
COLOMBIA
ECUADOR
PIURA
LORETO
Chira River
AMAZONAS
LAMBAYEQUE
CAJAMARCA
SAN MARTIN
BRAZIL
PERU
LA LIBERTAD
ANCASH
HUANUCO
UCAYALI
SOUTH PASIFIC OCEAN
PASCO
LIMA
リマ州
JUNIN
MADRE DE DIOS
Canete River
CUSCO
HUANCAVELICA
Chincha River
APURIMAC
Pisco River
AYACUCHO
PUNO
Legend
ICA
BOLIVIA
Yauca River
AREQUIPA
Majes-Camana River
MOQUEGUA
TACNA
CHILE

Study Area

ABBREVIATION

Abbreviation	Official Form or Meaning
ANA	Autoridad Nacional del Agua/National Water Authority
ALA	Autoridad Local del Agua/Local Water Authority
B/C	Costo Benefit Ratio/Benefit Cost Ratio
GDP	Gross Domestic Product/Gross Domestic Product
GIS	Geographic Information System/Geographic Information System
DGAA	Dirección General de Asuntos Ambientales/General Directorate of Environmental Affairs
DGFFS	Dirección General de Forestal y de Fauna Silvestre/Directorate General of Forest and Wildlife
DGIH	Dirección General de Infraestructura Hidráulica/Directorate General for Water Infrastructure
DGPI (Paleo-DGPM)	Dirección General de Política de Inversiones/Directorate General of Investment Policy
DNEP	Dirección Nacional de Endeudamiento Público/National Directorate of Public Debt
DRA	Dirección Regional de Aguricultura/Regional Directorate Aguriculture
EIA	Evaluación de Impacto Ambiental/Environmental Impact Assessment
FAO	Agricultura y la Alimentación Organización de las Naciones Unidas/ Food and Agriculture Organization of the United Nations
F/S	Estudio de Factibilidad/ Feasibility Study
GORE	Gobierno Regional/Regional Government
HEC-HMS	Centros de Ingeniería Hidrológica Sistema de Modelación Hidrológica Método /Hydrologic Engineering Centers Hydrologic Modeling System Method
HEC-RAS	Centros de Ingeniería Hidrológica del Río de Análisis del Sistema Métode /Hydrologic Engineering Centers River Analysis System Method
IGN	Instituto Geográfico Nacional/National Geographic Institute
IGV	Impuesto General a Ventas/General Sales Tax
INDECI	Instituto Nacional de Defensa Civil/National Institute of Civil Defense
INEI	Instituto Nacional de Estadística/National Institute of Statistics
INGEMMET	Instituto Nacional Geológico Minero Metalúrgico/National Geological and Mining Metallurgical Institute
INRENA	Instituto Nacional de Recursos Naturales/Natural Resources Institute
IRR	Tasa Interna de Retorno (TIR)/Internal Rate of Return
JICA	Japonés de Cooperación Internacional /Japan International Cooperation Agency
JNUDRP	Junta Nacional de Usuarios de Distritos del Perú/National Board of Peru Districts Users
L/A	Convenio de Préstamo/Loan Agreement
MEF	Ministerio de Economía y Finanzas/Ministry of Economy and Finance
MINAG	Ministerio de Agricultura/Ministry of Agriculture
M/M	Acta de la reunion/Minutes of Meeting
NPV	Valor Actual Neto (VAN)/NET PRESENT VALUE

O&M	Operación y Mantenimiento /Operation and maintenance
OGA	Oficina General de Administración/General Office of Administration
ONERRN	Oficina Nacional de Evaluación de Recursos Naturales/National Bureau of Natural Resource Evaluation
OPI (OPP)	Oficina de Programación e Inversiones/Programming and Investment Office (Oficina de Planificación e Prespuesto/Office of Planning and Budget)
PBI	Producto Bruto Interno/Gross Domestic Product
PE	Exp. Proyecto Especial (PE) Chira-Piura/Exp. Special Project Chira-Piura
PES	Pago por Servicos Ambientales (PSA)/Payment for Environmental Services
PERFIL	PERFIL/PROFILE (Preparatory survey of project before investment)
Pre F/S	Estudio de Prefactibilidad /Pre-Feasibility Study
PERPEC	Programa de Encauzamiento de Ríos y protección de Estructura de Captación
PRONAMACHIS	Programa Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos/National Program of River Basin and Soil Conservation Management
PSI	Programa de Sub Sectorial de Irrigaciones/Program of Sub Irrigation Sector
SCF	Factor de conversión estándar/Standard conversion factor
SENAMHI	Servicio Nacional de Meteorología y Hidrología/ National Service of Meteorology and Hydrology
SNIP	Sistema Nacional de Inversión Pública/National Public Investment System
UF	Unidad formuladora/Formulator unit
VALLE	Valle/Valley
VAT	Impuesto al valor agregado/Value-added tax

THE PREPARATORY STUDY ON PROJECT OF THE PROTECTION
OF
FLOOD PLAIN AND VULNERABLE RURAL POPULATION AGAINST FLOOD
IN THE REPUBLIC OF PERU
FEASIBILITY STUDY REPORT
SUPPORTING REPORT

Annex-8
Facility Plan and Design

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CHAPTER 1 BASIC POLICY FOR RIVER FACILITY PLAN

The sections which should be improved with high priorities for targeted six (6) rivers were selected based on requests by interview and outputs by flood analysis, etc. Basic policies for the river improvement works are shown as follows.

(1) The Basic Policy of Improvement Works

The basic policies for improvement works are to design flood control facilities for floods and sediment control in consideration of the characteristic of the rivers. The basic policies of the technical viewpoints are shown below.

1) Dike which fixes channel and riverbed excavation and channel widening which secure the discharge capacity
2) Revetment work which protects dike (including groin work)
3) Retarding basin which controls flood water
4) Erosion control facility which control sediment discharge (sand pocket, etc.)

As for the design method and the construction method, not only the cost and the technique of local contractors are taken into consideration, but also design for facilities is carried out in consideration of utilization of material with easy procurement near the sites.

(2) Considerations for Facility Plan and Design

1) Fixation of channel by dike, depth footing for revetment, and foot protection

In steep rivers with much sediment discharge like the targeted river, sand and gravel bars are formed on the river bed, and concentration of flood flow takes place.

Resulting from those phenomena, the dike collapse by the scouring and the erosion of riverbank makes a factor of flood disaster. A lot of sediment flow also makes a factor which urges advance of sand and gravel bar, and moves water colliding front. In consideration of making fix channel with dike and coping against move of water colliding front, sufficient depth of footing and revetment should be planned and designed. Moreover, installation of foot protection for the protection of dike and revetment shall be also planned and designed.

2) Groin

As one of the protection works for dike body and riverbank, groin is major measures. As for groins, length and intervals are important factors. In experiences of rivers in Japan, length of groin is commonly set less than 10% of river width in order to minimize influence to the opposite riverside. The structure of groin shall be planned and designed to bear with the high velocity in the river and collisions by stones and gravels.

3) Retarding Basin and Sand Pocket

Retarding basin and sand pocket are considered as mitigation measures for the flood and sediment discharge to downstream. Retarding basin is expected to be filled up immediately by sediment inflow and becomes difficult to secure the design storage volume. Therefore, it is considered to arrange the facility which can be expected the function of both for retarding water and storage of sand. In this case, the land acquisition and the periodical sediment removal for maintenance works shall be required.

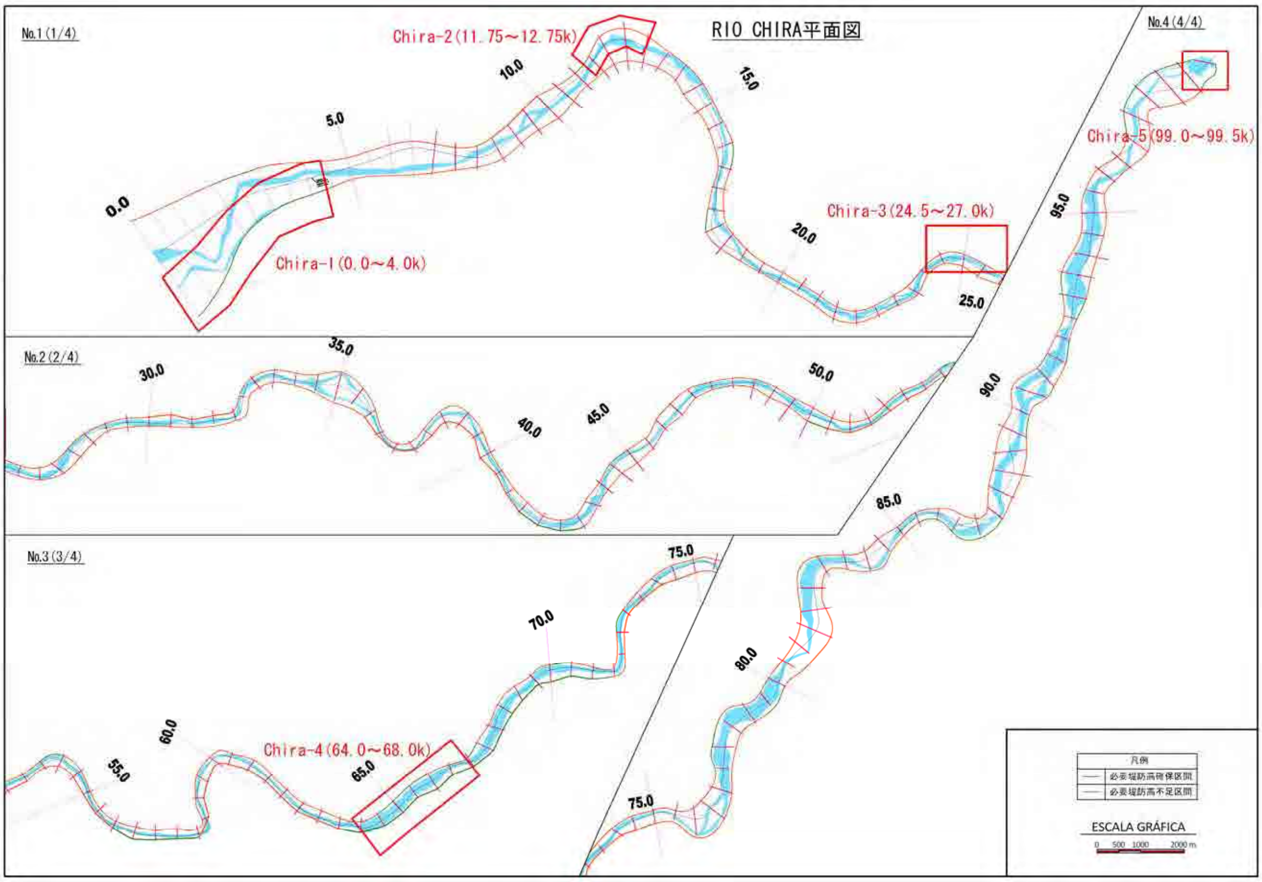
4) Sediment Control Facility Plan

The sediment control facility such as sand pocket shall be planned and designed in order to control the sediment discharge, and prevent the channel blockade as well as the river bed aggradation.

CHAPTER 2 RIVER FACILITY PLAN AND DESIGN

The improvement sections and facility plans in each river are shown as below.

2.1 Chira River



Overall plan

Since the discharge capacity is insufficient on the whole in the Chira River, flood water tend to overflows at all the points and flood flow spreads widely in the lowland along the river channel. In the Chira River, Poechos Dam has a role of flood control for small scaled floods, however, it cannot control for the scale exceeding the design probability of the dam operation, and make severe damages in downstream section.

Fundamentally, it is important for the river improvement plan for floods in the Chira River to commence from the downstream section. For planning, these sections for improvement plan are selected by taking into account the situations of hinterland, the important infrastructures in the areas as well as protecting damaged areas in the past.

Outline of Facility (Chira River－1)

No	Sections for Improvement	Improvement Plan
Chira River -1	0.0km～4.0km (Left-bank side)	This section is in the situation that the revetment works is not done, although the present dike is constructed, and the dike had scoring by the flood in 1998. Therefore, when flood continues over long period, erosion progresses and dike break occurs, the important facilities (gas fields, farmlands, etc.) located in the hinterland will be damaged. Moreover, the sections which groin installed instead of revetment are also damaged. Although the groin has a function for turning of water course, taking into consideration on importance of infrastructures in the hinterland, revetment work shall be done in these sections. **<Characteristic of Sections for Improvement>** • Sections where the dike received erosion by the flood in 1998 • Sections which has the possibility that the dike receives erosion and collapses in case of large-scale flood due to no revetment. • Sections which needs the revetment works for measures against erosion **<Protected Areas>** o Vast farmland and natural-gas field, etc. Which spread in the left-bank side in the section for improvement **<Improvement Plan (How? / How much?)>** ▼ Existing bank shall be used effectively, the embankment works and the revetment works shall be carried out, and discharge capacity shall be secured, and the measures against bank erosion shall be also implemented. ▼ In order to protect the vast farmlands and gas fields, the facilities shall be designed in consideration of enduring against the discharge of about 3600m3/s (about 1/50 year probable flood scale) suffering damages at the time of El Nino in the past.

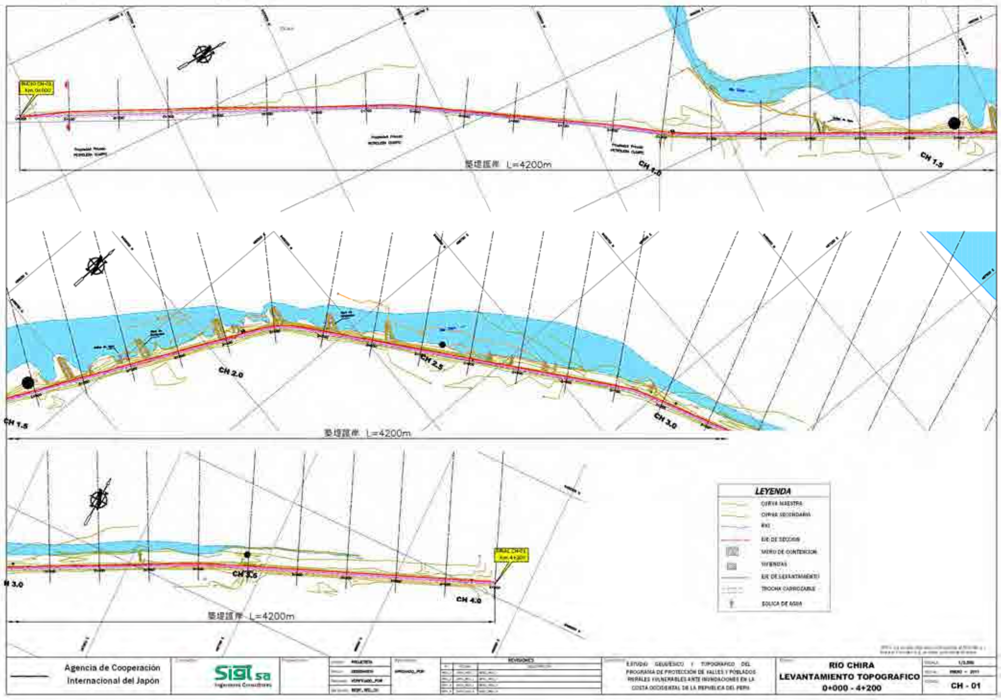


Figure 2.1 Facility Plan in Chira River -1

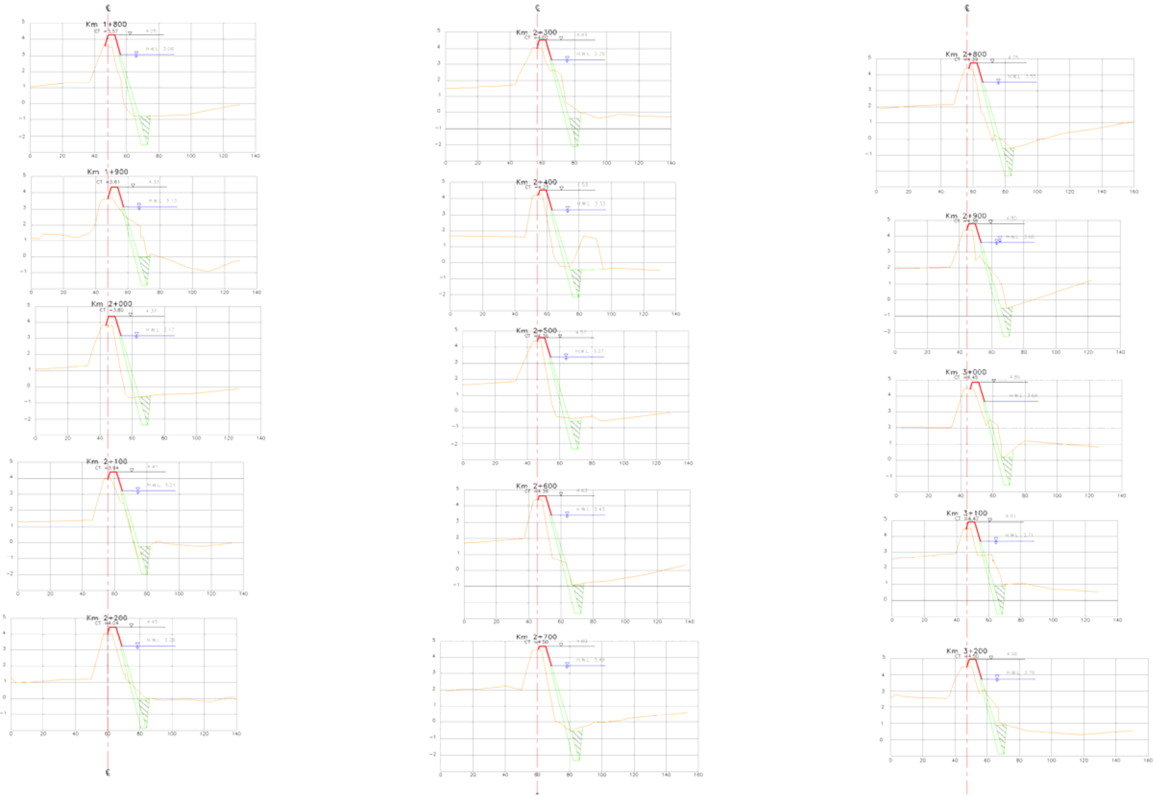


Figure 2.2 Typical Cross Section in Chira River-1

Outline of Facility (Chira-2)

No	Sections for Improvement	Improvement Plan
Chira River -2	11.75km～12.75km (Right-bank side)	This section curves greatly, the right-bank is eroded remarkably, and the present channel is formed. When leave present situation as it is, there is very high possibility of collapse in local main roads located in the right-bank. Therefore, revetment works shall be done, and present channel shall be maintained as much as possible. Maintaining the storage effects by river channel, the planning for road shall be done. (In consideration of the impacts to the regional economy caused by road collapse). **<Characteristic of Sections for Improvement>** • Sections where there is high danger of local main road collapsing by the dike erosion at the time of flood • Sections which should carry out the erosion control of riverbank and the functional preservation for local main roads, simultaneously. **<Protected Areas>** o Local main roads located in the right-bank **<Improvement Plan >** ▼ Since the impact by collapsing of local main road is great, the safety level shall be ensured for the scale of occurrence of El Nino, etc. (about 1/50 year probable flood scale). ▼ Revetment works shall be done in sections eroded by disasters.

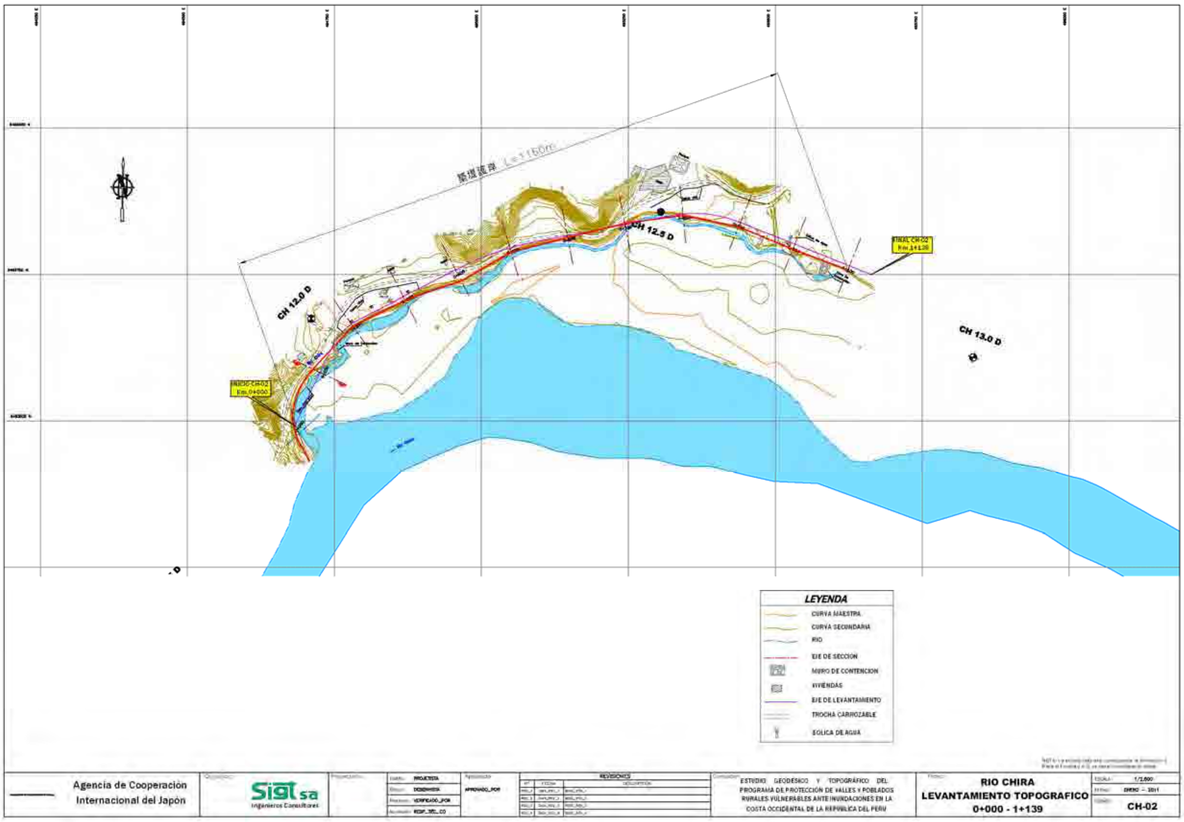


Figure 2.3 Facility Plan in Chira River-2

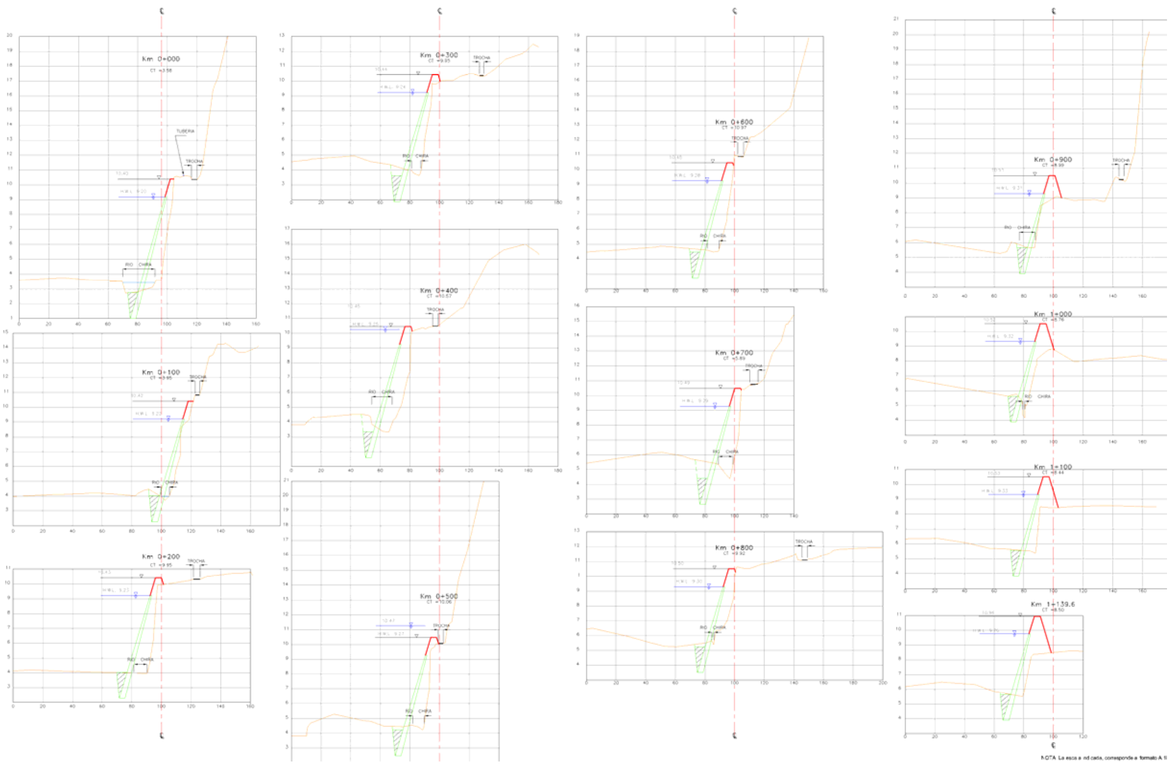


Figure 2.4 Typical Cross Section in Chira River-2

Outline of Facility (Chira River-3)

No	Sections for Improvement	Improvement Plan
Chira River-3	24.5km～27.0km (Right-bank side)	Sections where the right-bank side suffered serious damage by the past flood. The tentative dike with road combination has been constructed, and the maintenance which utilized this facility is important. By constructing the tentative dike with large width than usual, the retarding effects are enhanced, and the water level in the upstream is raise. In order to raising the safety factor in flood control plan in the Chira River , it is important to design many retention areas like these sections, and to lower the water level in the whole river. Since height of current tentative dike is not planned by designated design height, raise of bank shall be needed for the secure of retention function as much as possible against the floods. **<Characteristic of Sections for Improvement>** • Sections where the dike had eroded by the flood in 1998 • Sections which should use the present tentative dike effectively, should heighten the retention effect, and should plan the upstream water-level going down **<Protected Areas>** o Farmland in the right-bank in the planned sections **<Improvement Plan (How? and How much?)>** ▼ In order to protect the vast farmlands of the right-bank side, and to raise retention effect as much as possible, while utilizing the function of present tentative bank effectively, based on experiences which suffered damage from past El Nino, river improvement which does not suffer a great deal of damages even if El Nino occurs shall be done. ▼ By heightening the bank road improved after disaster, the discharge capacity and the retarding effect shall be secured.

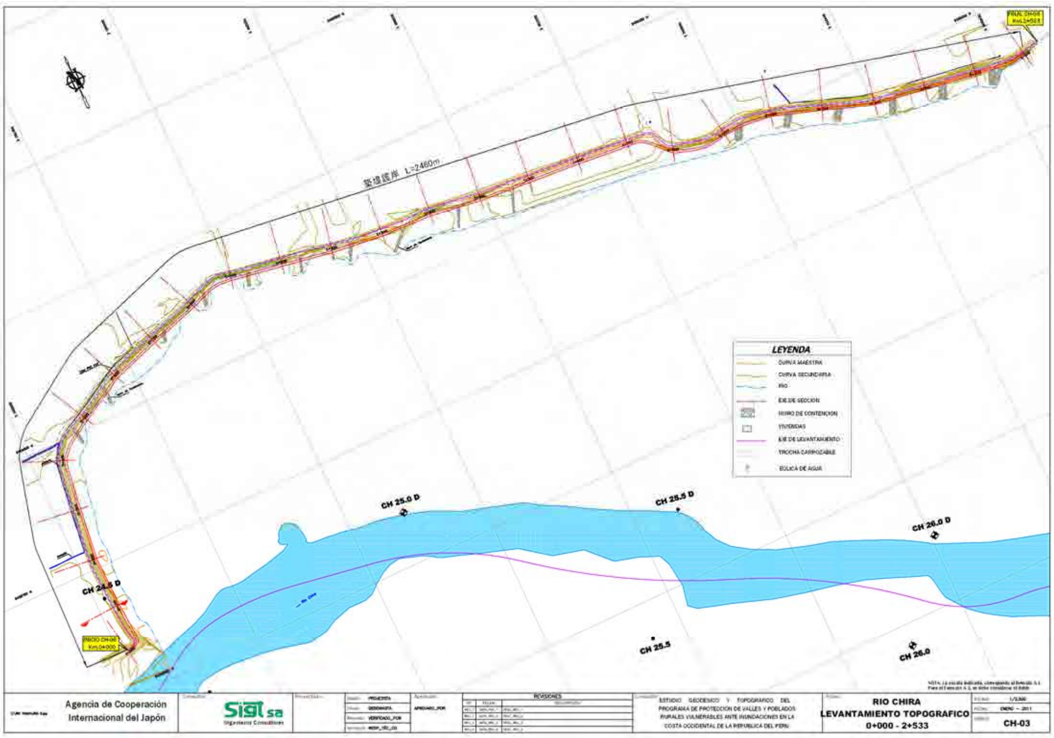


Figure 2.5 Facility Plan in Chira River-3

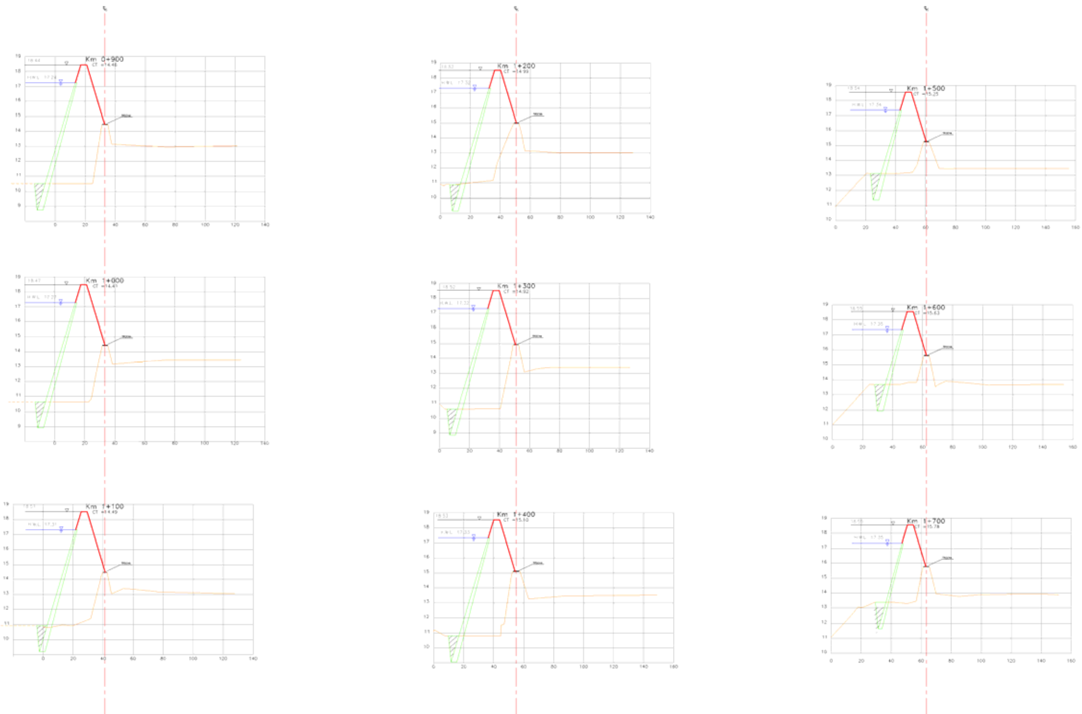


Figure 2.6 Typical Cross Section in Chira River-3

Outline of Facility (Chira River-4)

No	Sections for Improvement	Improvement Plan
Chira River-4	64.0km～68.0km (Whole area)	Sections where the large-scale intake weir (Sullana Weir) is constructed. In the present condition of Sullana Weir, sediment deposits and growth of trees are in progress in the upstream part of the right-bank of the fixed weir (spillway). Caused by influences, the left-bank side which is the opposite side is eroded. If it is neglected as it is, there is possibility that the growth of trees and the function of the sluicegate weir in the left-side bank will be spoiled. Therefore, from the viewpoint of importance of the weir and safety securement of the movable weir, removing the trees and sedimentation in the right-bank of the upstream part of the fixed weir is important in order to stabilize the flow regime at the time of flood, and also to maintain the facility. **<Characteristic of Sections for Improvement>** • Sections where sediment accumulates and trees grow in the right-bank side in the upstream part of the intake weir • Sections where the flood flow concentrates to the movable weir, and the erosion advances in left-bank side. **<Protected Areas>** o Intake weir (Sullana Weir) **<Improvement Plan (How? and How much?)>** ▼ Since the Sullana Weir has the most important roles as river facilities, and has the big influences when damaged by floods, this weir shall be designed to avoid severe damages. ▼ In order to secure the discharge capacity of the upstream of the Sulyana Weir, the trees thickly covered in the upper right-bank of the weir should be cut down, and sediment deposit shall be also dredged.

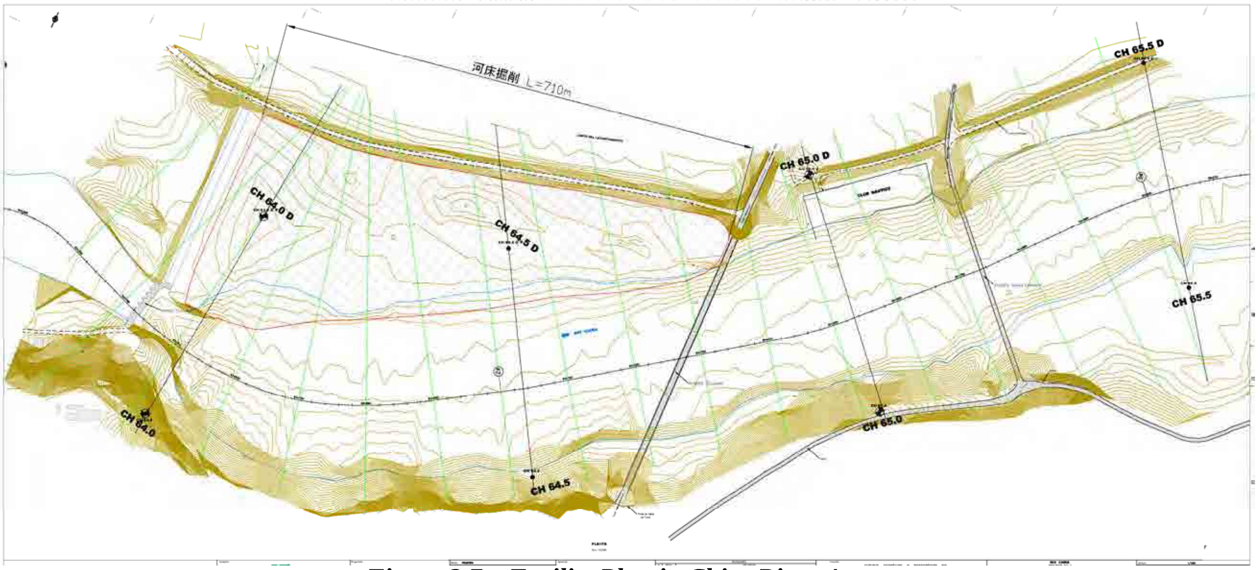


Figure 2.7 Facility Plan in Chira River-4

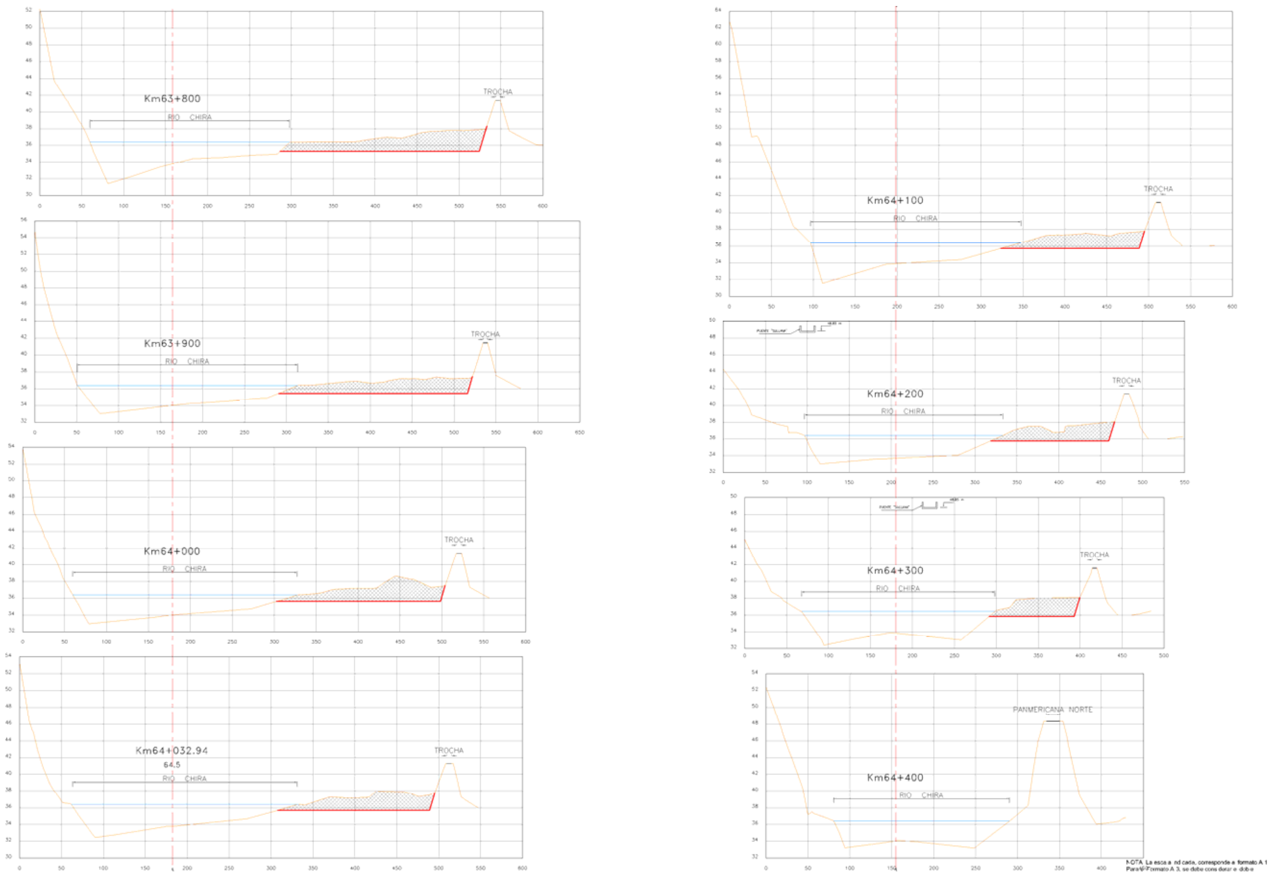
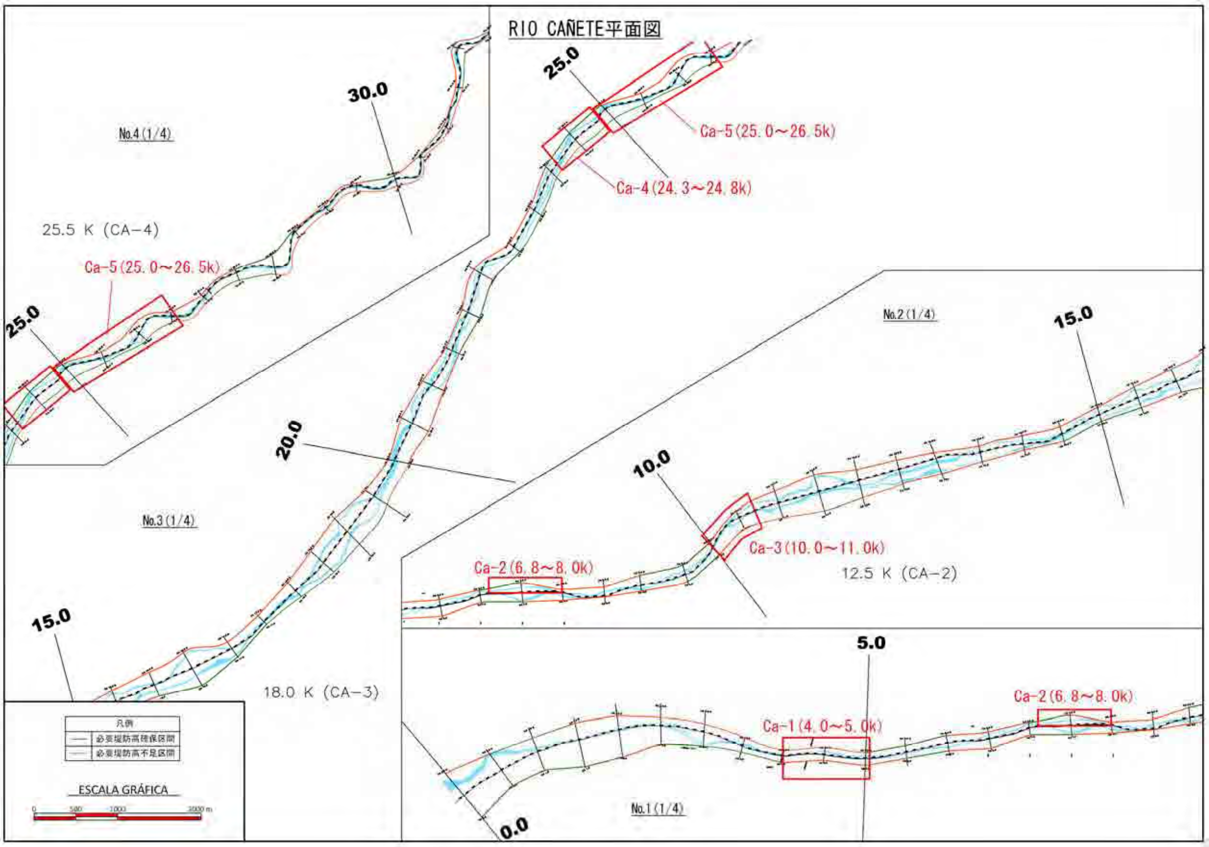


Figure 2.8 Typical Cross Section in Chira River-4

2.2 Canete River



Overall Plan

In the Canete River, main bridges and intake weirs are located in narrow areas, and it tends to occur inundation just upstream of each narrow area. Additionally, as characteristic of inundation, although inundation remains within the farmland along the river channel in the upstream section from the 10km distance mark, whereas the flood flow spreads greatly especially in the right-bank side in the downstream section from the 10km distance mark, and damages by flow is to be large.

Therefore, the river plans to be carried out in Canet River are the securement of discharge capacity in narrow areas and embankment/revetment works in the downstream from 10km mark where the damage potential is to be large.

In addition, discharge of the Canete River is rich and this river is close to the capital Lima, the tourist resorts are formed in the upstream areas. The protected plans (measures for bank erosion) for the important main roads as access to the upstream area are also selected from a viewpoint of effects in regional economy.

As for road bridge located in the narrow area of Pan American Road, the renewal was also considered, however, the traffic volume is very large and a substitute bridge and approach roads are needed, so that the project cost become huge. Through the meetings on renewal of bridge, DGIH replied that it was difficult to construct new bridge. Renewal plan of bridge is excluded from river improvement plan.

Outline of Facility (Canete-1)

No	Sections for Improvement	Improvement Plan
Canete River-1	4.0km～5.0km (Right-bank side) ＋ (Riverbed dredging in a part)	The road bridge of the Pan Americana which travels through the South American Continent exists in the sections. The narrow areas is existed and it is one of the section with the most low discharge capacity in the downstream of the Canete River . (Sections with remarkably insufficient discharge capacity in the downstream from 10km mark are this section and 6.5-8.5km section (right-and-left side bank) described in (2).) In the El Nino Flood in 1998, the riverbed aggradation occurred in the upper part and flood damage was occurred. Since the renewal of the bridge, etc. is judged to be impossible as the present stage, it is important to heighten the dike of the right-bank side to secure the discharge capacity by riverbed excavation near the bridge. **<Characteristic of Sections for Improvement>** • Narrow area (bridge section) and one of sections with the most insufficient discharge capacity in the Canete River • Sections which accumulates sediment in upstream according to the riverbed aggradation by narrow segment, and is promoting the flood of the upstream • Sections which can be planned in the water-level reduction effect of the upstream part by securing the discharge capacity by riverbed excavation **＜Protected Areas＞** o The vast farmland and dwelling areas which spread in downstream from the sections for improvement **<Improvement Plan >** ▼ A flood will begin at 1/10 year probable discharge scale, and damage will become serious at the 1/50 year probable discharge scale. ▼ For this reasons, the facilities which can flow down the discharge of 1/50 year probable flood scale are improved. ▼ While the existing dikes are used, the maintenance of the embankment of dike and the revetment in the right bank with insufficient height, and the riverbed excavation are adopted in order to secure the discharge capacity.

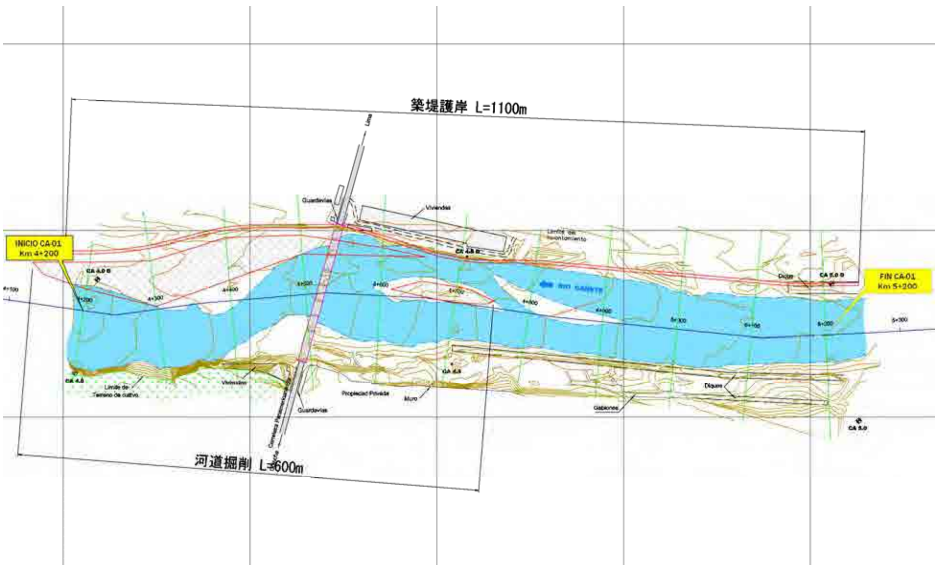


Figure 2.9 Facility Plan Chart of Canete River-1

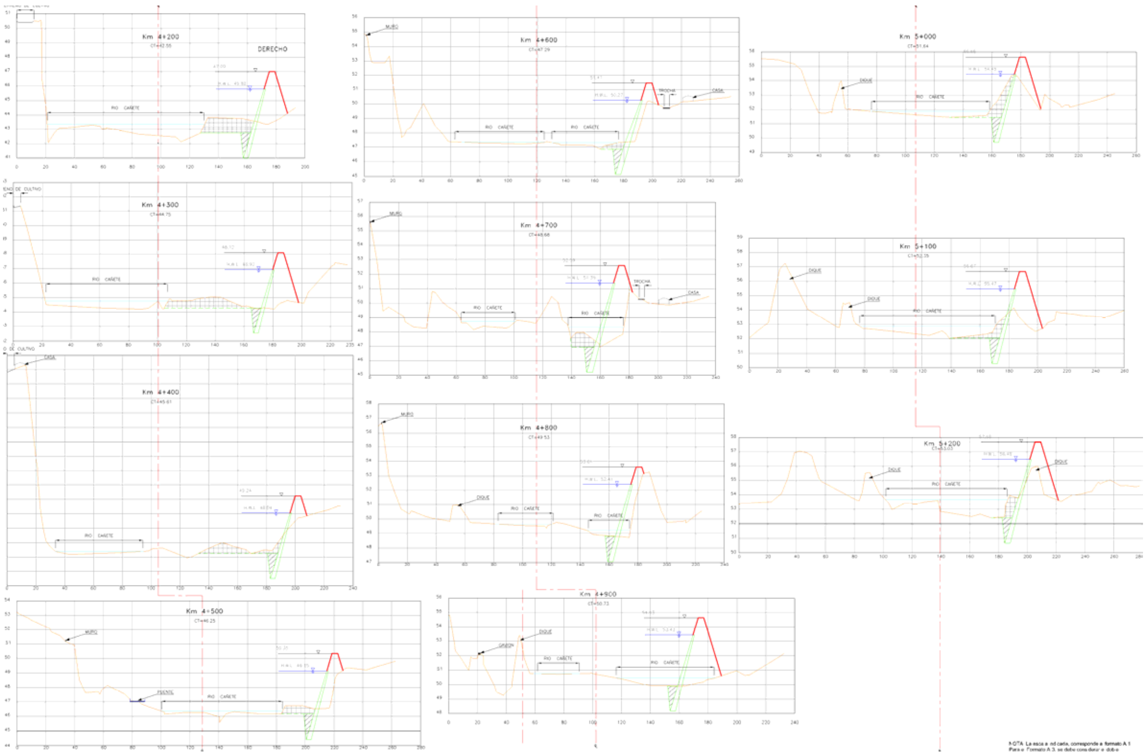


Figure 2.10 Typical Cross Section in Canete River-1

Outline of Facility (Canete River-2)

No	Sections for Improvement	Improvement Plan
Canete River-2	6.5km～8.1km (Right-bank side) + (Left-bank side)	The right bank of this section is damaged by bank erosion at the flood in the past, the bank collapsed, and great damage generated. Moreover, since this section is insufficient for discharge capacity, embankment/ revetment works as measures for bank erosion is required. In downstream from 10km, the flood flow spreads greatly especially in the right-bank side, and the damage becomes large. In left-bank side, the flood does not spread more greatly than the right-bank side, and the flood water expands limitedly to surrounding farmland. (The inundation area is wider than the upstream section) **< Characteristic of Sections for Improvement >** • Sections where the discharge capacity is most insufficient in the downstream of the Canete River • Sections where the flow velocity of flood flow is high, the riverbank is eroded, the dikes collapse, and the river overflows • Sections where the measures for bank erosion, embankment/ revetment works for securement of discharge capacity are required **< Protected Areas >** o Farmland which spreads in the right-and-left bank side **< Improvement Plan >** ▼ Flood will start at 1/10 year probable discharge scale, and damage will become serious to the 1/50 year probable discharge scale. For this reason, the river plan which can flow down the discharge of 1/50 year probable flood scale is adopted. ▼ In order to secure the discharge capacity, using the existing dike, the embankment and the revetment works are carried out (effective use of the existing bank in the right-bank side).

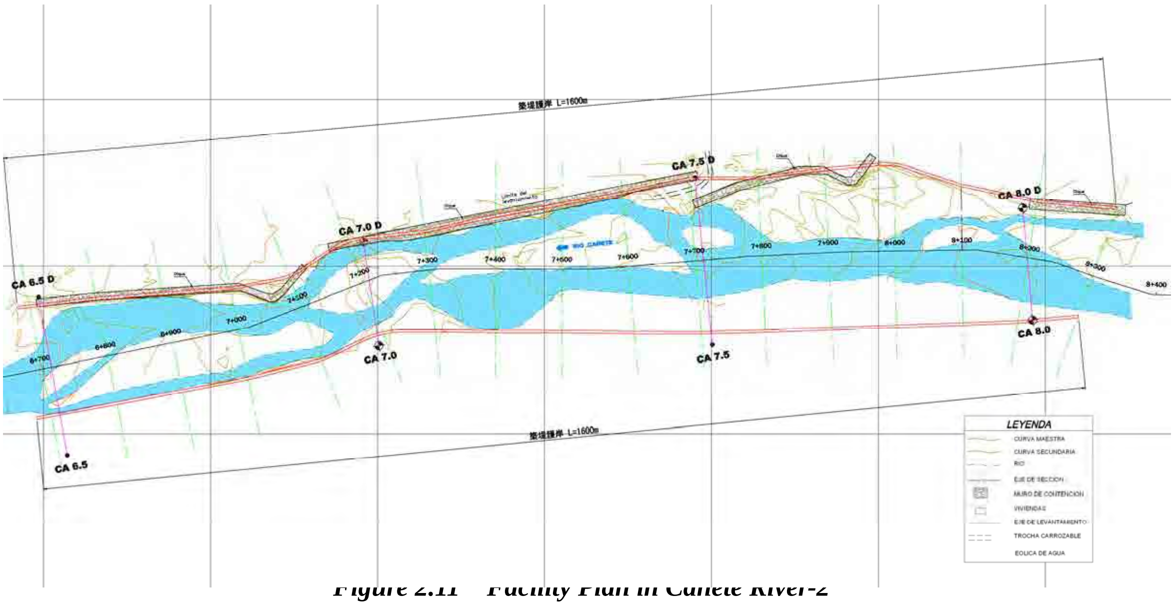


Figure 2.11 Facility Plan in Canete River-2

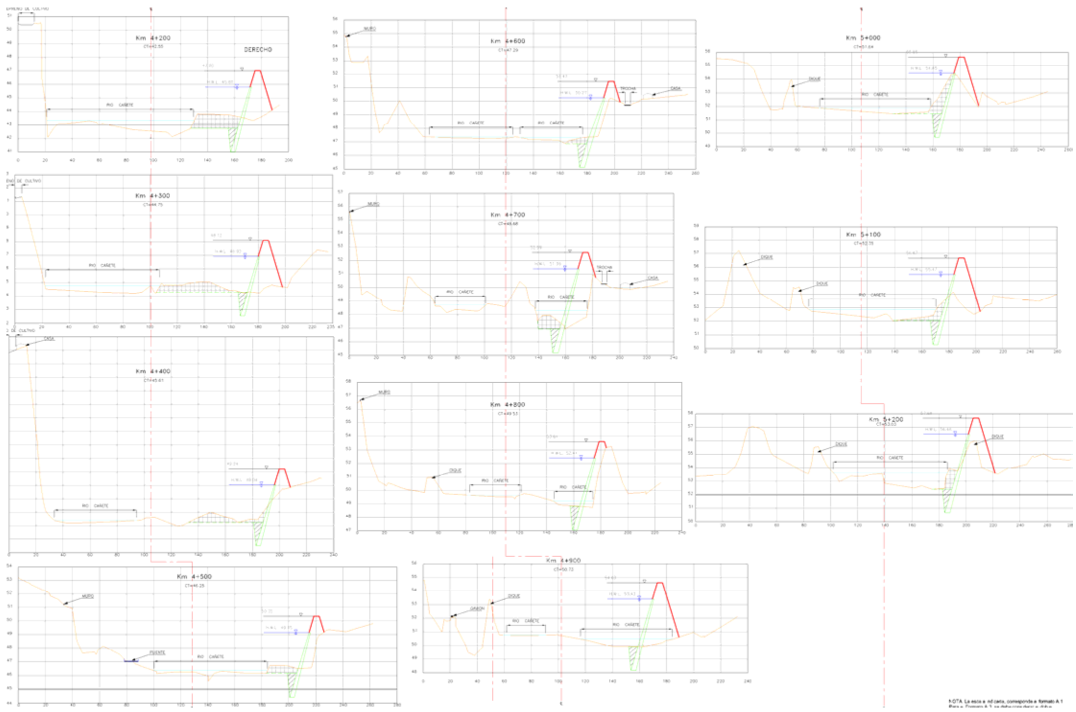


Figure 2.12 Typical Cross Section of Canete River-2

Outline of Facility (Canete River-3)

No	Sections for Improvement	Improvement Plan
Canete River-3	10.0km～11.0km (Channel widening in the left-bank side)	The intake weir currently existing in this section forms the narrow area, and makes water level in the upstream area goes up at the time of flood, and causes damage. In addition, the damage to farmland is most expanded in the upstream area from this section (10km mark). Therefore, in order to secure the discharge capacity, the channel widening and the riverbed excavation, etc. are required. Moreover, the effectiveness of increasing discharge capacity in the upstream can also be expected by excavation of the channel and lowering the water level in the channel. **<Characteristic of Sections for Improvement>** • Sections to be protected for intake weir • Sections which is narrow area compared with the up-and-down streams and has insufficient discharge capacity • Sections which can be planned in the effect of water-level reduction in upstream when channel excavation is carried out **<Protected Areas>** o Intake weir o Farmland which spreads in the left-bank side of the sections for Improvement **<Improvement Plan >** ▼ Intake weir is the most important facility in the river, and the influence affected to the area is serious in case of damaged by floods. ▼ For this reason, the safety is ensured at the scale of El Nino, etc. (1/50 year probable flood scale) occurs. ▼ River channel is widened, and it is devised so that flood flow may not concentrate near the intake weir.

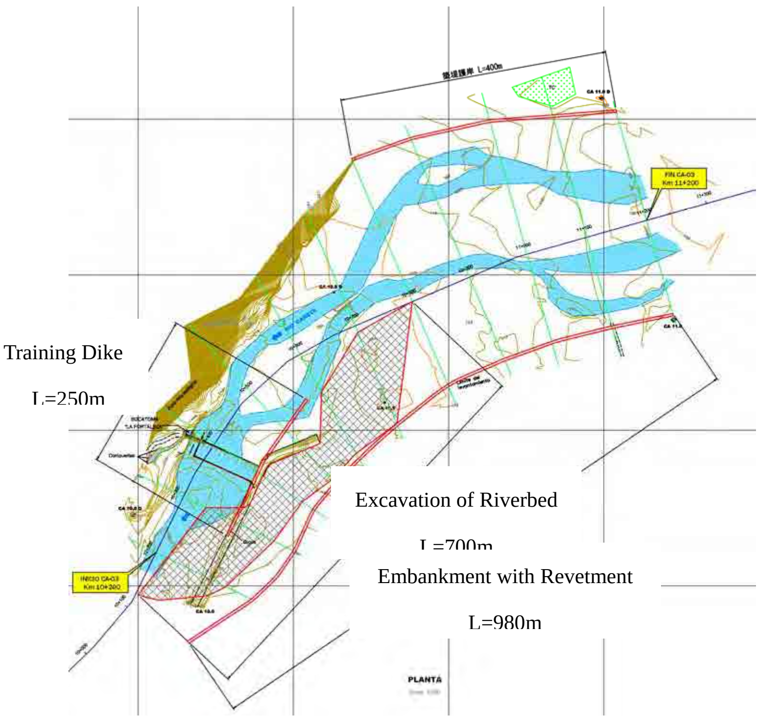


Figure 2.13 Facility Plan in Canete River-3

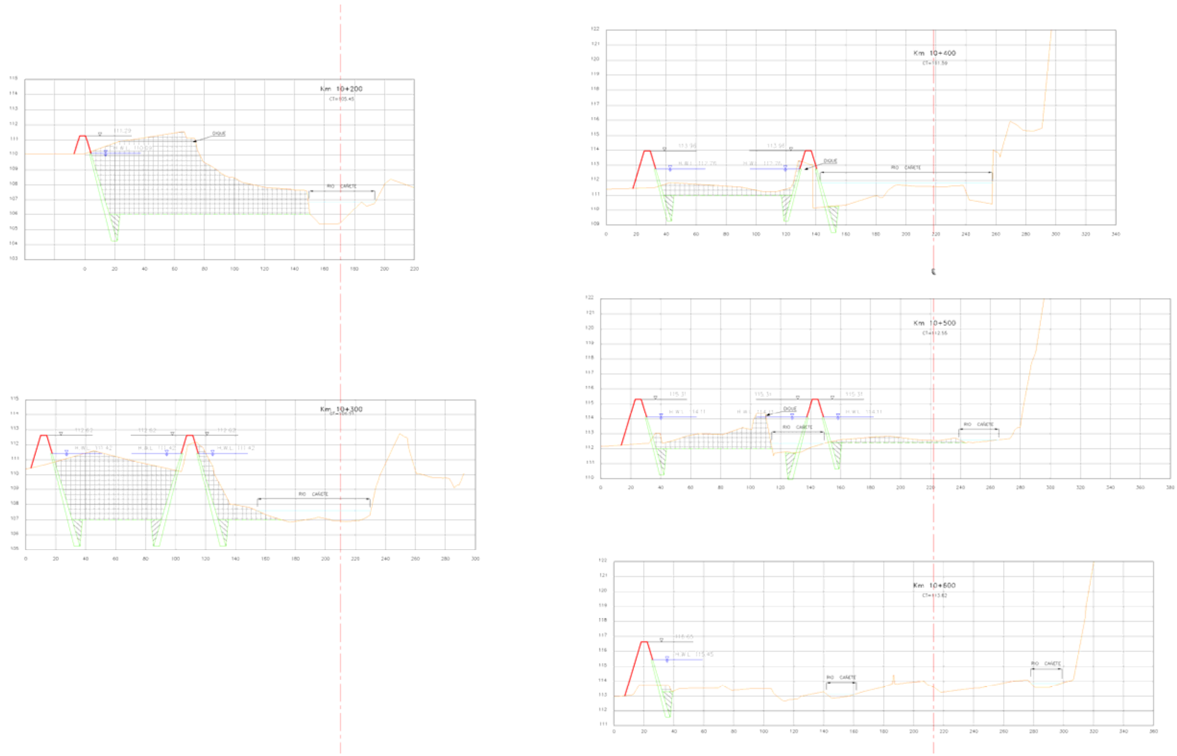


Figure 2.14 Typical Cross Section in Canete River-3

Outline of Facility (Canete River-4)

No	Sections for Improvement	Improvement Plan
Canete River-4	24.25km ～24.75km (Channel widening in the left-bank side)	The intake weir is installed in the sections. A lot of sediment deposited by the past El Nino flood, and the intake did not functioned during one month or more. Since sediment by floods has accumulated still now, and it is in the situation that the intake weir functions barely by maintenances such as excavation. When a large-scale flood is generated in the future, the function of the intake weir is lost, it is anxious about the great adverse effect to related farmland etc. Therefore, improvement of the diversion facility for proper discharge distribution is very important. **<Characteristic of Sections for Improvement>** • The sections which needs the measures for sediment inflow in intake weir **<Protected Areas>** o Intake weir **<Improvement Plan (How? / How much?)>** ▼ Since the intake weir is the most important facility in the river, and the influence affected to the area in case of no operation of the facility function is serious. Safety is ensured for the scale when El Nino, etc. (1/ 50 year probable scale) occurs. ▼ River improvement by taking into the current characteristics of river is carried out.

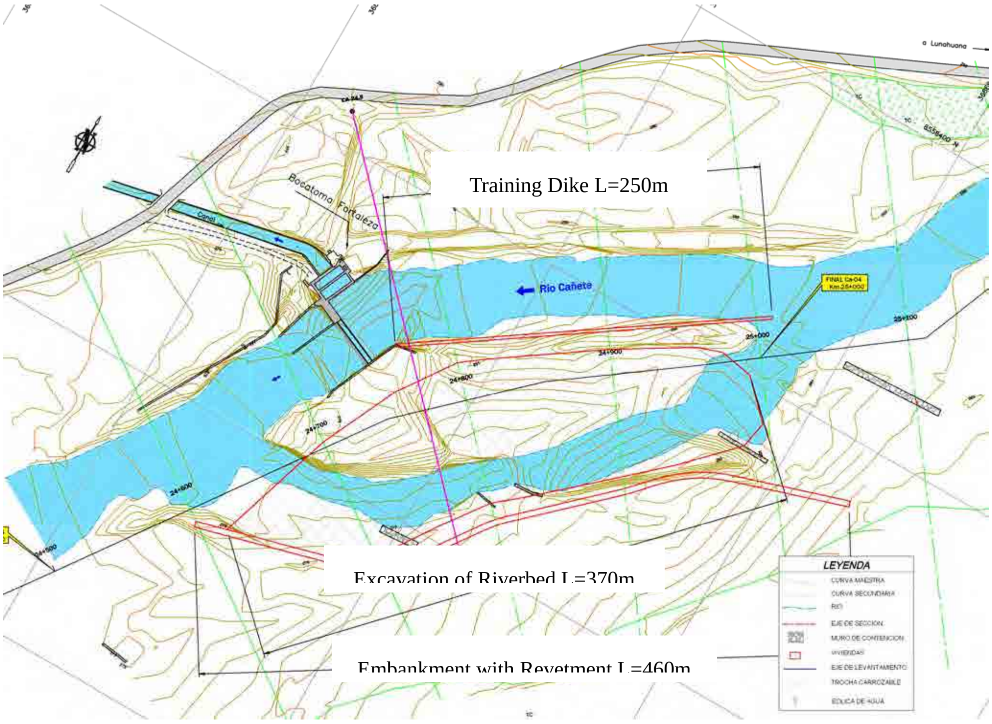


Figure 2.15 Facility Plan in Canete River-4

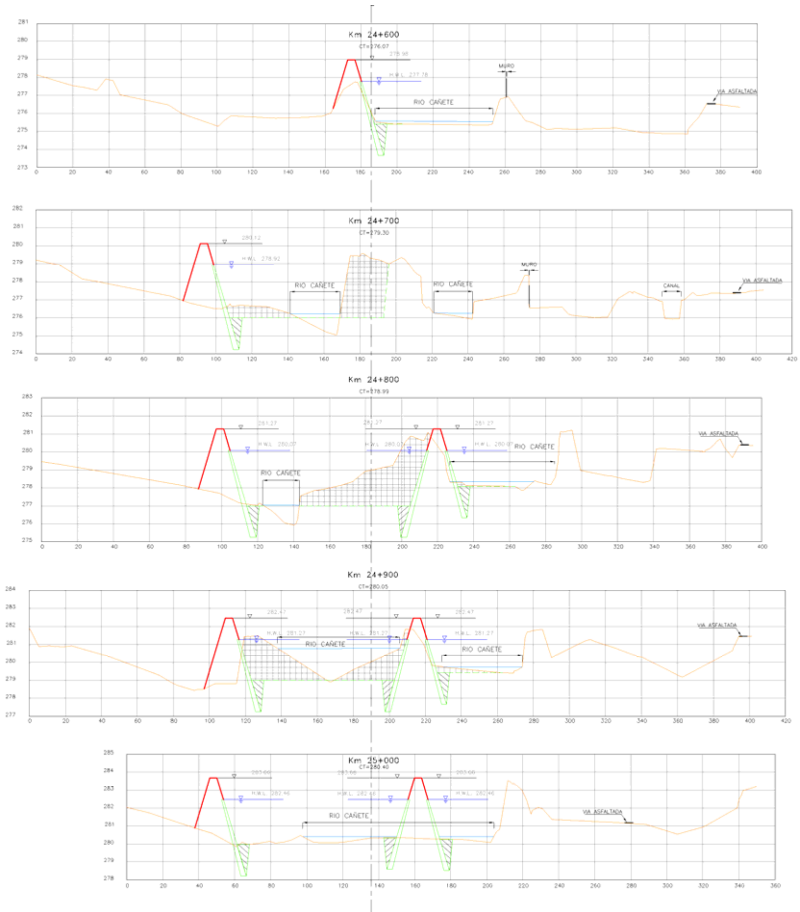


Figure 2.16 Typical Cross Section in Canete River-4

Outline of Facility (Canete River-5)

No	Sections for Improvement	Improvement Plan
Canete River-5	24.75km ～26.5km (Right-bank side)	In the sections concerned, bank erosion is processing caused by flood flow and the influence of erosion has reached even near the local main road. If it is neglected as it is, road will be collapsed and impacts in regional economy will be large (especially for tourist industry), the measures for erosion should be implemented immediately. **<Characteristic of Sections for Improvement>** • Sections with high possibility that the local main road will collapse by bank erosion. • Sections which should carry out erosion control for riverbank and functional preservation for the local main road, simultaneously. **<Protected Areas>** o The local main road located in the right-bank **<Improvement Plan >** ▼ Since the impacts to the regional economies is large, caused by collapsing in the local main road, the safety measures is ensured even if El Nino, etc. (1/50-year probable scale) is occurred. ▼ Although improving only the road part is to be considered for improvement plan, it is anxious that the farmland in the right-bank side during flood is eroded because of locating in the low land area. Improvement with easy flowing for discharge is the key measures.

Figure 2.17　Facility Plan in Canete River-5

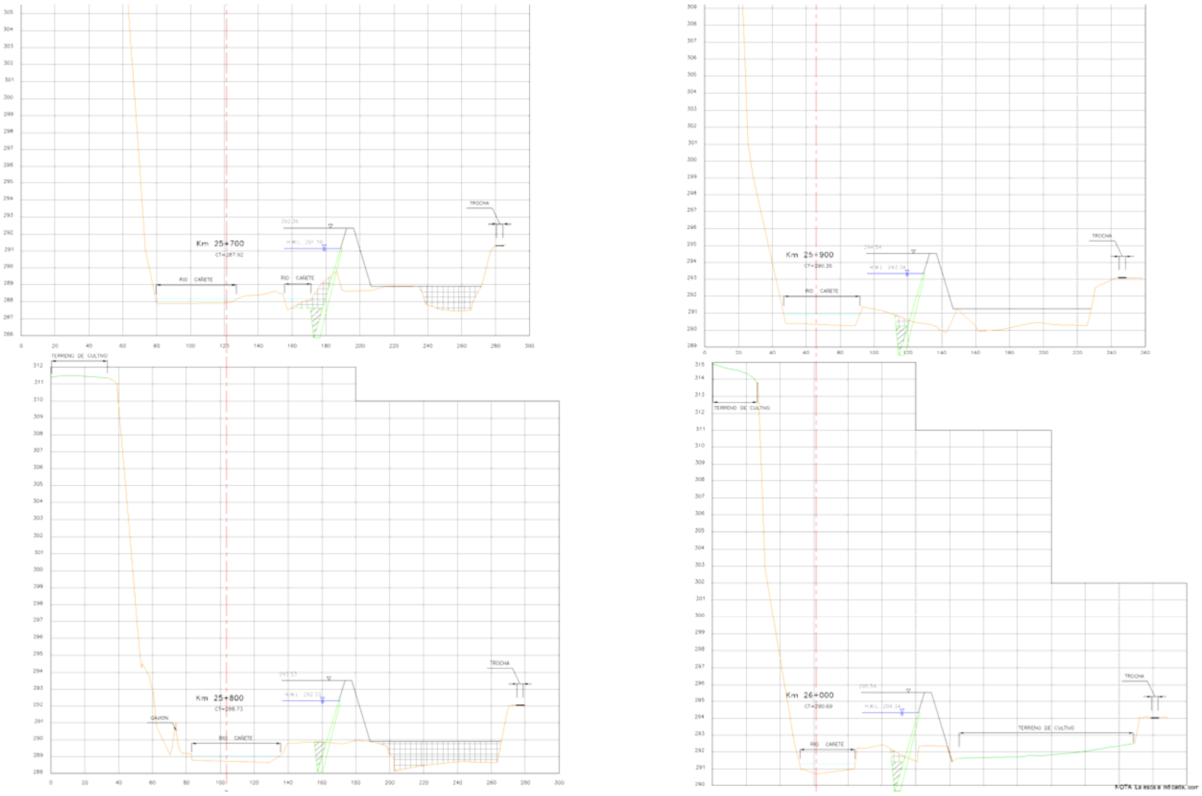
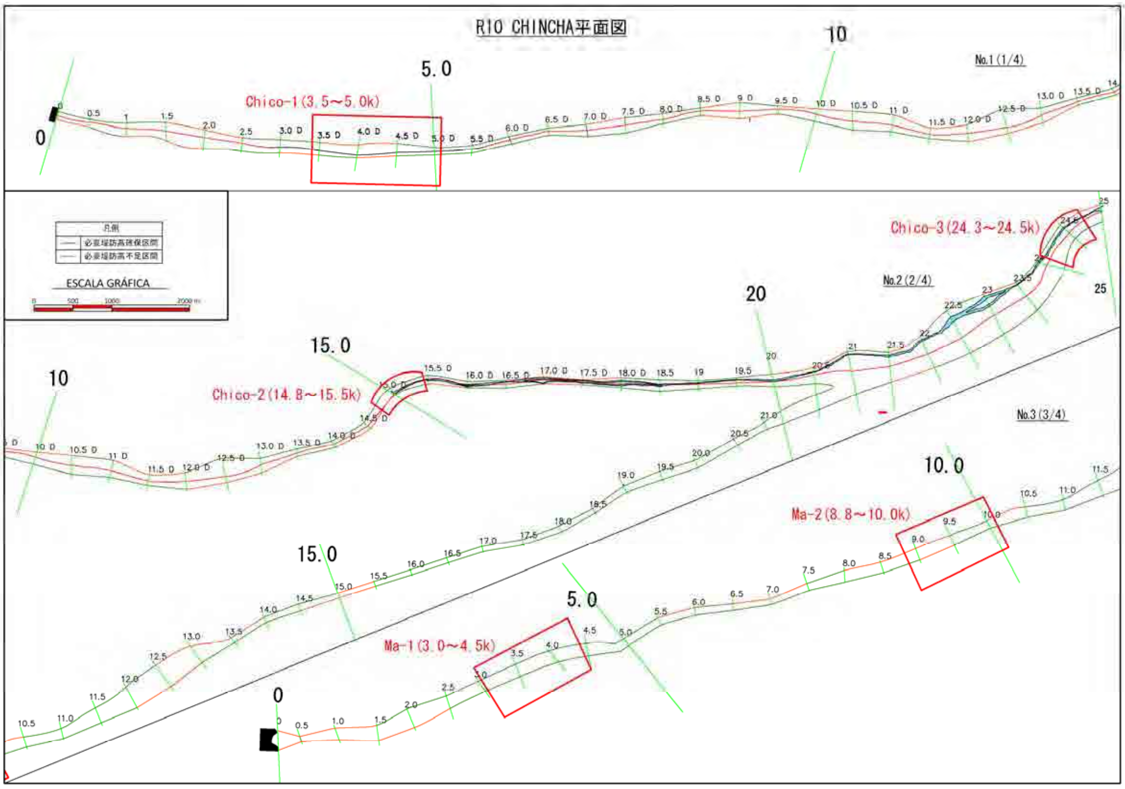


Figure 2.18 Typical Cross Section in Canete River-5

2.3 Chincha River



(1) Chico River

Issue in the Chincha River is insufficient function to divert flood water the Chico River and the Matagente River in the upstream part. When flood water flow either river, the discharge capacity is insufficient in all sections both the Chico River and the Matagente River, and then the possibility of severe damage is high. Furthermore, even if the flow diverts toward the Chico River and the Matagente River with properly ratio such as 1:1, their river banks are still insufficient for design discharge. In Chico River, there are sections of overflow in the vicinity of 15km mark and 4km mark from the river mouth, and the flood flow tend to spread greatly in the left-bank side. In Matagente River, there are also sections of overflow in the vicinity of 9km mark and 3km mark from the river mouth, the flood flow tend to spread greatly in the right-bank. Therefore, the fundamental river improvement plan is the construction of the diversion weir and improvement for securement of discharge capacity by embankment and reverbed excavation in existing insufficient sections.

The proposed improvement plan for every section is arranged on the basis of the case that flood flow is distributed properly to both the Chico River and the Matagente River.

Outline of Facility (Chico-1)

No	Sections for Improvement	Improvement Plan
Chico River-1	**Chico River** 3.0km～5.1km (Right-bank side) + (Left-bank side)	Since Discharge capacity in the sections mentioned above is most small in the downstream of the Chico Rive, the embankment/ revetment works which prevents expansion of damages in the left bank is required. Moreover, in the case of improvement in the upstream section, it is thought that overflow also occurs and water expands in the right-bank side, the sections concerned needs the embankment in both banks. **<Characteristic of Sections for Improvement>** • Sections where flood overflowed into the right-and-left both banks areas, and damaged to farmlands in the past. • Although sections where partial embankments are done in the left bank currently, flood expand accompanied by improvement in the upstream. • Sections where the discharge capacity is the most insufficient in the downstream **<Protected Areas>** o Vast farmland which spreads in the right-and-left both sides (especially left side) **<Improvement Plan >** ▼ Inundation starts at the scale of 1/10 year probable discharge, and damage occurs at the scale of the 1/50 year probable discharge seriously. For this reason, the river improvement which can flow down the discharge of 1/50 year probable flood is curried out. ▼ Since the existing dike is improved partially, they are utilized effectively and the embankment and the revetment works which secures the discharge capacity are also carried out.

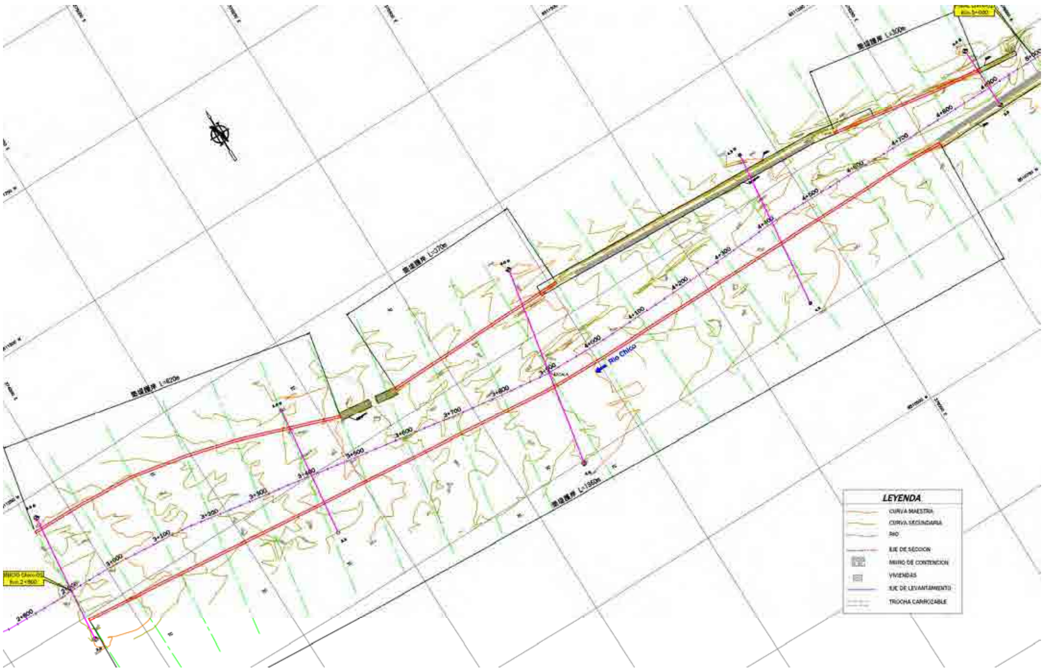


Figure 2.19　Facility Plan Chart in Chico River-1

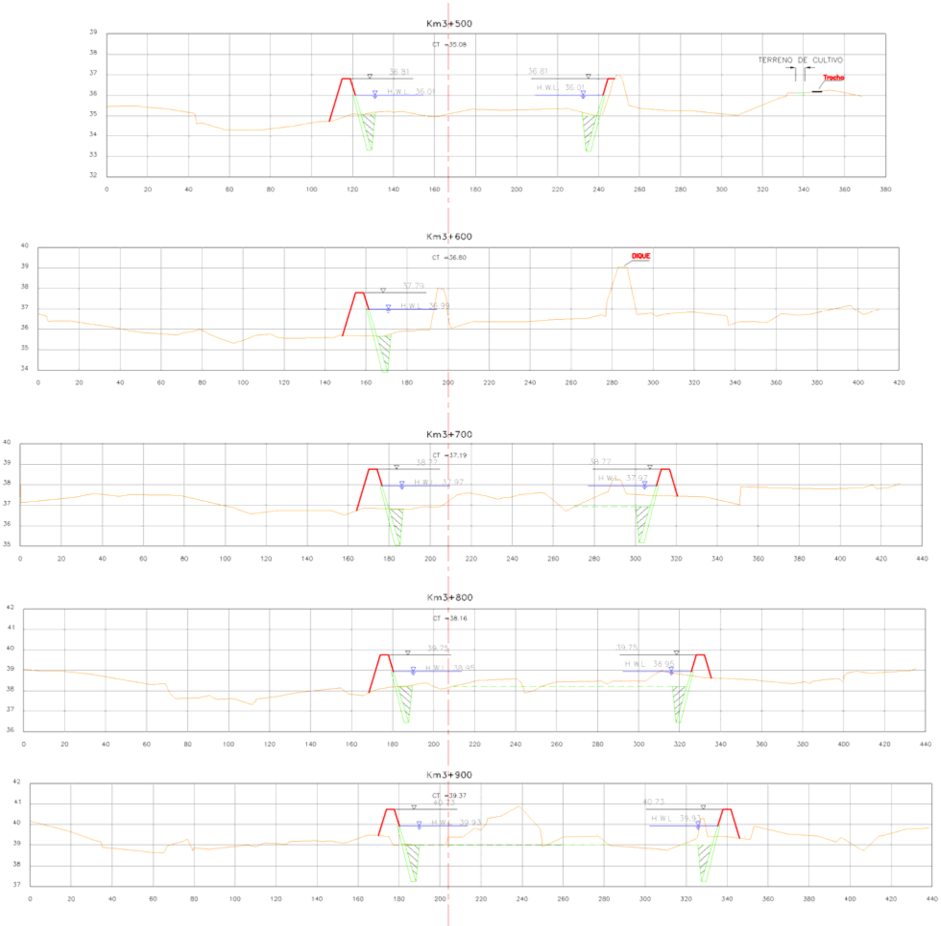


Figure 2.20 Typical Cross Section in Chico River-1

Outline of Facility (Chico River-2)

No	Sections for Improvement	Improvement Plan
Chico River-2	**Chico River** 14.8km～15.5km (Channel widening in left-bank side)	Sections where sedimentation of the vicinity of intake weir is remarkable and the discharge capacity is considerably insufficient. Therefore, the measures for sediment inflow around intake weir (construction of diversion weir with proper discharge distribution) and the securement of discharge capacity are adopted **<Characteristic of Sections for Improvement>** • Sections overflowed by the past floods • Sections in which the channel should be widen, and the measures against sediment inflow around intake weir and the increase of discharge capacity should be carried out. • Sections which the sedimentation is in progress in the tunnel of irrigation channel **<Protected Areas>** o Intake weir o Farmland which spreads in the left-bank side **<Improvement Plan >** ▼ Inundation starts at the scale of 1/10 year probable discharge, and damage occurs at the 1/50 year probable discharge. For this reason, the improvement which can flow down the discharge of 1/50 year probable flood is improved. ▼ Channel width is widened, and it is devised so that flood flow may not concentrate around the intake weir.

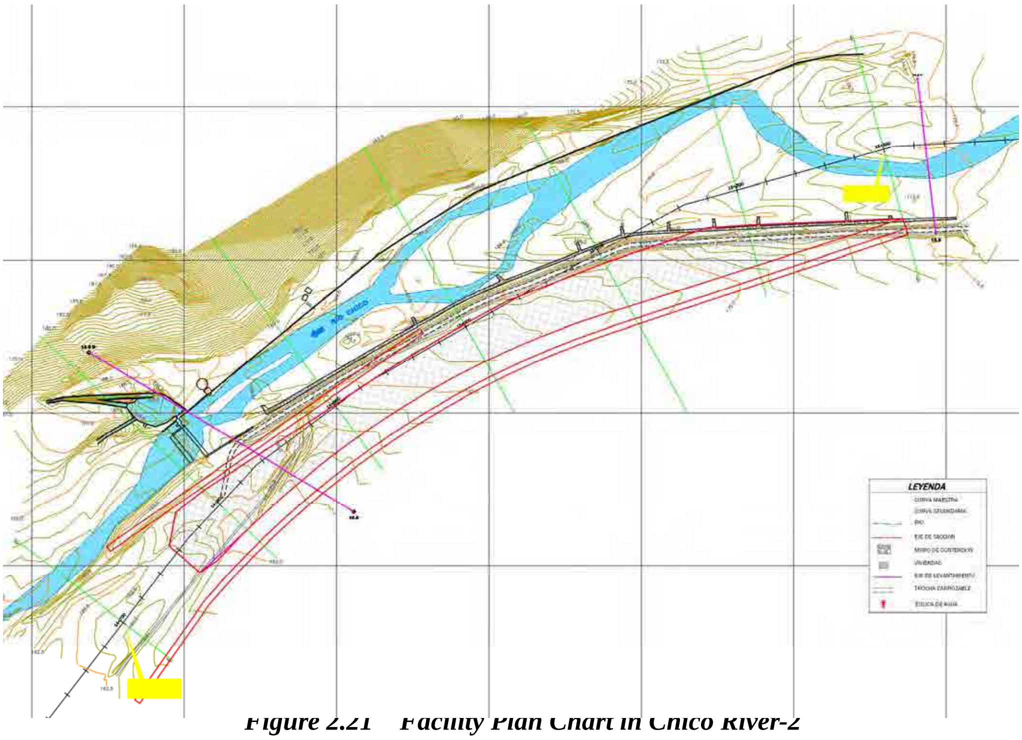


Figure 2.21 Facility Plan Chart in Chico River-2

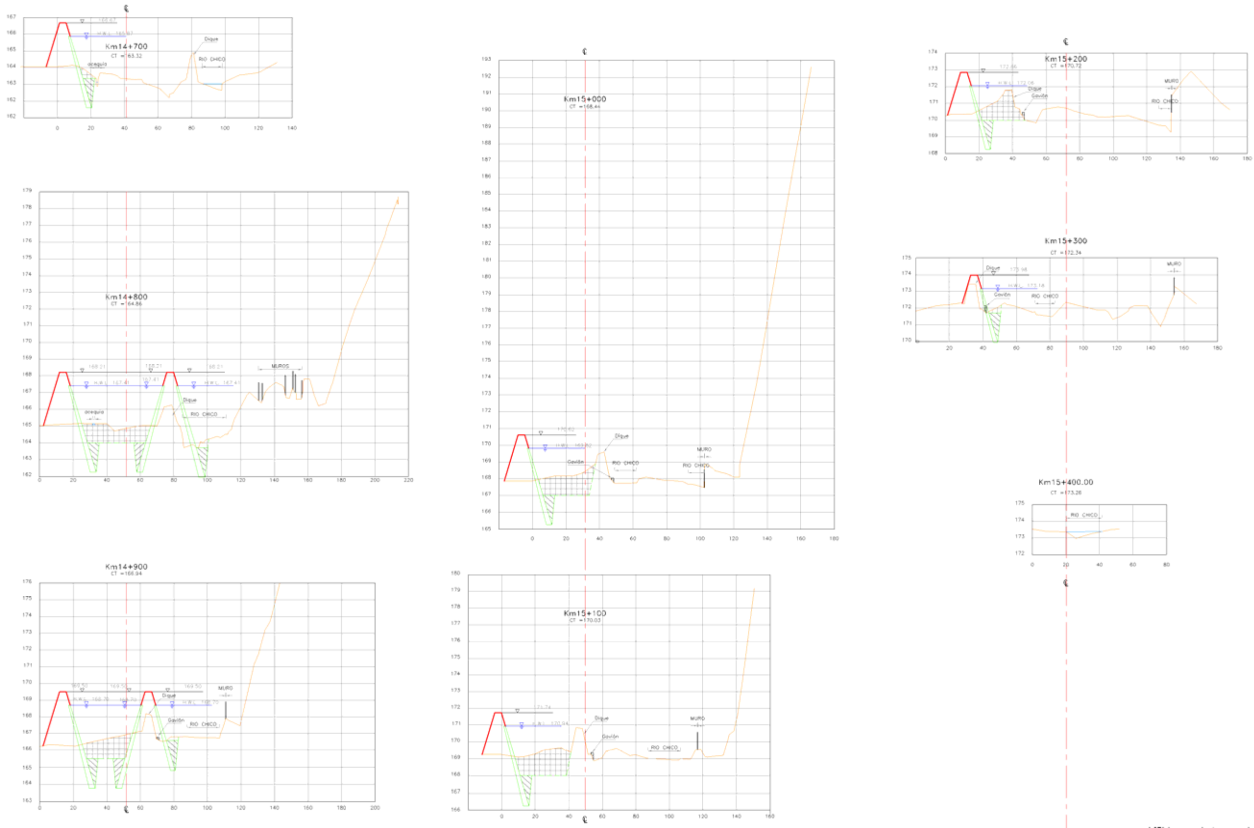


Figure 2.22 Typical Cross Section in Chico River-2

Outline of Facility (Chico River-3)

No	Sections for Improvement	Improvement Plan
Chico River-3	**Chico River** 24.2km～24.5km (Whole area)	Sections which the Chico River divert to both the Matagente River and the Chincha River, and is the most important section from the view point of improvement. (Bases for the flood control plan) Although the old diversion weir built in 1954 exists, and facility is aged remarkable. When floods coming and it continues, flood flow moves to the upstream of the weir, and flows into either the Chico River or the Matagente River. Finally, distribution function becomes insufficient situation. Therefore, the construction of the new diversion weir which distributes flood flow to both the Chico River and the Matagente River properly is the integral measures from the view point of the flood control plan in the Chincha River . **<Characteristic of Sections for Improvement>** • Due to meandering stream, in the case of which cannot distributed the discharge as designed ratio at 1:1, sections where there is possibility of large scale inundation occurrence in either the Chico River or the Matagente River so that suitable diversion facility is required. **<Protected Areas>** o All the areas in the Chico River and the Matagente River (It brings serious damage in one river of the two when discharge distribution is not carried out properly) **<Improvement Plan >** ▼ The facility which can distribute flood flow is improved.

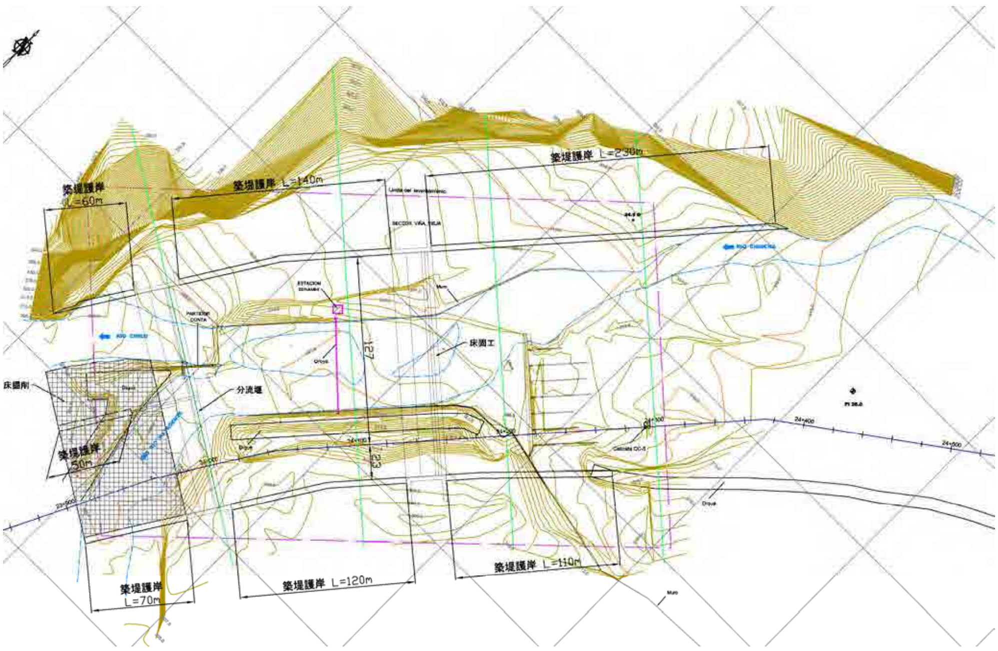


Figure 2.23 Facility Plan in Chico River-3

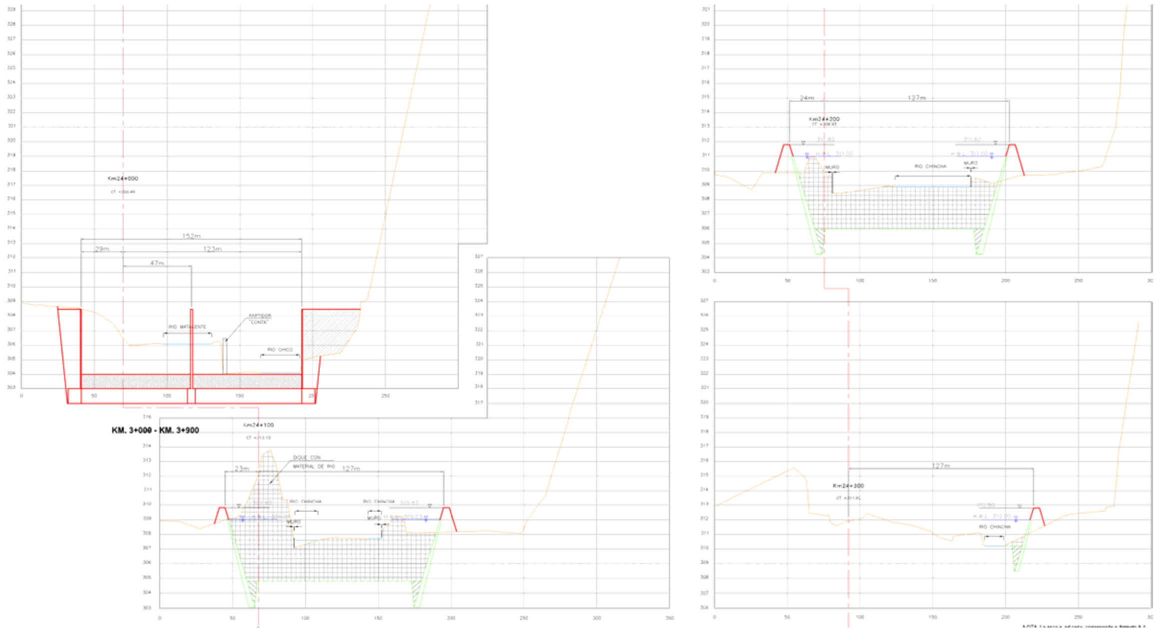


Figure 2.24 Typical Cross Section in Chico River-3

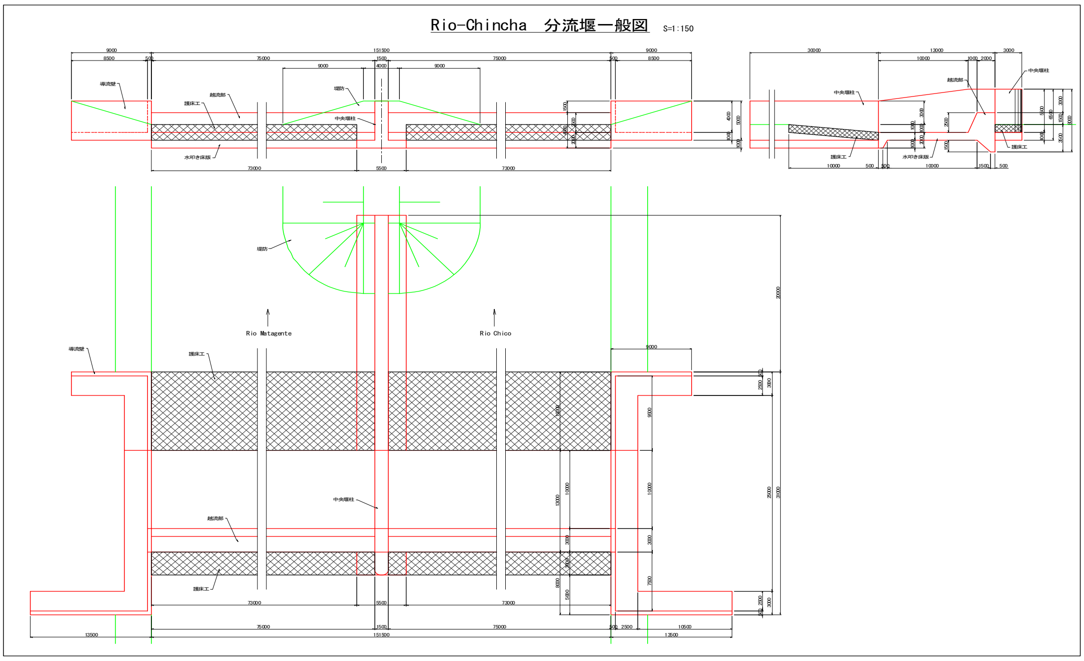


Figure 2.25 Diversion Weir in Chico River-3

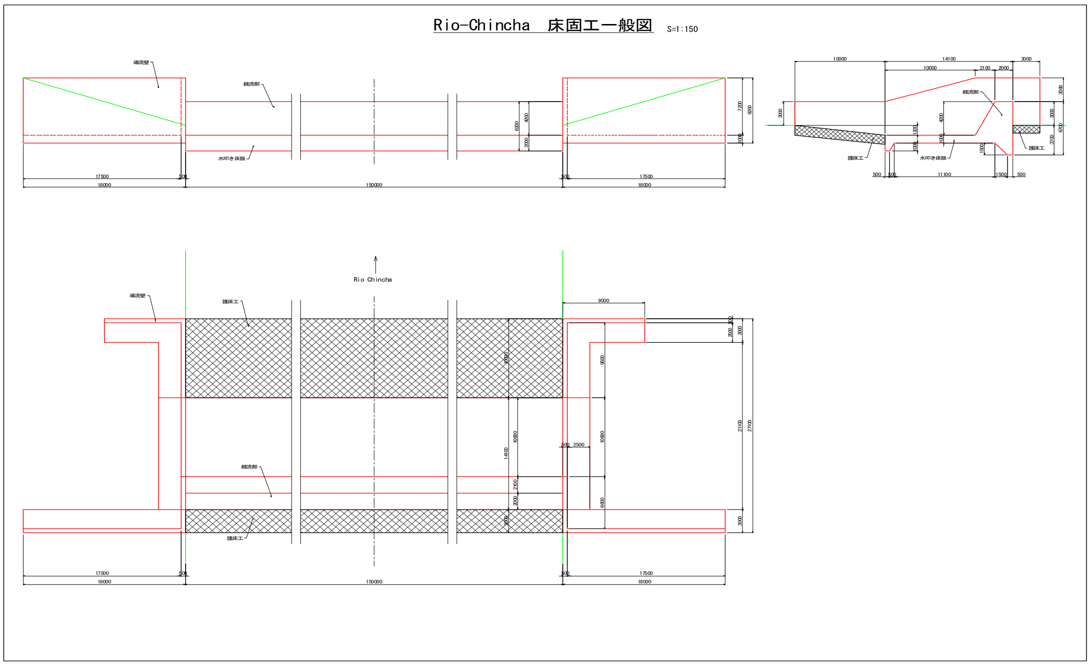


Figure 2.26　Consolidation Works in Chico River-3

(2)　Matagente River

Outline of Facility (Matagente-1)

No	Sections for Improvement	Improvement Plan
(4)	**Matagente River** 2.5km～5.0km (Whole area)	Sections concerned is the past overflow point, and flood flow tend to spread greatly in the right-bank side. Moreover, since the embankment was made disorderly for rehabilitation by flood, it is thought that inundation will also occur and expand in the left-bank in case of upstream improvement. For this reason, the section concerned needs the embankment in both sides of bank. **<Characteristic of Sections for Improvement>** • Sections where the discharge capacity is insufficient in the downstream • Sections where it overflowed in both sides and serious damage caused to farmland etc. by past floods. • Section where disorderly embankment was carried out **<Protected Areas>** o Vast farmland which spreads in the right-and-left both sides in the sections for improvement (especially the right-bank side) **<Improvement Plan >** ▼ Bank improvement and revetment woks and slope protection shall be done. ▼ Inundation starts at the scale of 1/10 year probable discharge, and damage will become serious at the 1/50 year probable discharge. For this reason, the facility plan which can flow down the discharge of 1/50 year probable flood scale shall be adopted.

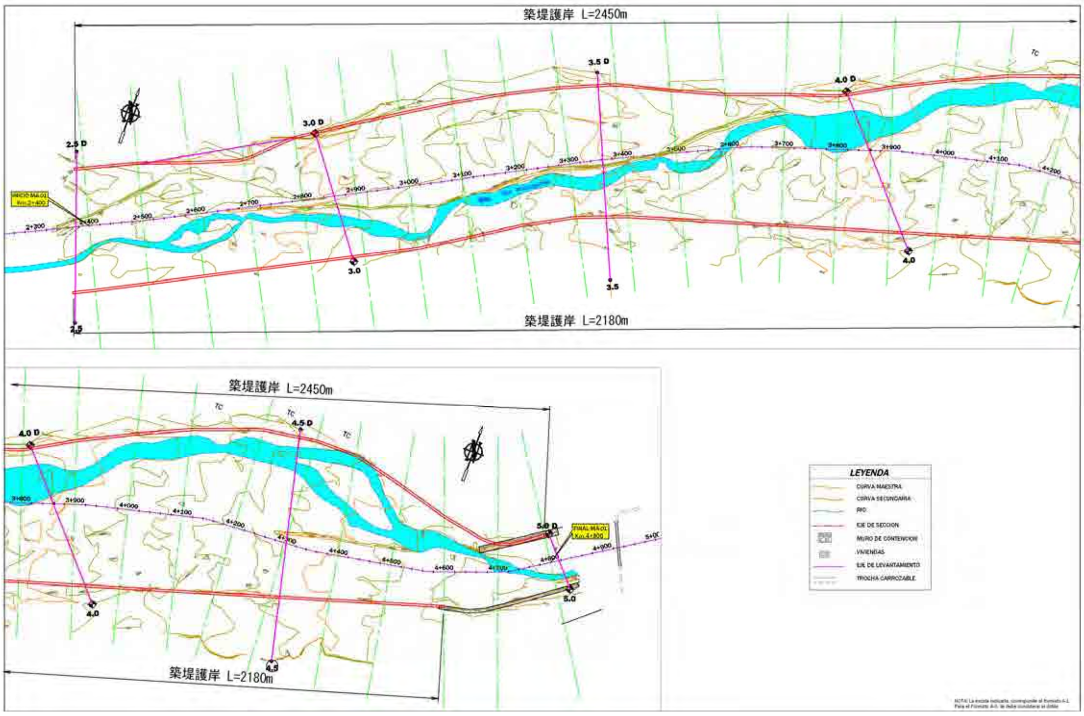


Figure 2.27 Facility Plan in Matagente River-1

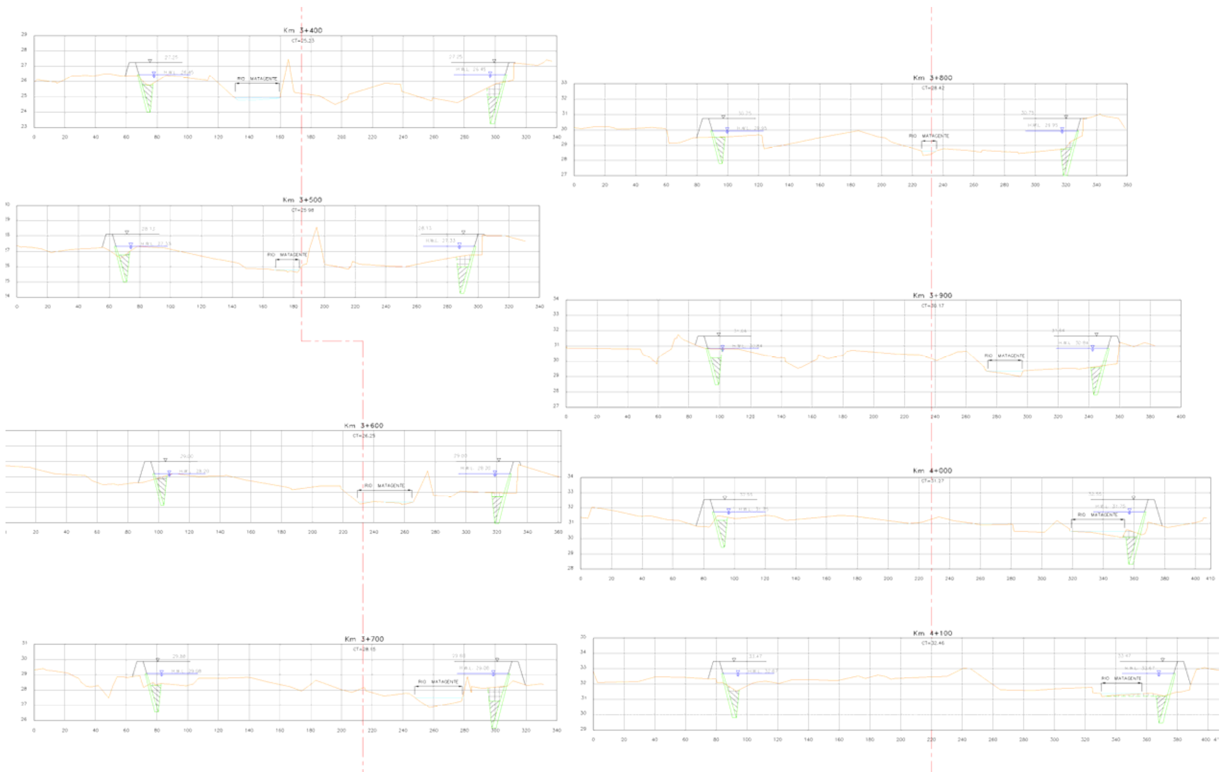


Figure 2.28 Typical Cross Section in Matagente River-1

Outline of Facility (Matagente-2)

No	Sections for Improvement	Improvement Plan
(5)	**Matagente River** 8.0km～10.5km (Whole area)	The sections concerned are damaged by the past floods. While the discharge capacity have been insufficient in the narrow area (at road bridge), the riverbed has risen by about 4-5m in the last 50 years. While the riverbed is excavated, and discharge capacity is enhance (taking into account the foundation at the road bridge), the embankment is needed in the both banks. **<Characteristic of Sections for Improvement>** • Sections where discharge capacity is insufficient for the narrow area near 8.9km mark (road bridge) • Sections where sediment have deposited in an upper part caused by riverbed aggradation by road bridge **<Protected Areas>** o Vast farmland which spreads in both sides of the sections for improvement (especially the right-bank side) **<Improvement Plan >** ▼ Since the riverbed tend to rising, the channel excavation, which can expect the securement of discharge capacity of the area concerned and the water-level lowering effect in the upstream, shall be carried out. ▼ Inundation will start at the scale of 1/10 year probable discharge, and damage will become serious at the scale of 1/50 year probable discharge. For this reason, the improvement plan which can flow down the discharge of 1/50 year probable flood shall be done.

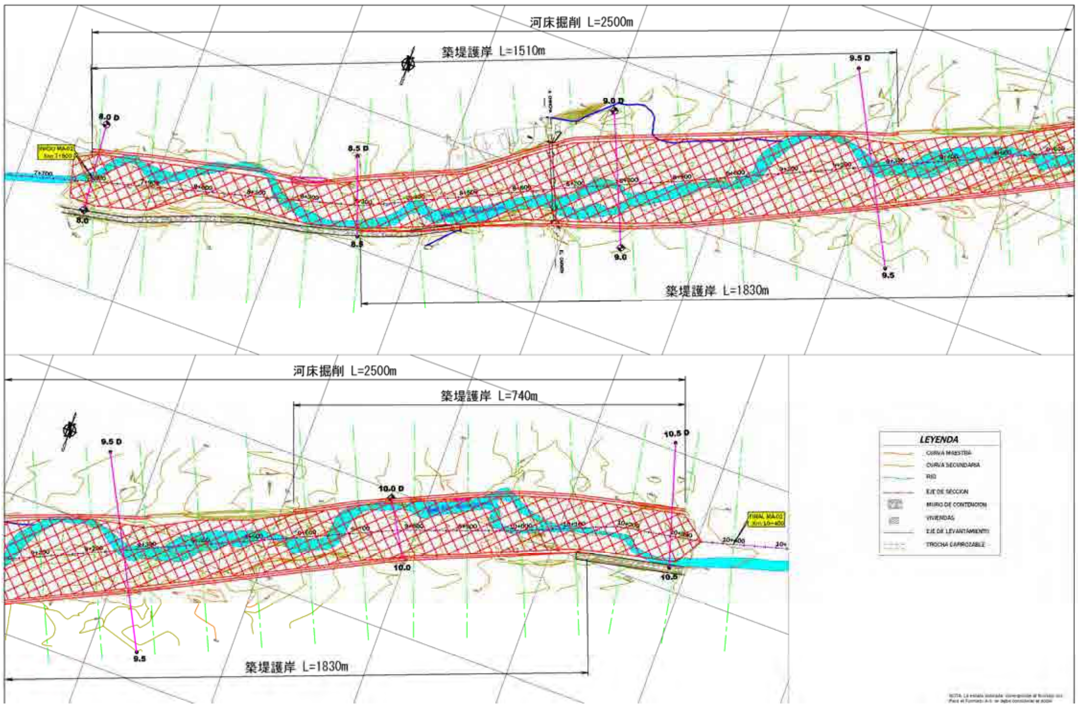


Figure 2.29 Facility Plan in Matagente River-2

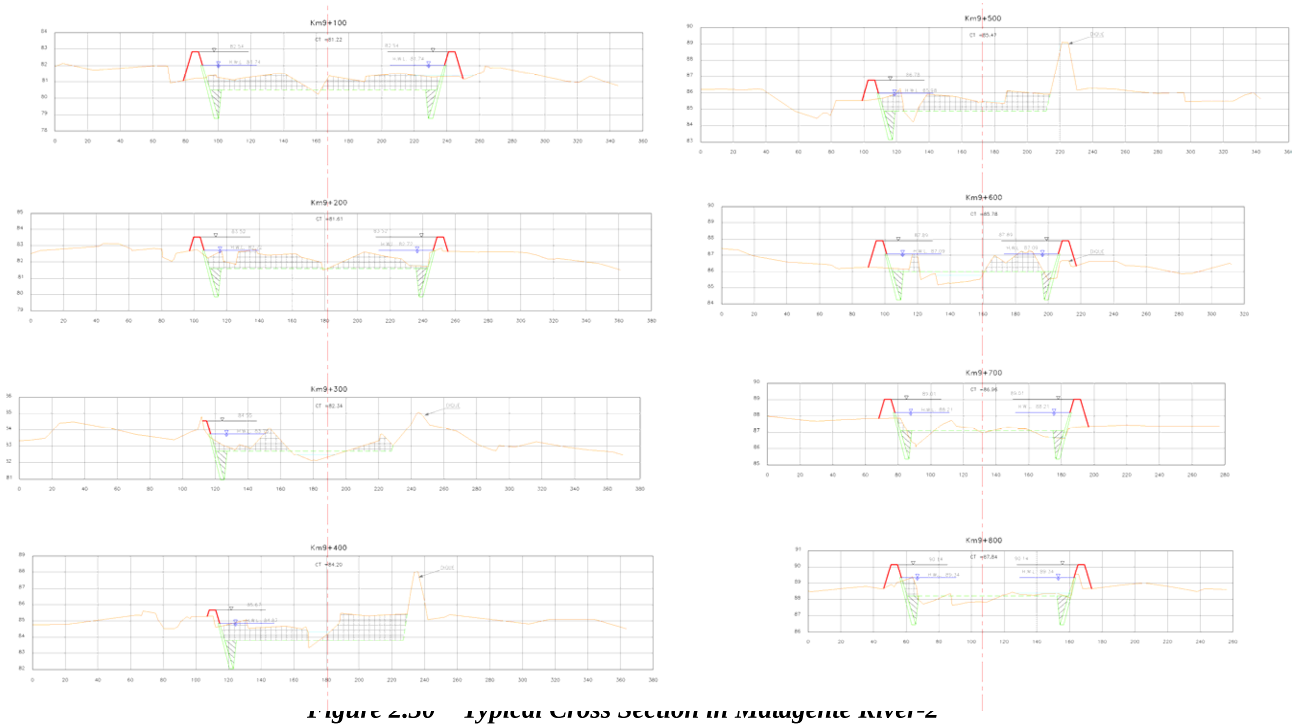
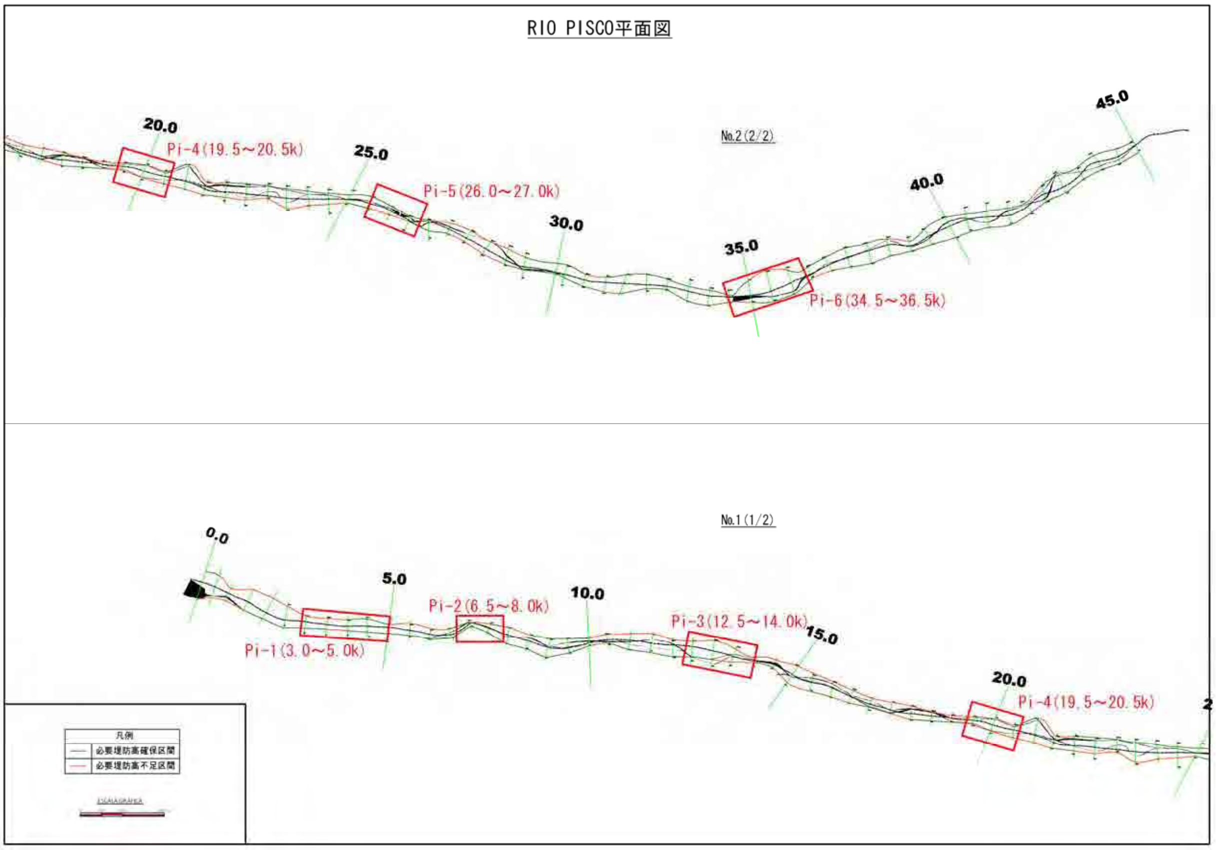


Figure 2.30 Typical Cross Section in Matagente River-2

2.4 Pisco River



In the upstream section from 7km mark, the inundation flow spreads farmland along the channel due to low discharge capacity, however, inundation flow does not spread widely. On the other hand, in the downstream section from 7 km mark, flood flow spreads greatly in the left-bank side, and serious damage to be occurred occurs in the Pisco City. Therefore, for the improvement measures, the embankment in the downstream section of 7 km mark where the highest risks for overflowing is carried out, and the improvement works in low discharge capacity sections and bridge and diversion weir in the upstream section from 7km mark is also conducted.

As for road bridge located in the narrow area of Pan American Road, the renewal was also considered, however, the traffic volume is very large and a substitute bridge and approach roads are needed, so that the project cost become huge. Through the meetings on renewal of bridge, DGIH replied that it was difficult to construct new bridge. Renewal plan of bridge is excluded from river improvement plan.

Outline of Facility (Pisco River-1)

No	Sections for Improvement	Improvement Plan
Pisco River-1	3.0km～5.0km (Right-bank side) + (Left-bank side)	Sections concerned where the impacts to the regional economy should be considered in case of inundation flow reaches urban areas. Moreover, when the upstream section is improved, it is thought that flood also starts and expands in the right-bank side. Since it is meandering section, protection works for slope and foot of bank embankment shall be needed. For this reason, the embankment and the revetment in both sides are required. Moreover, it is also necessary to take notice that the existing dike near 5.0km-5.5km (right-and-left both sides). **<Characteristic of Sections for Improvement>** • Sections where it overflows by flood in the past and the Pisco City area was inundated • Sections which needs the embankment and the revetment in order to prevent the flood of the city area • Sections where the flood also expands to the right-bank side by improvement of the upstream **<Protected Areas>** o Vast farmland which spreads to the both sides of the sections for improvement o Pisco city area of the left-bank side **<Improvement Plan >** ▼ Inundation will begin at the scale of 1/10 year probable discharge, and damage will become serious at the scale of 1/50 year probable discharge. For this reason, the improvement plan which can flow down the discharge of 1/50 year probable flood scale shall be adopted. The improvement shall be done so that the damage does not occurs at 950m3/s (equivalent of 1/50 year probable discharge scale) which brought serious damage in the past. ▼ The embankment and the revetment works shall be carried out in consideration of rover condition in upstream section as well as in downstream section.

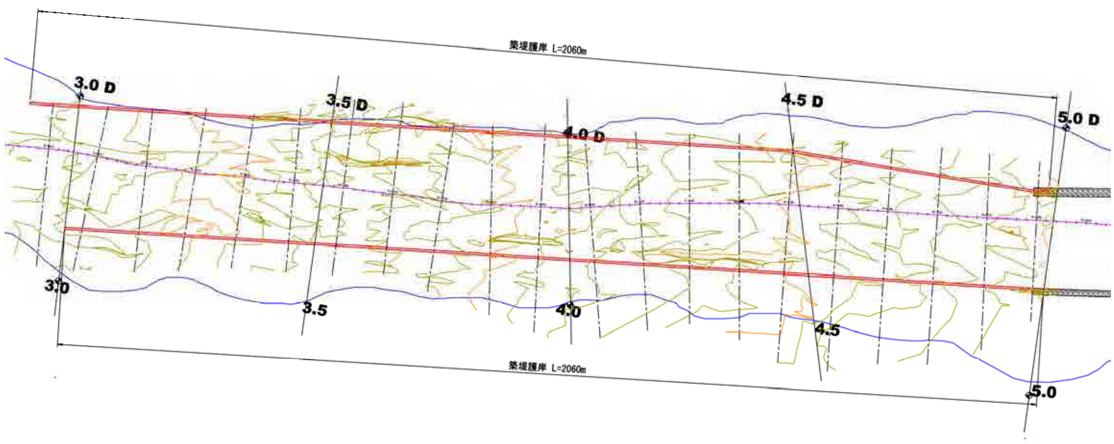


Figure 2.31 Facility Plan in Pisco River-1

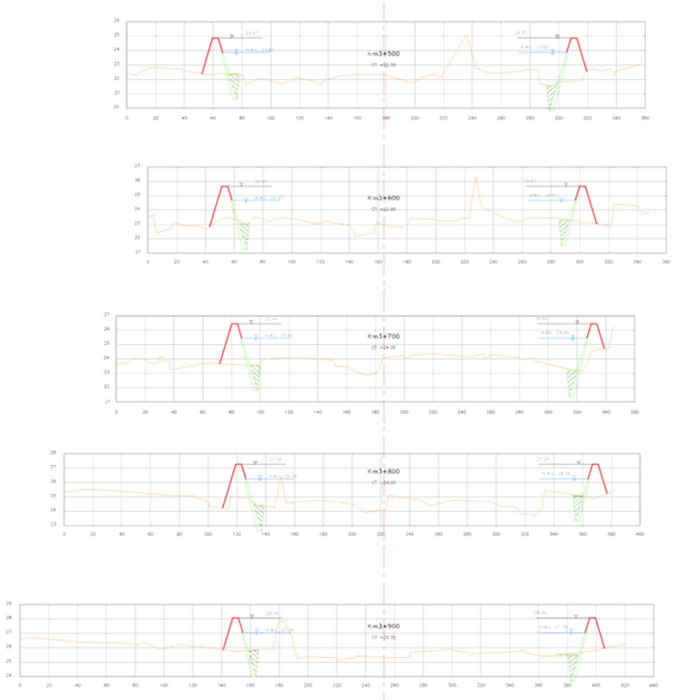


Figure 2.32 Typical Cross Section in Pisco River-1

Outline of Facility (Pisco River-2)

No	Sections for Improvement	Improvement Plan
Pisco River-2	6.5km～8.0km (Channel Dredging)	Section concerned is narrow areas locating road bridge and processing of sedimentation, and the discharge capacity is insufficient. The water level in the upstream section goes up by back water of bridge at the time of flood, and inundation is accelerated. Although improvement of the road bridge is proposed as one of the measures, it is difficult as the present stage (as mentioned above). Therefore, while carrying out channel excavation near the bridge, etc., and the discharge capacity is secured. Lowering water level is also expected. **<Characteristic of Sections for Improvement>** • Sections where there is a narrow area (at the site of road bridge) and where the discharge capacity is low. • Sections where riverbed aggradation is remarkable due to sediment deposition • Sections which can be planned in the water-level lowering in the upstream by carrying out the channel excavation **<Protected Areas>** o The farmland in the left-bank side in the upstream section. **<Improvement Plan >** ▼ Since inundation of the upstream tend to promote due to the shortage of the discharge capacity in the sections, the river facilities which can flow down the discharge of 1/50 year probable discharge scale shall be improved. ▼ The facilities is also improved so that the damage does not occurs in 950m3/s (equivalent of 1/50 year probable discharge scale) which brought serious damage in the past. ▼ The sections concerned which secures the discharge capacity by the excavation of the channel without widening the road bridge (Pan Americana).

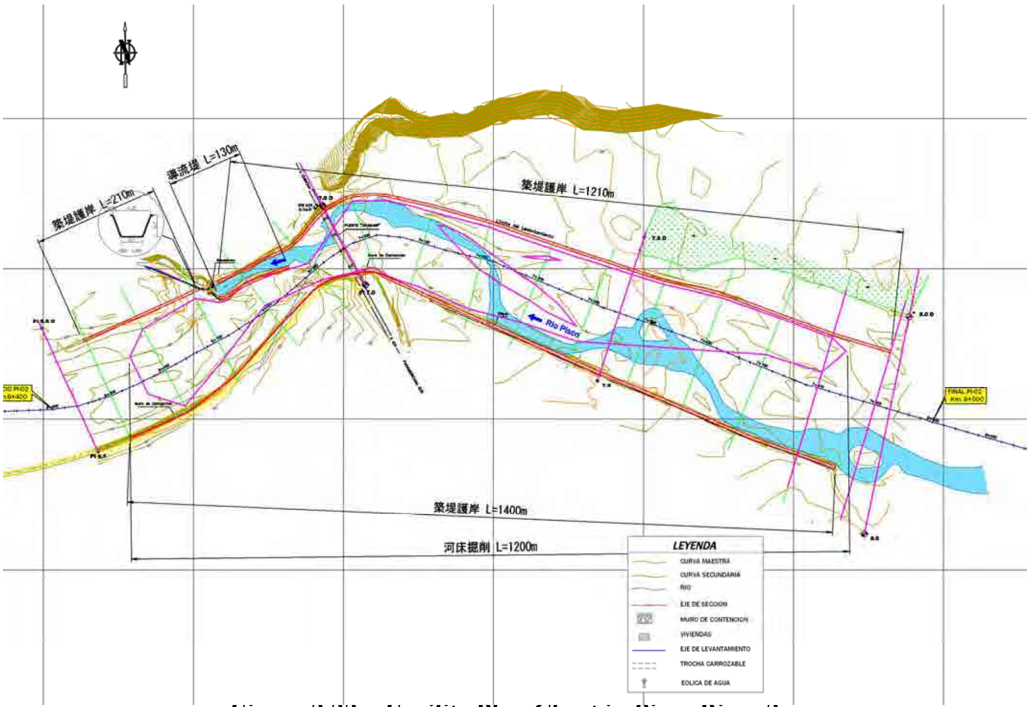


Figure 2.33   Facility Plan Chart in Pisco River-2

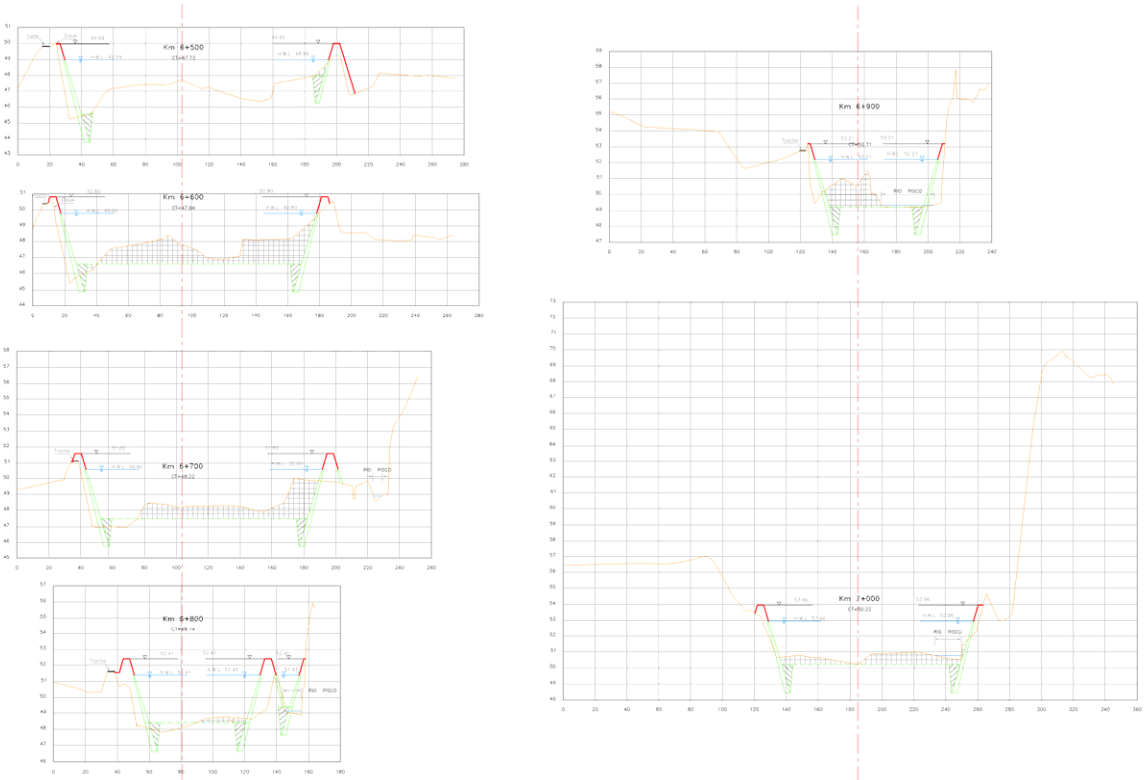


Figure 2.34   Typical Cross Section in Pisco River-2

Outline of Facility (Pisco River-3)

No	Sections for Improvement	Improvement Plan
Pisco River-3	12.5km～14.0km (Left-bank side)	The section concerned has the lowest discharge capacity in the left-bank side, and the possibility of overflowing also in small-scale floods is remarkably high. Since there is high possibility of bringing damages to the farmland of the left-bank side, and causing serious damages by large-scale floods, it is necessary to construct the embankments and the revetments immediately. In addition, since the new embankment works near 14.5km -14.0km has already carried out, it is necessary to take enough attention for the works in transition section. **<Characteristic of Sections for Improvement>** • Sections where the left bank broken by the past flood flow • Sections where the bank improvement progressed in the past, but stops now on the way **<Protected Areas>** o The left-bank side of the protected sections and the farmlands in the downstream **<Improvement Plan >** ▼ Flood will begin at the scale of 1/10 year probable discharge, and damage will become serious at the 1/50 year probable discharge. For this reason, the improvement plan which can flow down the discharge of 1/50 year probable flood scale shall be done. ▼ In order to enhance the discharge capacity, the embankment and the revetment works in the insufficient section shall be carried out efficiently by taking advantage of the existing dikes and land features.

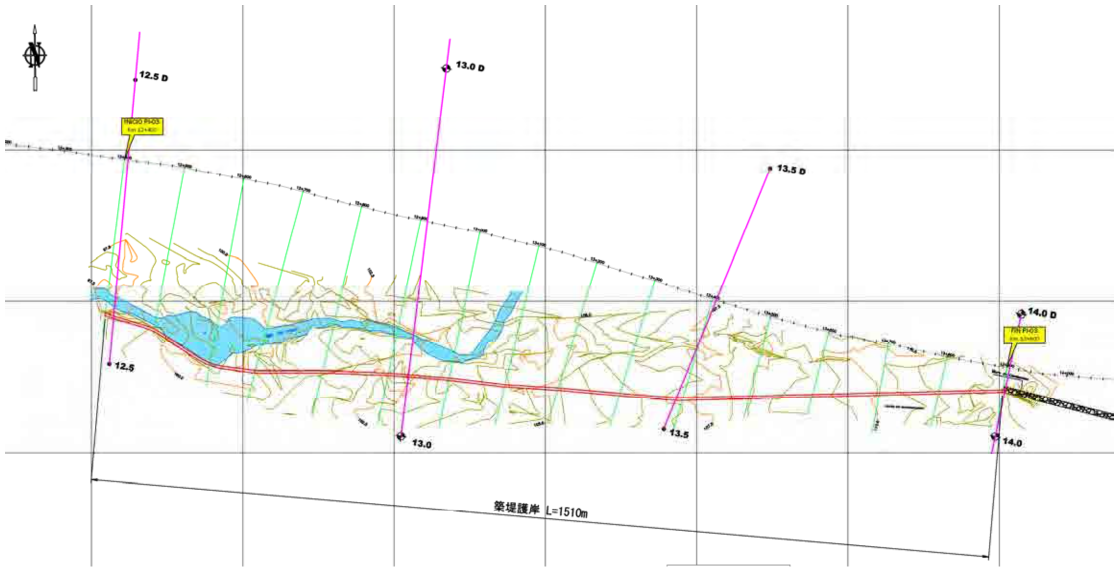


Figure 2.35 Facility Plan Chart in Pisco River-3

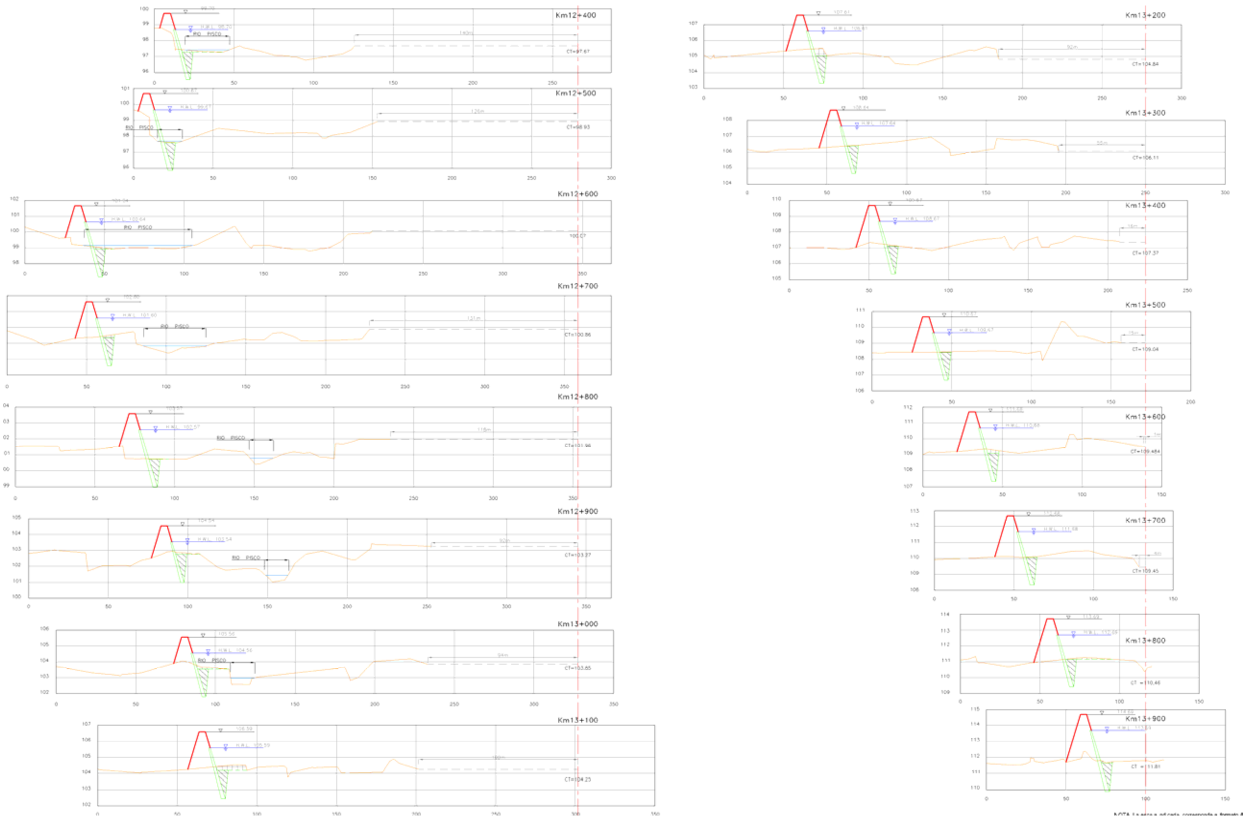


Figure 2.36 Typical Cross Section in Pisco River-3

Outline of Facility (Pisco River-4)

No	Sections for Improvement	Improvement Plan
Pisco River-4	19.5km～20.5km (Right-bank side)	In the sections concerned, the discharge capacity of the left-bank is the lowest in the circumference, and the possibility of overflowing by small-scale floods is very high. Since there is high possibility of bringing damage repeatedly to the farmland in the side of the left bank, and occurring serious damage by large-scale floods, it is necessary to improve the dikes and the revetments immediately. **<Characteristic of Sections for Improvement>** • Sections where both banks were flooded due to no dikes, and the water conduit to the Pisco City was washed away. • Sections where the riverbed has been rising in recent years • Sections which needs the embankments and the revetments in order to improve the shortage of discharge capacity. **<Protected Areas>** o Farmland in the left-bank in the protected area. o Water conduit for Pisco City (Important facility) **<Improvement Plan >** ▼ Flood will begin at the scale of 1/10 year probable discharge, and damage will become serious at the scale of the 1/50 year probable discharge. For this reason, the facilities which can flow down the discharge of 1/50 year probable flood scale shall be introduced. Moreover, the protection of the water conduit to Pisco city area should be taken account. ▼ In order to enhance the discharge capacity, the embankment of the insufficient section in the dike sections shall be done with taking advantage of the existing dike, land features.

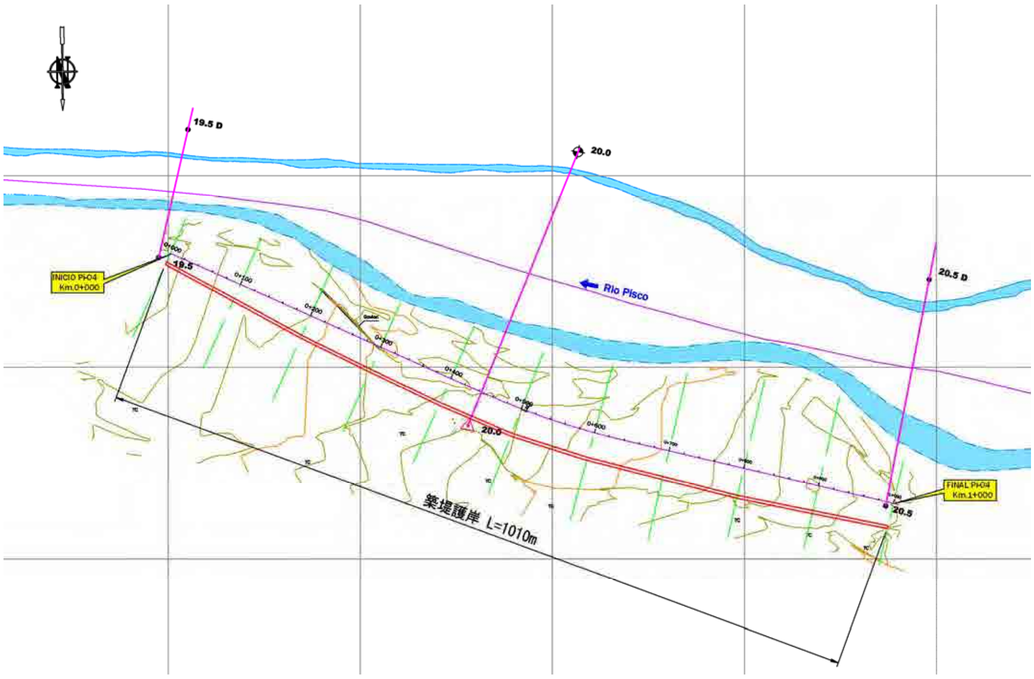


Figure 2.27 Facility Plan Chart in Pisco River-4

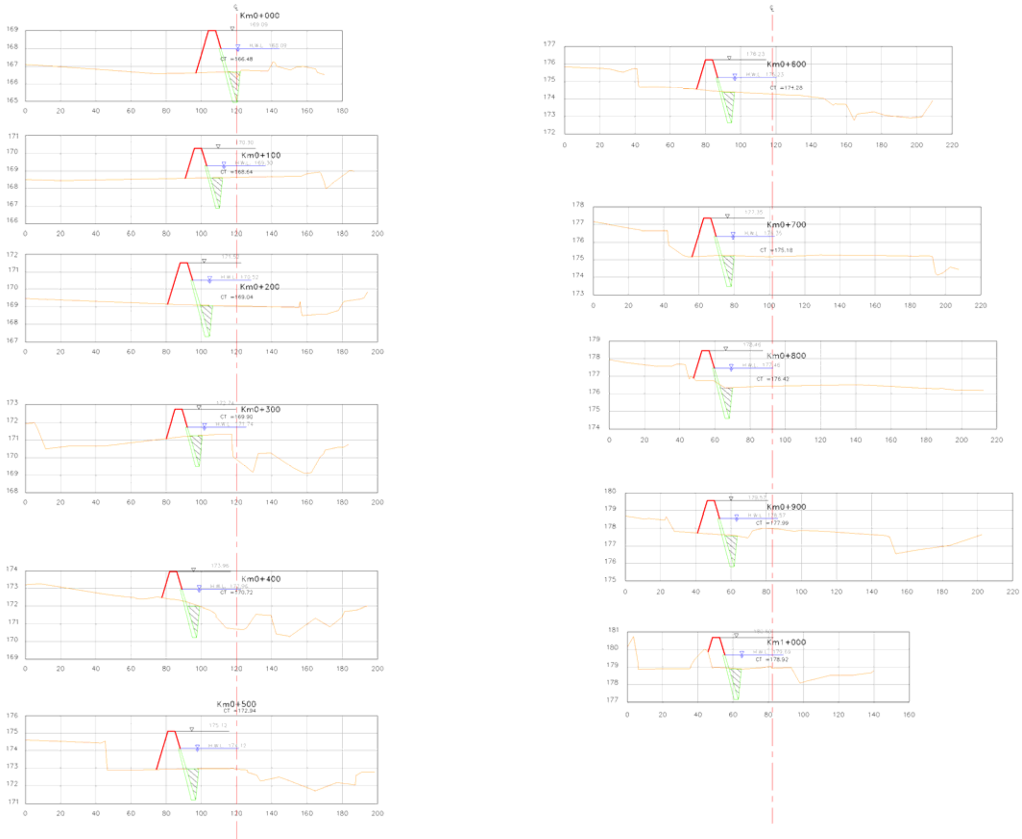


Figure 2.28 Typical Cross Section in Pisco River-4

Outline of Facility (Pisco River-5)

No	Sections for Improvement	Improvement Plan
Pisco River-5	26.0km～27.0km (Channel widening in left-bank side)	Section concerned is important to protect the function of the intake facility. It is the sections where the sluice gate was destroyed by the past flood, sediment accumulated, and the irrigation canal also damaged with no operation. For this reason, at the 26.75km mark (at the upstream of the weir), it is necessary to construct the diversion weir which the flow water flows into the right-bank side at the time of low water level, and much flow water flows into the left-bank side at the time of floods. **<Characteristic of Sections for Improvement>** • Sections where the sluice gate was destroyed by the flood in 1998, and the irrigation canal was also buried with sediment • Sections which needs a diversion facility because of functional securement for intake weir. **<Protected Areas>** o Intake weir in the right-bank side **<Improvement Plan >** ▼ Weir is the most important facility for taking water, it is very serious in case that the facility function is damaged. For this reason, it is necessary to improve the facility so that the damage does not occurs at the scale of 950m3/s (equivalent of 1/50 year probable discharge) which brought serious damage in the past. ▼ Since there are no existing dikes, in consideration of the current situations and the characteristics, the widening of the channel shall be carried out. (In the road bridge section in the channel shall be excavated)

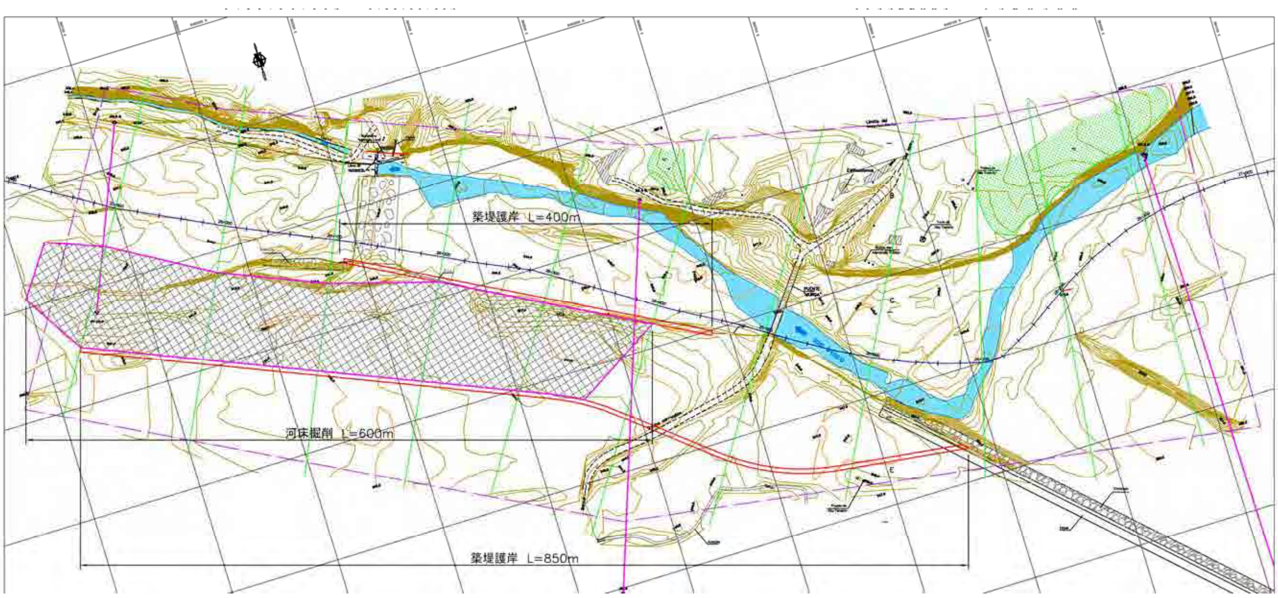


Figure 2.29 Facility Plan Chart in Pisco River-5

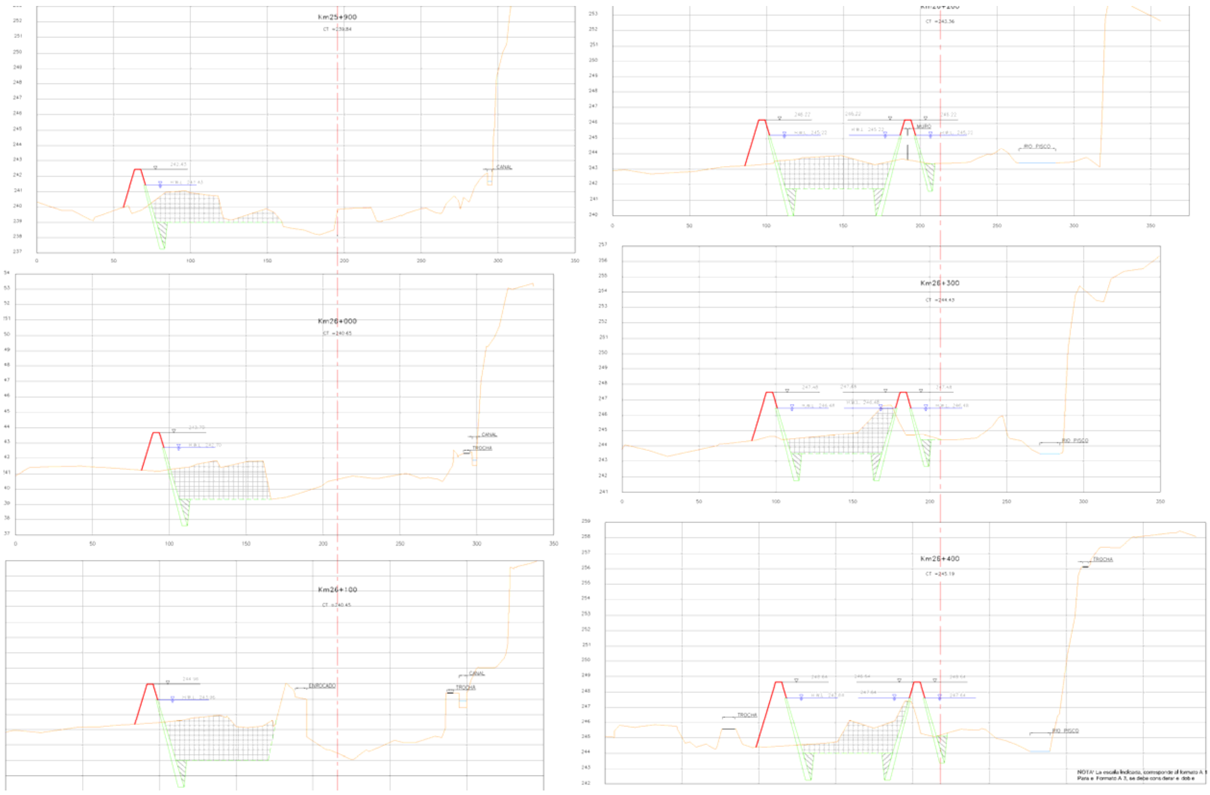


Figure 2.30 Typical Cross Section in Pisco River-5

Outline of Facility (Pisco River-6)

No	Sections for Improvement	Improvement Plan
Pisco River-6	34.5km～36.5km (Whole area)	Section at weir of the 34.5 km mark is narrow area, and great quantity of sediment has accumulated in the upstream. Therefore, it is important to devise so that the section concerned may be utilized effectively, and the upstream section at the weir may be used as retarding reservoir and sand pocket in order to demonstrate retarding effect at the time of the floods. While utilizing effectively the facility concerned against flood which exceeds the planned scale, the deposit function of sediment discharge shall be secured. Ideally, it is desirable to secure the safety factors at the scale of 1/50 year probable flood from the downstream section to upstream section by gradation. It is important, at present stage, to consider the effective use river facilities concerned so that the inundation water exceeding the designed scale (1/50 year probable flood scale) does not flow to downstream. section **<Characteristic of Sections for Improvement>** • Overflow in the right-bank in the upstream of the weir • Sections where effective use of the existing facility (sediment measures, etc.) is important **<Protected Areas>** o The whole downstream areas **<Improvement Plan >** ▼ Sections concerned locates in the upstream of the Pisco River , and is most suitable part for controlling the sediment and the flow water. Pisco River has the characteristics that the inundated area increases gradually whenever the discharge increases. When the discharge increases to the scale for 1/10 year probability flood, the amount of damage trends to increase greatly. When the discharge exceeded at

		the scale of 1/50 year, the amount of damage is thought to increase further. Therefore, considering the characteristics of the Pisco River , it is important to take measures against the excess flood more than the 1/50 year probable flood. ▼ Accordingly, when the flood more than the 1/50 year probable flood is generated, improvement which stores the excess volume of the flood flow water, and further improvement with the sediment storage function which does not discharge sediment to downstream immediately shall be done.

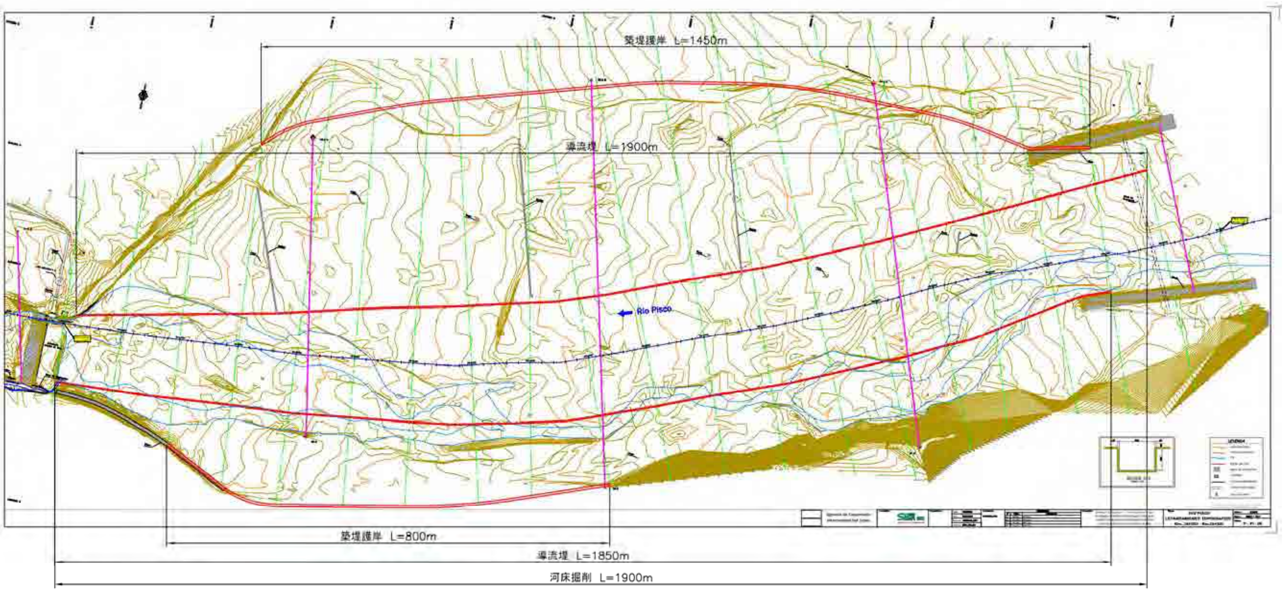


Figure 2.31 **Facility Plan in Pisco River-6**

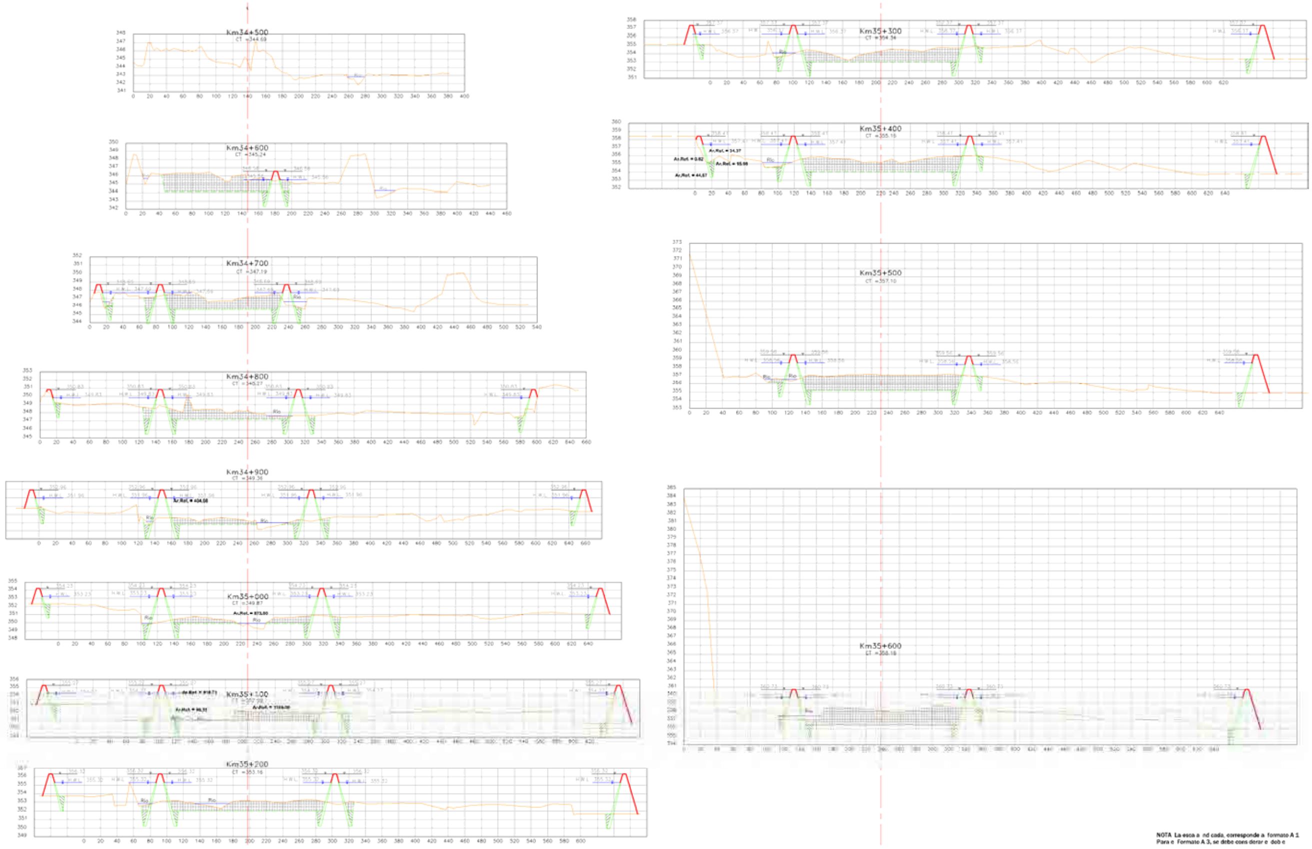
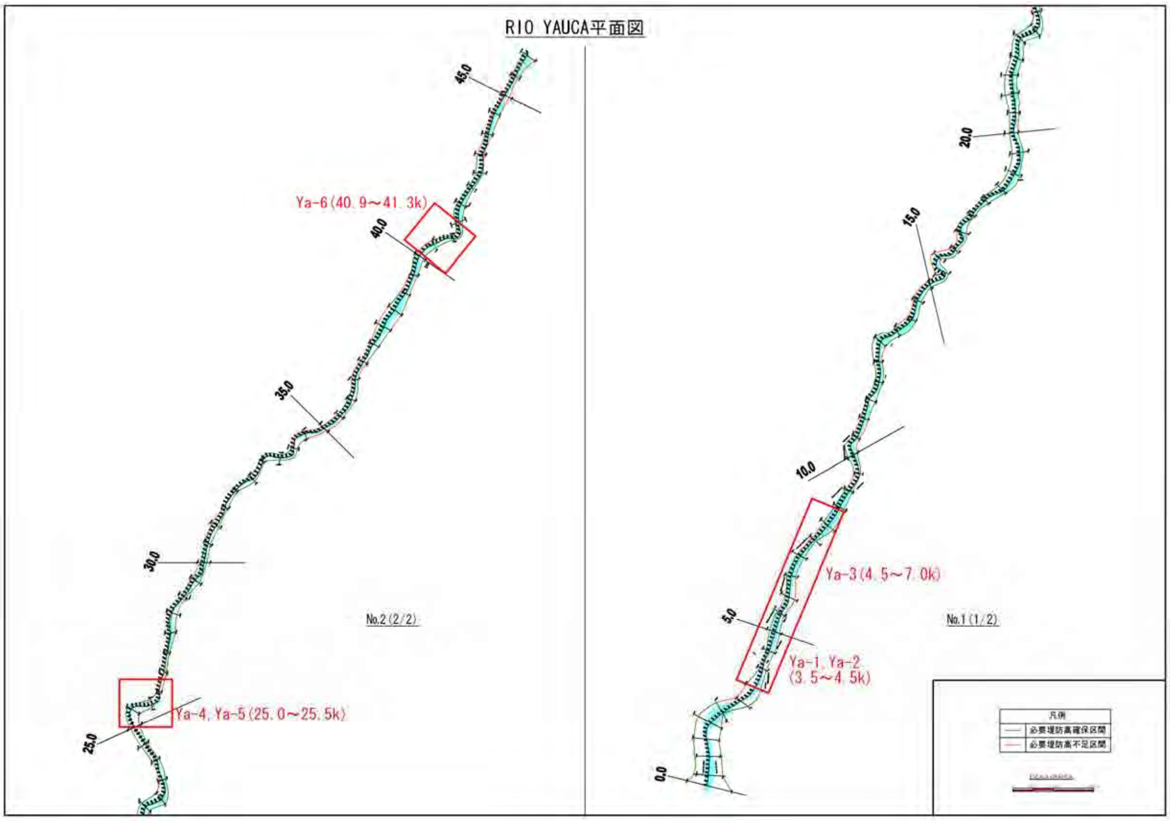


Figure 2.32 Typical Cross Section in Pisco River-6

2.5 Yauca River



As the characteristics of the Yauca River , it overflows in the downstream section from near 7km mark of the river mouth, and flood flow tend to spread in the farmland of the right-bank side. Therefore, the measures for preventing the inundation to farmland in the downstream section from the 7km mark, and the countermeasures for the part affected to intake weir or local main road by bank erosion in the upstream section from 7km mark are implemented preferentially.

Outline of Facility (Yauca River-1)

No	Sections for Improvement	Improvement Plan
Yauca River-1	3.5km～7.5km (Left-bank side)	On the existing dike located in the sections concerned, since erosion occurs at the time of floods and there is possibility of bank collapse, it is necessary to carry out restoration reinforcement and revetment works. **<Characteristic of Sections for Improvement>** • Sections where the flood occurred in the downstream and the olive trees of the local specialty products washed away • Sections where the existing dike has damaged and should be repaired **<Protected Areas>** o Farmland of the right-bank side (Olive fields for the local specialty products) **<Improvement Plan >** ▼ Protected Areas in the river is olive fields which product of the local specialty of the area. Therefore, the revetment works with existing dikes for preventing the erosion affected by the past flood (1/50 year probable flood scale) shall be done.

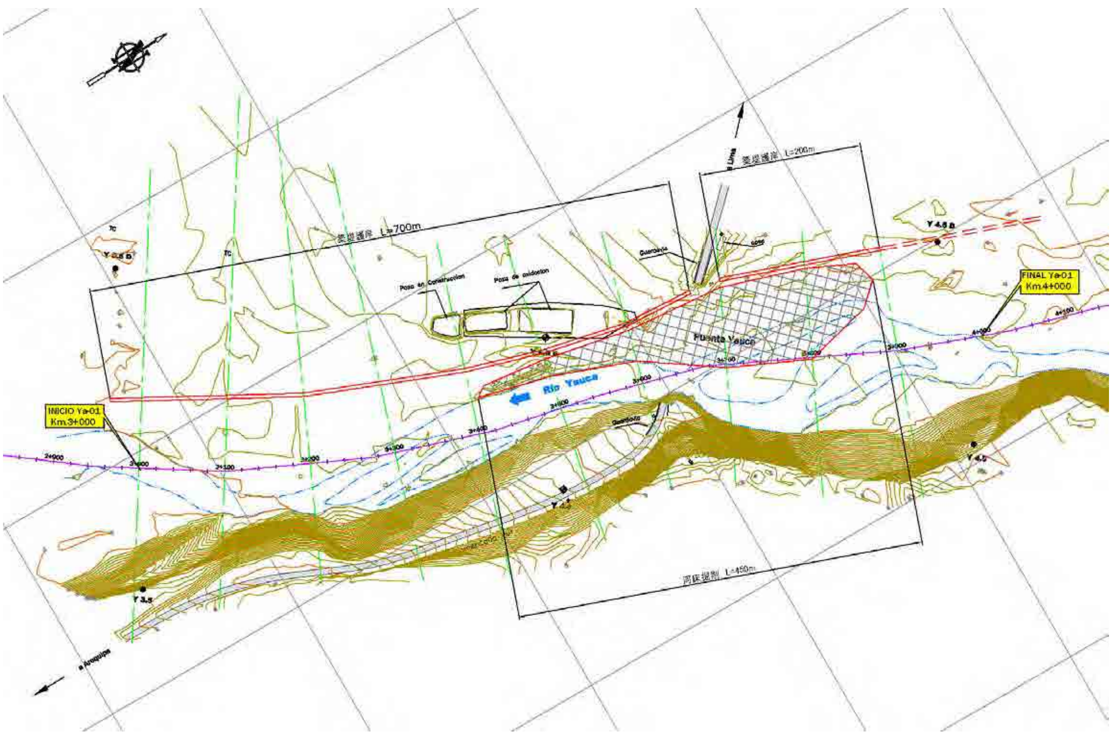


Figure 2.33 Facility Plan in Yauca River-1, Yauca River-2, Yauca River-3

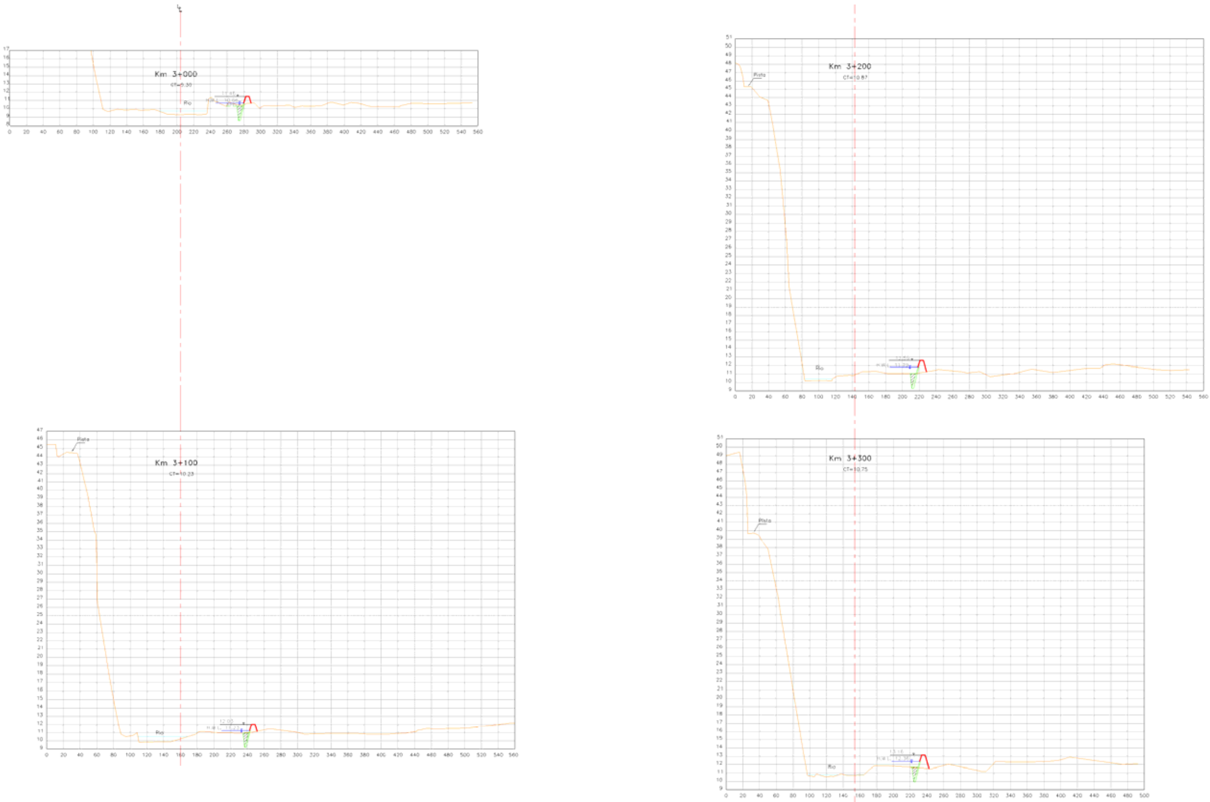


Figure 2.34 Typical Cross Section in Yauca River-1

Outline of Facility (Yauca River-2)

No	Sections for Improvement	Improvement Plan
Yauca River−2	3.5km～7.5km (Left-bank side)	It overflows in the downstream from near the 7km mark, and the inundation flow spreads in the farmland in the right-bank side. The securement of the discharge capacity near the road bridge is required. **<Characteristic of Sections for Improvement>** ●Sections which is the narrow area (near the road bridge) and is the insufficient part for the discharge capacity ●Sections which are riverbed aggradation caused by sediment deposition due to the narrow area. ●Sections where the water-level lowering effect in the upstream by carrying out channel excavation can be planned **<Protected Areas>** ○Farmland in the right-bank of the Improvement (Olive fields) **<Improvement Plan >** Considering on hydraulic balance in upstream and downstream section, channel excavation and securing the discharge capacity as well as the water-level lowering shall be planned.

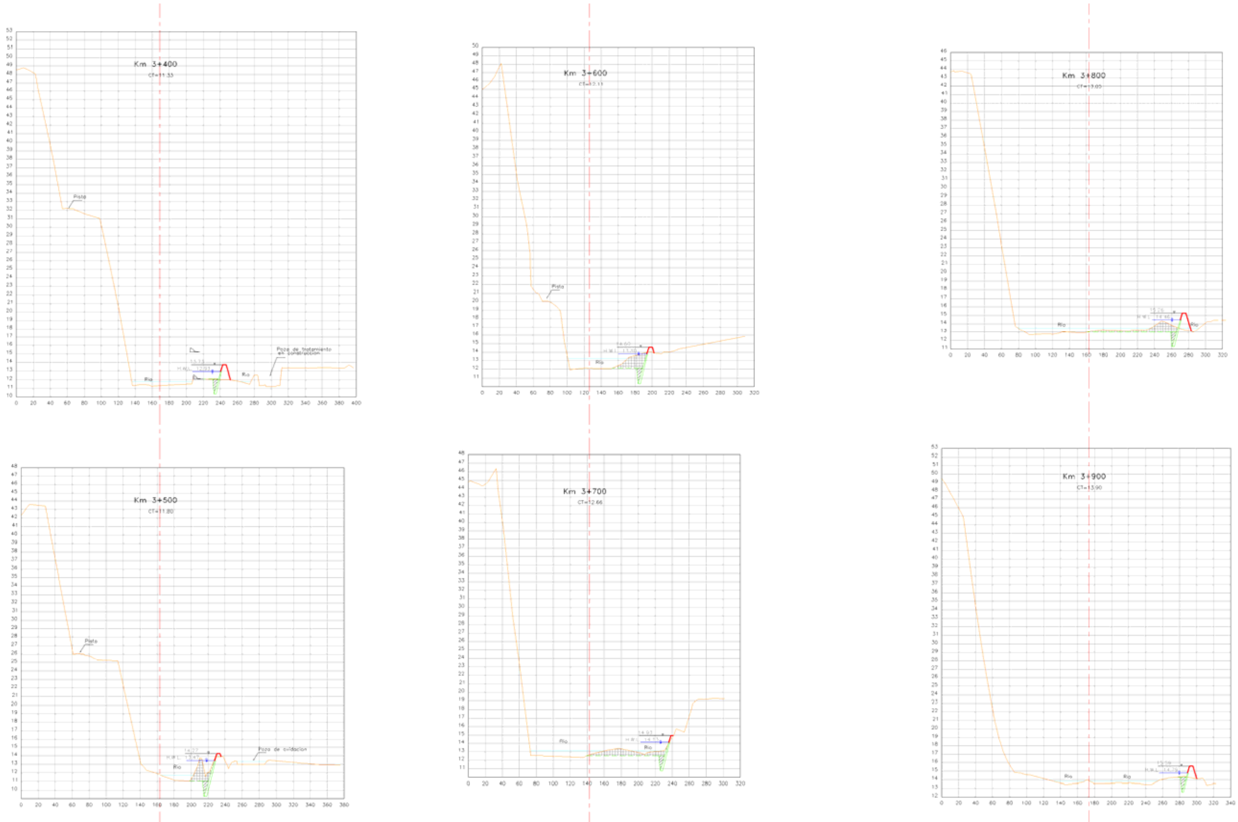


Figure 2.35 Typical Cross Section in Yauca River-2

Outline of Facility (Yauca River-3)

No	Sections for Improvement	Improvement Plan
Yauca River-3	3.5km～7.5km (Left-bank side)	It overflows in the downstream from near 7km mark, and the inundation flow spreads in the farmlands of the right-bank side. In the sections concerned, since the existing dike has the possibility of erosion at the time of flood, the improvement and the reinforcement of the existing dike, and the revetment work shall be required. **<Characteristic of Sections for Improvement>** ● The dike is located partially in the both sides. The sections where the embankment is carried out experientially every year ● Sections where olive fields are washed away with floods ● Sections where the existing dike has damaged and the repair is required **<Protected Areas>** o Farmlands in the right-bank (Olive fields) **<Improvement Plan >** ▼ Protected Areas in the river is olive fields which product of the local specialty of the area. Therefore, the revetment works with existing dikes for preventing the erosion affected by the past flood (1/50 year probable flood scale) shall be done.

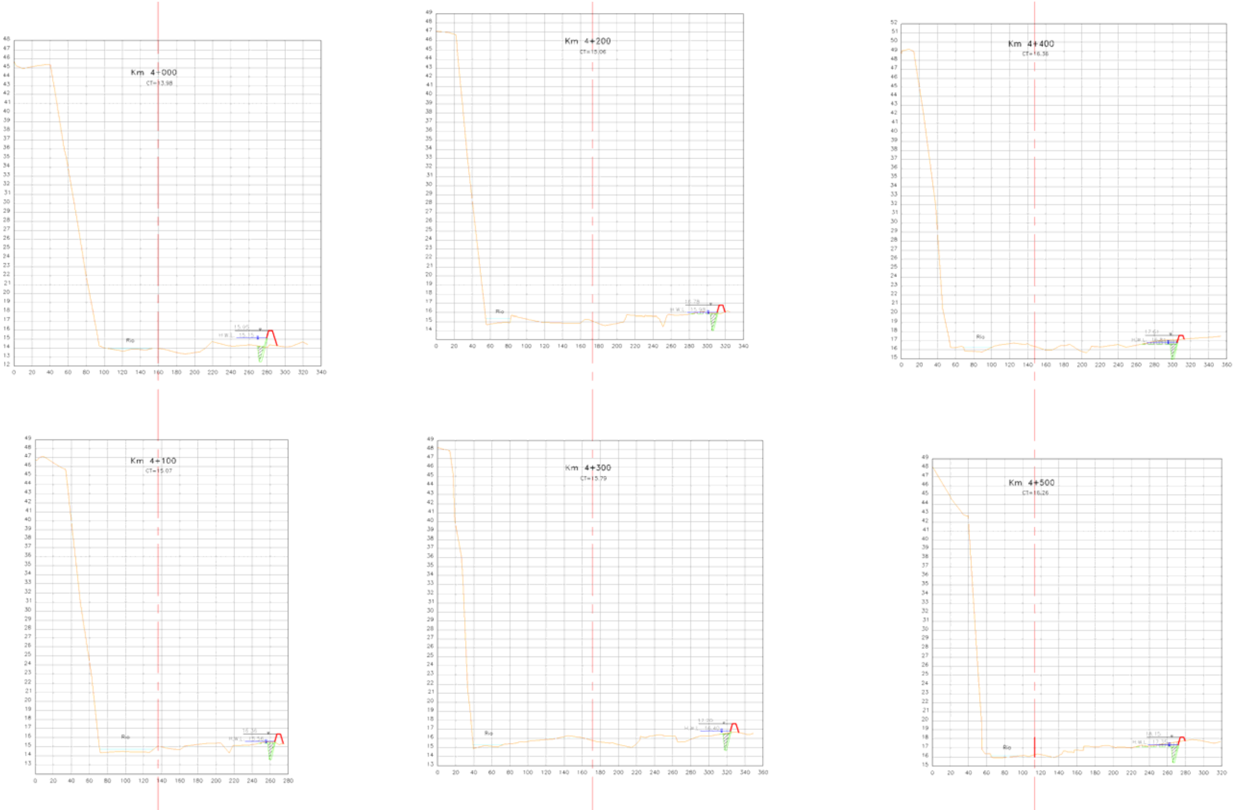


Figure 2.36 Typical Cross Section in Yauca River-3

Outline of Facility (Yauca River-4)

No	Sections for Improvement	Improvement Plan
Yauca River-1	25.0km～25.7km (Whole area)	Intake weir is located in the right-bank side of the sections concerned. Since the private land in the left-bank side has stretched out into the river side largely, and the inundation flows directly come into intake weir. Intake weir becomes a difficult situation by sedimentation or damage of facility. Therefore, it is necessary to set the channel cross section in consideration of the flow regime of the river. **<Characteristic of Sections for Improvement>** • Sections where functional in operation of the intake weir is prioritized. • Sections where the clarification of river zone in the left-bank and the securement of flow capacity in channel cross section is important **<Protected Areas>** o Intake weir **<Improvement Plan >** ▼ It is the most important intake facility in the river, and the influence affected to the area is serious when the facility is destroyed. Therefore, the facility improvement shall be required so that damage does not occur at scale of 210m3/s (equivalent for 1/50 year probable flood) which brought damage in the past. ▼ Sediment deposits in the intake weir of the sections concerned, and the intake is in difficult situation. Moreover, since the private land in the left-bank is stretched out into the river side largely and inundation water flows directly into the intake weir in the right-bank at the time of floods, the alignment of the river is set in consideration of the flow regime in the whole sections.

Outline of Facility (Yauca River-5)

No	Sections for Improvement	Improvement Plan
Yauca River-5	25.0km～25.7km (Whole area)	Section concerned is the meandering section, the flow velocity of the right-bank is high, and bank erosion is in progress. Local main road running in the right-bank of the upstream of the sections, and if it is neglected as it is, the riverbank will be eroded and finally the transportation of road. Will become difficult situation. Therefore, in order to protect the road, the measures for erosion such as the revetment works, etc. are shall be required. **<Characteristic of Sections for Improvement>** • Sections in which the erosion of right-bank side (local main road on the bank) in progress • Sections which the erosion control of the riverbank and the functional preservation of the local main road should be carried out, simultaneously **<Protected Areas>** o Main road located in the right-bank side in the sections **<Improvement Plan >** ▼ Since the impact to the regional economy caused by the local main road collapsing is large, the facility shall be improved so that the damage does not generate in 210m3/s (equivalent for 1/50 year probable flood) which brought damage in the past. ▼ If it is neglected as it is, it is anxious that the riverbank will be eroded and the road will collapse. The measure against erosion is implemented by the revetment works in order to protect the roads.

Figure 2.37 Facility Plan Chart in Yauca River-4, Yauca River-5

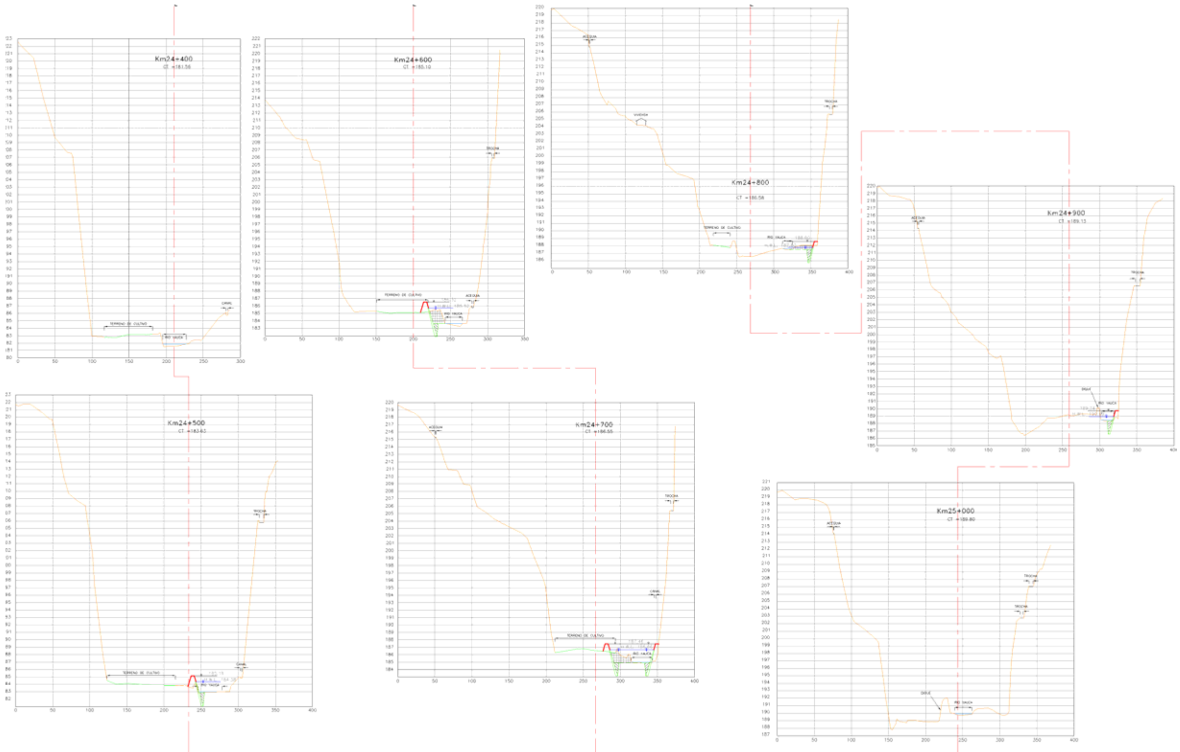


Figure 2.38 Typical Cross Section in Yauca River-4, Yauca River-5

Outline of Facility (Yauca River-6)

No	Sections for Improvement	Improvement Plan
Yauca River-1	40.9km～41.3km (Left-bank side)	Intake located in the upstream of the Yauvca River is an important facility from the viewpoint of supply of city water. However, while the erosion in the left-bank side of the weir has progressed, transportation for the local main road located on the left-bank of the upstream has also interfered. Therefore, the measures against bank erosion of the sections concerned shall be immediately required. **<Characteristic of Sections for Improvement>** • Sections where the lower part of the road located in upstream and downstream of the intake weir has received erosion • Sections which the erosion control of the riverbank, and the functional preservation of the local main road should be carried out, simultaneously **<Protected Areas>** o Intake weir o Local main road located in the left-bank **<Improvement Plan >** ▼ It is the most important intake in the river, and the influence affected to the area is serious when the facility function is damaged. Therefore, the facility improvement is required so that damage does not generate in 210m3/s (equivalent for 1/50 year probable flood) which brought damage in the past. ▼ Since the intake weir is important to secure water supply, and there is high possibility that the local main road will collapse when the erosion in the left-bank side of the upstream of the weir progresses, the measures against bank erosion shall be implemented.

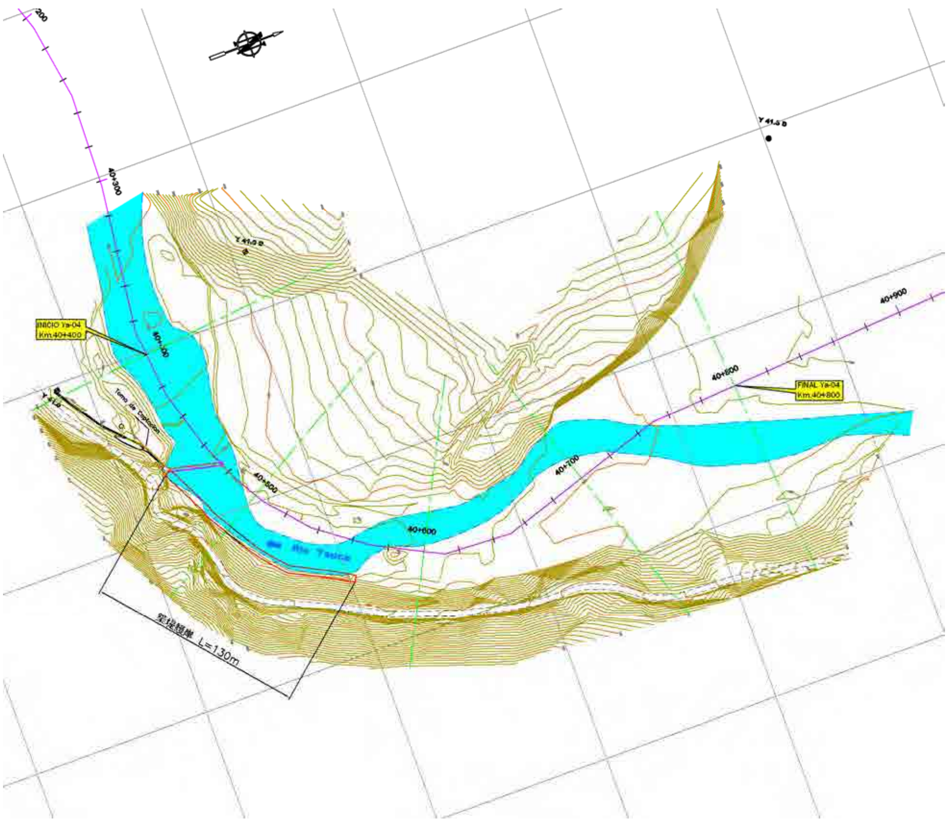


Figure 2.39 Facility Plan in Yauca River-6

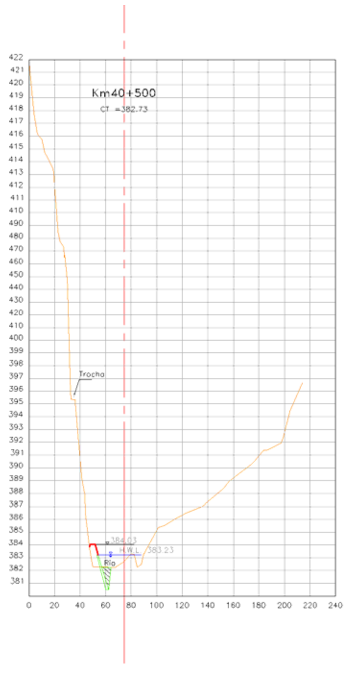


Figure 2.40 Typical Cross Section in Yauca River-6

2.6 Majes-Camana River

Existing bank in the Camana River in the downstream is degraded, and many erosion parts appear there.

Since inundation occurs in the upstream (Majes River) at present, inundation in the targeted section (Camana River) is mitigated. If improvement of the upstream will progress from now on, the influence affected to the Camana River will become large, and the flood areas become large.

Moreover, the intake weir for water supply to the Camana City is installed near the 13km mark, and the irrigation canal run along the riverside. The part of the left bank of 12km is eroded now, and the influence on the adjoining irrigation canal is anxious. On the other hand, no dike sections are located in the Majes River in the upstream, the overflow by flood water and the farmland damage by flood have generated every year.

Therefore, improvement for aged dikes and the securement of the dike height is the key measures for the prevention in the left-bank side in the downstream of the Camana River where damage potential by flood is high. Bank improvement in the sections where damage occurs frequently due to no dikes in the upstream of the Majes River shall be carried out preferentially. In addition, since improvement in the Majes River also affects the Camana River in the downstream, it is necessary to consider the order of implementation measures, etc.

Outline of Facility (Camana River-1)

No	Sections for Improvement	Improvement Plan
Camana River-1	0.0km-4.5km (Left-bank side)	The existing dike in the sections concerned is superannuated and many erosion parts appear here and there. Since floods occurs in the upstream (in Majes River) at present, the flood of the area (in Camana River) is mitigated. When the improvement in the upstream will progress from now on, the influence by improvement in the area will become large and the inundated area will become large. **<Characteristic of Sections for Improvement>** • Sections where the measures against aged existing dike and securement of dike height are important • Sections which affects the influence to Camana City and vast farmlands by the flood in the left-side bank • Sections where the danger of the flood increases accompanying with the improvement of the upstream **<Protected Areas>** o Vast farmland which spreads in the left-bank o Camana City area **<Improvement Plan >** ▼ As the characteristics of the most downstream section in the Camana River , when the Majes River overflows, the flood damage is mitigated, but when improvement of the Majes River progresses, the damage in the left-side in the downstream is expanded greatly, and the influence will also reach the Camana City. Moreover, as the characteristics of the Camana River , when the flood exceeding the scale 1/50 year probable flood will be generated, the damage will become serious. Therefore, the facility should be designed to be safe for the flood of 1/50 year probable flood scale. ▼ Embankment and the revetment works for the existing dikes in the sections where discharge capacity is insufficient shall be carried out.

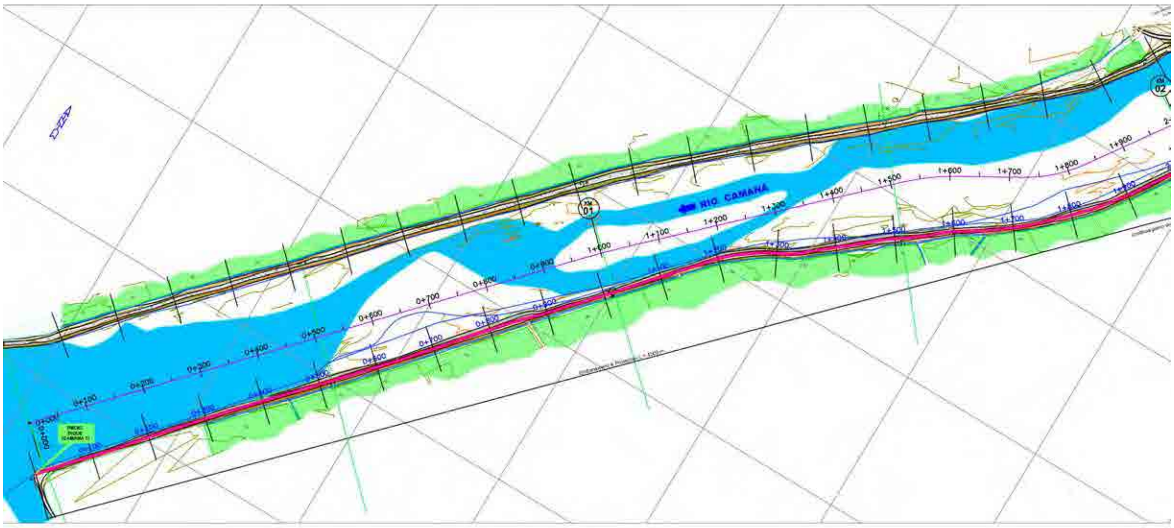


Figure 2.41 Facility Plan in Camana River-1 (1)

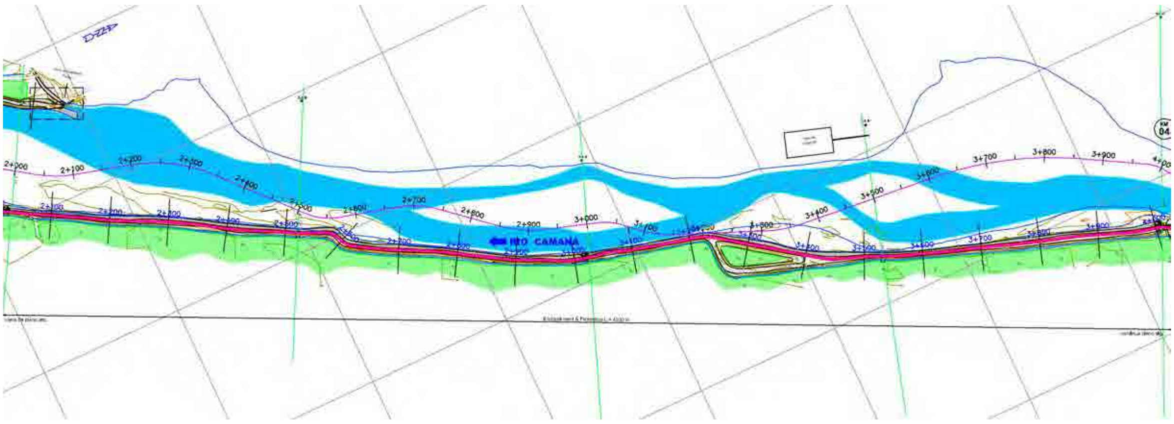


Figure 2.42 Facility Plan in Camana River-1 (2)

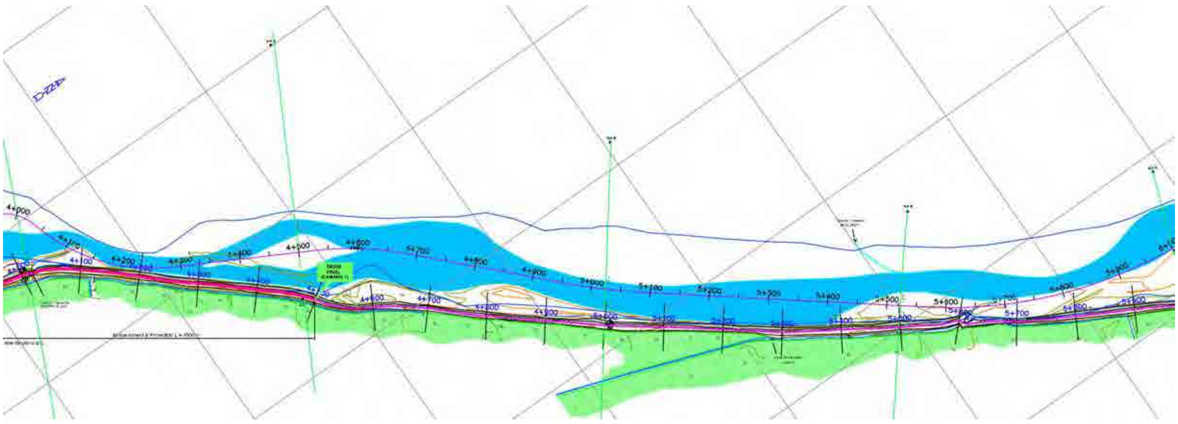


Figure 2.43 **Facility Plan in Camana River-1 (3)**

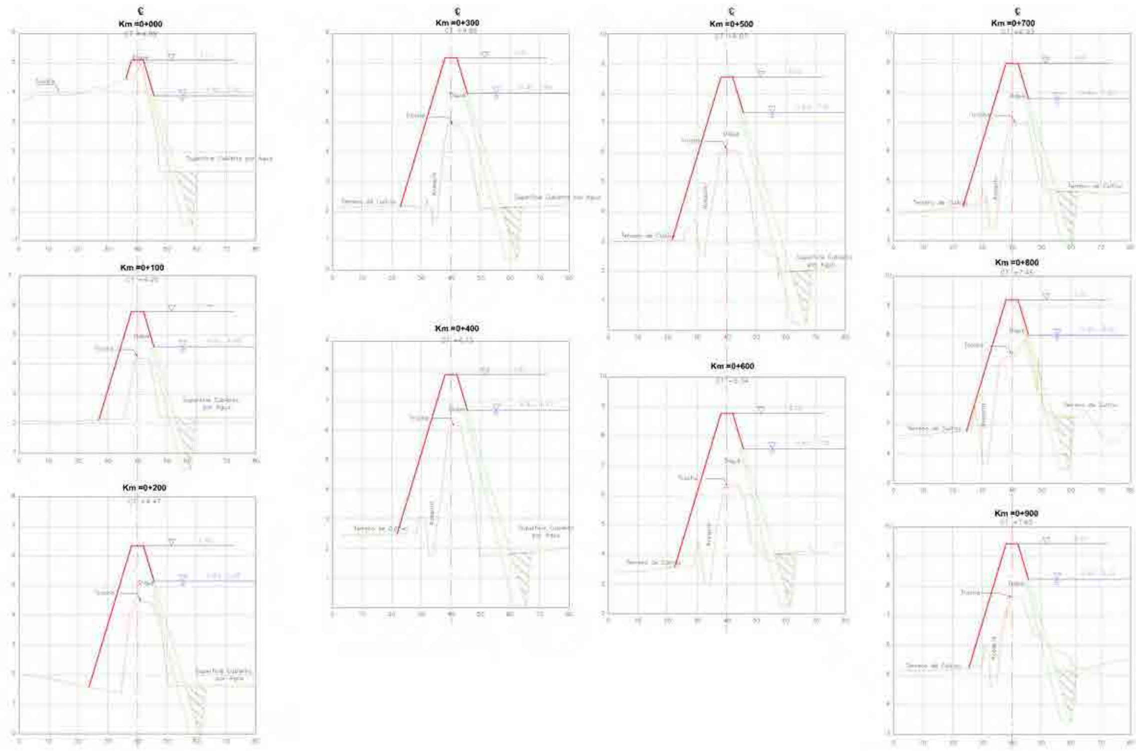


Figure 2.44 Typical Cross Section in Camana River-1 (1)

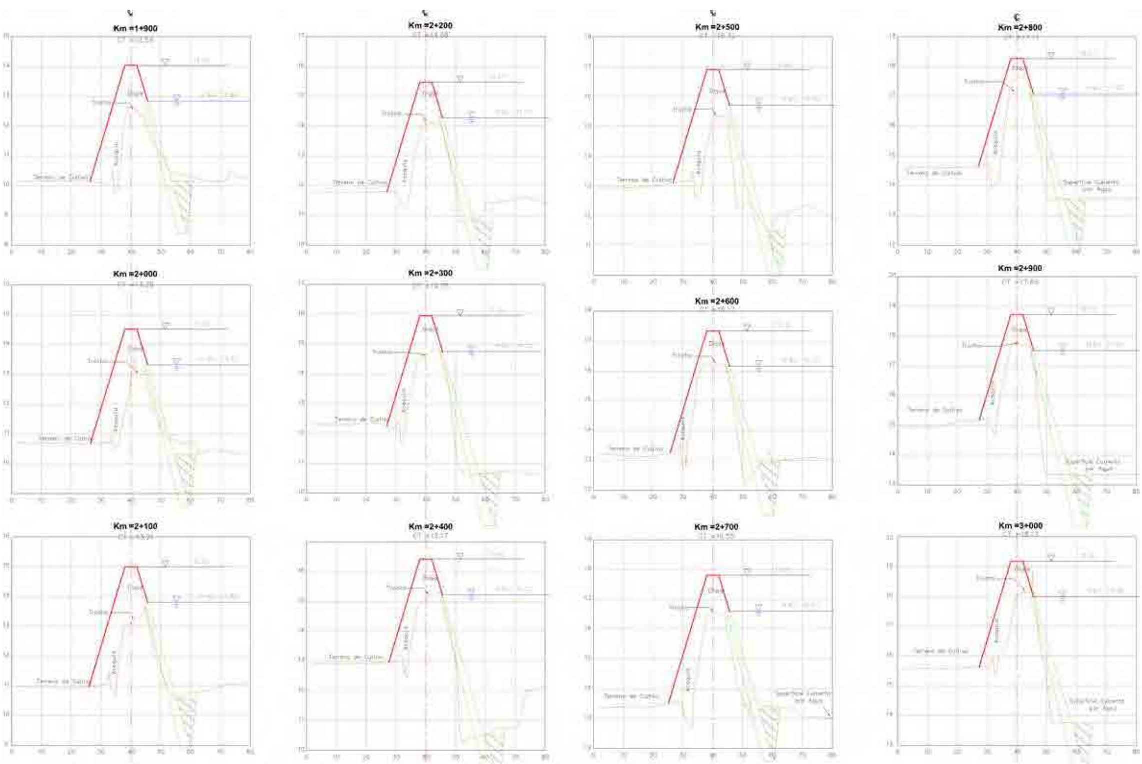


Figure 2.45 Typical Cross Section in Camana River-1 (2)

Outline of Facility (Camana River-3)

No	Sections for Improvement	Improvement Plan
Camana River-2	7.5km-9.5km (Left-bank side)	The existing dike in the sections concerned is superannuated and many erosion parts appear here and there. Since floods occurs in the upstream (in Majes River) at present, the flood of the area (in Camana River) is mitigated. When the improvement in the upstream will progress from now on, the influence by improvement in the area will become large and the inundated area will become large. **<Characteristic of Sections for Improvement>** • Sections where the measures against aged existing dike and securement of the dike height are important • Sections which affects the influence on the Camana City area and vast farmland in the left-bank side by floods • Sections where the danger of the flood increases accompanying with improvement in the upstream **<Protected Areas>** o Vast farmland which spreads in the left-bank side of the Sections for Improvement o Camana City area **<Improvement Plan >** ▼ As the characteristics of the most downstream section in the Camana River , when the Majes River overflows, the flood damage is mitigated, but when improvement of the Majes River progresses, the damage in the left-side in the downstream is expanded greatly, and the influence will also reach the Camana City. Moreover, as the characteristics of the Camana River , when the flood exceeding the scale 1/50 year probable flood will be generated, the damage will become serious. Therefore, the facility should be designed to be safe for the flood of 1/50 year probable flood scale. ▼ Embankment and the revetment works for the existing dikes in the sections where discharge capacity is insufficient shall be carried out

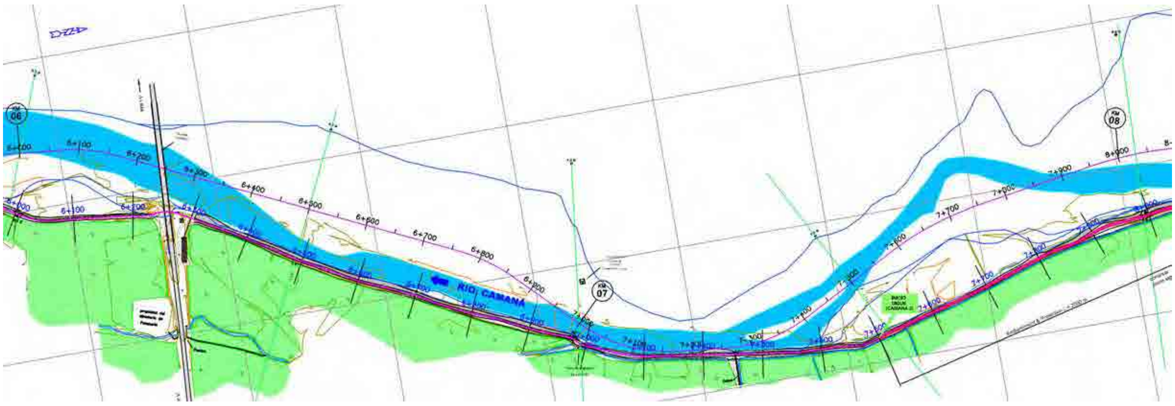


Figure 2.46 Facility Plan in Camana River-2 (1)

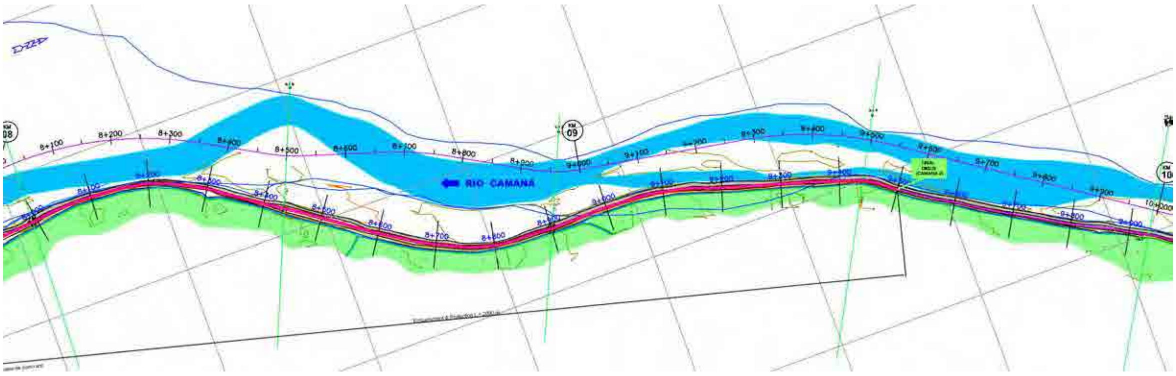


Figure 2.47 Facility Plan in Camana River-2 (2)

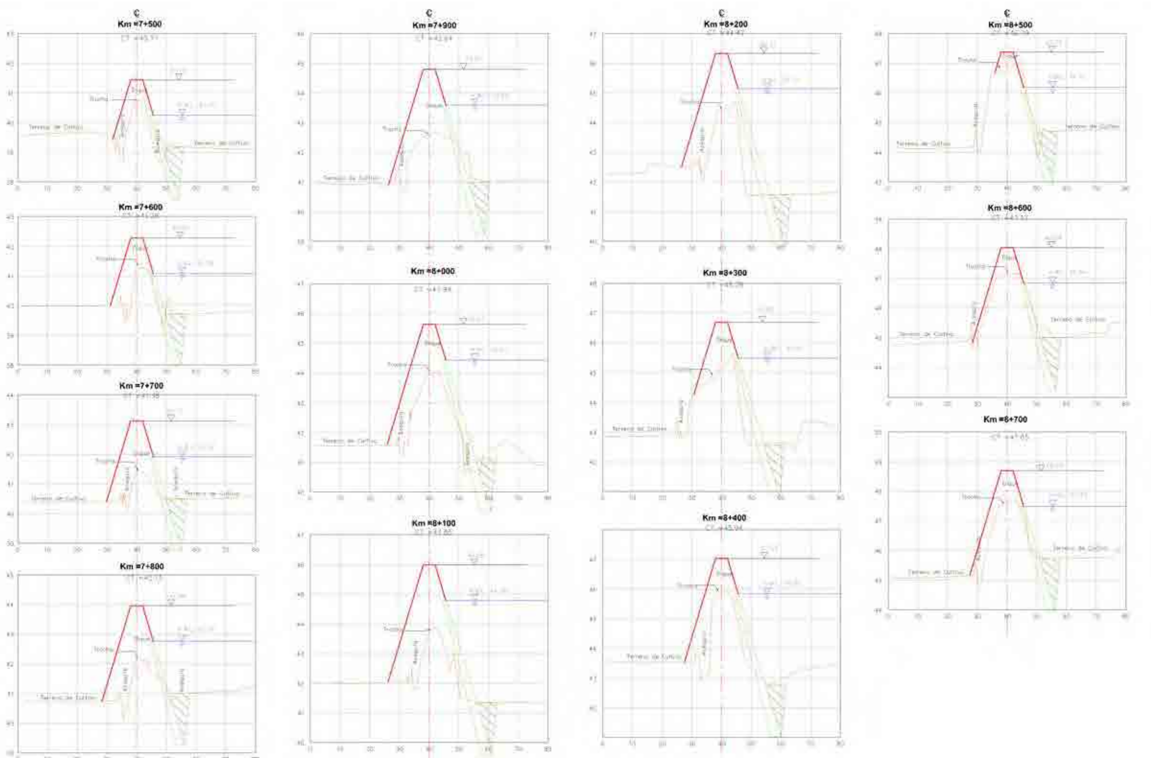


Figure 2.48 Typical Cross Section in Camana River-2 (3)

Outline of Facility (Camana River-3)

No	Sections for Improvement	Improvement Plan
Camana River-3	11.0km-17.0km (Left-bank side)	The existing dike of the sections concerned is superannuated and many erosion parts appear here and there. Moreover, the intake weir for water supply to the Camana city area is located near 13km, and the irrigation canal is built along the riverside. The riverbank of the left-bank side of 12km mark is eroded now, and the influence on the adjoining irrigation canal is anxious. **<Characteristic of Sections for Improvement>** ●Sections where the measures against superannuation of the existing dike and securement of the dike height are important ●Sections which brings serious damage to the water supply canal when it overflows **<Protected Areas>** ○The canal (for water supply) along the left bank of the Sections for Improvement **<Improvement Plan >** ▼As the characteristics of the most downstream section in the Camana River , when the Majes River overflows, the flood damage is mitigated, but when improvement of the Majes River progresses, the damage in the downstream is expanded greatly, and the influence will also reach to the channel for water supply. When the flood exceeding the scale 1/50 year probable flood will be generated, the damage for channel will become serious. Therefore, the facility should be designed to be safe for the flood of 1/50 year probable flood scale. ▼For enhancing the discharge capacity, embankment and the revetment works for the existing dikes in the sections where discharge capacity is insufficient shall be carried out

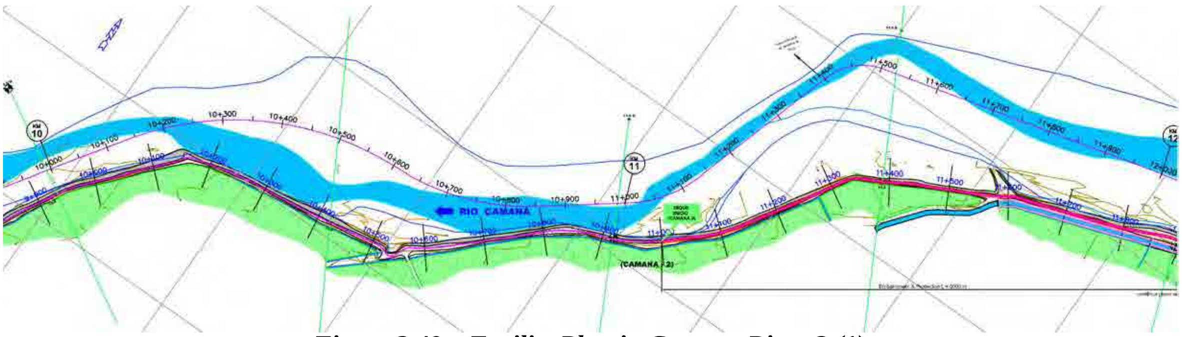


Figure 2.49 Facility Plan in Camana River-3 (1)

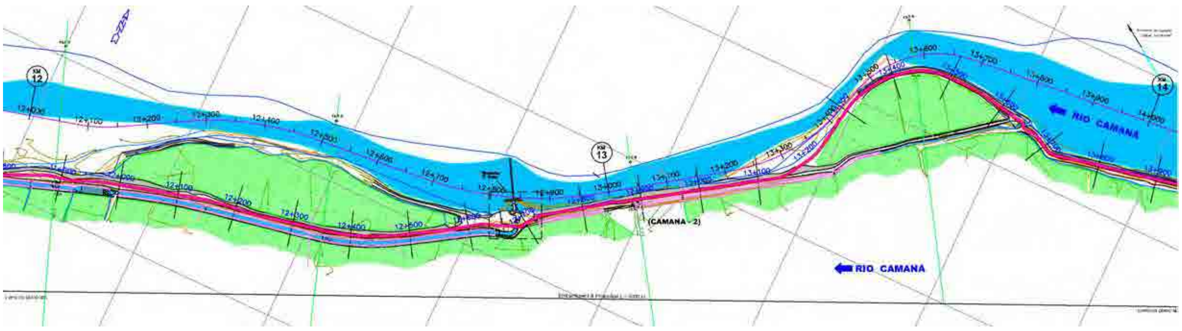


Figure 2.50 Facility Plan in Camana River-3 (2)

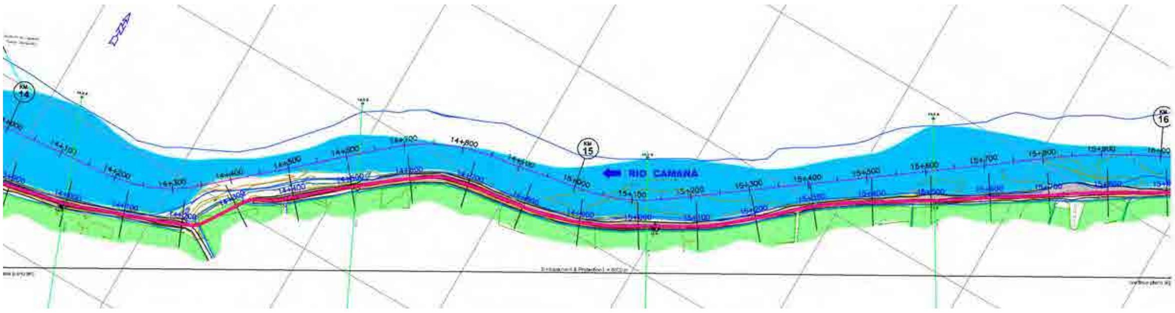


Figure 2.51 **Facility Plan in Camana River-3 (3)**

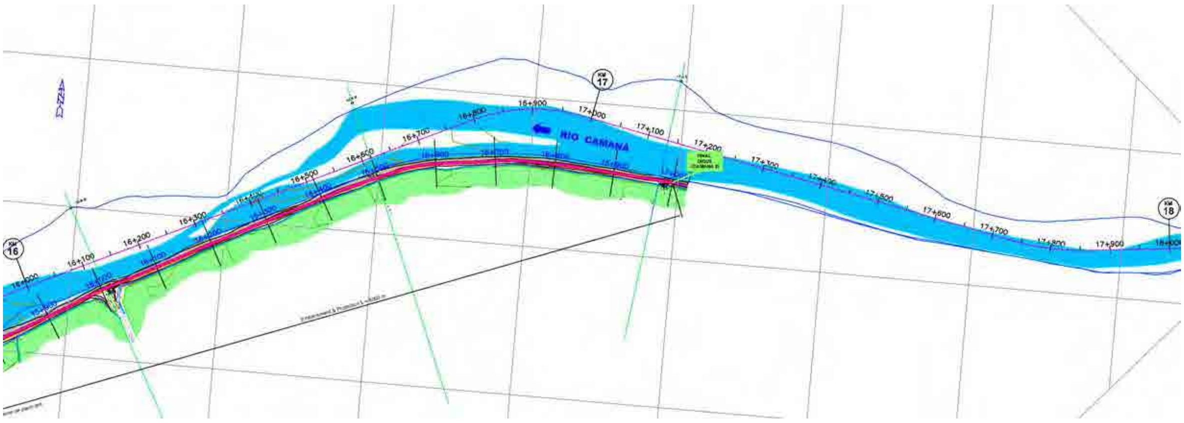


Figure 2.52 **Facility Plan in Camana River-3 (4)**

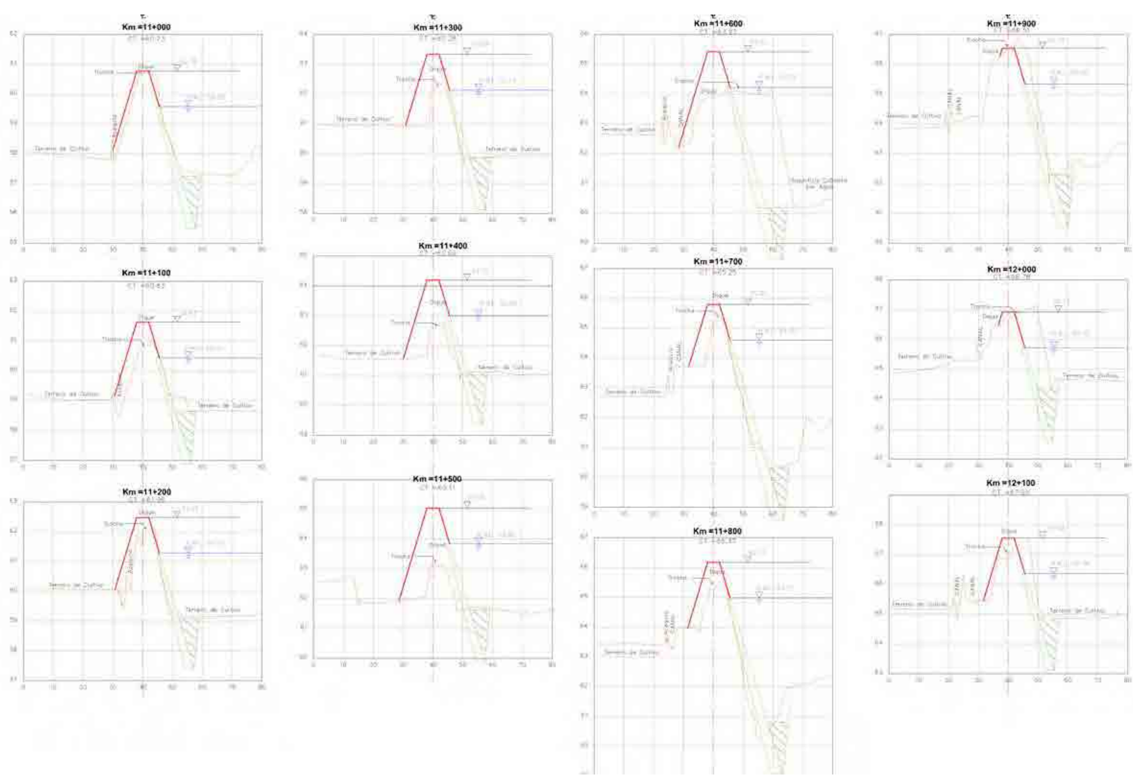


Figure 2.53 **Typical Cross Section in Camana River-3 (1)**

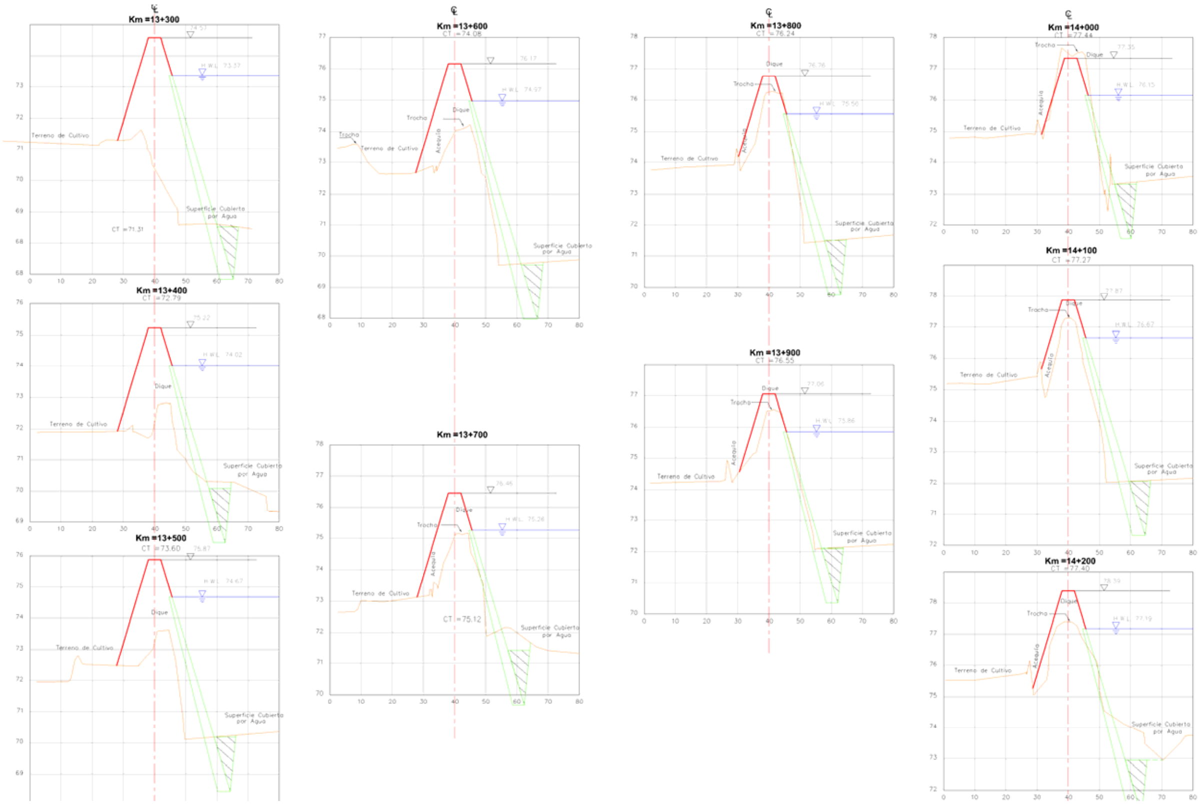


Figure 2.54 **Typical Cross Section in Caman-3 (2)**

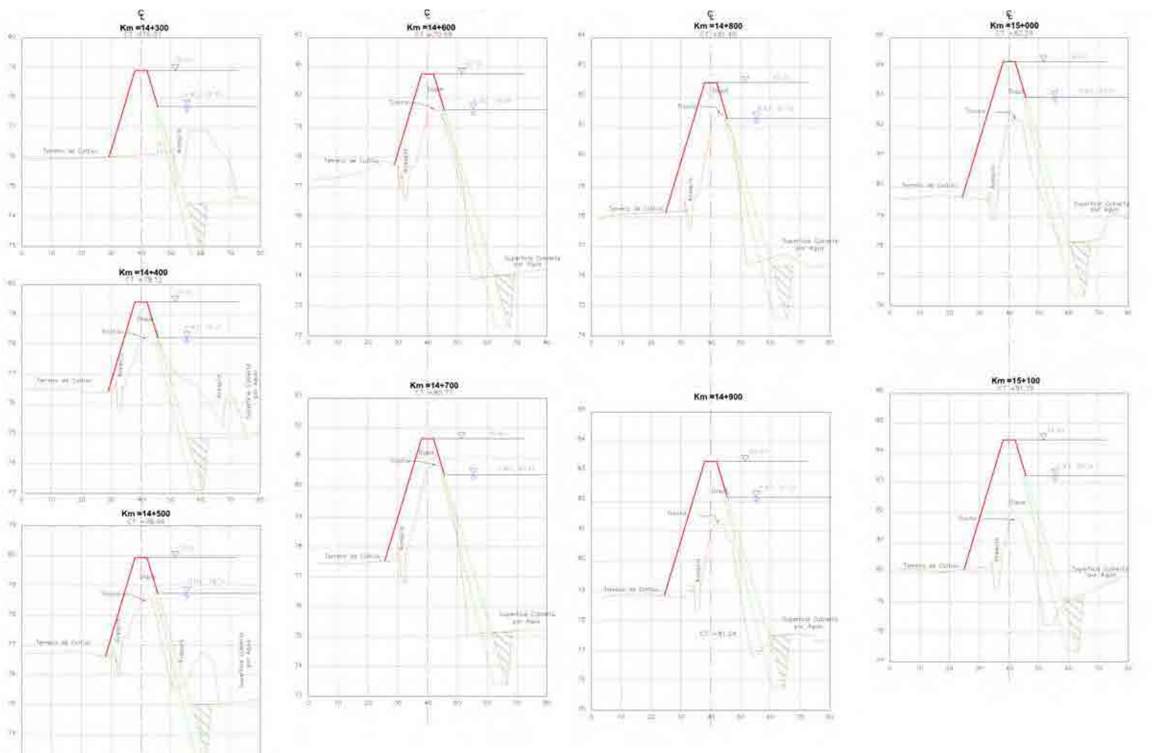


Figure 2.55 **Typical Cross Section in Camana River-3 (3)**

Outline of Facility (Majes-4)

No	Sections for Improvement	Improvement Plan
Majes River-4	48.0km-50.5km (Left-bank side)	In the river concerned, it is one of the most insufficient sections for the discharge capacity. The overflow starts also at the time of small discharge, and as the flood scale becomes large, the damage is expanded. **<Characteristic of Sections for Improvement>** • Sections where the securement of the discharge capacity and the dike improvement is important in order to protect the 2nd order farmland in the Majes area **<Protected Areas>** o Farmland in the left-bank side (2nd order farmland in the Majes area: the maximum inundated area) **<Improvement Plan >** ▼ Flood will begin at the scale of the discharge of the 1/5 year, and since the damage will become serious remarkably at the 1/50 year probable flood, the facility which can flow down the discharge with the 1/50 year probable flood scale shall be improved. ▼ Embankment and the revetment work combining works in upstream shall be carried out, and the effectiveness of improvement shall be heightened.

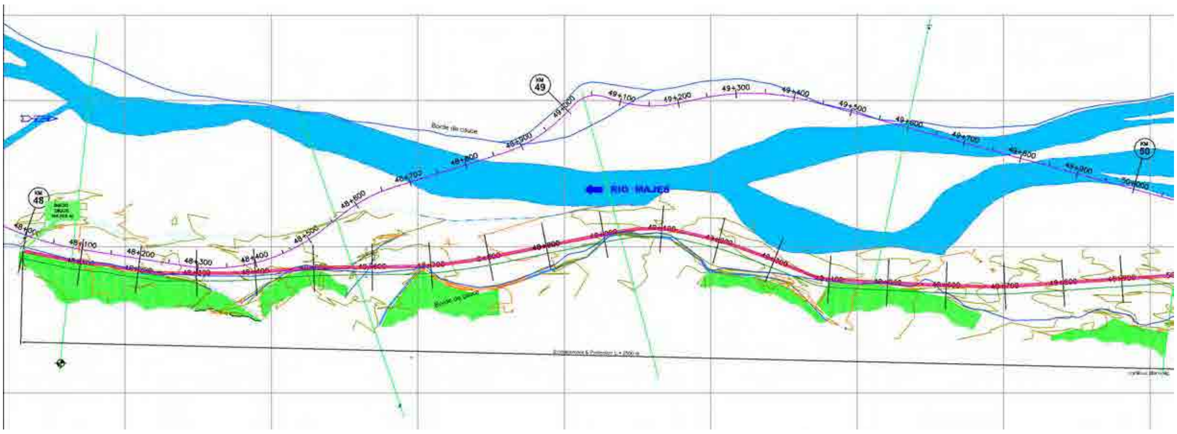


Figure 2.56 **Facility Plan in Majes River-4 (1)**

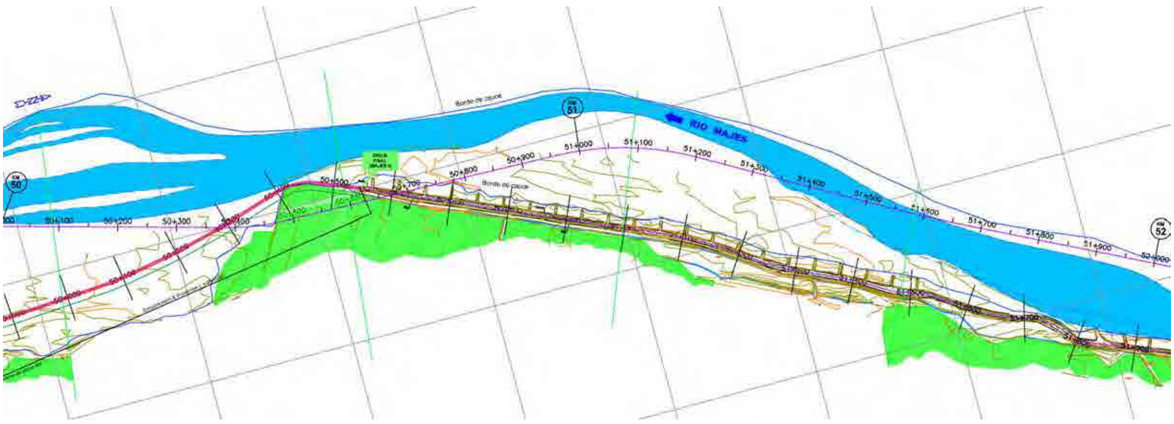


Figure 2.57 **Facility Plan in Majes River-4 (2)**

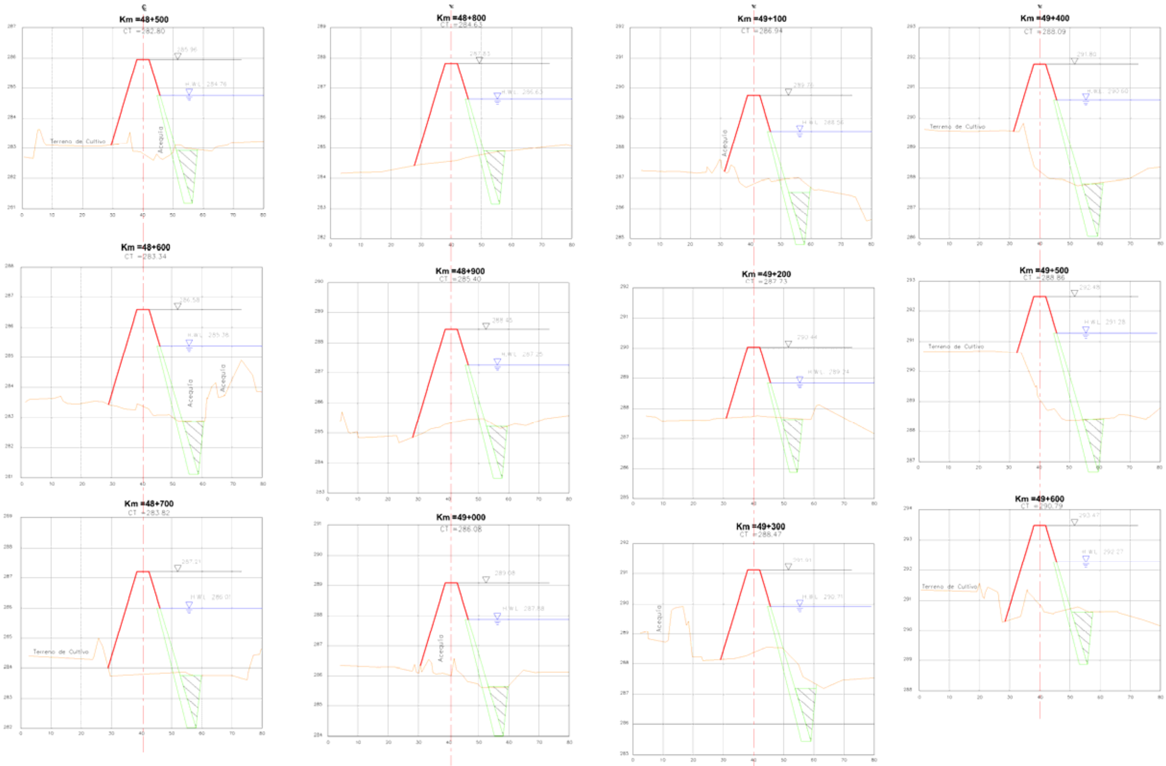


Figure 2.58 **Typical Cross Section in Majes River-4 (1)**

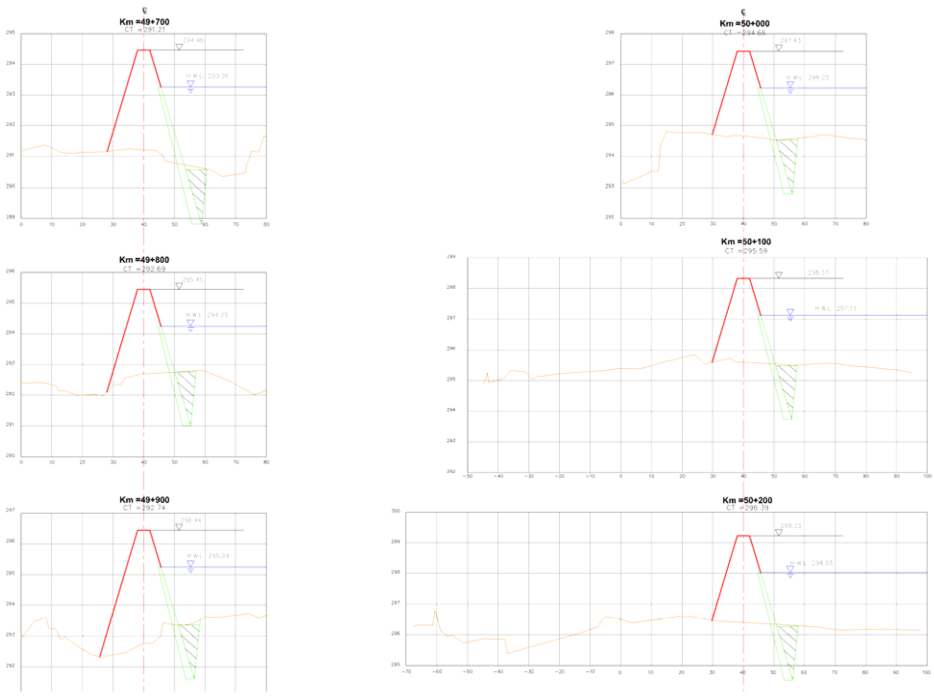


Figure 2.59 **Typical Cross Section in Majes River-4 (2)**

Outline of Facility (Majes River-5)

No	Sections for Improvement	Improvement Plan
Majes River-5	52.0km-56.0km (Left-bank side)	It is one of the most insufficient section for the discharge capacity. The overflow starts also at the time of small flood discharge, and as the flood scale becomes large, the damage is expanded. In the flood in 1998, the area inundated, and the serious damage arose. **<Characteristic of Sections for Improvement>** ●Sections where the securement of the discharge capacity and the dike improvement is important in order to protect the 2nd order farmland in the Majes area **<Protected Areas>** ○Farmland in the left-bank side of the Sections for Improvement (the maximum inundated area) **<Improvement Plan >** ▼Flood will begin at the discharge of the 1/5 year probable flood, and since the damage will become serious remarkably at the 1/50 year probable flood, improvement which can flow down the discharge with the 1/50 year probable flood scale shall be done. ▼Embankment and the revetment works combining with works in downstream section shall be carried out, and the effectiveness of improvement shall be heightened.

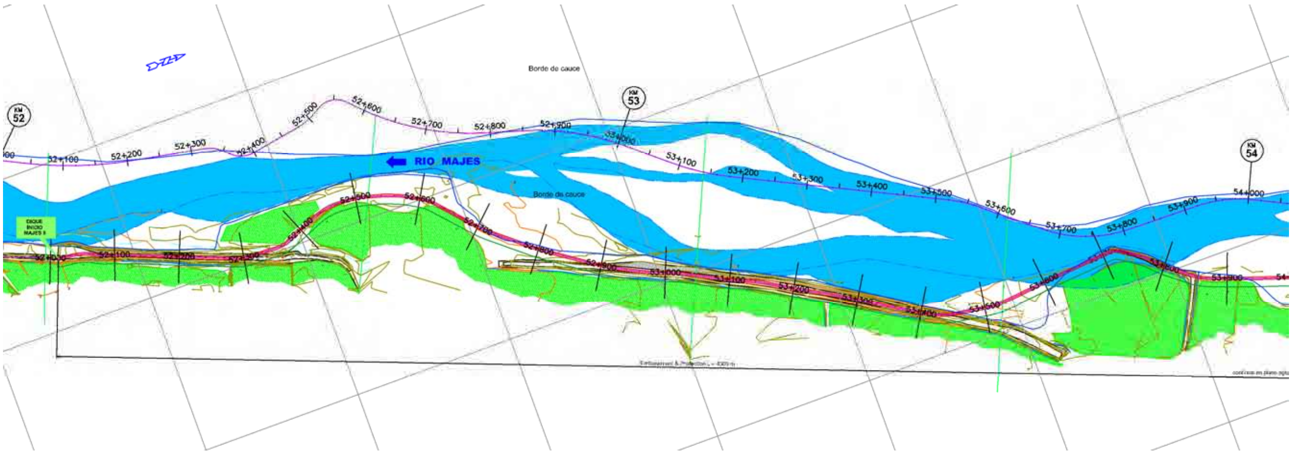


Figure 2.60 **Facility Plan Chart in Majes River-5 (1)**

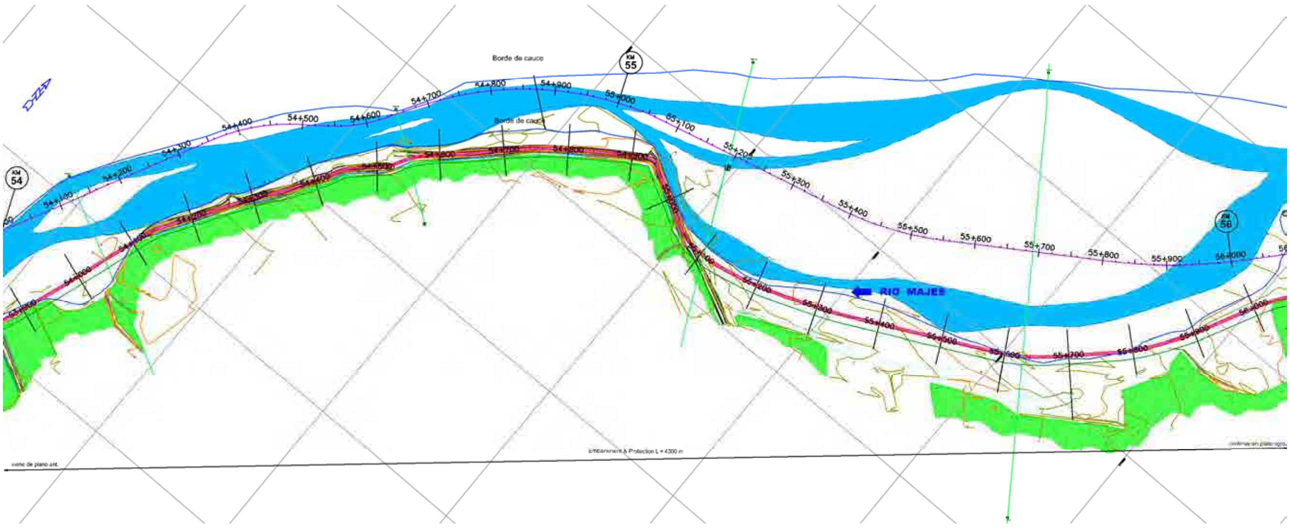


Figure 2.61 **Facility Plan Chart in Majes River-5 (2)**

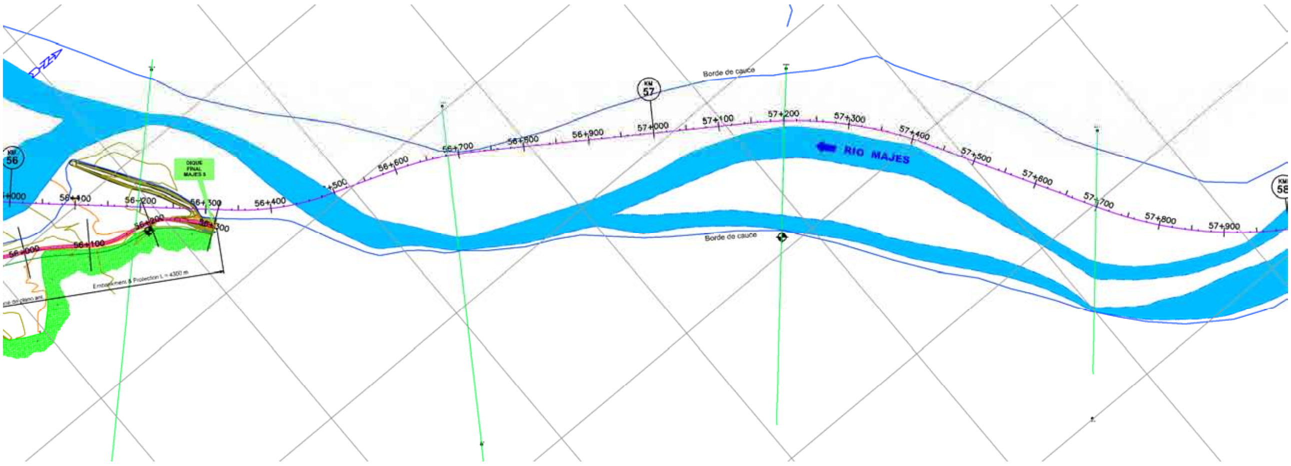


Figure 2.62 **Facility Plan Chart in Majes River-5 (3)**

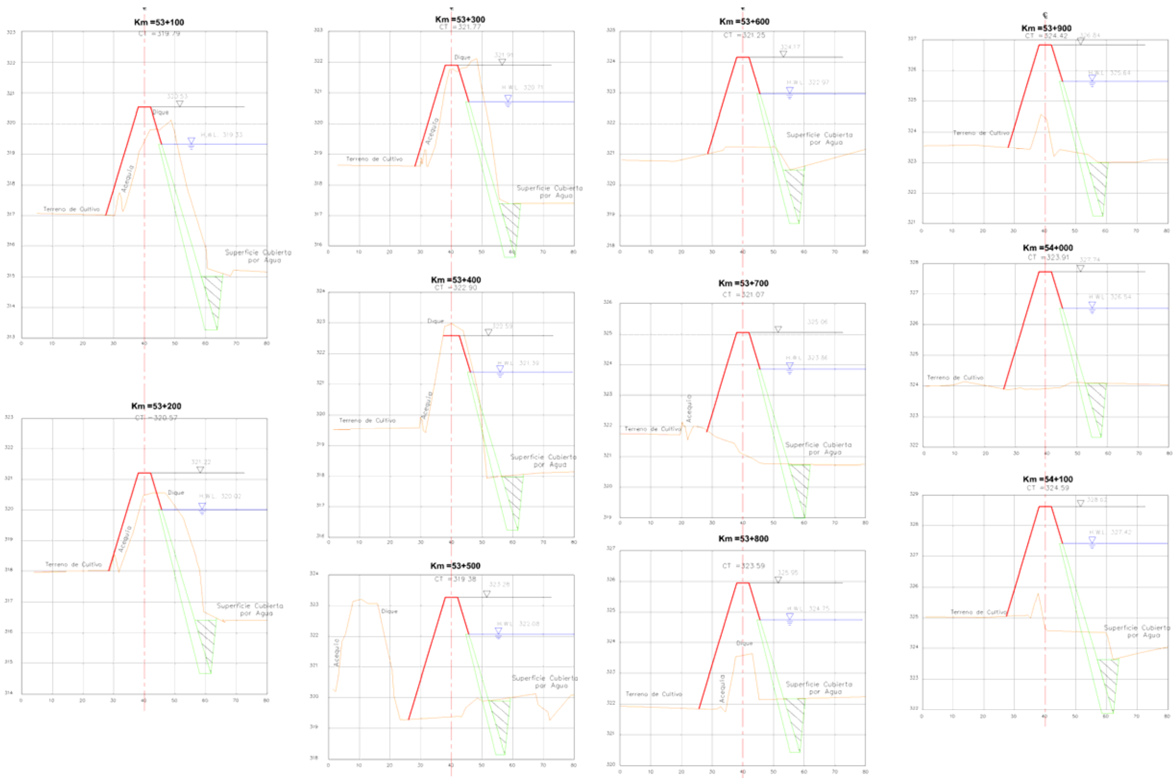


Figure 2.63 **Typical Cross Section in Majes River-5 (1)**

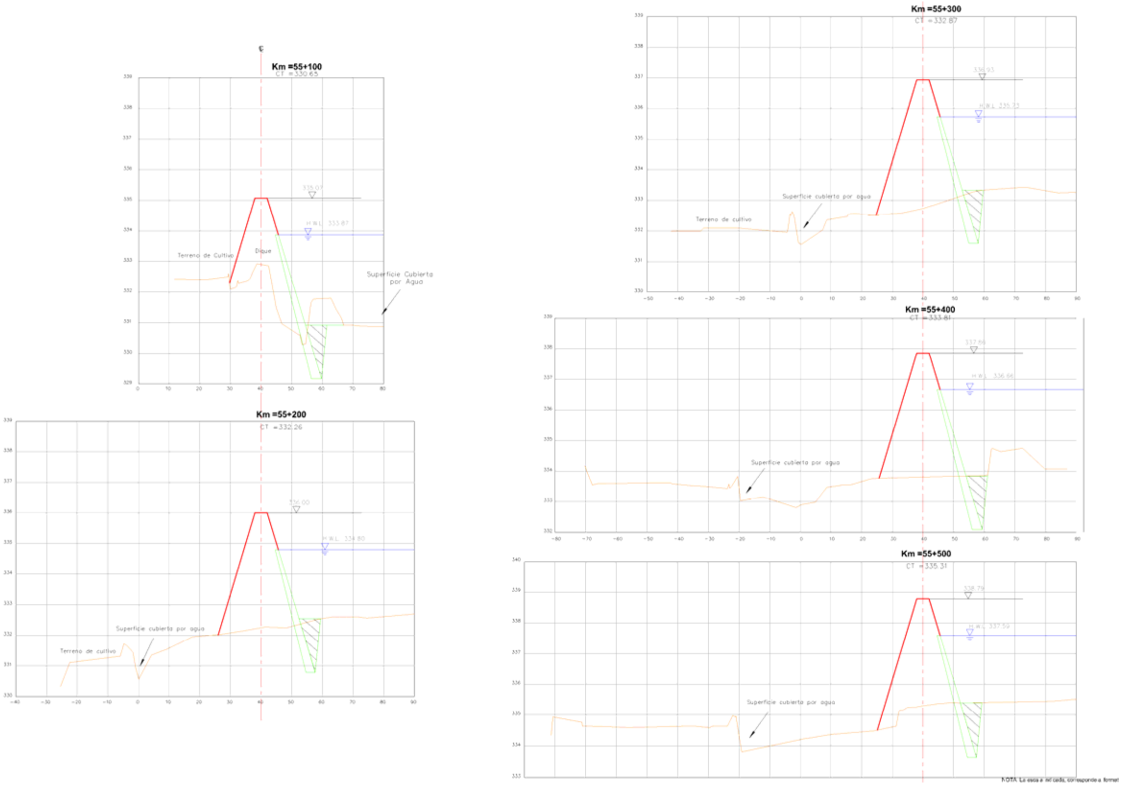


Figure 2.64 **Typical Cross Section in Majes River-5 (2)**

Outline of Facility (Majea River-6)

No	Sections for Improvement	Improvement Plan
Majes River-6	59.0km-62.5km (Right-bank side) 59.5km-62.5km (Left-bank side)	For a narrow segment, the discharge capacity is insufficient and flood damage has occurred frequently in the farmland of the upstream section. **<Characteristic of Sections for Improvement>** • Sections where the securement of the discharge capacity and the dike improvement is important in order to protect the 1st order wide farmland in the Majes area **<Protected Areas>** o Farmland in the left-bank side of the Sections for Improvement (the widest farmland in the Majes area) **<Improvement Plan >** ▼ Flood will begin at the discharge of the 1/5 year probable flood, and since the damage will become serious remarkably at the 1/50 year probable flood, improvement which can flow down the discharge with the 1/50 year probable flood scale shall be done. ▼ Embankment and the revetment works combining with works in the upstream section shall be carried out, and the effectiveness of improvement shall be heightened

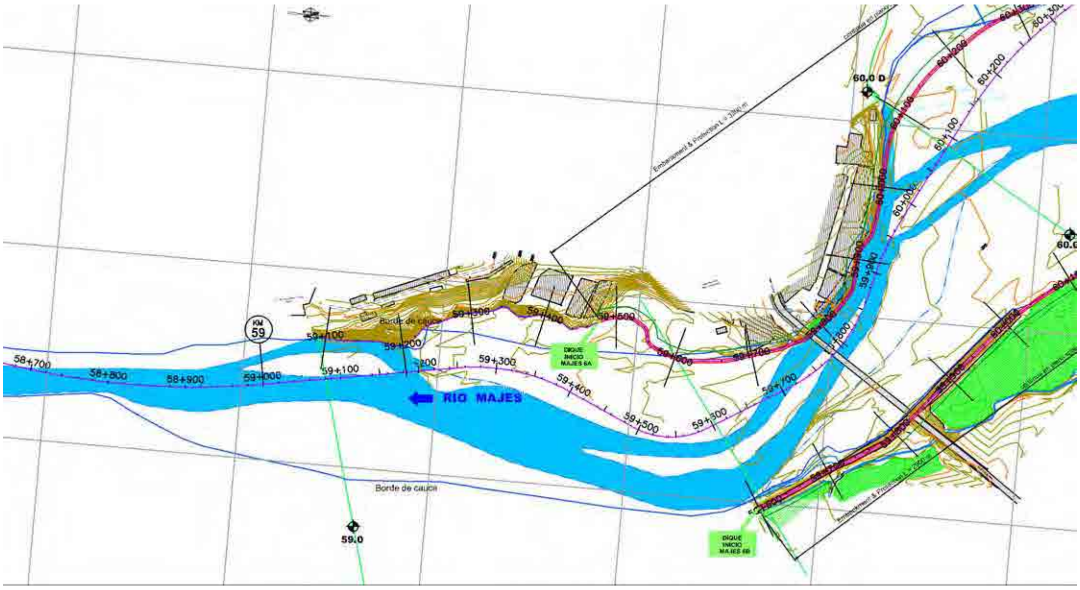


Figure 2.65 **Facility Plan Chart in Majes River-6 (1)**

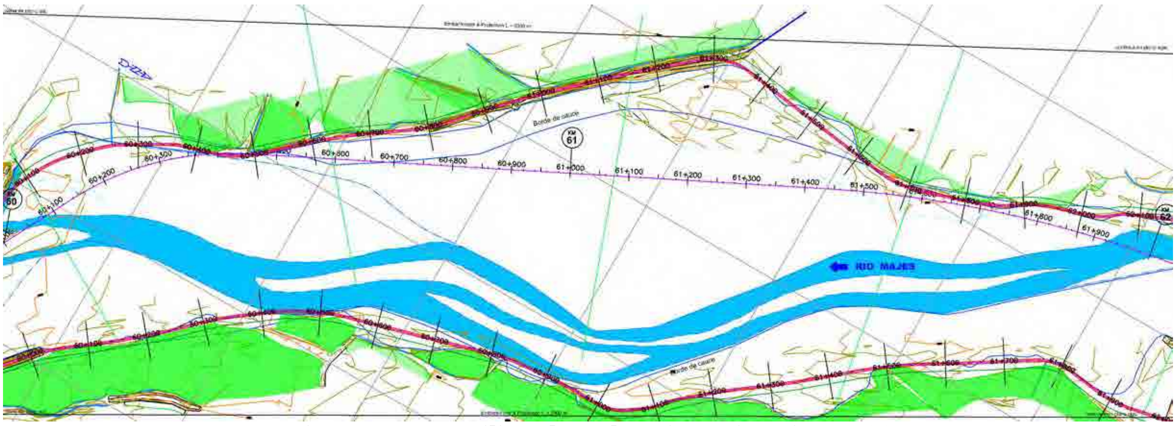


Figure 2.66 **Facility Plan Chart in Majes River-6 (2)**

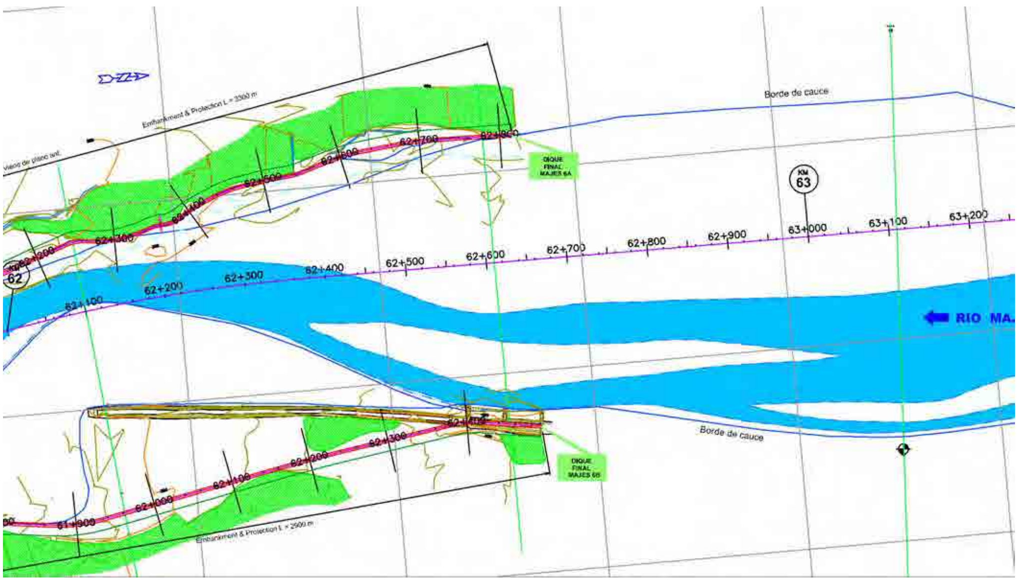


Figure 2.67 **Facility Plan Chart in Majes River-6 (3)**

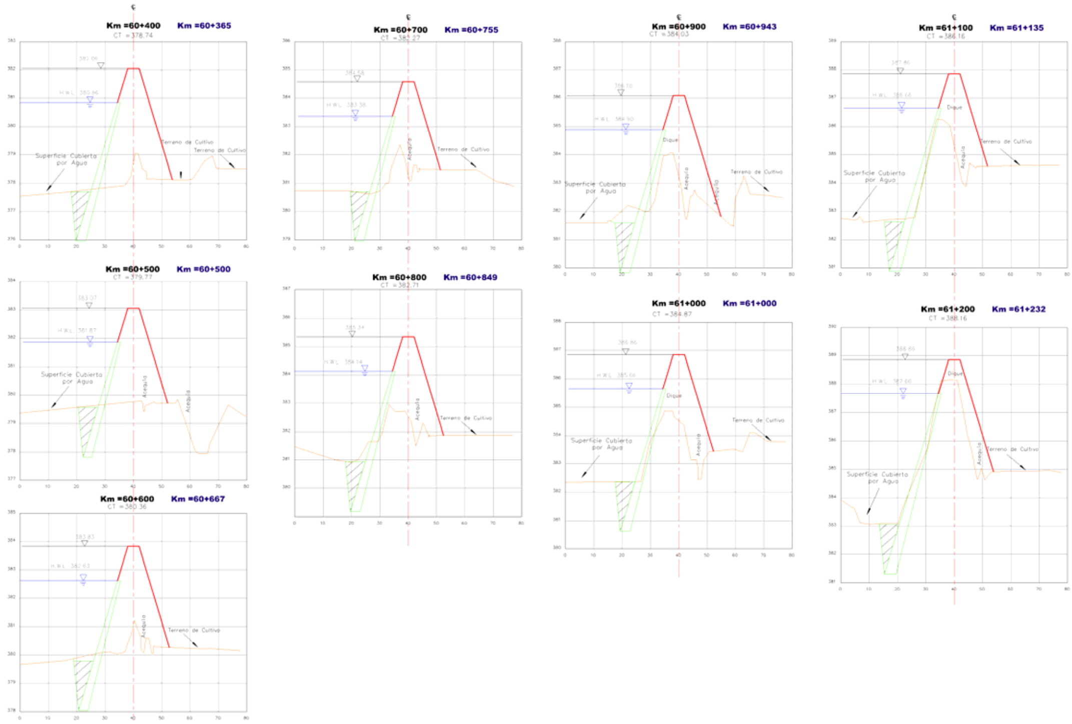


Figure 2.68 **Typical Cross Section in Majes River-6 (1)**

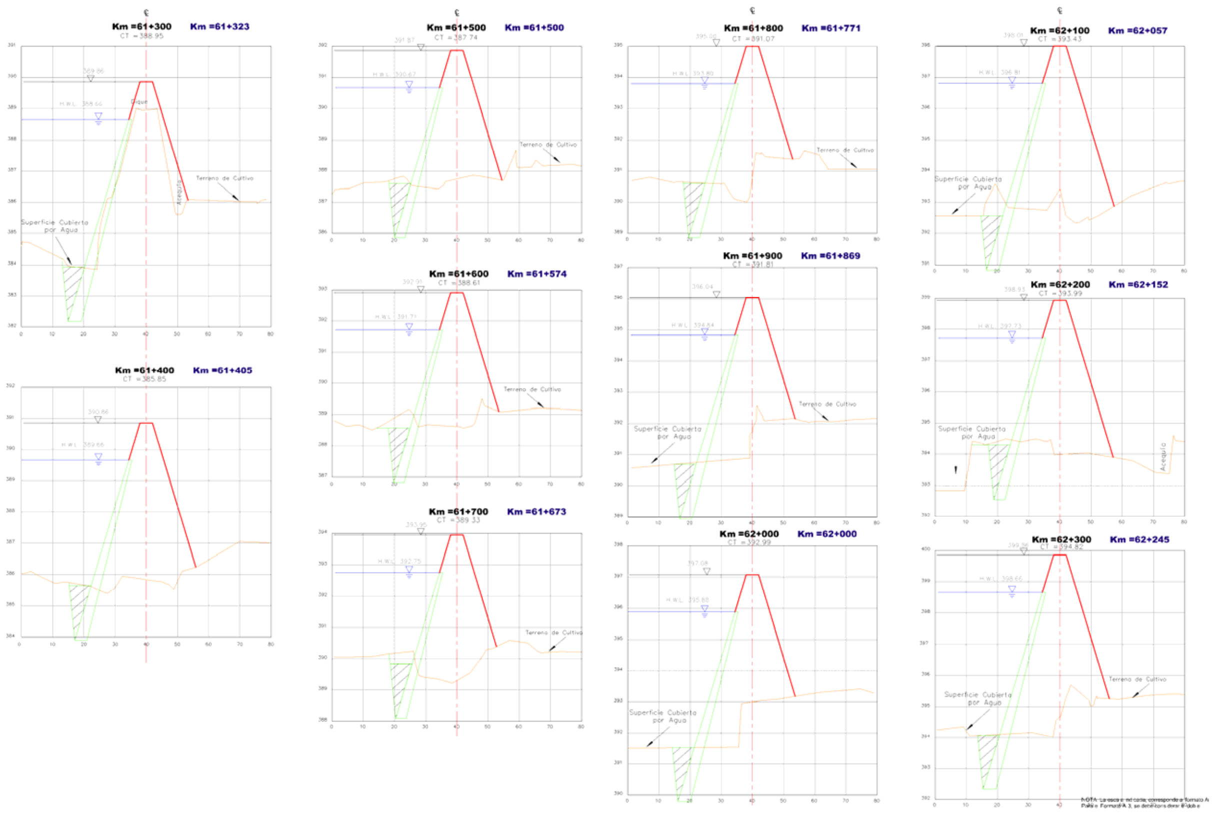


Figure 2.69 **Typical Cross Section in Majes River-6 (2)**

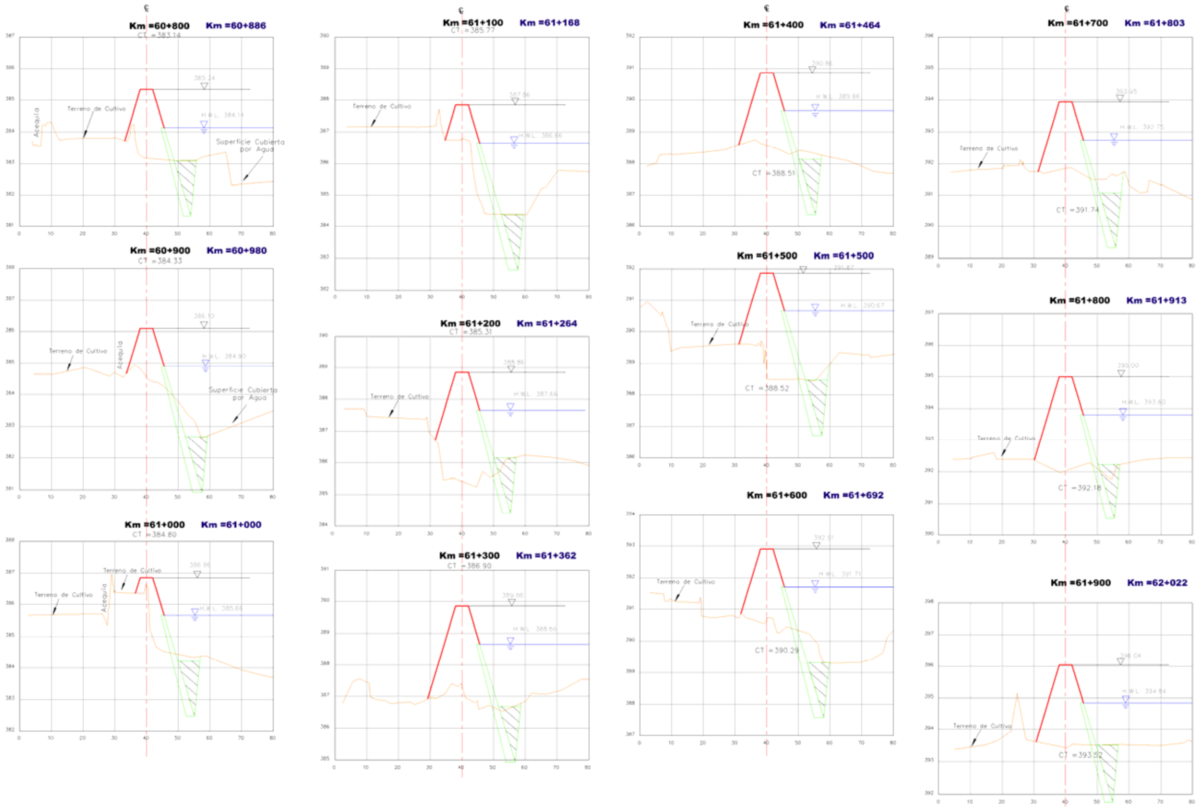


Figure 2.70 **Typical Cross Section in Majes River-6 (3)**

Outline of Facility (Majes River-7)

No	Sections for Improvement	Improvement Plan
Majes River-7	65.0km-66.5km (Right-bank side) 64.5km-66.5km (Left-bank side)	In the river concerned, it is one of the most insufficient section for the discharge capacity. Overflow starts also at the time of small flood discharge, and as the flood scale becomes large, the damage is expanded. **<Characteristic of Sections for Improvement>** • Farmland in the left-bank side of the Sections for Improvement (the widest farmland in the Majes area) **<Protected Areas>** o Farmland in the left-bank side of the Sections for Improvement (the widest farmland in the Majes area) **<Improvement Plan >** ▼ Flood will begin at the discharge of the 1/5 year probable flood, and since the damage will become serious remarkably at the 1/50 year probable flood, improvement which can flow down the discharge with the 1/50 year probable flood scale shall be done. ▼ Embankment and the revetment works combining with works in downstream section shall be carried out, and the effectiveness of improvement shall be heightened

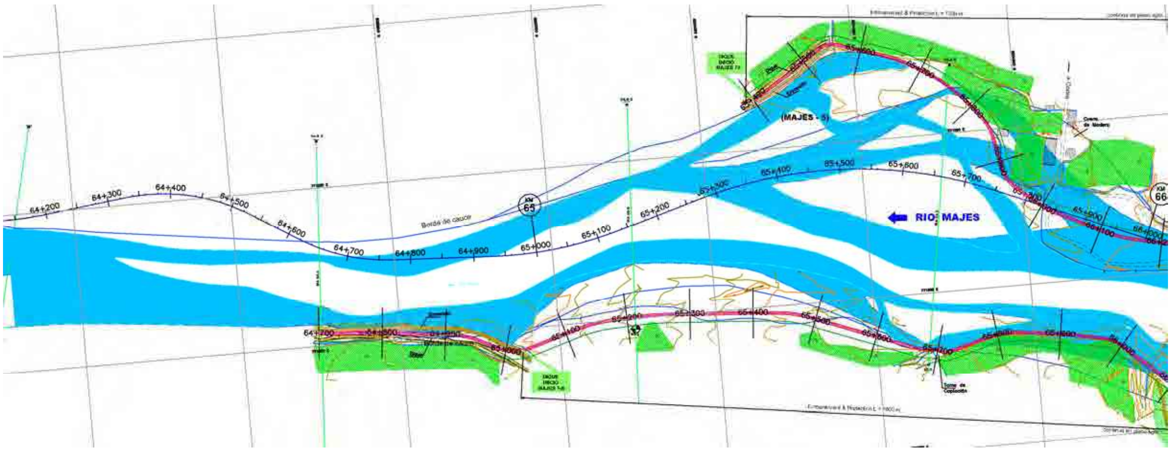


Figure 2.71 **Facility Plan in Majes River-7 (1)**

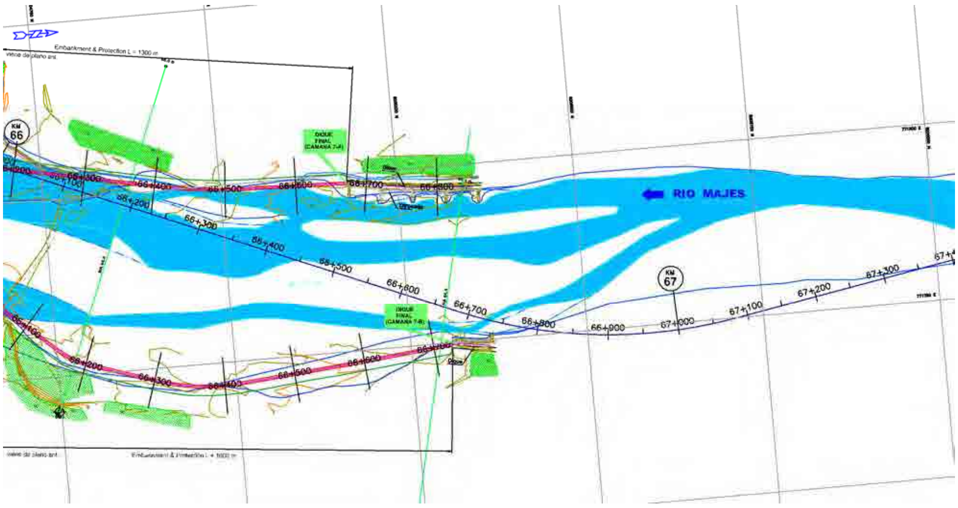


Figure 2.72 **Facility Plan in Majes River-7 (2)**

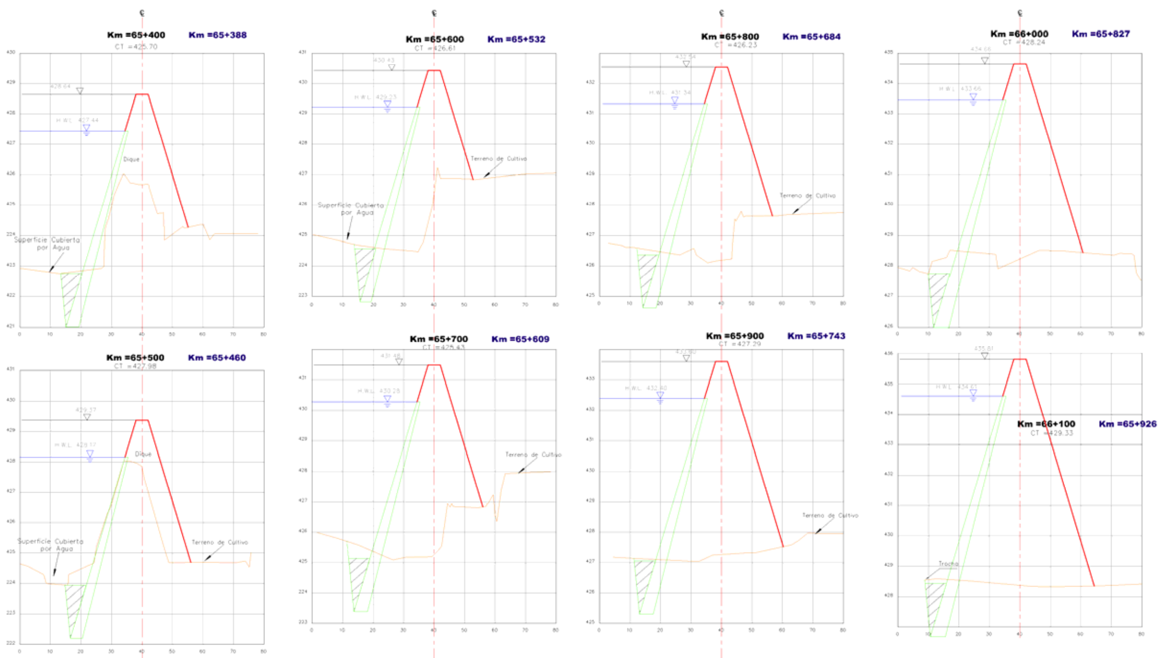


Figure 2.73 **Typical Cross Section in Majes River-7 (1)**

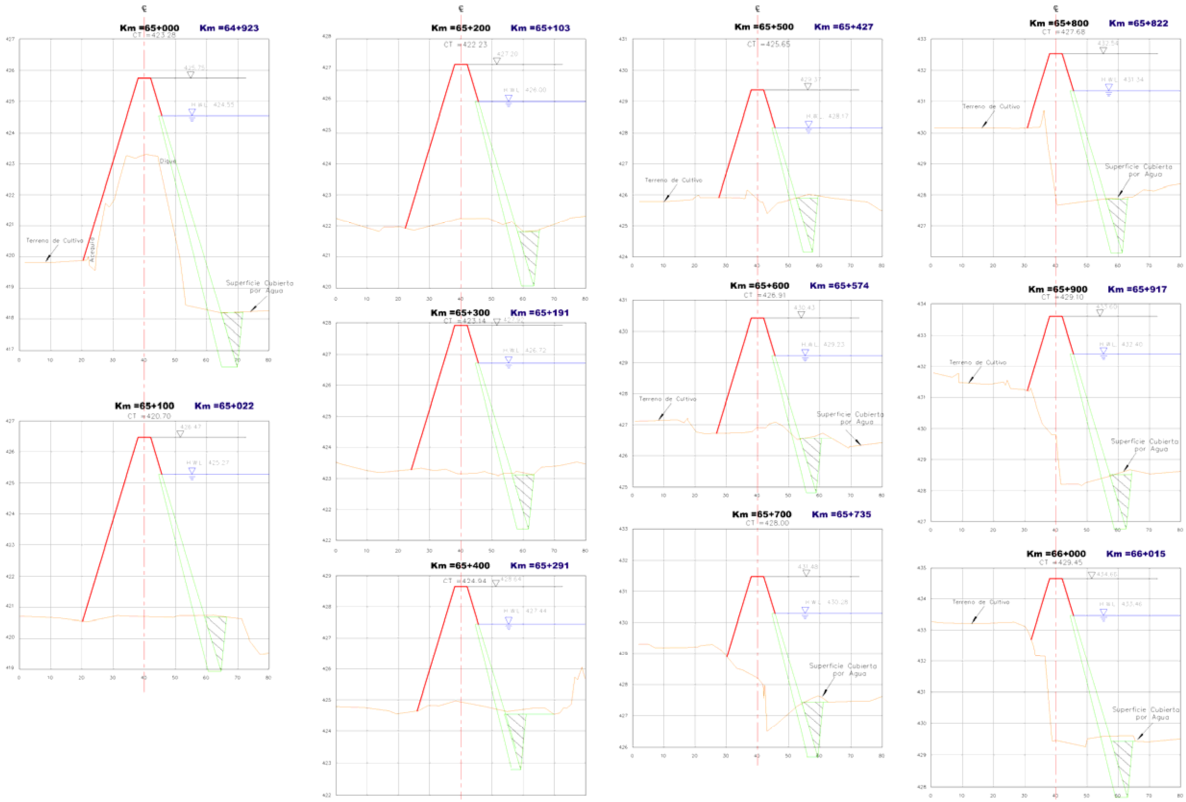


Figure 2.74 **Typical Cross Section in Majes River-7 (2)**

CHAPTER 3 DESIGN FOR DIKE

Dike (Levee) is required to have the necessary designed height and cross section for the flood flow below the design discharge, and revetment works (slope protection works and foot protection works, etc.) is also needed, as required.

(1) Height and Alignment of Dike

The height and the alignment of dike are planned based on the channel plan. Planned facilities are designed to connect the existing facilities smoothly.

(2) Typical Cross Section of Dike

1) Crest Width of Dike

Crest width of the bank shall be designed as 4m in consideration of the stability of the dike for design flood level, the width of the existing dikes and the monitoring road or the local traffic road.

2) Structure of Dike

The structure of the dike shall be planned taking into consideration the disaster records in the past, the ground condition, the situation of hinterland. All of the dike structures in six rivers are made of earth materials. Although the structure of dike differs a little for every area, the results, which identified and checked through interviews with management persons, are as follows.

i) The slope gradient apply for about 1:2 gradient with vertical 1 to horizontal 2. Depend on the river characteristics and local condition, and slope gradient has little differences.

ii) Riverbed materials are used for the embankment materials. They consist of sand gravel to sandy soil with gravel, and the plasticity is low. The cohesion by the soil for embankment cannot be expected.

iii) The embankment material of the Canete River consists of rudaceous soil which is composed of sand gavel with large and small particle size, and is comparatively well compacted.

iv) The embankment material in the downstream from Sullana in the Chira River consists of sandy soil with silt. As for the dike body, the design of the zone type structure is adopted. A low permeable material is arranged comparatively on river side front of the dike, and a high permeable material is arranged on back side slope of the dike. However, acquisition of low permeable material is actually difficult. Moreover, strict construction management is not performed for the material distribution by the control of grain size, etc.

v) As a result of investigating for damaged places in each river, there were no differences on the embankment materials and the foundations between section broken by floods and the section which no damaged. The dike break mainly caused by overflow.

vi) Groins are placed in the Chira River and the Canete River, most of them are destroyed. Although groins consist of boulder, some of them were composed of earth and sand within it, and may have been destroyed by sucking of internal material.

vii) There are revetments which consist of large boulders in the river mouth area of the Pisco River. According to information from manager, that structure is strong for dyke break. Boulder materials were conveyed from the quarry within the distance of about 10km. The photographs of typical dikes are shown below.

Figure 3.1 **Groin Work in Canete River**

Figure 3.2 **Dike Revetment by Mattress Basket in Chincha River**

Figure 3.3 **Revetment Works by Boulder near the River Mouth in Pisco River**

Figure 3.4 **Dike and Revetment Works by Boulders in the Upstream in Pisco River**

Figure 3.5 **Dike in Yauca River**

Figure 3.6 **Dike in Majes-Camana River**

The structure of dike shall be planned and designed as follows based on those situations.

i) Dike

Dike is constructed using available earth materials in the riverbed or riverbank near the site.

In this case, the earth material is sand gravel to sandy soil with gravel, and the permeability shall become high. When dike is constructed with comparatively high permeable materials, the problems on stability for the dike are as follows.

a) Seepage failure by the washing away of the fine-grained soil and sand accompanying piping

b) Slip failure by the osmotic pressure accompanying infiltration.

In order to secure the safety of the dike, in the detailed design, it is necessary to survey the unit weight, the strength, and the permeability of materials, to perform examination of the seepage flow analysis and the slip failure. Further, it is also necessary to determine the proper cross-sectional profile.

ii) Dike Slope

The internal friction angle is assumed to be about 30-35 degree in case of sandy soil without adhesion. The gradient of slope of the dike which consists of materials without adhesion is obtained by tan θ = tan ϕ / n. (θ : slope gradient, ϕ : internal friction angle, n: factor of safety 1.5)

A required stable gradient is set to V:H=1:2.6 (tan θ =0.385) to 30 degrees of internal friction angle. Against the calculated required gradient, the slope gradient is set 1:3.0 which is gentler than the slope of the existing dike in consideration of the following conditions.

a) As the result of runoff analysis, the duration of design flood is 24 hours or more, and it is long time,

b) There are many damaged examples for existing dike with twenty-percept slope, and

c) The dike should be bear against the overflow at the time of the large-scale flood over the design flood.

In the study, the seepage flow analysis and the stability calculation of the dike based on geological investigation, material test and design value were not carried out. Therefore, from the material checked by site reconnaissance, the strength parameter was assumed as an estimated value, freeboard were taken into consideration in simple stability examination, and the slope gradient was set up. The assumed value of material was set up based on the criteria of Japan ("Road Earthwork – Earth Fill Work Guide 2010, Japan Road Association, P101 and Table 4-2-4 Soil constants used for design). According to the same bibliography, the assumed value of the angle of shear resistance is 35 degrees in case of compacted and not good sorting sand with wide particle size in embankment, and 30 degrees in case of compacted and good sorting sand with narrow particle size in embankment. From these data, the estimated value of the internal friction angle was assumed to be 30 to 35 degrees. Furthermore, at the site reconnaissance, although section of the material of the existing dike is also composed of material with wide particle size like rudaceous soil, many of them consist of sandy soil with narrow particle size. Therefore, the slope gradient was set up by simple stability calculation on the basis of $\phi = 30$ degrees. It is necessary to take an external force of osmotic pressure into consideration in detailed stability calculation. Here, clearances were taken into consideration on the simple stability calculation result. Moreover, it was taken into consideration that, in dikes of Japan, although 1:2.0 is made into the minimum slope, banquette is installed for every 2 - 3m in height, and many of average slope gradients of dikes are 1:3.0 or less.

iii) Revetment Works

Since the riverbed gradient is comparatively steep and the flow velocity is high, revetment works are arranged in the river side slope of dikes. Since concrete products like continuous block as a format of revetment is not distributing, the revetment format using the coarse aggregate or boulder, which can be obtained easily near the site, is adopted. Although the magnitude of stone material is finally set up by the flow velocity of each river, it is planned in general with 30cm - 1m of diameters. The minimum thickness of revetment is planned with 1m.

iv) Depth of Embedment for Revetment

The depth of embedment for revetment works is set in consideration of a) the difference of the present deepest riverbed and the present riverbed height of the location, and b) the experiential depth (about from 0.5m to 1.5m in Iapan). However, since the data of riverbed fluctuation during past many years are not obtained. For a), it is indefinite. Therefore, although about 1.5m is thought from as the experiential depth, the depth of 1.75m is adopted by referring to the repaired cross section of the Ika River in Peru.

v) Method of embankment and Alignment of Dike

As for design of dike, following characteristics and issues are taken into consideration.

a) There are many vulnerable dikes, such that the revetment works are damaged, or no data for the compaction situation. For widening the embankment, additional embankment in land side (back side) for existing dike has slight risk on the stability.

b) Widening the embankment in river side makes heightening of dike crest as well as narrowing of river channel.

c) Inland areas surrounded dikes, land use is mainly composed of precious farmland, and the land compensation shall be reduced as much as possible.

d) In the sections with narrow channel and main stream flows near the dike, widening the embankment in the back side of the dike is planned. In such sections, the river side slope of the existing dike is planned to be reinforced with revetment.

Taking into account the above mentioned characteristics, alignment of dike was set as assumed designed alignment, and dike raise by covering whole existing dike with earth materials was planned and designed for the safety of dike.

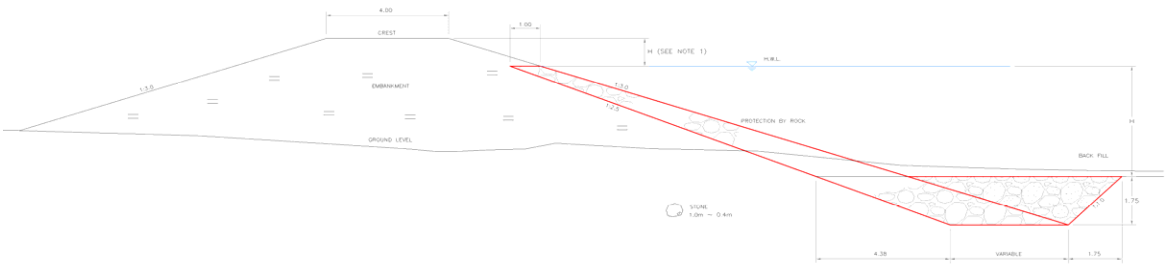
3) Freeboard of Dike

Since the dike is constructed with earth materials, it is generally a very weak structure for overflow. Therefore, the dike should be design not to allow the overflow of the water flow below design flood discharge. The necessary freeboard for the dike needs to be taken to a temporary water level rising by wind wave, wave undulation, hydraulic jump, etc. at the time of flood. Moreover, in addition to this, the necessary height of freeboard needs to be taken in order to cover various components, such as securement of the safety in the case of carrying out the inspection and prevention-of-floods activities and correspondence to the flow materials like driftwood at the time of flood.

The view of the freeboard for dike based on the design criteria in Japan is as follows. Although there are no criteria about freeboard in Peru, since the situation of river is similar with Japanese river, the criteria of Japan applied to design in this study.

Table 3.1 **Freeboard for each Design Flood Discharge**

Design Flood Discharge	Freeboard
200 m^3/s or less	0.6 m
200 m^3/s or more to less than 500 m^3/s	0.8 m
500 m^3/s or more to less than 2,000 m^3/s	1.0 m
2,000 m^3/s or more to less than 5,000 m^3/s	1.2 m
5,000 m^3/s or more to less than 10,000 m^3/s	1.5 m
More than 10,000 m^3/s	2.0 m



TIPICAL CROSS SECTION

Figure 3.7 **Typical Standard Cross Section for Dike Revetment**

4) Method of Dike Raising

The total length of the dike raising and the dike are 17.4km and 60.9km respectively. The length of the dike raising in each river is 1.0km of the total dike length of 7.7km in Canete River, 0.6km of the total length of 13.2km in Chincha River, 0.8km of the total dike length of 15.2km in Pisco River and 15.0km of the total length of 24.8km in Majes- Camana River. The alignment of the dike in the dike raising section is planned to follow the alignment of the existing dike basically under the river-widening way, however the details are different in each river and point. The reason for this are as follows.

- Widening of river-side embankment, which raises a dike on the river side, narrows the river width and as a result, this makes higher the dike.
- Widening of land-side embankment, which raises a dike on the land side, requires a large building site in the protected land. It is necessary to minimize the building site because of the land in a gorge being a valuable farmland.
- However, the details of the construction of the existing embankment, such as the state of its compactness, and the characteristics of its materials are unknown, it is easy to secure the raised dike by the river-widening way which covers the existing embankment with the high strength new embankment in view of the fact that it has fulfilled a function for floods. And this is to minimize economic burdens on the compensation of the building site.

In the meanwhile, the widening of land-side embankment is planned to be carried out at an area where the river gets very narrow and the river channel runs close to the embankment.

And at this area, the slope face of the existing embankment of river-side is planned to be strengthened by revetment.

CHAPTER 4 RECOMMENDATIONS

The following comments are made from the view points of the design and the construction management for the flood control facilities.

(1) Stability Securement for Dike Structure

The embankment materials consist of high permeable sandy soil or rudaceous soil in each river basin.

Judging from the land form feature and the geological condition of river, it seems that availability of low permeable material is difficult.

In case of construction of dike made of relatively high permeable materials, the problems on the stability of dike are i) the seepage failure due to washing away of fine grained soil sand by piping, and ii) the slip failure by osmotic pressures accompanying seepage. In order to secure the safety of dike, based on the tests and examinations such as the unit weight and the permeability test on dike materials and the seepage flow analysis as well as an examination of slip failure, the proper cross-sectional shape will be designed.

The important mater for construction of dike is carrying out sufficient tamping. Although, in the present standard for cost estimate in Peru, the tamping work is estimated as tractor work, the application of compacting machinery such as a vibration roller is preferable in order to carry out secure tamping. Moreover, the density test and the grain size test for managing tamping situation are also an important matter. It is necessary to make these matters reflect in cost estimate.

(2) Reduction of Construction Cost of Revetment

The cost of construction work for the revetment occupies over 80% of the direct cost of the project in the embankment section. Moreover, the conveyance cost for the rocks from quarry site occupies 45% of the revetment works. In the places where existing revetment works and groin works still remain, such as in the Majes-Camana River and the Canete River, it is thought that reusing of materials leads to reduction of construction costs.

(3) Balance of Earth Volume for Embankment and Excavation Volume

As for balance of earth volume for embankment and excavation, there are shortages earth materials for embankment with 240,000m^3 in the Canete River, 122,000m^3 in the Chincha River, 203,000m^3 in the Pisco River, and 695,000m^3 in the Majes-Camana River. Since land along the river is used for farmland, the earth materials for embanked shall be taken from riverbed material. In case of excavation in riverbed, making flow capacity increase, there is possibility that dike height will be lower a little. On the other hand, there is possibility for promoting riverbed scouring due to steep river. In the detail design phase, the selection of adequate places for borrow pits shall be important.

(4) The Diversion Weir Structure in the Chincha River

As for the diversion weir planning in the place which distributes to the Chincha River and the Matagente River, since the existing weir was destroyed by floods and is not in operation, the mechanism of destruction by floods shall be clarified and the detail design shall be done by taking into consideration of the safety for floods. The ground sills in direct upstream of the diversion weir is also destroyed by floods. Destruction in this section is caused by concrete structures, scouring of foundation and impacts by sediment flow. Hydraulic model test should be conducted and hydraulic phenomenon should be clarified.

Moreover, the upstream consolidation work is close to filling up by sediments. The riverbed fluctuation for the design should be also considered.