Ministry of Agriculture Republic of Peru

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

FINAL REPORT I-6 SUPPORTING REPORT ANNEX-2 INUNDATION ANALYSIS ANNEX-3 RIVERBED FLUCTUATION ANALYSIS ANNEX-4 FLOOD CONTROL PLAN ANNEX-5 FLOOD FORECASTING AND WARNING SYSTEM IN THE CHIRA BASIN ANNEX-6 SEDIMENT CONTROL

March 2013

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

> YACHIYO ENGINEERING CO., LTD. NIPPON KOEI CO., LTD. NIPPON KOEI LATIN AMERICA – CARIBBEAN Co., LTD.



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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 Método /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	Oficina de Programación e Inversiones/Programming and Investment Office	
(OPP)	(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-2 Inundation Analysis

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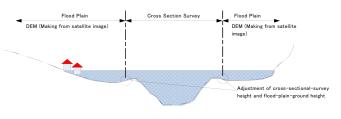
CHAPTER 1 INUNDATION ANALYSIS METHOD

The possible inundation areas are required to identify for each probable flood such as in 10 years, 25 years, and 50 years. Flood inundation analysis is reviewed, corrected if needed and utilized in consideration of the result of the analysis using HEC-RAS in the program-level perfil by DGHI.

1.1 Selection of Calculation Method

Methods for inundation analysis consist of generally the following three kinds of models.

- 1) One-dimensional non uniform-flow model
- 2) Pond model
- Horizontal two-dimensional unsteady-flow model



Since the time and the cost differ sharply depending on the kind of analysis method, the more efficient



analysis method which can secure the accuracy required for preparation of the possible inundation areas map is chosen.

The characteristics of the inundation analysis method are shown in *Table 1.1*. At the beginning of the Study, the inundation type in the targeted river was assumed to be "the flow-down-type" based on the existing inundation simulation results and the riverbed gradient 1/100-1/300, the inundation analysis was planned to be carried out adopting one-dimensional-non-uniform-flow model. However, since the inundation flow type was assumed to be spread type (diffusion type) in the downstream of the targeted section in the river, it was decided to use the horizontal- two-dimensional-unsteady flow model in order to raise accuracy.

Analysis Model	One-dimensional non uniform-flow model	Pond model	Horizontal- two-dimensional-unsteady- flow model
Concept for setup of inundation areas	The flood plain is also treated as a part of main channel, and the inundation area is set up by the computation of water level in the main channel equivalent to the peak discharge of the flood.	The flood plain and the main channel are separated and the flood plain is dealt with as one "closed domain". This unified domain is called "pond" and the flood water level in it is the same. The inundation area is set up from the relation of the flood volume overflowed from the main channel into the flood plain and the topographical feature (water level-capacity (volume)-area) in the flood plain.	The flood plain and the main channel are dealt with separately. The inundation area is set up by analyzing the behavior of the inundation flow from the channel to the flood plain as two-dimensional fluid movement.
Image of models	Handling burdled up channel and flood plan Flood plain Channel	Pool plan	Boundary Flood plain Channel
Characteristics of the Model	It can apply to the "flow-down-type" flood which inundation flow down along river. The inundation analysis area is dealt as "non-dike condition" taking account the characteristic of the analysis model.	It can apply to the "non-spreading-type" flood which is surrounded by mountains, high lands embankments, etc. Since the inundation in the closing domain treats as same water surface gradient and no flow velocity, and water level is assumed as the same. However, when continuous embankments exist in the inundation area, the domain of hinterland is classified and required to be treated as "multi-pond model".	It is fundamentally applicable in any Inundation Type. Not only the maximum inundation area or the maximum flood level but also the inundation flow velocity or those temporal changes are reproducible. Moreover, the calculation accuracy is also generally high as compared with other methods. Therefore, there are many operating experiences also in the creation of the possible inundation area map. However, the inundation analysis accuracy is limited depending on the grid size of the analytic model on the characteristic of the model.



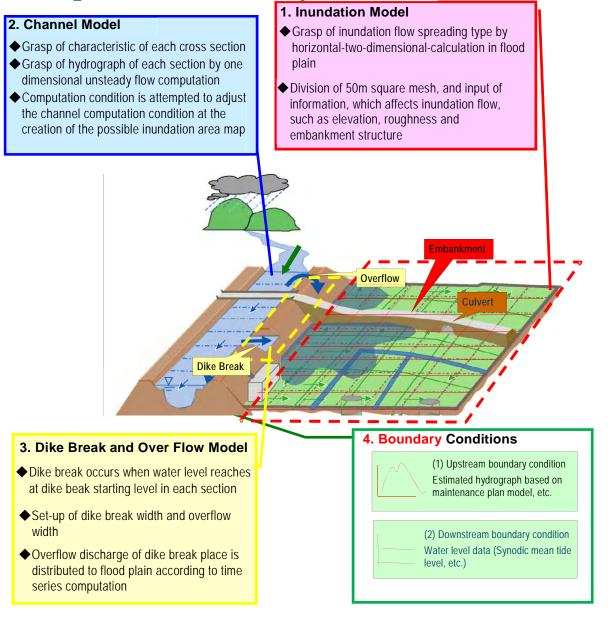


Figure 1.2 Conceptual Diagram of Inundation Analysis Model

1.2 Setup of Calculation Condition

1.2.1 Outline of river basin

Inundation analysis is carried out in the river shown in *Table 1.2*. The outline for each river basin is shown from the next page.

Table 1.2	Rivers Conducted Inundation Analysis
-----------	---

1)	Chira River
2)	Canete River
3)	Chinca River (Chico River, Matagente River)
4)	Pisco River
5)	Yauca River
6)	Majes-Camana River

(1) Chira River

As for the land use of the surrounding hinterland in the Chira river, the farmland is spreading widely in the downstream area, the farmlands gather partially in the middle stream area, etc., and small farmlands are distributed in the riverside as compared with the downstream area.

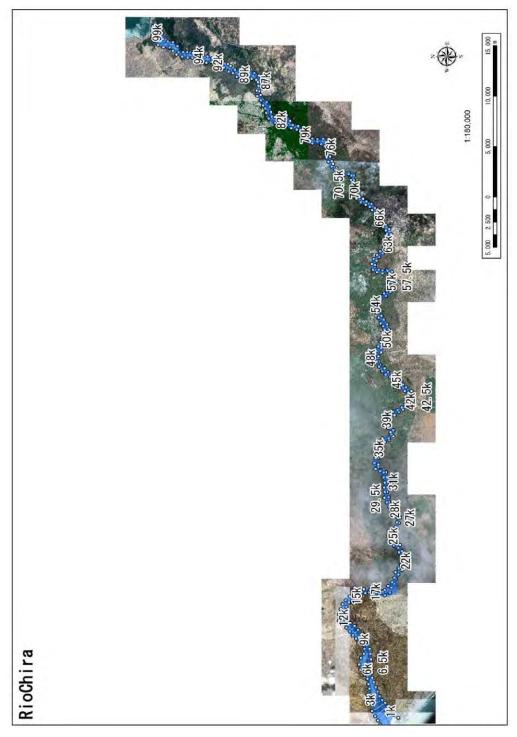


Figure 1.3 Satellite Image of Chira River (by Google Earth)

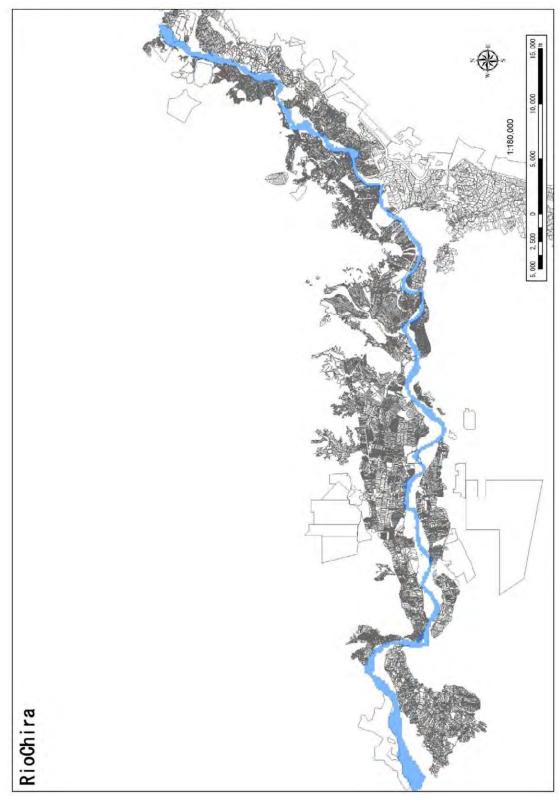


Figure 1.4 Land Use Map of Chira River

(2) Canete River

As for the land use of the surrounding hinterland in the Canete river, the farmland is spreading widely in the downstream area, the farmlands gather partially in the middle stream area, etc., and small farmlands are distributed in the riverside as compared with the downstream area.

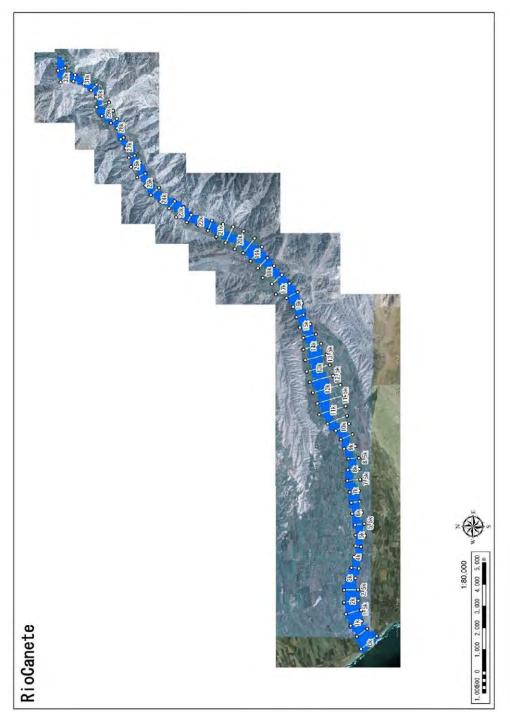


Figure 1.5 Satellite Image of Canete River (by Google Earth)

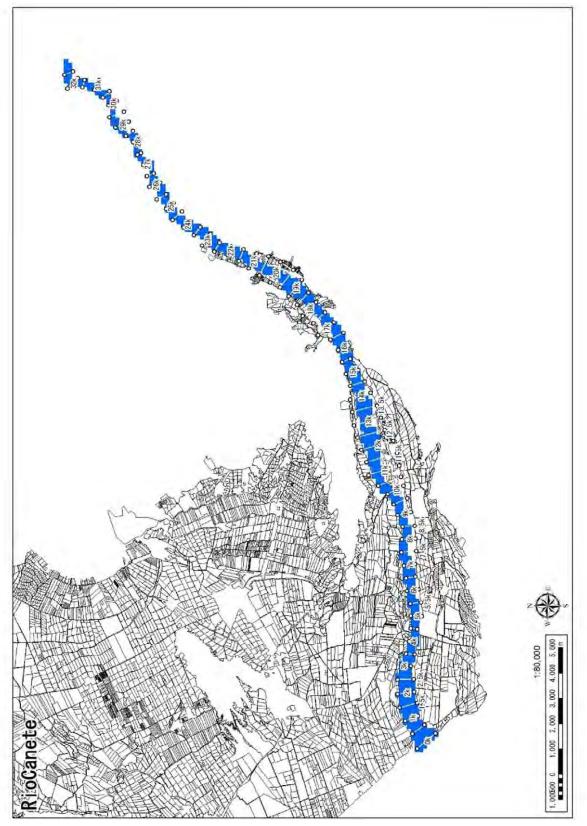


Figure 1.6 Land Use Map of Canete River

(3) Chincha River

As for the land use of the surrounding hinterland in the Chincha River (Chico River, Matagente River), farmlands and city area spread in the downstream area, and it is the assembled farmlands also spread out in the middle stream area.

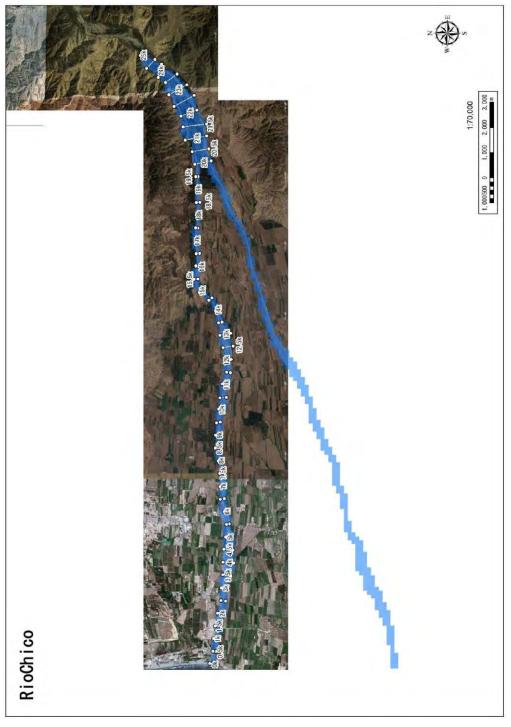


Figure 1.7 Satellite Image of Chico River (by Google Earth)

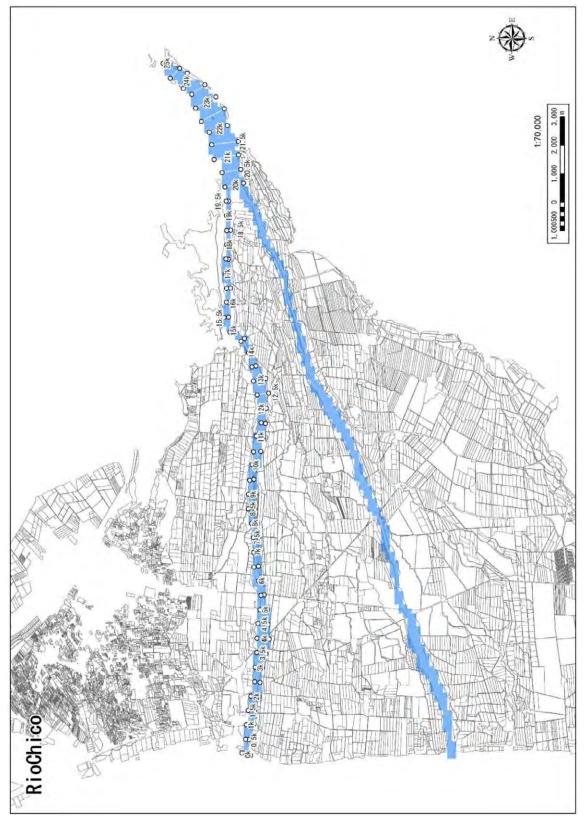


Figure 1.8 Land Use Map of Chico River

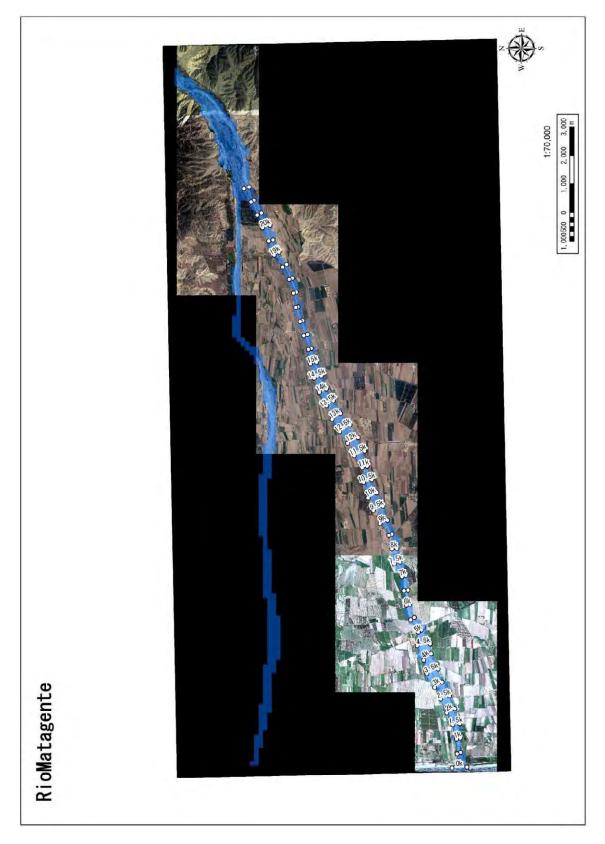


Figure 1.9 Satellite Image of Matagente River (by Google Earth)

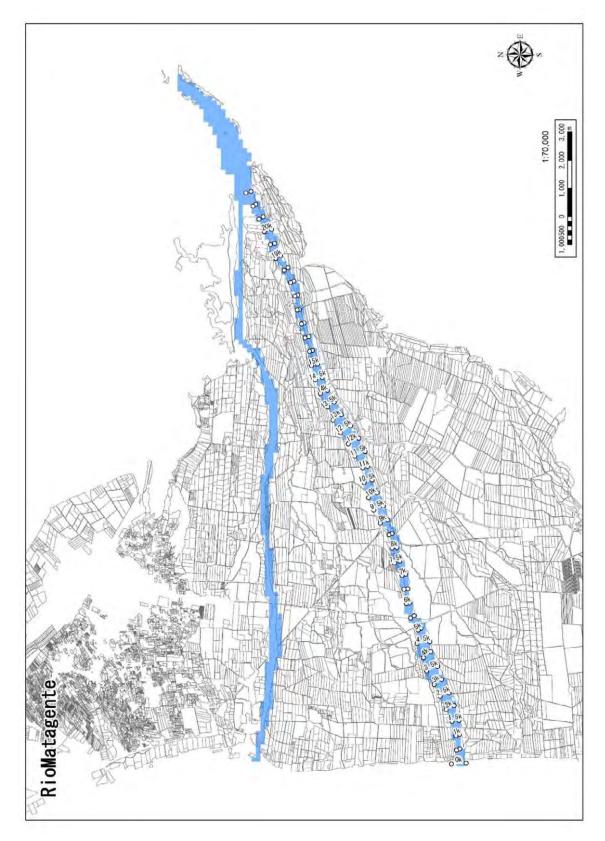


Figure 1.10 Land Use Map of Matagente River

(4) **Pisco River**

As for the land use of the surrounding hinterland in the Pisco river, the farmland is spreading widely in the downstream area, the farmlands gather partially in the middle stream area, etc., and small farmlands are distributed in the riverside as compared with the downstream area.

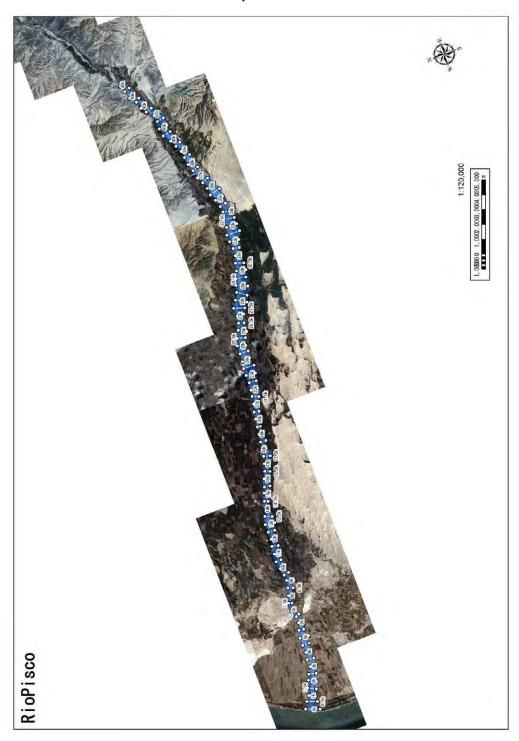


Figure 1.11 Satellite Image of Pisco River (by Google Earth)

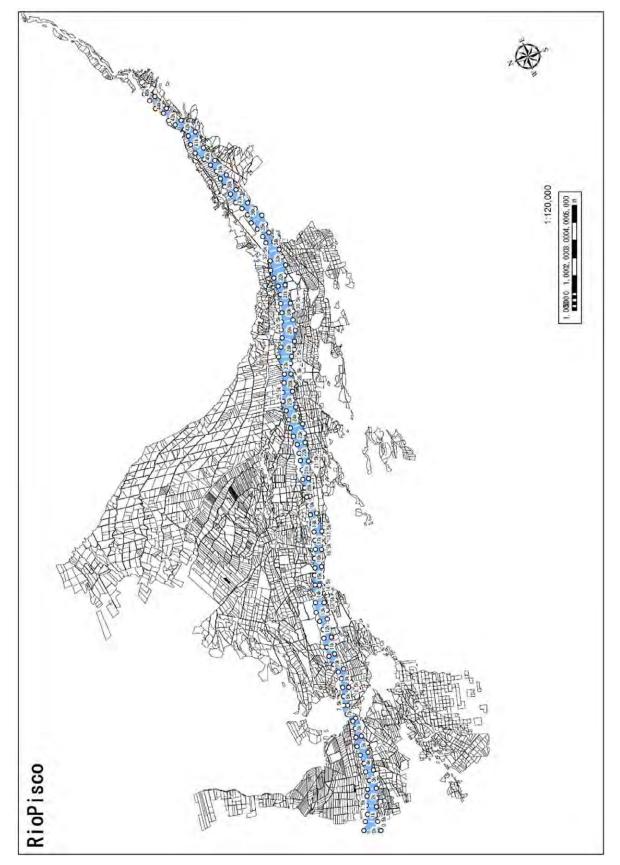


Figure 1.12 Land Use Map of Pisco River

(5) Yauca River

As for the land use of the surrounding hinterland in the Yauca river, the farmland is spreading widely in the downstream area, the farmlands gather partially in the middle stream area, etc., and small farmlands are distributed in the riverside as compared with the downstream area.

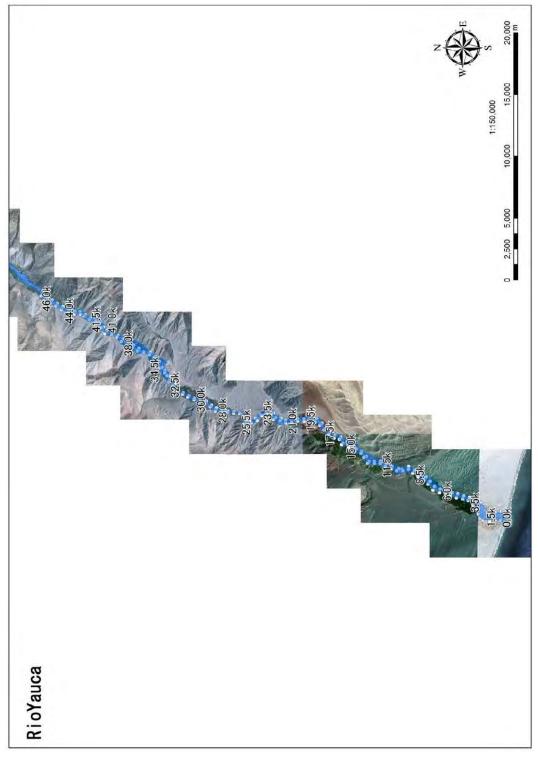


Figure 1.13 Satellite Image of Yauca River (by Google Earth)

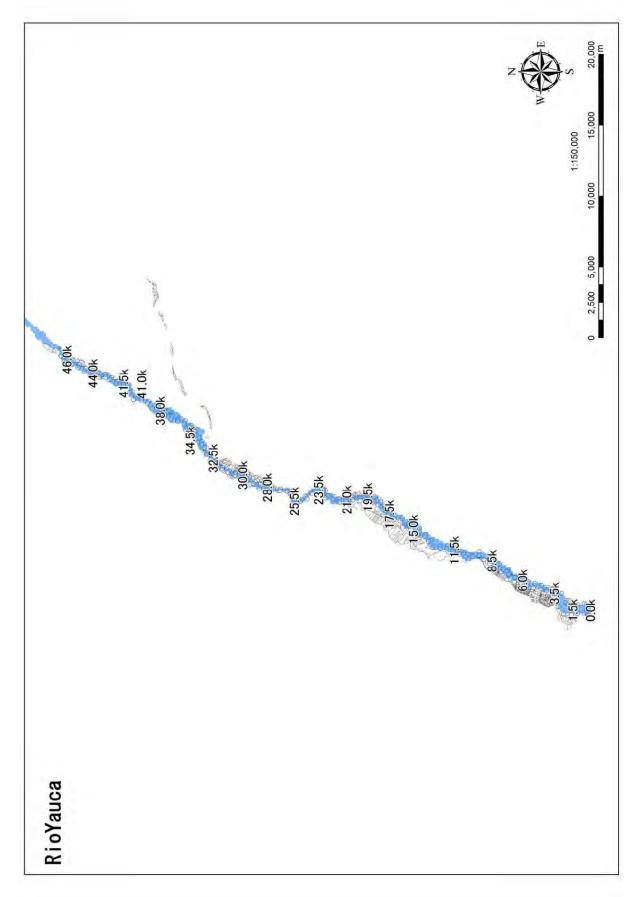


Figure 1.14 Land Use Map of Yauca River

(6) Majes-Camana River

As for the land use of the surrounding hinterland in the Majes-Camana river, the farmland is spreading widely in the downstream area, the farmlands gather partially in the middle stream area, etc., and narrow farmlands are distributed in the riverside as compared with the downstream area.



Figure 1.15 Satellite Image of Majes-Camana River (by Google Earth)

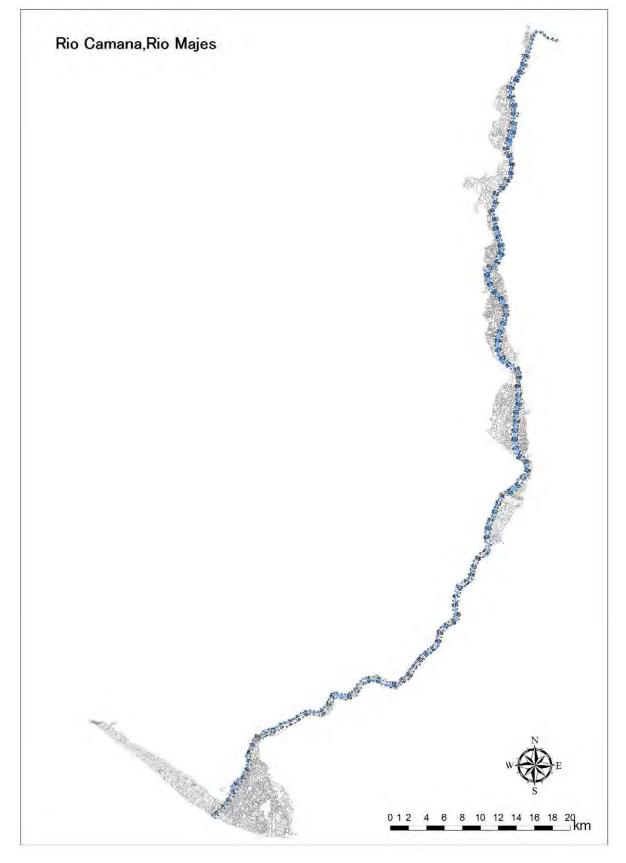


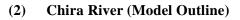
Figure 1.16 Land Use Map of Majes-Camana River

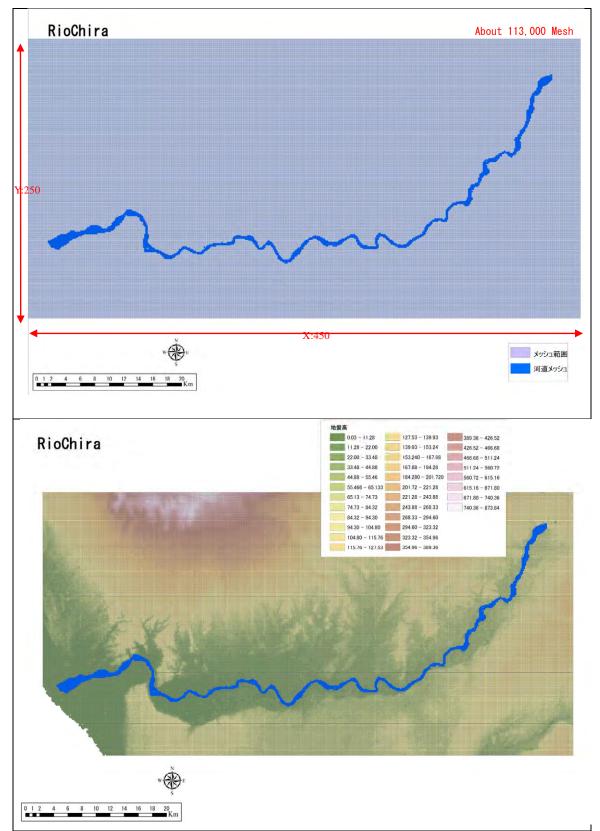
1.2.2 Setup of the Calculation Condition

The calculation conditions and the model outline of the inundation analysis for each river are shown from the next page.

(1)	Chira River (Cal	culation Condition)
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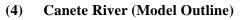
	Item Condition for Inundation Model			Rio Chira
Item Inundation Type			Situation of channel and hinterland (land form and land use) is grasped	Various inundation
		indication Type	based on collected data and field reconnaissance, and classified type of each section.	types such as spreading, retarding and flowing are identified.
		Calculation mesh	East-west direction: about 150m x north -south direction: about 150m	150m mesh
el	lain	Inundation Model area	Inundation flow spreading area from channel (x: 450, y: 250)	About 113,000 meshes
Iod	d Þ	Mesh ground height	ASTER global data (GDEM)	150m mesh
Inundation Model	Flood Plain	Roughness	Based on the weighted average depending on area of farmland: n=0.06, road: n=0.047, others: n=0.05, as well as building occupancy rate and water depth, composite hydraulics roughness is set up. Downstream: Visual inspection based on land use, building occupancy rate and 1/2,500 topographic map Upstream: Visual inspection based on land use, digital national land information, land use mesh in 2006, building occupancy rate and 1/10,000 topographic map	Whole mesh n=0.10
	Struct ure	Continuous embankment	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
	Stı u	structure	NY 1 1	NT .
el		Drainage condition Section for Modeling	No drainage Downstream: river mouth part, Upstream: 99.5 km	No setup 0 - 99.5 km
	nne	Channel data	Channel section survey in this project	Survey in 2010
	Channel	Roughness coefficient	Roughness coefficient of dike side revetment and river bed part is set up by field survey in each divided section.	Side wall: n=0.030 River bed: n=0.030
Iod		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
Channel Model		Discharge Distribution	No inflow from the tributaries	No setup
Chai	Condition	Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 99.5 km
		Downstream Boundary condition	Setup of uniform flow water level in downstream cross section $(I=1/2,500)$	Uniform flow depth I=1/2500
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional- non-uniform-flow calculation
	Basic Condition	Computation time	Setup according to external force (hydrograph of upstream end)	About 90 hours
		Computation interval	Δ t second	2 seconds
	Overflow Condition	Overflow section	When water level in the river overs the dike height, the dike height is set to base height for the computation of revers flow and computation is carried out.	No setup
		Overflow width	$(\log 10x)3.8+62$ / refer to "The Flood Simulation Manual (Draft)" in Japan.	No setup
E			or Assumption as 2 to 3 times of channel width / refer to "The Guideline of Creation of Flood Inundation Area Map in Class B Rivers" in Japan	
Flood Condition		Calculation of overflow water level	Channel discharge computed by one-dimensional-non-uniform-flow model is converted to water level based on H-Q equation made by one-dimensional- non-uniform-flow model. H-Q equation is set up in this project.	No setup
	Dike Break Condition	Broken point	Among maintenance places, dike construction place: either of right-and-left bank side, Excavation place: excavation as dike break in both sides.	Dike break at object point
		Start condition for inundation	When water level in the river reaches the present dike height, dike break starts.	Present dike height
		Height for dike break	Reading based on channel cross section	Present dike height
		Broken width of dike	Setup in consideration of distance interval of cross section and model mesh	450m (150m x 3 mesh)
		Flood discharge calculation method	Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood Simulation Manual
		River bed gradient used for overflow equation	Riverbed gradient at the maximum riverbed depth: about 1/2,500-1/3,000 in the middle stream section, and about 1/1000 in the upstream section.	Setup as 1/1000 or 1/2500 or 1/3000

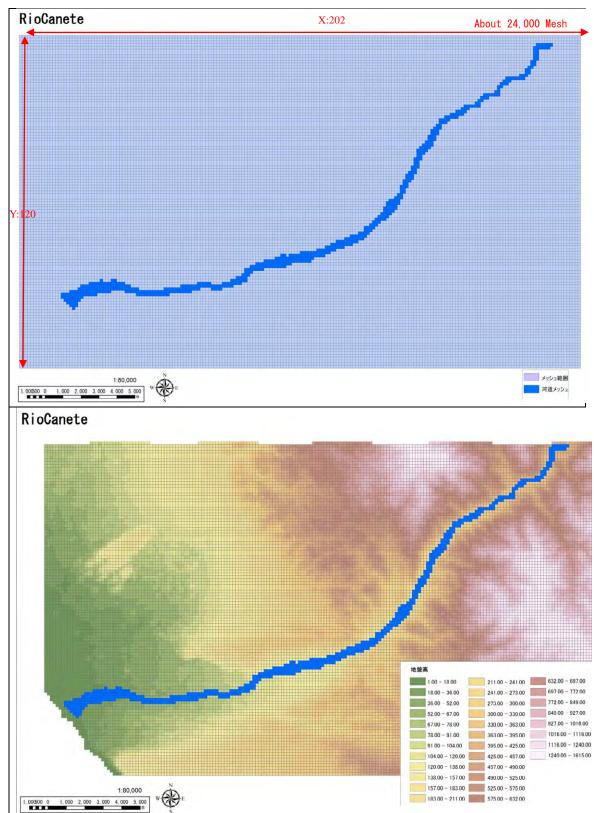




(3)	Canete River	(Calculation	Condition)
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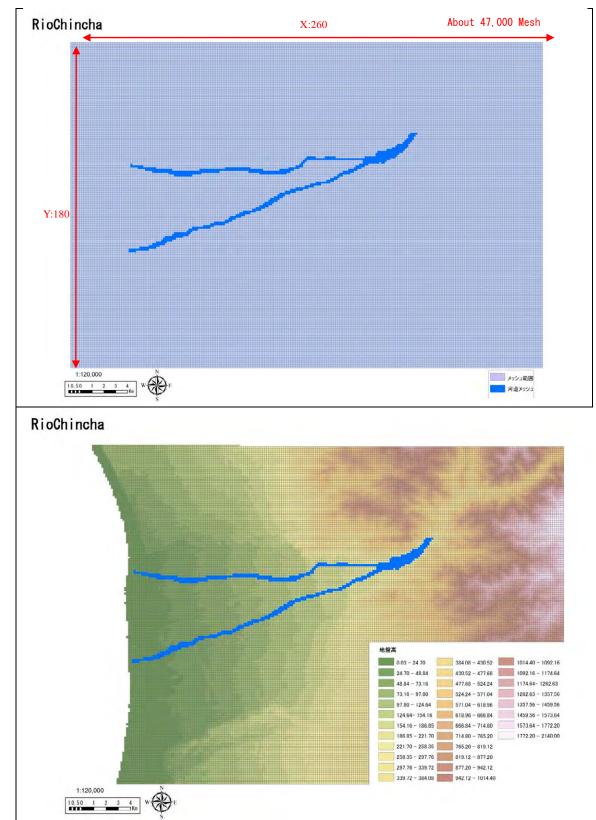
Item		Item	Condition for Inundation Model	Rio Chira
	Inundation Type		Situation of channel and hinterland (land form and land use) is grasped	Various inundation
			based on collected data and field reconnaissance, and classified type of	types such as
			each section.	spreading, retarding
				and flowing are identified.
		Calculation mesh	East-west direction: about 150m x north -south direction: about 150m	150m mesh
	-	Inundation Model	Inundation flow spreading area from channel (x: 202, y: 120)	About 24,000 meshes
lel	lai	area	indidation now spreading area nom enamer (x. 202, y. 120)	7100ut 24,000 mesnes
Iod	d P	Mesh ground height	ASTER global data (GDEM)	150m mesh
n N	Flood Plain	Roughness	Based on the weighted average depending on area of farmland:	Whole mesh n=0.10
tio			n=0.06, road: n=0.047, others: n=0.05, as well as building occupancy	
Inundation Model			rate and water depth, composite hydraulics roughness is set up.	
Inu			Downstream: Visual inspection based on land use, building occupancy rate and 1/2,500 topographic map	
I			Upstream: Visual inspection based on land use, digital national land	
			information, land use mesh in 2006, building occupancy rate and	
			1/10,000 topographic map	
	t	Continuous	Set up of open mouth condition in main roads, rail ways, culverts, etc.	Not setup
	Struct ure	embankment		
	Stı u	structure	NT- Junioran	NI-44
		Drainage condition Section for	No drainage Downstream: river mouth part, Upstream: 32.5 km	Not setup 0 – 32.5 km
	lel	Modeling	Downsteam. nver mouth part, Opsiteam. 52.5 Kill	0 · 52.5 KIII
	Channel	Channel data	Channel section survey in this project	Survey in 2010
	Chi	Roughness	Roughness coefficient of dike side revetment and river bed part is set	Side wall: n=0.040
F		coefficient	up by field survey in each divided section.	River bed: n=0.040
Channel Model		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
IM		Discharge	No inflow from the tributaries	No setup
nel	-	Distribution Upstream boundary	As boundary condition, the discharge hydrograph is set up at the end	Upstream end: 32.5 km
har	tio	condition	of upstream of model area	Opstream end: 52.5 km
C	Condition	Downstream	Setup of uniform flow water level in downstream cross section	Uniform flow depth
		Boundary condition	(I=1/550)	I=1/550
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional-
				non-uniform-flow calculation
		Computation time	Setup according to external force (hydrograph of upstream end)	About 24 hours
	Basic Condit	Computation time	Setup according to external force (hydrograph or upstream chd)	Roout 24 nouis
		Computation	Δ t second	2 seconds
		interval		
		Overflow section	When water level in the river overs the dike height, the dike height is	No setup
			set to base height for the computation of revers flow and computation is carried out.	
	uo	Overflow width	Confluence: $y=2.0(\log 10x)3.8+77$, Others except confluence: $y=1.6$	No setup
	litic	Overnow width	$(\log 10x)3.8+62$ / refer to "The Flood Simulation Manual (Draft)" in	No setup
	ono		Japan.	
	v C		or Assumption as 2 to 3 times of channel width / refer to "The	
uo	Overflow Condition		Guideline of Creation of Flood Inundation Area Map in Class B	
		Calculation of	Rivers" in Japan Channel discharge computed by one-dimensional-non-uniform-flow	No setup
dit		overflow water	model is converted to water level based on H-Q equation made by	No setup
Con		level	one-dimensional- non-uniform-flow model. H-Q equation is set up in	
Flood Condition			this project.	
	Dike Break Condition	Broken point	Among maintenance places, dike construction place: either of	Dike break at object
F			right-and-left bank side, Excavation place: excavation as dike break in	point
		Start condition for	both sides. When water level in the river reaches the present dike height, dike	Present dike height
		inundation	break starts.	i iesem uike height
		Height for dike	Reading based on channel cross section	Present dike height
		break		
		Broken width of	Setup in consideration of distance interval of cross section and model	450m (150m x 3 mesh)
	e B	dike Flood discharge	mesh Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood
	Dik	calculation method	Setup subset on the Frood Simulation Manual (Drait) in Japan	Simulation Manual
	Q	River bed gradient	River bed gradient at the maximum river bed depth: about 1/100 or	Setup as 1/100
		used for overflow equation	less	





(5)	Chincha Rive	r (Calculation	Condition)
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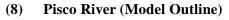
Item		Item	Condition for Inundation Model	Rio Chira
		Inundation Type	Situation of channel and hinterland (land form and land use) is grasped based on collected data and field reconnaissance, and classified type of each section.	Various inundation types such as spreading, retarding and flowing are
Inundation Model	Flood Plain	Calculation mesh Inundation Model	East-west direction: about 150m x north -south direction: about 150m Inundation flow spreading area from channel (x: 260, y: 180)	identified. 150m mesh About 47,000 meshes
		area Mesh ground height	ASTER global data (GDEM)	150m mesh
		Roughness	Based on the weighted average depending on area of farmland: n=0.06, road: n=0.047, others: n=0.05, as well as building occupancy rate and water depth, composite hydraulics roughness is set up. Downstream: Visual inspection based on land use, building occupancy rate and 1/2,500 topographic map Upstream: Visual inspection based on land use, digital national land information, land use mesh in 2006, building occupancy rate and 1/10,000 topographic map	Whole mesh n=0.10
	Struct ure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
	9 1	Drainage condition	No drainage	No setup
	lel	Section for Modeling	Downstream: river mouth part, Upstream: 25.0 km	0 – 25.0 km
	Channel	Channel data Roughness	Channel section survey in this project	Survey in 2010 Side wall: n=0.040
lel	Сһ	coefficient	Roughness coefficient of dike side revetment and river bed part is set up by field survey in each divided section.	River bed: n=0.040
Mod		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
nel I		Discharge Distribution	No inflow from the tributaries	No setup
Channel Model	Condition	Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 26.0 km
		Downstream Boundary condition	Setup of uniform flow water level in downstream cross section Chico (I=1/2000), Matagente (I=300)	Uniform flow depth I=1/200, I=1/300
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional- non-uniform-flow calculation
	Basic Conditio	Computation time	Setup according to external force (hydrograph of upstream end)	About 48 hours
		Computation interval	Δ t second	2 seconds
	Overflow Condition	Overflow section	When water level in the river overs the dike height, the dike height is set to base height for the computation of revers flow and computation is carried out.	No setup
		Overflow width	Confluence: $y=2.0(log10x)3.8+77$, Others except confluence: $y=1.6$ $(log10x)3.8+62$ / refer to "The Flood Simulation Manual (Draft)" in Japan.	No setup
Flood Condition			or Assumption as 2 to 3 times of channel width / refer to "The Guideline of Creation of Flood Inundation Area Map in Class B Rivers" in Japan	
		Calculation of overflow water level	Channel discharge computed by one-dimensional-non-uniform-flow model is converted to water level based on H-Q equation made by one-dimensional- non-uniform-flow model. H-Q equation is set up in this project.	No setup
	Dike Break Condition	Broken point	Among maintenance places, dike construction place: either of right-and-left bank side, Excavation place: excavation as dike break in both sides.	Dike break at object point
		Start condition for inundation	When water level in the river reaches the present dike height, dike break starts.	Present dike height
		Height for dike break	Reading based on channel cross section	Present dike height
		Broken width of dike	Setup in consideration of distance interval of cross section and model mesh	450m (150m x 3 mesh)
		Flood discharge calculation method	Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood Simulation Manual
		River bed gradient used for overflow equation	Based on the riverbed gradient.	Temporary setup as 1/100

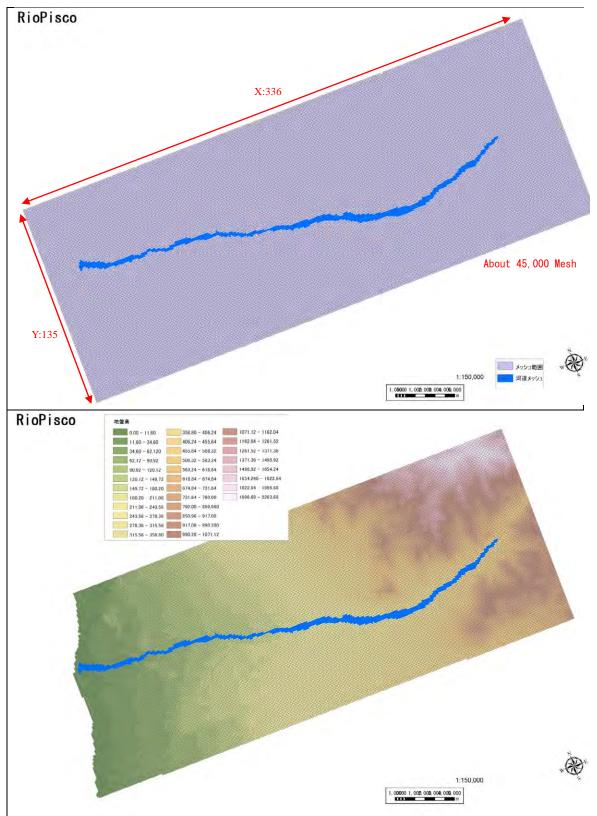


(6) Chincha River (Model Outline)

		Item	Condition for Inundation Model	Rio Chira
		Inundation Type	Situation of channel and hinterland (land form and land use) is grasped based on collected data and field reconnaissance, and classified type of each section.	Various inundation types such as spreading, retarding and flowing are identified.
		Calculation mesh	East-west direction: about 150m x north -south direction: about 150m	150m mesh
del	Flood Plain	Inundation Model area	Inundation flow spreading area from channel (x: 336, y: 135)	About 45,000 meshes
Mo	d P	Mesh ground height	ASTER global data (GDEM)	150m mesh
Inundation Model	Floo	Roughness	Based on the weighted average depending on area of farmland: n=0.06, road: n=0.047, others: n=0.05, as well as building occupancy rate and water depth, composite hydraulics roughness is set up. Downstream: Visual inspection based on land use, building occupancy rate and 1/2,500 topographic map Upstream: Visual inspection based on land use, digital national land information, land use mesh in 2006, building occupancy rate and 1/10,000 topographic map	Whole mesh n=0.10
	Stru ctur	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
	So	Drainage condition	No drainage	No setup
	=	Section for Modeling	Downstream: river mouth part, Upstream: 45.0 km	0 – 45.0 km
	Chann el	Channel data	Channel section survey in this project	Survey in 2010
	Ch	Roughness coefficient	Roughness coefficient of dike side revetment and river bed part is set up by field survey in each divided section.	Side wall: n=0.040 River bed: n=0.040
E.		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
l Mod		Discharge Distribution	No inflow from the tributaries	No setup
Channel Model	Condition	Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 45.0 km
C	Cone	Downstream Boundary condition	Setup of uniform flow water level in downstream cross section $(I=1/2,500)$	Uniform flow depth I=1/2,500
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional- non-uniform-flow calculation
	Basic Condit	Computation time	Setup according to external force (hydrograph of upstream end)	About 48 hours
	Ba Coi	Computation interval	Δ t second	2 seconds
	-	Overflow section	When water level in the river overs the dike height, the dike height is set to base height for the computation of revers flow and computation is carried out.	No setup
	Overflow Condition	Overflow width	Confluence: y=2.0(log10x)3.8+77, Others except confluence: y=1.6 (log10x)3.8+62 / refer to "The Flood Simulation Manual (Draft)" in Japan. or Assumption as 2 to 3 times of channel width / refer to "The Guideline of Creation of Flood Inundation Area Map in Class B	No setup
Flood Condition	Overf	Calculation of overflow water level	Rivers" in Japan Channel discharge computed by one-dimensional-non-uniform-flow model is converted to water level based on H-Q equation made by one-dimensional- non-uniform-flow model. H-Q equation is set up in this project.	No setup
Floc	L	Broken point	Among maintenance places, dike construction place: either of right-and-left bank side, Excavation place: excavation as dike break in both sides.	Dike break at object point
	Dike Break Condition	Start condition for inundation	When water level in the river reaches the present dike height, dike break starts.	Present dike height
	Col	Height for dike break	Reading based on channel cross section	Present dike height
	sreak	Broken width of dike	Setup in consideration of distance interval of cross section and model mesh	450m (150m x 3 mesh)
	Dike B	Flood discharge calculation method	Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood Simulation Manual
	I	River bed gradient used for overflow equation	Based on the riverbed gradient.	Set-up as 1/200

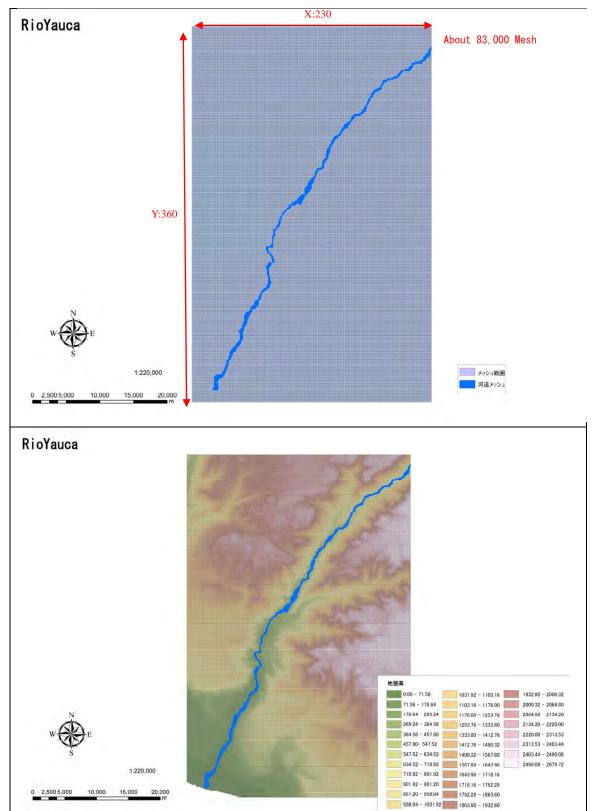
(7) **Pisco River (Calculation Condition)**





(9)	Yauca River	(Calculation	Condition)
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		Item	Condition for Inundation Model	Rio Chira
		Inundation Type	Situation of channel and hinterland (land form and land use) is grasped	Various inundation
			based on collected data and field reconnaissance, and classified type of	types such as
			each section.	spreading, retarding
Channel Model Inundation Model				and flowing are
				identified.
	_	Calculation mesh	East-west direction: about 150m x north -south direction: about 150m	150m mesh
-	ain	Inundation Model area	Inundation flow spreading area from channel (x: 230, y: 360)	About 83,000 meshes
odo	Flood Plain	Mesh ground height	ASTER global data (GDEM)	150m mesh
M	000	Roughness	Based on the weighted average depending on area of farmland: n=0.06,	Whole mesh n=0.10
ion	E		road: $n=0.047$, others: $n=0.05$, as well as building occupancy rate and	
dat			water depth, composite hydraulics roughness is set up.	
			Downstream: Visual inspection based on land use, building occupancy	
In			rate and 1/2,500 topographic map	
			Upstream: Visual inspection based on land use, digital national land	
			information, land use mesh in 2006, building occupancy rate and 1/10,000 topographic map	
		Continuous	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
	Struct ure	embankment		rio ootup
	struc ure	structure		
	9 2	Drainage condition	No drainage	No setup
		Section for	Downstream: river mouth part, Upstream: 46.0 km	0 – 46.0 km
	nel	Modeling		
	Channel	Channel data	Channel section survey in this project	Survey in 2010 Side wall: n=0.040
	Ch	Roughness coefficient	Roughness coefficient of dike side revetment and river bed part is set up by field survey in each divided section.	Side wall: $n=0.040$ River bed: $n=0.040$
E		coefficient	by field survey in each divided section.	Kivel bed. II=0.040
po		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
Ξ		Discharge	No inflow from the tributaries	No setup
me		Distribution		*
har	Condition	Upstream boundary	As boundary condition, the discharge hydrograph is set up at the end of	Upstream end: 46.0
0	ndit	condition Downstream	upstream of model area Setup of uniform flow water level in downstream cross section (I=1/550)	km Uniform flow depth
	Con	Boundary condition	Setup of uniform flow water level in downstream cross section $(1=1/330)$	I=1/1500
	· ·	H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional-
				non-uniform-flow
				calculation
	n	Computation time	Setup according to external force (hydrograph of upstream end)	About 90 hours
	Basic Condition	Computation	Δt second	2 seconds
	Ba	interval	Δ t second	2 seconds
	Ŭ	inter (ur		
		Overflow section	When water level in the river overs the dike height, the dike height is set	No setup
			to base height for the computation of revers flow and computation is	
	ion	0 // 11	carried out.	
	dit	Overflow width	Confluence: $y=2.0(\log 10x)3.8+77$, Others except confluence: $y=1.6$ (log10x)3.8+62 / refer to "The Flood Simulation Manual (Draft)" in	No setup
	Con		Japan.	
) w		or Assumption as 2 to 3 times of channel width / refer to "The Guideline	
a	Overflow Condition		of Creation of Flood Inundation Area Map in Class B Rivers" in Japan	
itio	Iəv	Calculation of	Channel discharge computed by one-dimensional-non-uniform-flow	No setup
puo	0	overflow water	model is converted to water level based on H-Q equation made by	
ŭ		level	one-dimensional- non-uniform-flow model. H-Q equation is set up in this project.	
Flood Condition		Broken point	Among maintenance places, dike construction place: either of	Dike break at object
FI		I I I	right-and-left bank side, Excavation place: excavation as dike break in	place
	_		both sides.	
	tior	Start condition for	When water level in the river reaches the present dike height, dike break	Present dike height
	ndi	inundation Height for dike	starts.	Dracont diles k - ! - 1.4
	Col	Height for dike break	Reading based on channel cross section	Present dike height
	ak	Broken width of	Setup in consideration of distance interval of cross section and model	450m (150m x 3
	Dike Break Condition	dike	mesh	mesh)
	ike	Flood discharge	Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood
	D	calculation method	Pivorbad gradiants About 1/250 in the downstream section of the 4.0.1	Simulation Manual
		River bed gradient used for overflow	Riverbed gradient: About 1/250 in the downstream section at the 4.0 km distance mark, About 1/150 in the upstream section at the 4.0 km distance	Setup as 1/250, 1/150
		equation	mark.	
		1		I

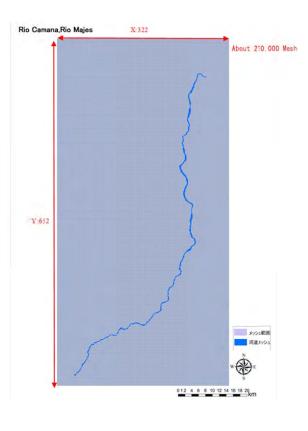


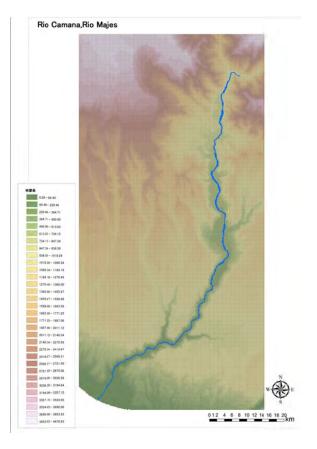
(10) Yauca River (Model Outline)

(11)	Majes-Camana	River (Calculation	Condition)
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		Item	Condition for Inundation Model	Rio Chira
		Inundation Type	Situation of channel and hinterland (land form and land use) is grasped	Various inundation
			based on collected data and field reconnaissance, and classified type of	types such as
			each section.	spreading, retarding and flowing are
				and flowing are identified.
		Calculation mesh	East-west direction: about 150m x north -south direction: about 150m	150m mesh
	.я	Inundation Model	Inundation flow spreading area from channel (x: 322, y: 653)	About 210,000
del	Plai	area		meshes
Mod	[pc	Mesh ground height	ASTER global data (GDEM)	150m mesh
tion I	Flood Plain	Roughness	Based on the weighted average depending on area of farmland: $n=0.06$, road: $n=0.047$, others: $n=0.05$, as well as building occupancy rate and	Whole mesh n=0.10
Inundation Model			water depth, composite hydraulics roughness is set up. Downstream: Visual inspection based on land use, building occupancy	
Ĩ			rate and 1/2,500 topographic map Upstream: Visual inspection based on land use, digital national land	
			information, land use mesh in 2006, building occupancy rate and	
		Continuous	1/10,000 topographic map	N to
	e ct	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
	Struct ure	Drainage condition	No drainage	No setup
	0 1	-		1
		Section for Modeling	Downstream: river mouth part, Upstream: 115.0 km	0-40.0 km (Camana
	nel			river), 40.0-115.0 km (Majes river)
	Channel	Channel data	Channel section survey in this project	Survey in 2010
	5	Roughness coefficient	Roughness coefficient of dike side revetment and river bed part is set	Side wall: n=0.040
lel		0	up by field survey in each divided section.	River bed: n=0.040
Aoč		Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
Channel Model		Discharge Distribution	No inflow from the tributaries	No setup
Chan	Condition	Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 115.0 km
	Cone	Downstream Boundary condition	Setup of uniform flow water level in downstream cross section $(I=1/100)$	Uniform flow depth I=1/100
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	one dimensional non-uniform flow calculation
	c it	Computation time	Setup according to external force (hydrograph of upstream end)	About 20 hours
	Basic Condit ion	Computation interval	Δ t second	2 seconds
		Overflow section	When water level in the river overs the dike height, the dike height is set to base height for the computation of revers flow and computation is carried out.	No setup
	Overflow Condition	Overflow width	Confluence: y=2.0(log10x)3.8+77, Others except confluence: y=1.6 (log10x)3.8+62 / refer to "The Flood Simulation Manual (Draft)" in Japan. or Assumption as 2 to 3 times of channel width / refer to "The	No setup
u	rflow		Guideline of Creation of Flood Inundation Area Map in Class B Rivers" in Japan	
litic	Ove	Calculation of	Channel discharge computed by one-dimensional-non-uniform-flow	No setup
Flood Condition	Ŭ	overflow water level	model is converted to water level based on H-Q equation made by one-dimensional- non-uniform-flow model. H-Q equation is set up in	
loo		Broken point	this project. Among maintenance places, dike construction place: either of	Dike break at object
Ŧ	E	Droken point	right-and-left bank side, Excavation place: excavation as dike break in both sides.	place
	Dike Break Condition	Start condition for inundation	When water level in the river reaches the present dike height, dike break starts.	Present dike height
	Col	Height for dike break	Reading based on channel cross section	Present dike height
	reak	Broken width of dike	Setup in consideration of distance interval of cross section and model mesh	450m (150m x 3 mesh)
	oike B	Flood discharge calculation method	Setup based on the Flood Simulation Manual (Draft) in Japan	Compliance of Flood Simulation Manual
	Q	River bed gradient used for overflow equation	About $1=1/150-1/100$ (Majes River), About $I=1/200-1/150$ (Camana River).	Setup as 1/200, 1/150, 1/100

(12) Majes-Camana River (Model Outline)





CHAPTER 2 RESULTS OF INUNDATION ANALYSIS

The results of inundation analysis such as inundation area with case and without case, or after the project implementation and before the project implementation, for each river are shown after next page.

2.1 Chira River

(1) Hydrograph for each Probable Flood Scale

The peak discharge according to probable flood scale in the Chira River is shown in *Table 2.1*, and the hydrographs are shown in *Figure 2.1*. Among these, 1/5, 1/10, 1/25, and 1/50 year probable flood hydrographs were made into the object for the inundation analysis.

Table 2.1Peak Discharge to EachProbable Flood Scale (Chira River)

	c
2	890.00
5	1,727.00
1	2,276.00
2	2,995.00
5	3.540.00
100	4.058.00

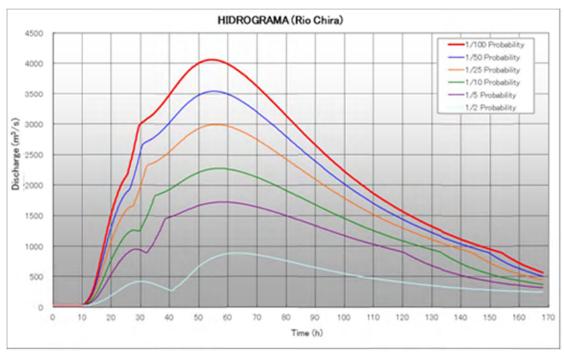


Figure 2.1 Probable Flood Hydrographs (Chira River)

(2) Result of Inundation Analysis (without case)

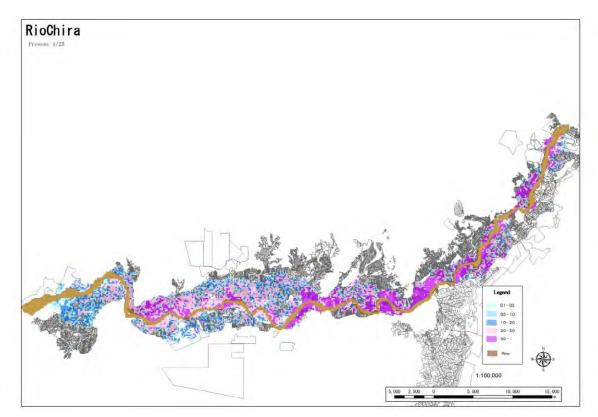
The result of inundation analysis for each probable flood without case in the Chira river is shown below.

Table 2.2	Inundation area for each I	Probable Flood Scale	in Chira River (Without case)

Without Case	1/5		1/10		1/25		1/50	
	No, of Mesh	ha						
Chira	6,233	14,024.3	7,340	16,515.0	8,661	19,487.3	9,589	21,575.3

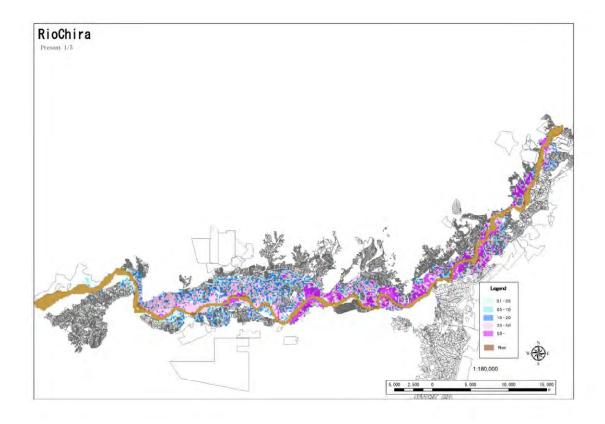
Chira River (1/50 Year Probable Flood) Without Case

Chira River (1/25 Year Probable Flood) Without Case



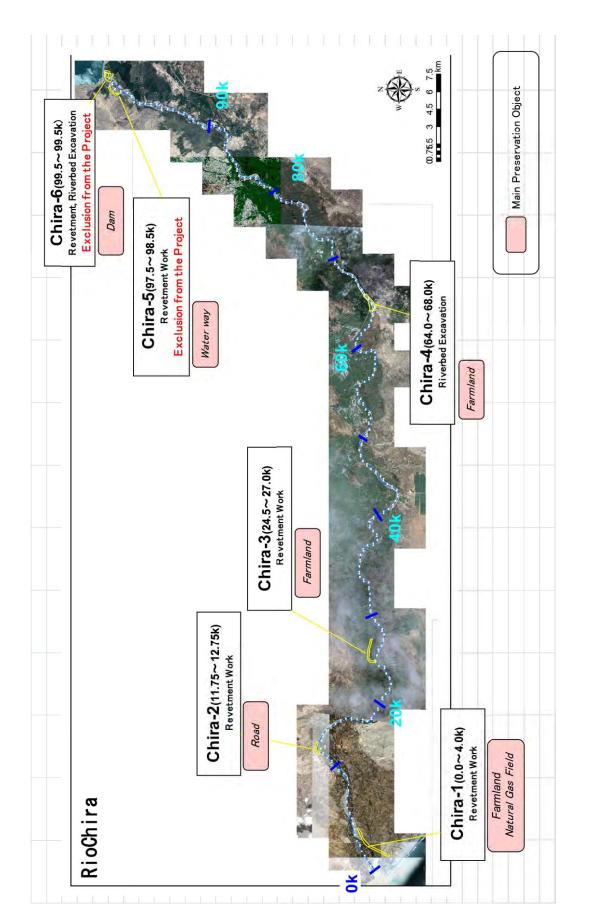
Chira River (1/10 Year Probable Flood) Without Case

Chira River (1/5 Year Probable Flood) Without Case



(3) Flood Mitigation Measures

From the result of inundation analysis without case, the locations of flood mitigation measures such as riverbed excavation, revetments and dykes for flood were planned by taking into account the spreading areas of flood. The locations of measures are shown in *Figure 2.2*.



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-2 Inundation Analysis

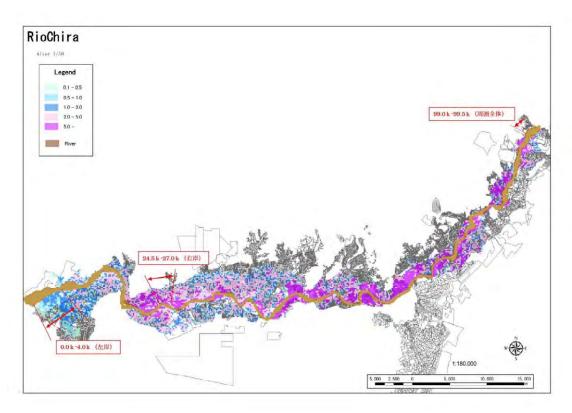
(4) **Result of Inundation Analysis for each Probable Flood (with case)**

The result of inundation analysis for each probable flood scale with case is shown below.

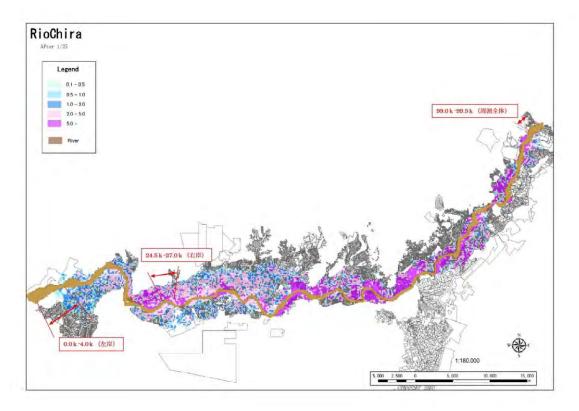
Table 2.3 Inundation Area for each Probable Flood Scale in Chira River With case)

	With Case	1/5		1/10		1/25		1/50	
		No, of Mesh	ha						
	Chira	6,233	14,024.3	7,340	16,515.0	8,661	19,487.3	9,586	21,568.5

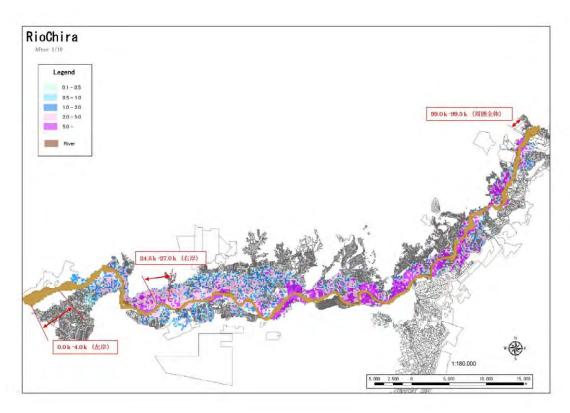
Chira River (1/50 Year Probable Flood) With Case



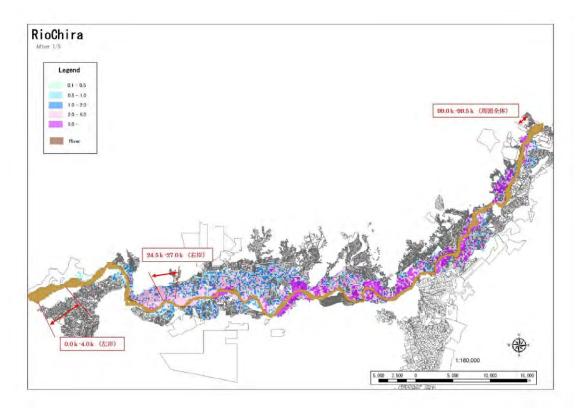
Chira River (1/25 Year Probable Flood) With Case



Chira River (1/10 Year Probable Flood) With Case



Chira River (1/5 Year Probable Flood) With Case



2.2 Canete River

(1) Hydrograph for each Probable Flood Scale

Table 2.4 Peak Discharge to Each Probable

Flood Scale (Canete River)

The peak discharge according to probable flood scale in the Canete River is shown in *Table 2.4*, and the hydrographs are shown in *Figure 2.3*. Among these, 1/5, 1/10, 1/25, and 1/50 year probable flood hydrographs were made into the object for the inundation analysis.

Heturn Period	Q (M3/S)
2	331
5	407
10	822
25	1 4 9 6
50	2175
100	2751

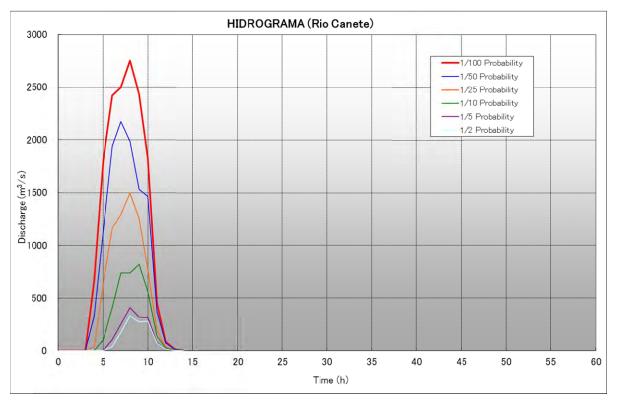


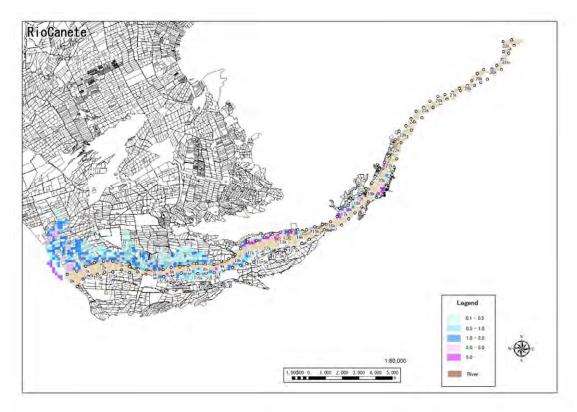
Figure 2.3 Probable Flood Hydrographs (Canete River)

(2) Result of Inundation Analysis (without case)

The result of inundation analysis for each probable flood without case in the Canete River is shown below.

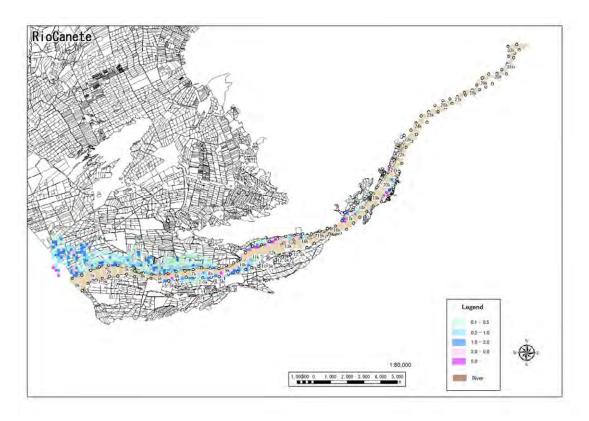
 Table 2.5
 Inundation Area for each Probable Flood Scale in Chanete River (Without case)

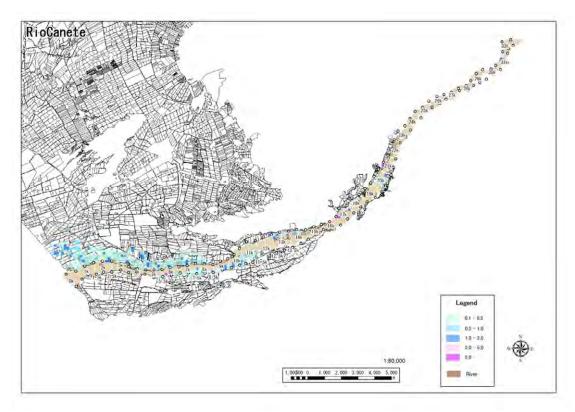
Without Case	1/5		1/10		1/25		1/50		
	No, of Mesh	ha	No, of Mesh	ha	No, of Mesh	ha	No, of Mesh	ha	
	Canete	73	164.3	391	879.8	552	1,242.0	678	1,525.5



Canete River (1/50 Year Probable Flood) Without Case

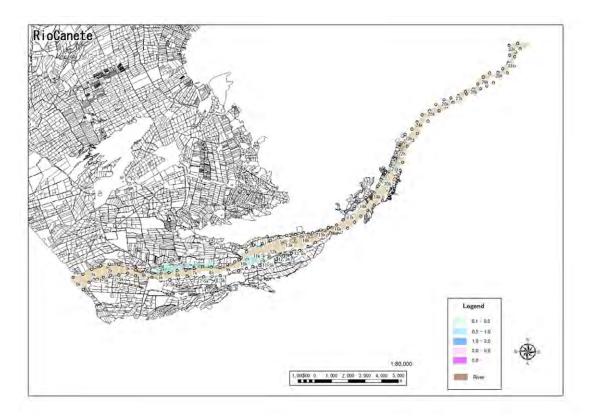
Canete River (1/25 Year Probable Flood) Without Case





Canete River (1/10 Year Probable Flood) Without Case

Canete River (1/5 Year Probable Flood) Without Case



(3) Flood Mitigation Measures

From the result of inundation analysis without case, the locations of flood mitigation measures such as riverbed excavation, revetments and dykes for flood were planned by taking into account the spreading areas of flood. The locations of measures are shown in *Figure 2.4*.

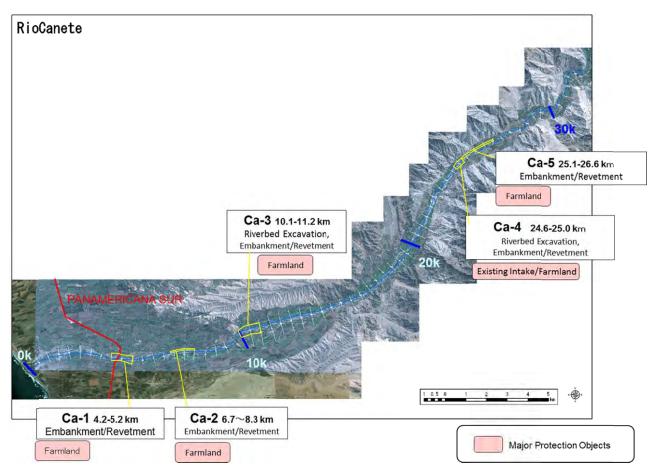


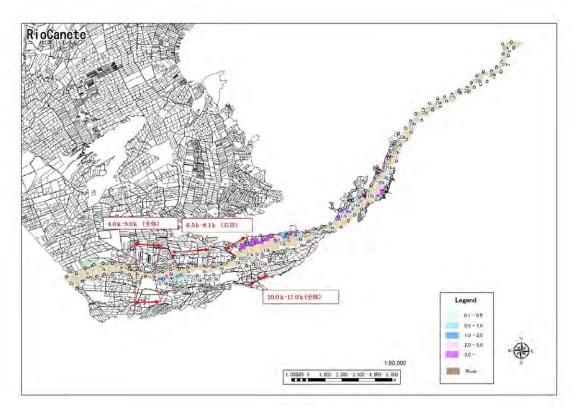
Figure 2.4 Locations for Flood Mitigation Measures in Canete River

(4) Result of Inundation Analysis for each Probable Flood (with case)

The result of inundation analysis for each probable flood scale with case is shown below.

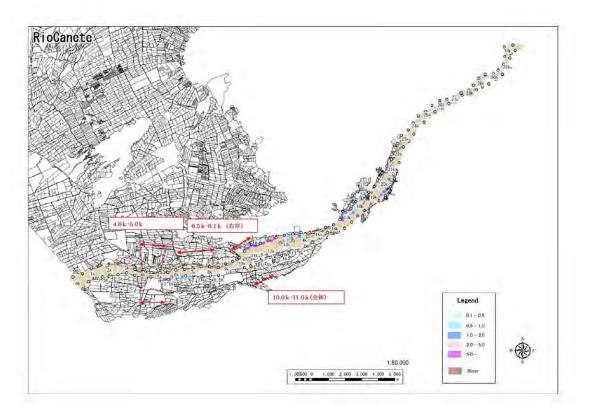
Table 2.6 Inundation area for each Probable Flood Scale in Canete River (with case)

With Case	1/5		1/10		1/25		1/50		
	No, of Mesh	ha							
	Canete	21	47.3	60	135.0	93	209.3	125	281.3

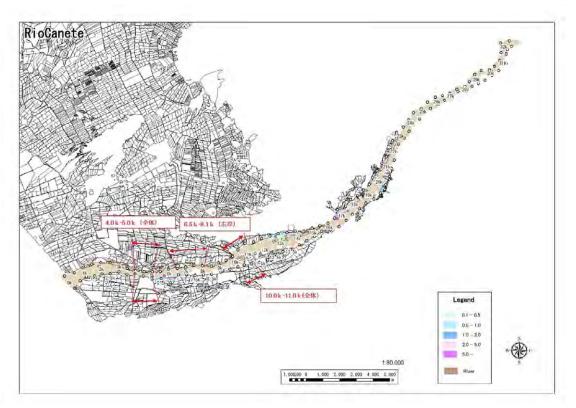


Canete River (1/50 Year Probable Flood) With Case

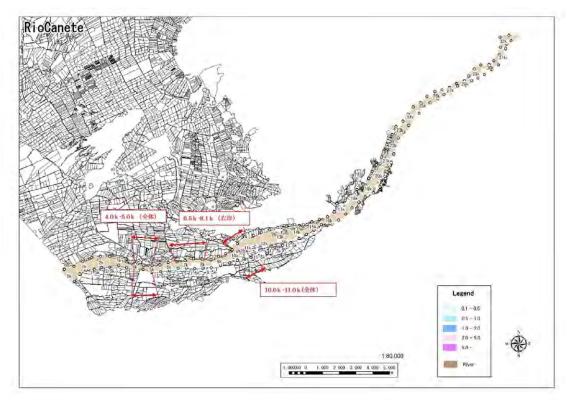
Canete River (1/25 Year Probable Flood) With Case



Canete River (1/10 Year Probable Flood) With Case



Canete River (1/5 Year Probable Flood) With Case



2.3 Chincha River

(1) Hydrograph for each Probable Flood Scale

The peak discharge according to probable flood scale in the Chinca River is shown in *Table 2.7*, and the hydrographs are shown in *Figure 2.5* Among these, 1/5, 1/10, 1/25, and 1/50 year probable flood hydrographs were made into the object for the inundation analysis.

Table 2.7Peak Discharge to Each ProbableFlood Scale (Chincha River)

Return Period	Q (M3/S)		
2	102		
5	236		
10	290		
25	403		
50	458		
100	586		

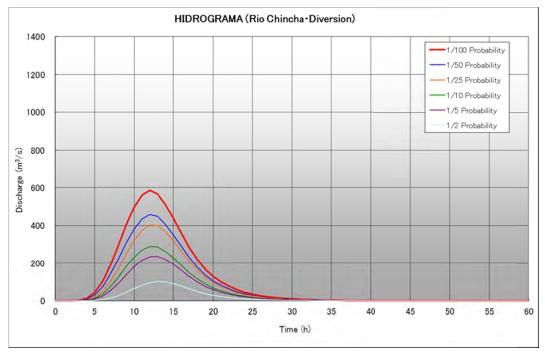
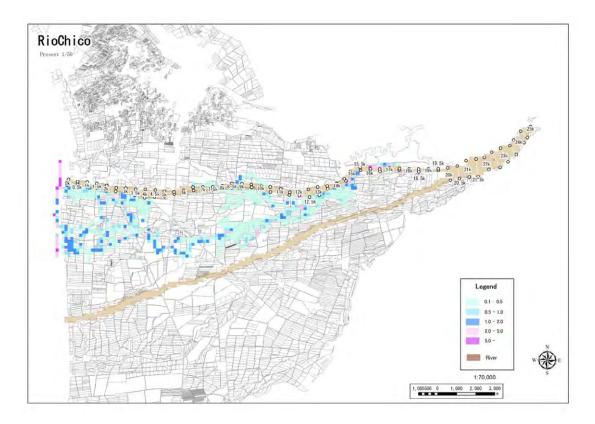


Figure 2.5 Probable Flood Hydrographs (Chincha River)

(2) Result of Inundation Analysis (without case)

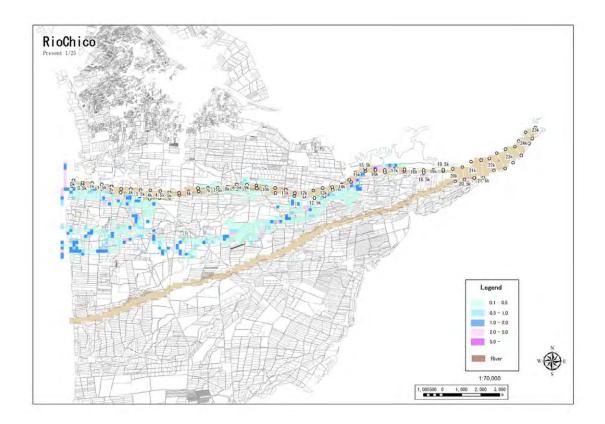
The result of inundation analysis for each probable flood without case in the Chincha River is shown below.

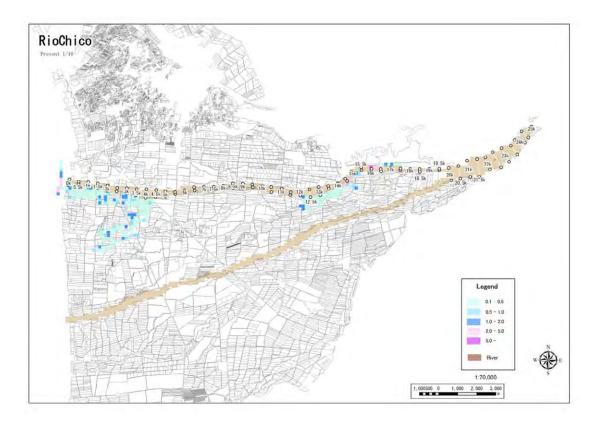
	Without Case		1/5		1/10		1/25		1/50	
			No, of Mesh	ha						
	Chincha	(1)Chico	270	607.5	293	659.3	714	1,606.5	827	1,860.8
01.1		2)Matagente	249	560.3	265	596.3	498	1,120.5	587	1,320.8
Chin		③No. of Overlap Mesh	0	0.0	0	0.0	249	560.3	256	576.0
		1+2-3	519	1,167.8	558	1,255.5	963	2,166.8	1,158	2,605.5



Chincha (Chico) River (1/50 Year Probable Flood) Without Case

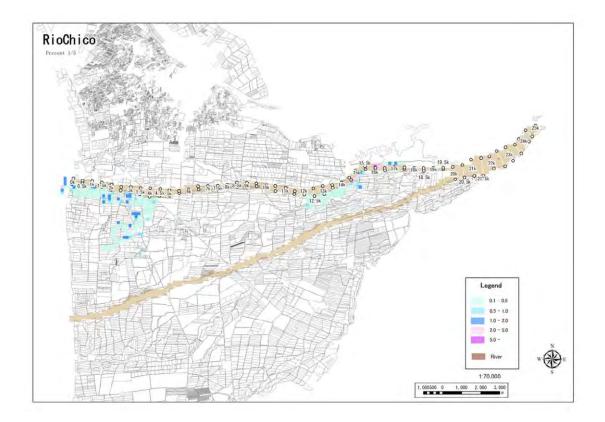
Chincha (Chico) River (1/25 Year Probable Flood) Without Case

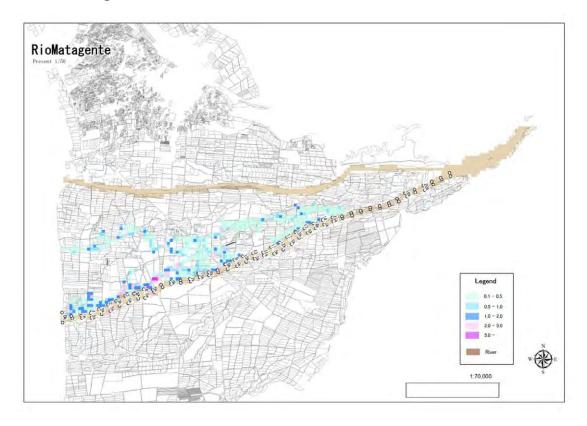




Chincha (Chico) River (1/10 Year Probable Flood) Without Case

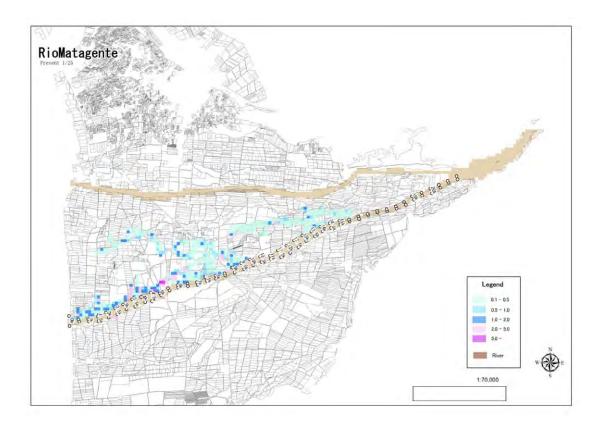
Chincha (Chico) River (1/5 Year Probable Flood) Without Case

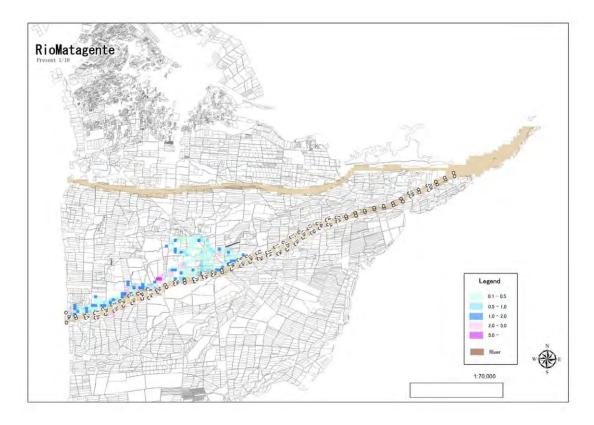




Chincha (Matagente) River (1/50 Year Probable Flood) Without Case

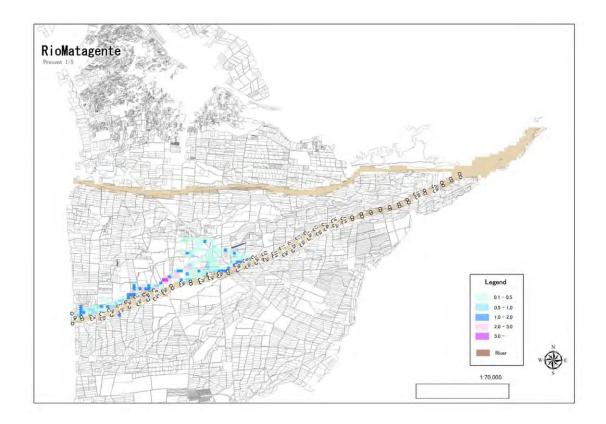
Chincha (Matagente) River (1/25 Year Probable Flood) Without Case





Chincha (Matagente) River (1/10 Year Probable Flood) Without Case

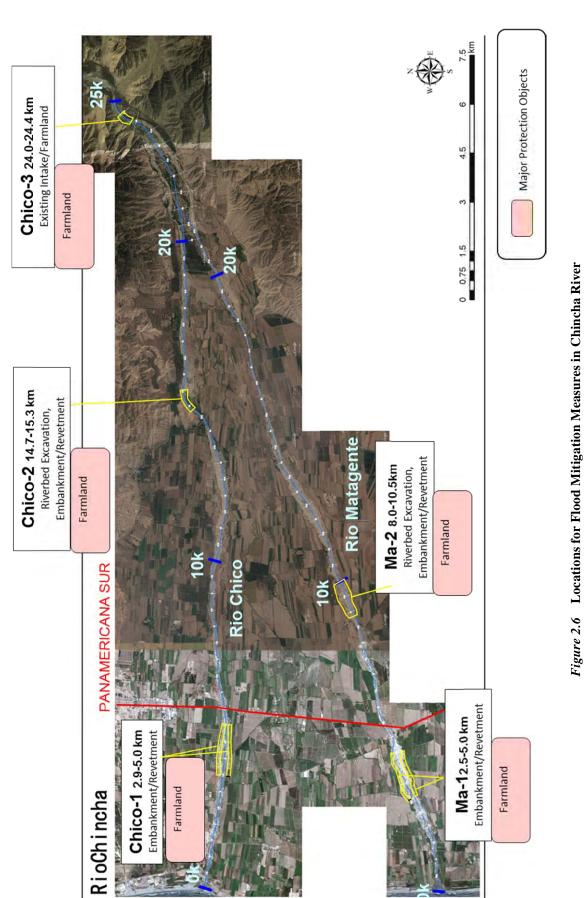
Chincha (Matagente) River (1/5 Year Probable Flood) Without Case



(3) Flood Mitigation Measures

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From the result of inundation analysis without case, the locations of flood mitigation measures such as riverbed excavation, revetments and dykes for flood were planned by taking into account the spreading areas of flood. The locations of measures are shown in *Figure 2.6*.



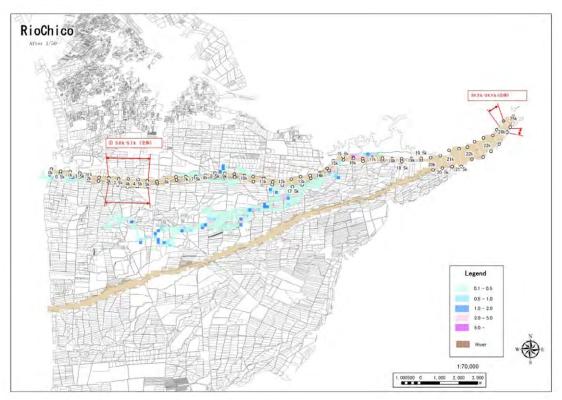
The Preparatory Study on Project of the Protection of Flood Plain and Vulnerable Rural Population against Flood in the republic of Peru Feasibility Study Report, Supporting Report, Annex-2 Inundation Analysis

(4) Result of Flood Analysis According to each Probable Flood Scale (with case)

The result of inundation analysis for each probable flood scale with case is shown Table 2.9.

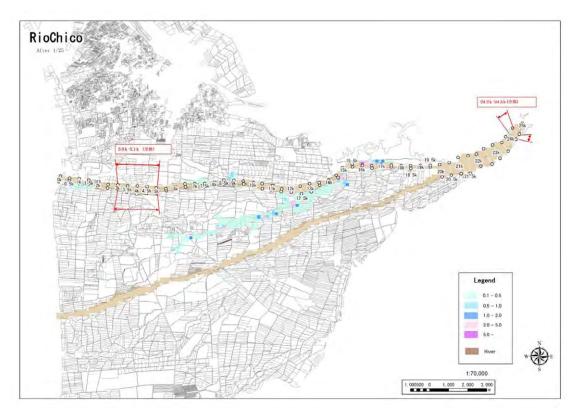
Table 2.9 Inundation area for each Probable Flood Scale in Chincha (With case)

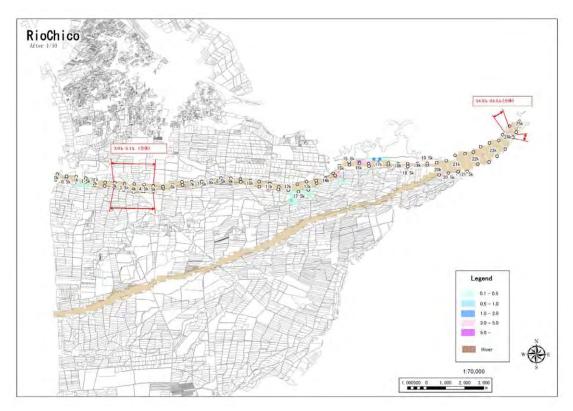
		1/5		1/10		1/25		1/50	
Y	With Case		ha	No, of Mesh	ha	No, of Mesh	ha	No, of Mesh	ha
Chincha	1)Chico	24	54.0	56	126.0	248	558.0	397	893.3
	②Matagente	-	-	-	-	148	333.0	245	551.3
	③No. of Overlap Mesh	-	-	-	-	76	171.0	140	315.0
	1+2-3	24	54.0	56	126.0	320	720.0	502	1,129.5



Chincha (Chico) River (1/50 Year Probable Flood) With Case

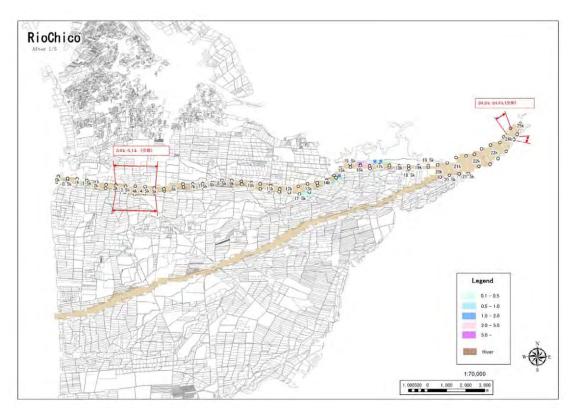
Chincha (Chico) River (1/25 Year Probable Flood) With Case

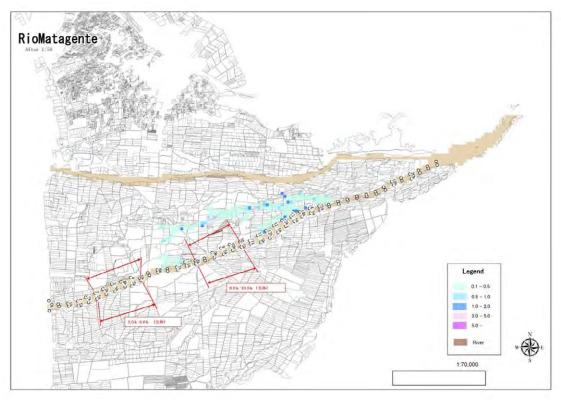




Chincha (Chico) River (1/10 Year Probable Flood) With Case

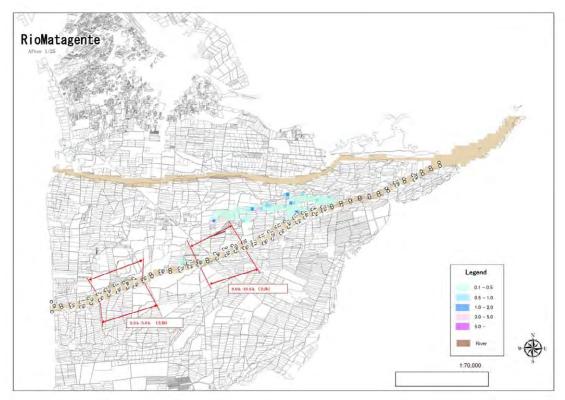
Chincha (Chico) River (1/5 Year Probable Flood) With Case

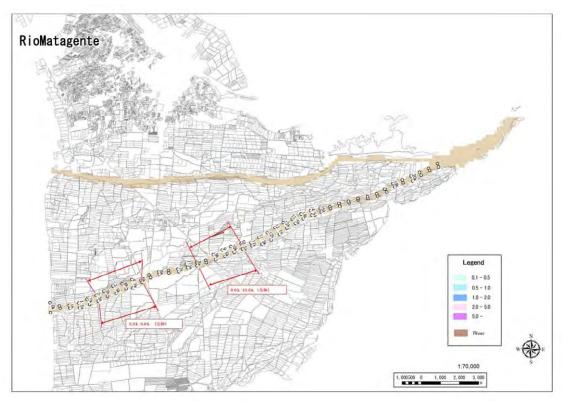




Chincha (Matagente) River (1/50 Year Probable Flood) With Case

Chincha (Matagente) River (1/25 Year Probable Flood) With Case





Chincha (Matagente) River (1/10 Year Probable Flood) With Case

Chincha (Matagente) River (1/5 Year Probable Flood) With Case

