\$ 10^3)	1,228	913	589
Enhancement	(\$ 10^3)	152	116	66
Total benefit	(\$ 10^3)	1,380	1,029	655

Remarks; m: Flood reduction ratio at damsite (see ANNEX D).

Table 76 ESTIMATED FLOOD CONTROL BENEFIT (2/2)

Flood Reduction Ratio		m = 0.2	m = 0.5	m = 0.8
Bonghwa				
Flood control space	(10^6 m^3)	145	80	30
Damage reduction	(\$ 10^3)	266	193	111
Enhancement	(\$ 10^3)	56	23	22
Total benefit	(\$ 10^3)	322	216	133
Imha				
Flood control space	(10^6 m^3)	115	60	20
Damage reduction	(\$ 10^3)	1,356	1,154	726
Enhancement	(\$ 10^3)	475	375	173
Total benefit	(\$ 10^3)	1,831	1,529	899
Hamyang				
Flood control space	(10^6 m^3)	65	35	10
Damage reduction	(\$ 10^3)	245	149	56
Enhancement	(\$ 10^3)	95	52	15
Total benefit	(\$ 10^3)	340	201	71
Juam				
Flood control space	(10^6 m^3)	200	105	35
Damage reduction	(\$ 10^3)	270	195	90
Enhancement	(\$ 10^3)	228	198	70
Total benefit	(\$ 10^3)	498	393	160

Remarks; m: Flood reduction ratio at damsite (see ANNEX D).

Table 77 PRINCIPAL FEATURE OF M&I ALTERNATIVE DAMS

Name of Dam		Weonseong B	Janghoweon	Yeoju	Gwangju I	Gwangju II
River System		Han	Han	Han	Han	Han
Catchment Area	(km^2)	3,839	399	5,278	284	154
Annual Inflow	(10^6 m^3)	2,160	290	3,678	221	120
HWS (El. m)		62	81	40	65	76
Drawdown	(m)	4	7	2	18	16
Active Storage	(10^6 m^3)	235	223	61	232	97
Reservoir Area	(km^2)	73	38	40	21	10
Dam Type		CG	CG + R	CG	CG	CG
Dam Height	(m)	35	31	29	45	48
Dam Volume	(10^3 m^3)	365	115 + 687	306	238	287
Economic Cost						
Investment	($ 10^6)	72.73	26.58	63.07	28.30	32.83
Replacement	($ 10^6)	27.23	7.34	29.21	6.32	4.72
O & M	($ 10^6)	0.31	0.12	0.30	0.12	0.13
Production Foregone	($ 10^6)	5.03	3.30	3.47	1.78	0.85
Net Supply Capacity	(m^3/s)	44.4	17.1	8.2	14.4	7.4
Cost of Water	(mill/m^3)	9.0	11.2	39.0	10.3	17.8

Name of Dam		Mungyeong	Gimcheon	Goryeong	Yeonggye
River System		Nagdong	Nagdong	Nagdong	Isa
Catchment Area	(km^2)	523	295	763	133
Annual Inflow	(10^6 m^3)	312	177	549	120
HWS (El. m)		150	145	55	90
Drawdown	(m)	25	22	20	30
Active Storage	(10^6 m^3)	290	106	750	93
Reservoir Area	(km^2)	22	8	51	5
Dam Type		CG	CG	CG	CG
Dam Height	(m)	72	56	50	70
Dam Volume	(10^3 m^3)	428	494	455	445
Economic Cost					
Investment	($ 10^6)	42.56	45.60	56.27	37.95
Replacement	($ 10^6)	7.07	5.33	7.93	2.73
O & M	($ 10^6)	0.20	0.22	0.24	0.18
Production Foregone	($ 10^6)	0.51	0.08	1.98	0.07
Net Supply Capacity	(m^3/s)	10.2	4.3	19.2	6.2
Cost of Water	(mill/m^3)	15.1	34.8	12.7	18.8

Remarks; Associated facilities cost excluded.
The catchment area and inflow of the Chungju dam deducted from Weonseong and Yeoju.

Table 78 OUTLINE OF M&I PIPELINE SYSTEM ASSOCIATED WITH THE YEONGGYE DAM

Operation Method		Constant draft	Variable draft
1. Net Water Supply Capacity	(m^3/s)	2.1	6.2
2. Yeonggye-Gwangyang Pipeline			
2.1 Nominal capacity	(10^3 m^3/d)	177	268
2.2 Dimensions	(D mm x L km x Nos)	1,500 x 36 x 1	1,760 x 36 x 2
2.3 Primary treatment plant	(10^3 m^3/d x Nos)	212 x 1	322 x 2
3. Hadong-Gwangyang Pipeline			
3.1 Nominal capacity	(10^3 m^3/d)	-	640
3.2 Intake pump water head	(m)	-	56
3.3 Intake pump capacity	(PS x Nos)	-	7,000 x 2
3.4 Trunk main	(D mm x L km x Nos)	-	1,800 x 17.5 x 2
3.5 Primary treatment plant	(10^3 m^3/d x Nos)	-	384 x 2
4. Tunnel			
4.1 Nominal capacity	(10^3 m^3/d)	-	768
4.2 Dimensions	(D m x L km x Nos)	-	2.5 x 1.5 x 1
5. Financial Cost			
5.1 Investment cost			
Yeonggye dam	($ 10^6)	46.0	46.0
Yeonggye-Gwangyang pipeline	($ 10^6)	20.5	52.1
Hadong-Gwangyang pipeline	($ 10^6)	-	47.6
Total	($ 10^6)	66.5	145.7
5.2 Replacement cost	($ 10^6)	19.2	75.0
5.3 O & M cost			
Fixed cost	($ 10^6)	0.40	1.64
Material cost	($ 10^6)	0.10	0.32
Energy cost	($ 10^6)	-	0.88
5.4 Production foregone	($ 10^6)	0.07	0.07
Total	($ 10^6)	0.57	2.91
6. Annual Equivalent of Economic Cost			
Capital cost	($ 10^6)	5.46	12.33
O & M cost	($ 10^6)	0.57	2.91
Total	($ 10^6)	6.03	15.24
7. Unit Cost/Capacity	(mill/m^3)	91.0	77.9

Remarks; Items 1 & 2 corresponds to the supply capacity of a Yeonggye dam.
Items 3 & 4 assumed for a stage of a serial construction of M&I dams.
Items 5 to 7 estimated reducing the costs of the Hadong-Gwangyang pipeline including the tunnel by the ratio of the net water supply capacity to the nominal capacity.

Table 79 ESTIMATED UNIT ECONOMIC INVESTMENT COST OF 500 MW OIL FIRED THERMAL POWER PLANT

Unit: $/kW

Item	Cost
Boiler	106
Fuel gas desulfurization equipment	111
Turbine & generator	111
Transforming facilities	14
Civil work & others	139
Total	481

Table 80 COMPOSITION OF ALTERNATIVE POWER COST

Item	Cost
Capital Costs	
- Investment cost	$589.23/kW
- Replacement cost less salvage value	$530.30/kW
Annual Costs	
- Fixed cost	$11.79/kW
- Variable cost	22.87 mill/kWh