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.
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Boundary representation is not necessarily authoritative
COLOMBIA
ECUADOR
BRAZIL
PERU
BOLIVIA
CHILE
SOUTH PASIFIC OCEAN
PIURA
Chira
LIMA
Canete
Chincha
Pisco
ICA
Yauca
AREQUIPA
Camana/Majes
LORETO
AMAZONAS
LAMBAYEQUE
CAJAMARCA
SAN MARTIN
LA LIBERTAD
ANCASH
HUANUCO
PASCO
UCAYALI
JUNIN
MADRE DE DIOS
CUSCO
HUANCAVELICA
AYACUCHO
APURIMAC
PUNO
MOQUEGUA
TACNA
Legend
International boundary
Province boundary
National capital
Department capital
Railroad
Road
Amazon

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 (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
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IN THE REPUBLIC OF PERU
FEASIBILITY STUDY REPORT
SUPPORTING REPORT

Annex-2
Inundation Analysis

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

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
3) Horizontal two-dimensional unsteady-flow model

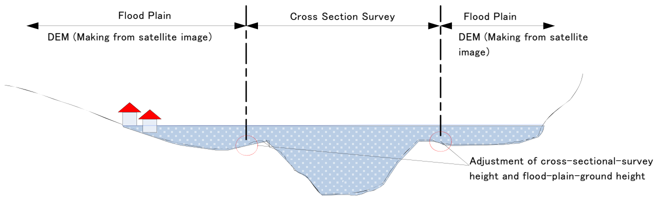
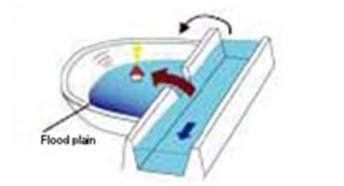
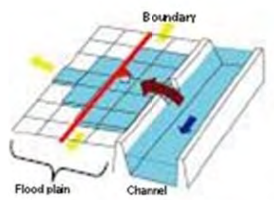


Figure 1.1 **Image of One-Dimensional Analysis Model**

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.

Table 1.1 **Method of Inundation Analysis**

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			
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.

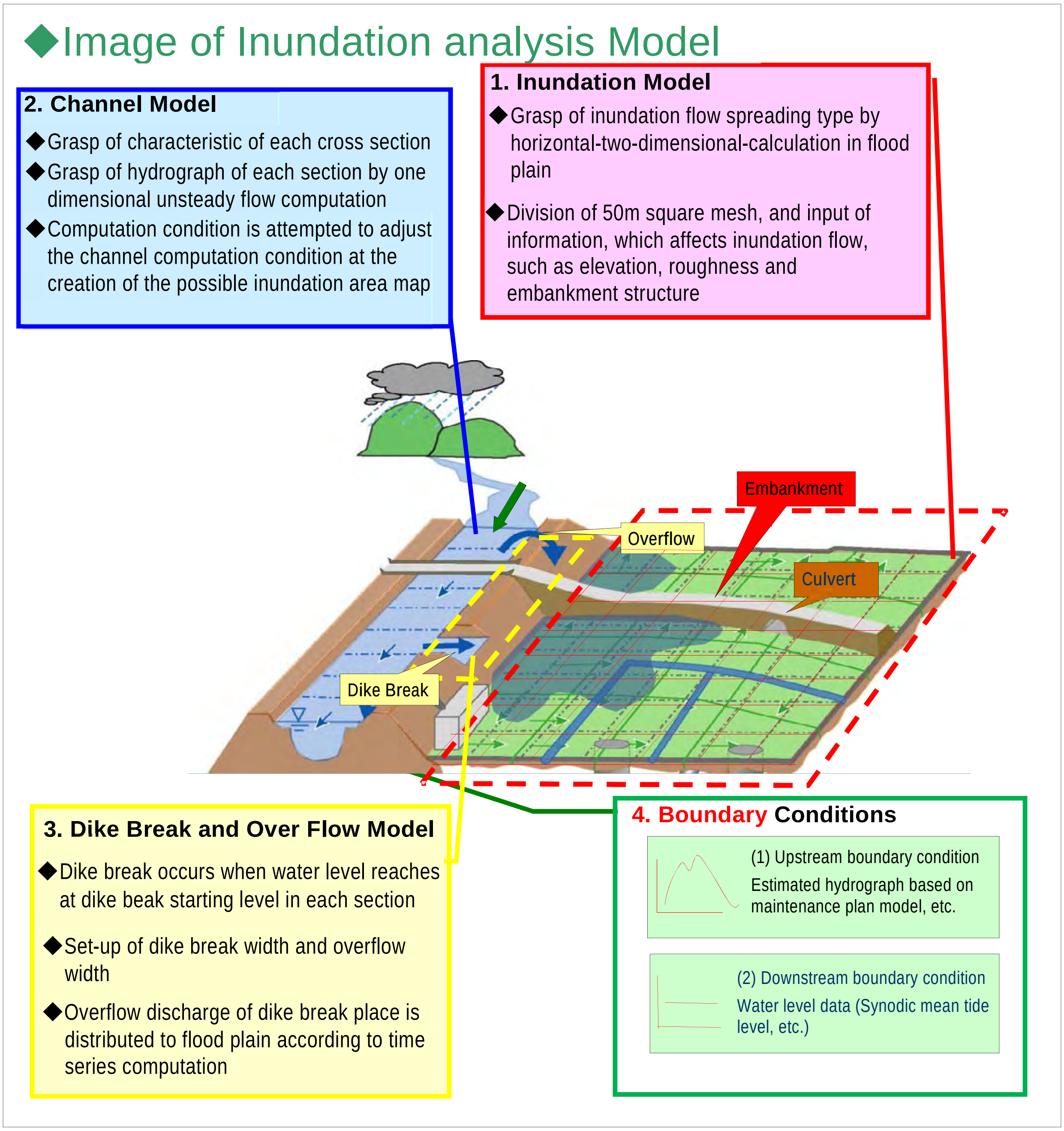


Figure 1.2 **Conceptual Diagram of Inundation Analysis Model**

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.

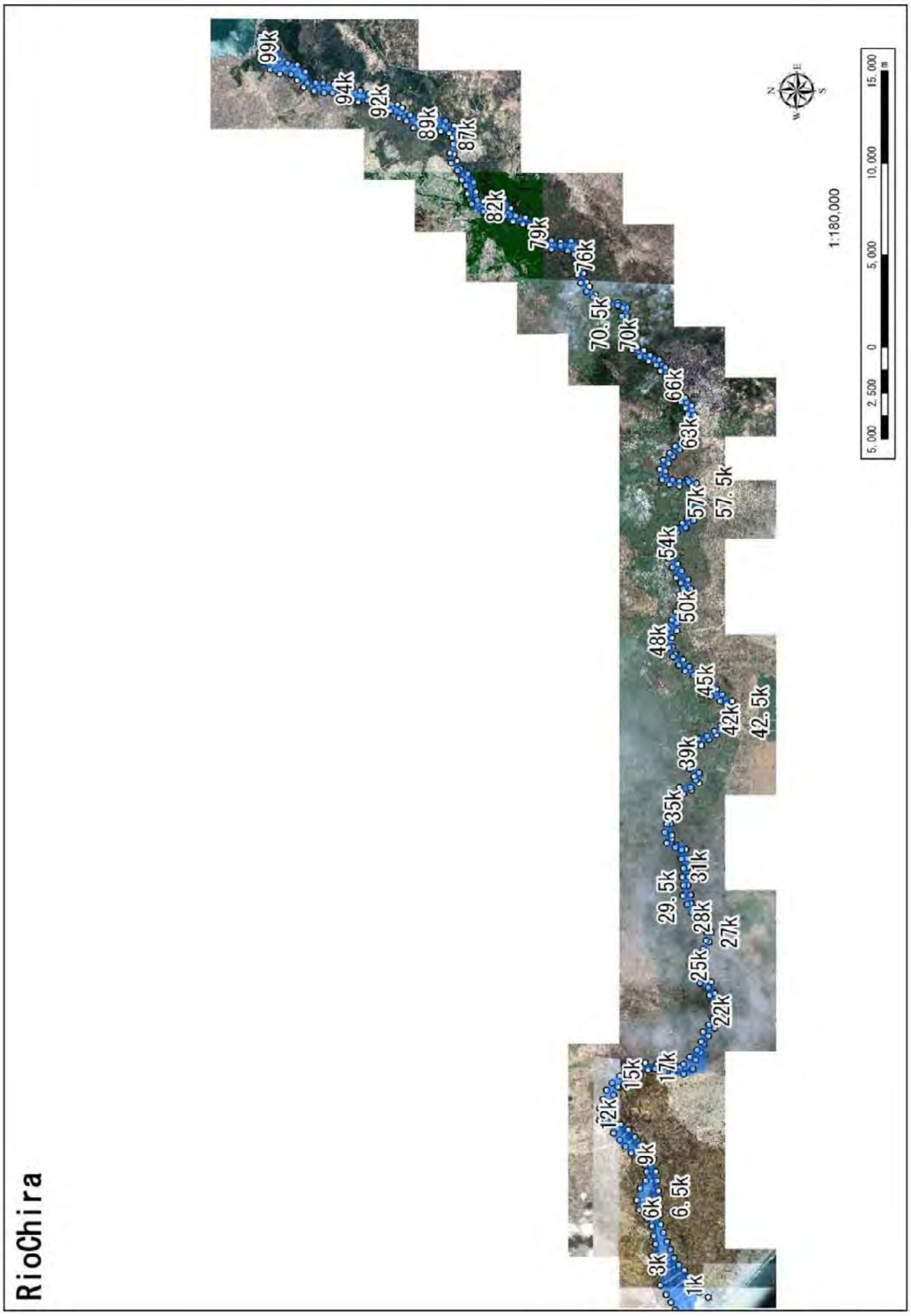


Figure 1.3 **Satellite Image of Chira River (by Google Earth)**

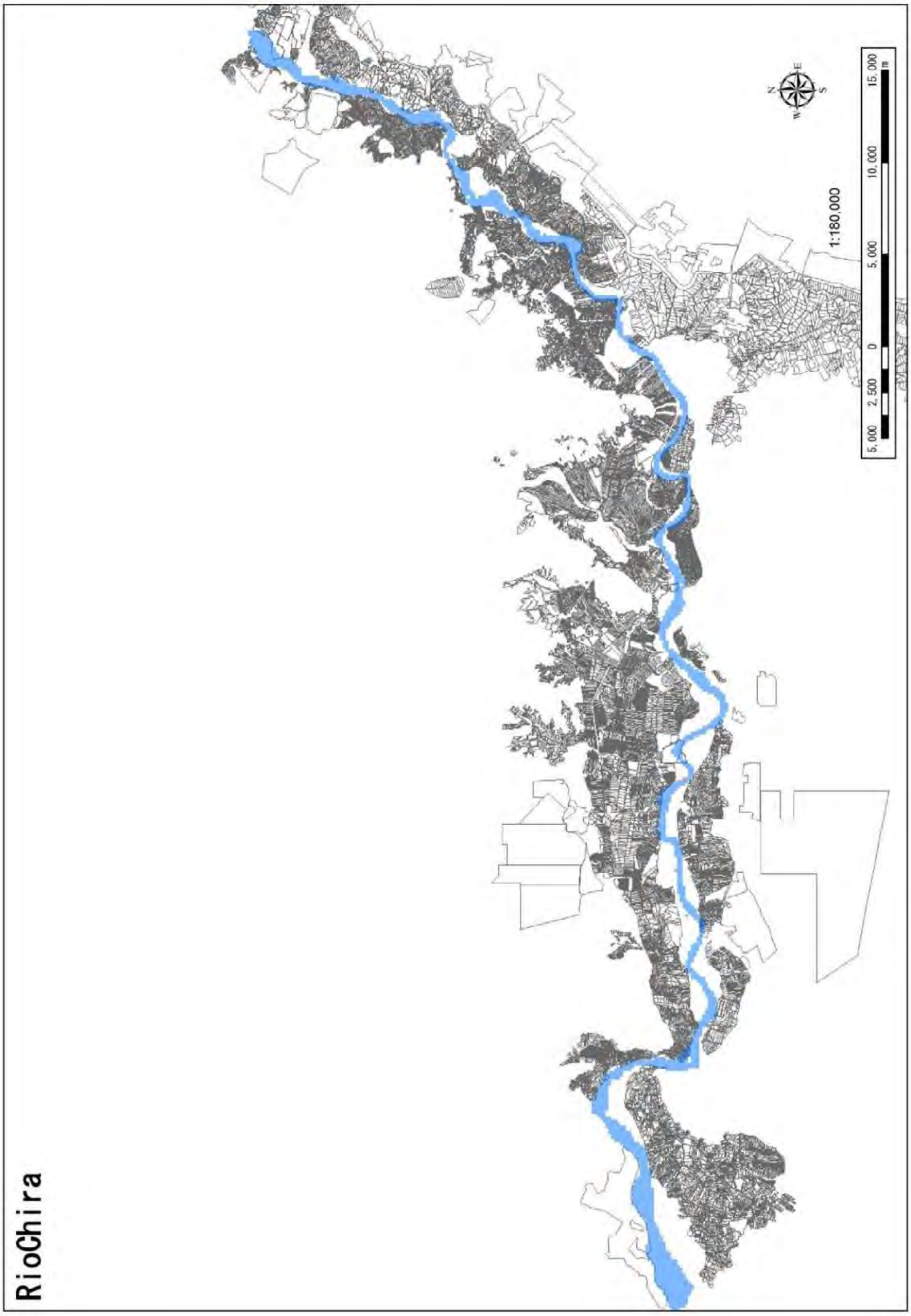


Figure 1.4 **Land Use Map of Chira River**

(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.

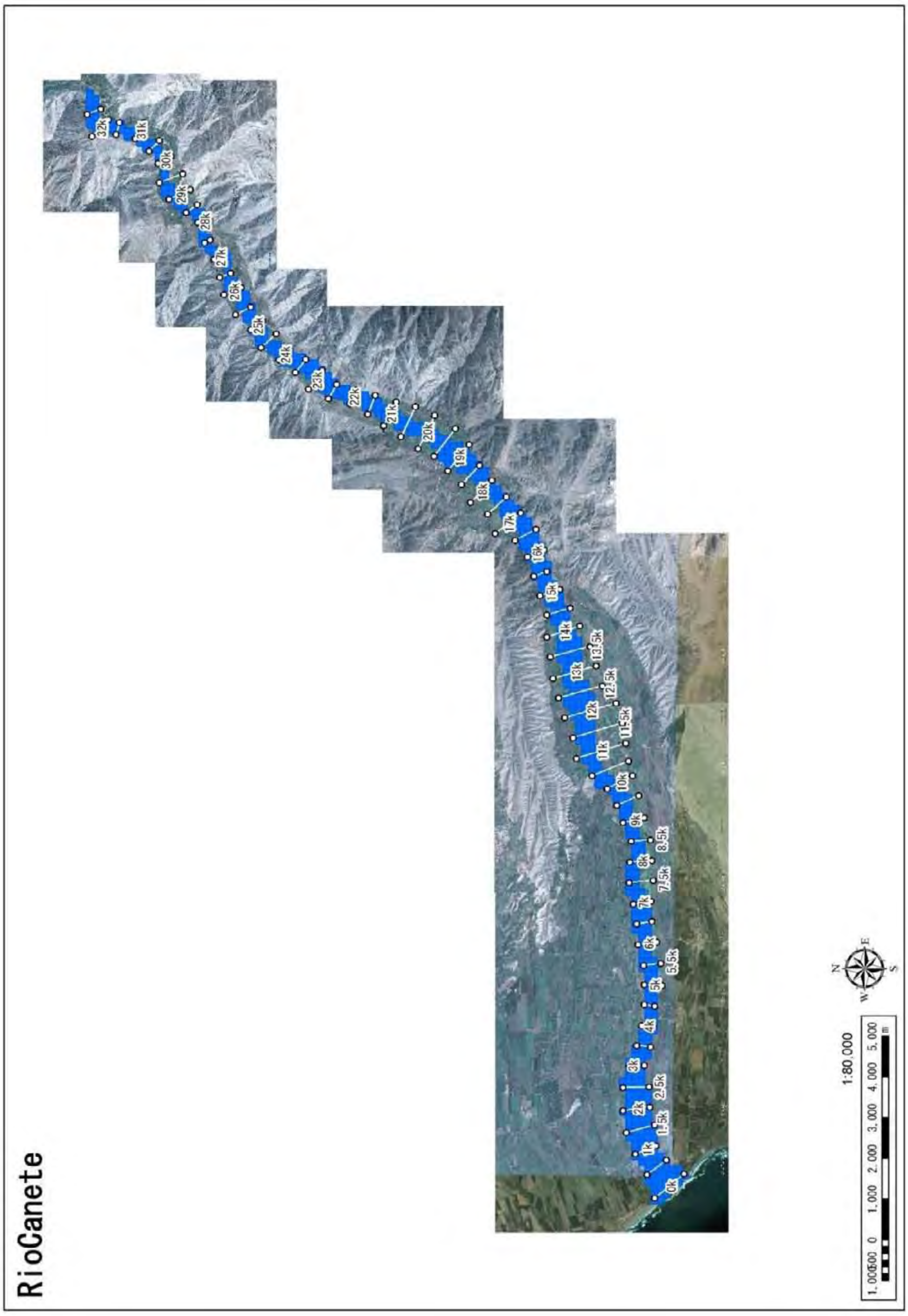


Figure 1.5 **Satellite Image of Canete River (by Google Earth)**

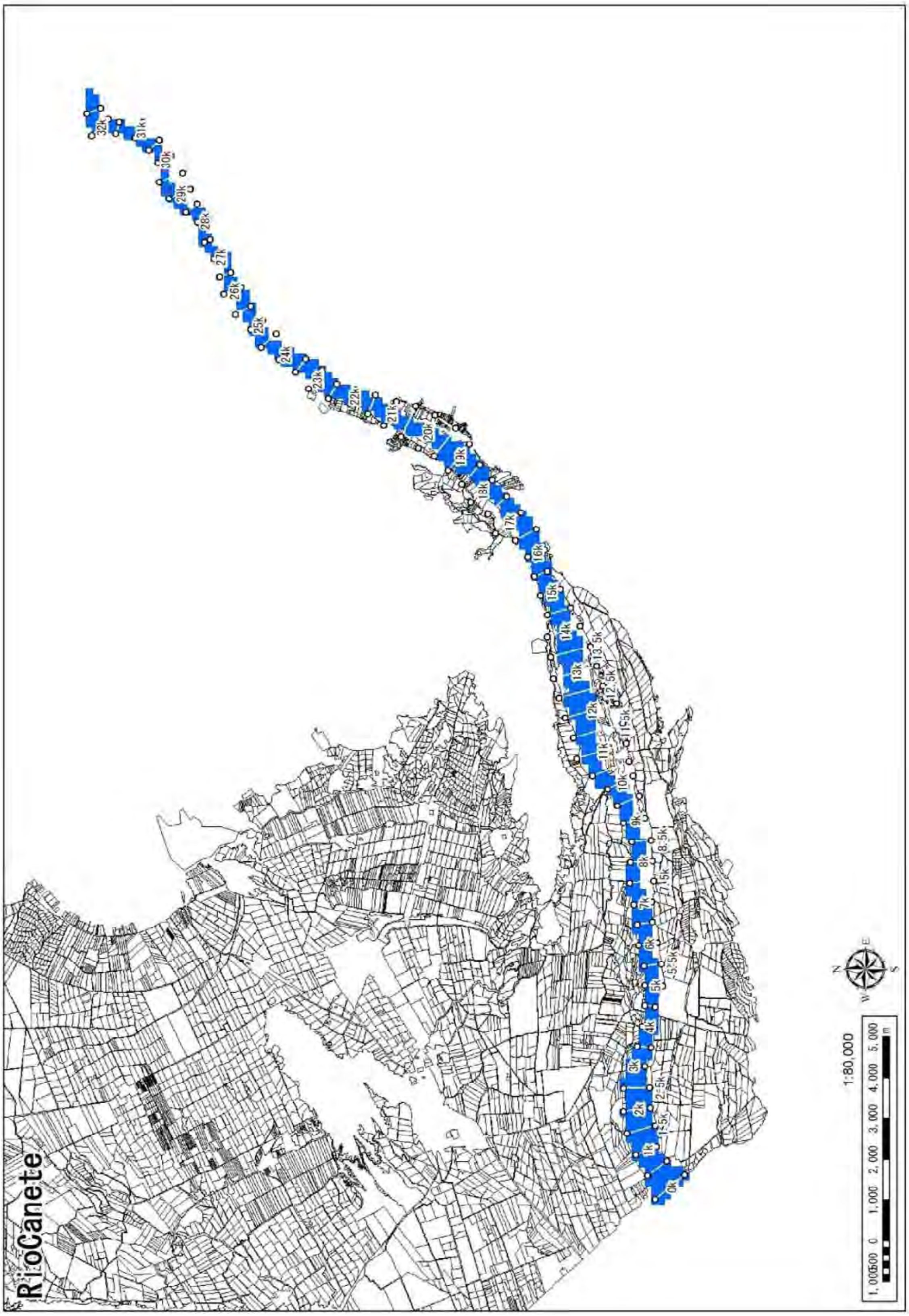


Figure 1.6 **Land Use Map of Canete River**

(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.

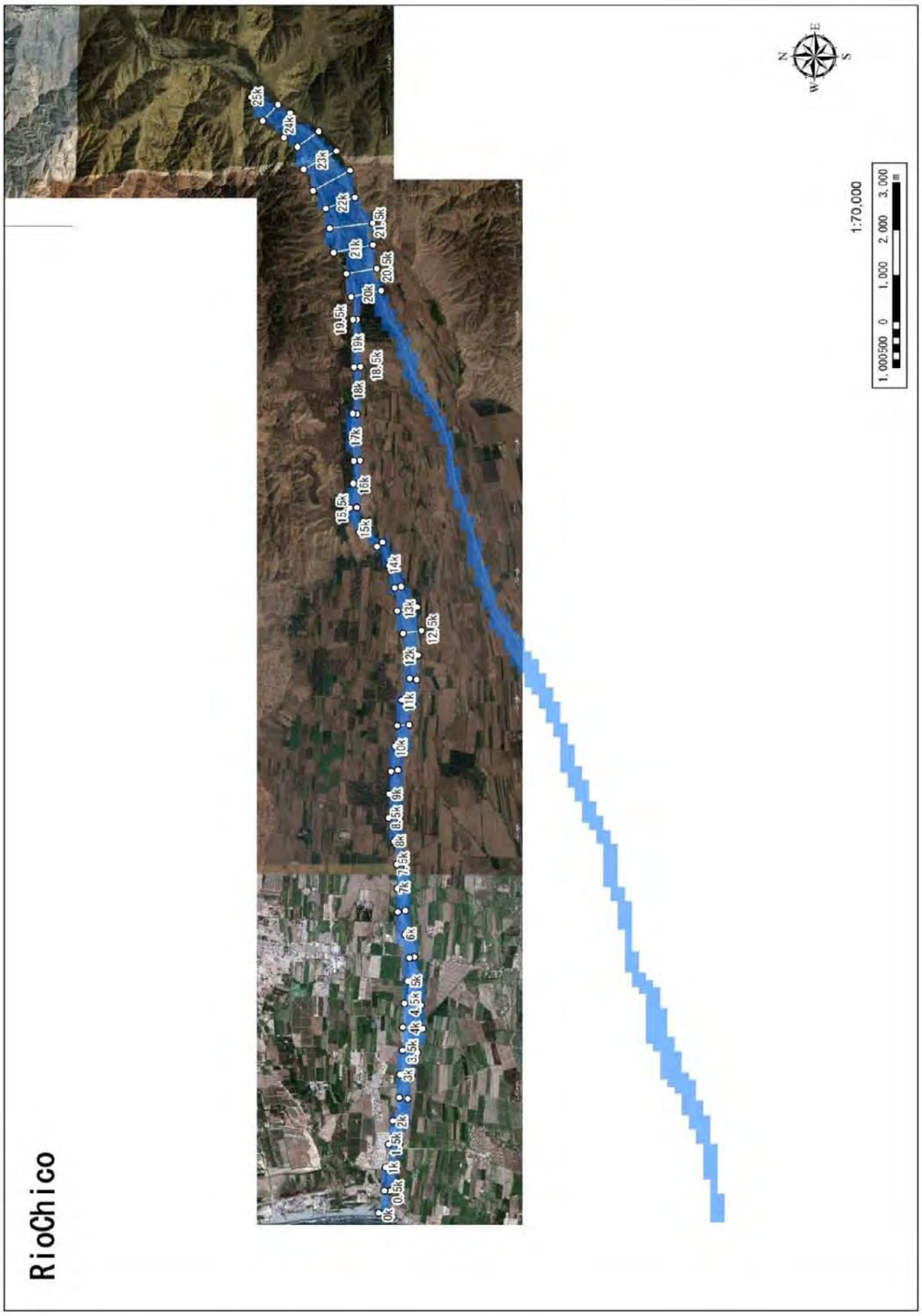


Figure 1.7 **Satellite Image of Chico River (by Google Earth)**

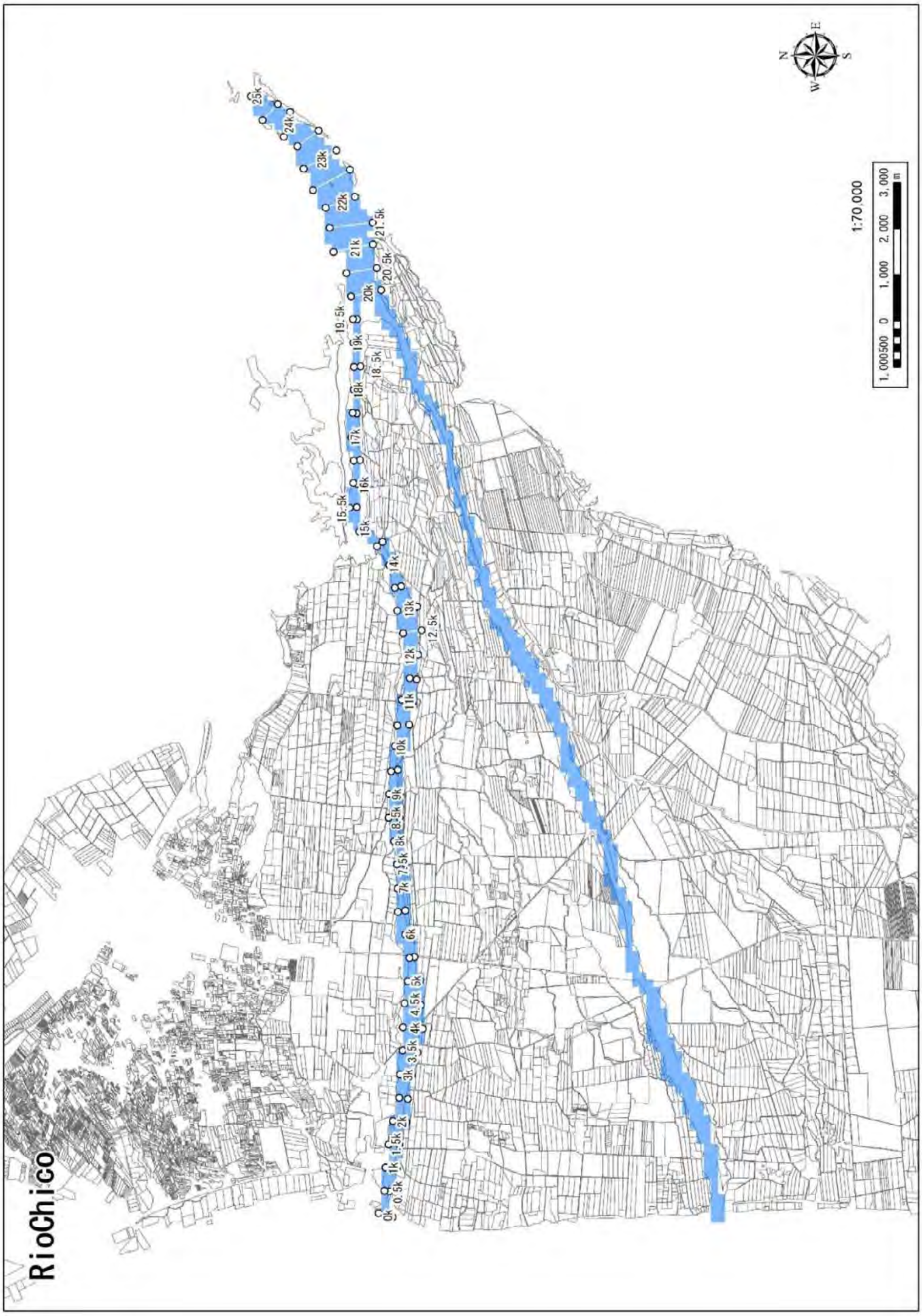


Figure 1.8 **Land Use Map of Chico River**

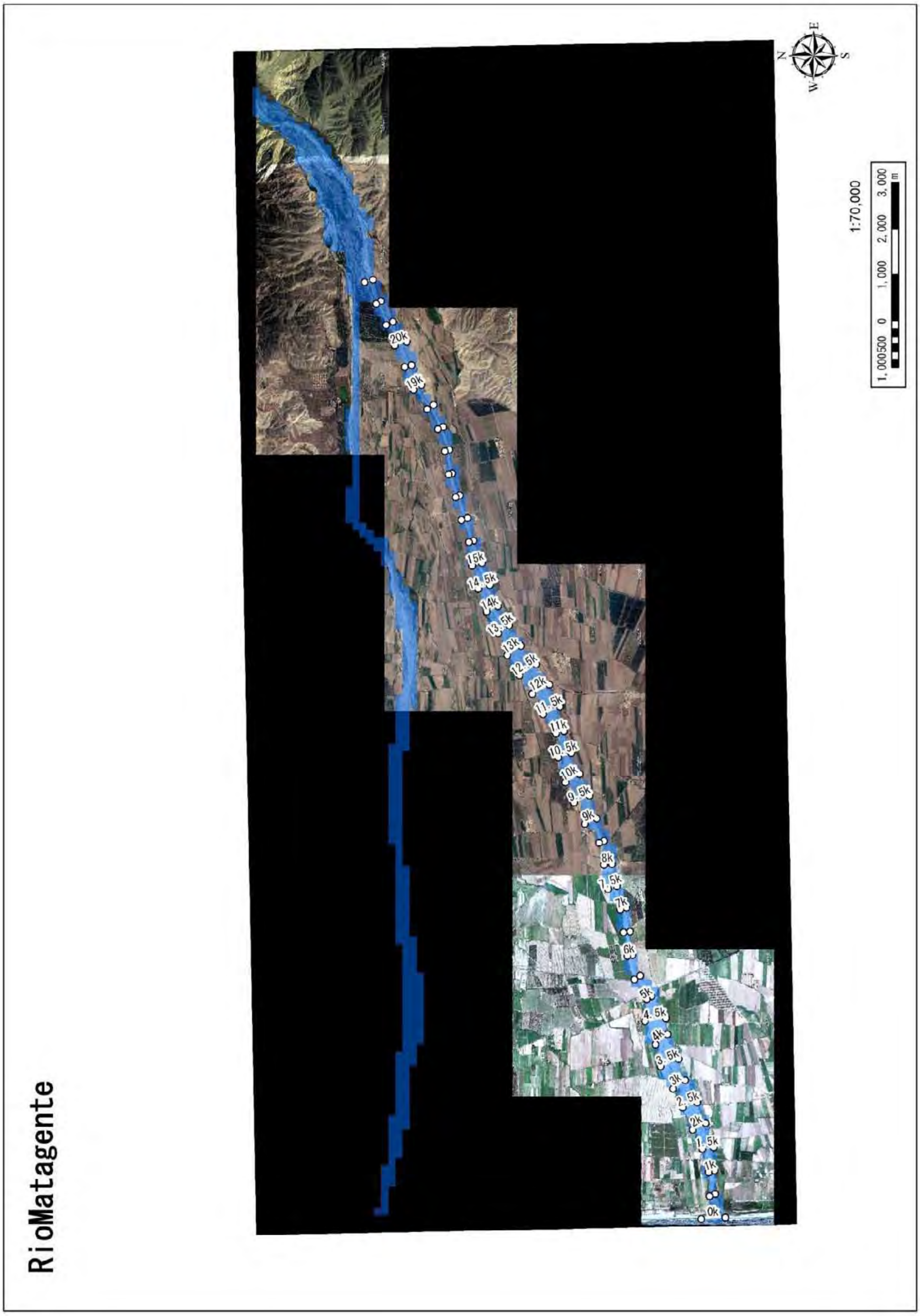


Figure 1.9 **Satellite Image of Matagente River (by Google Earth)**

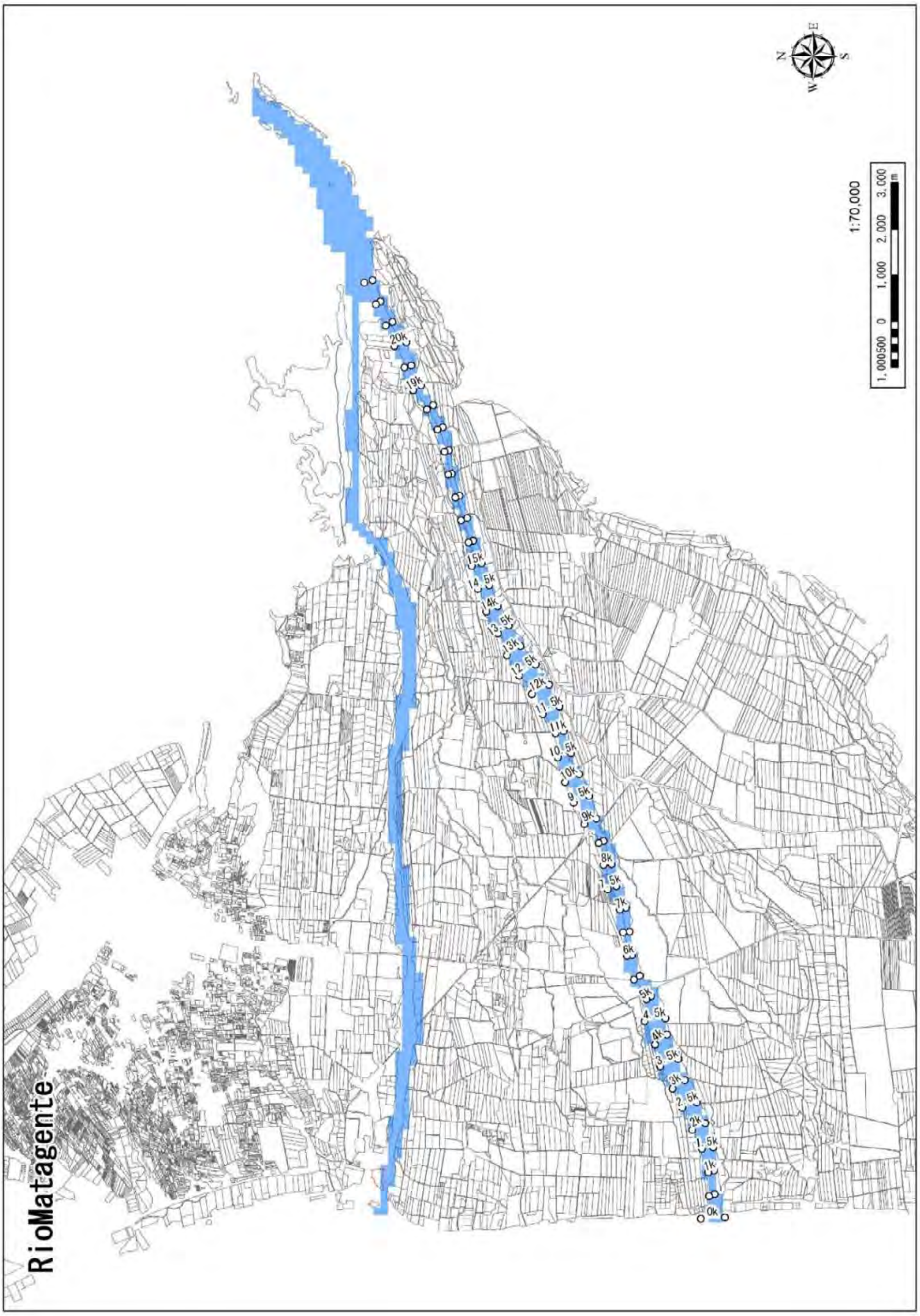


Figure 1.10 **Land Use Map of Matagente River**

(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.

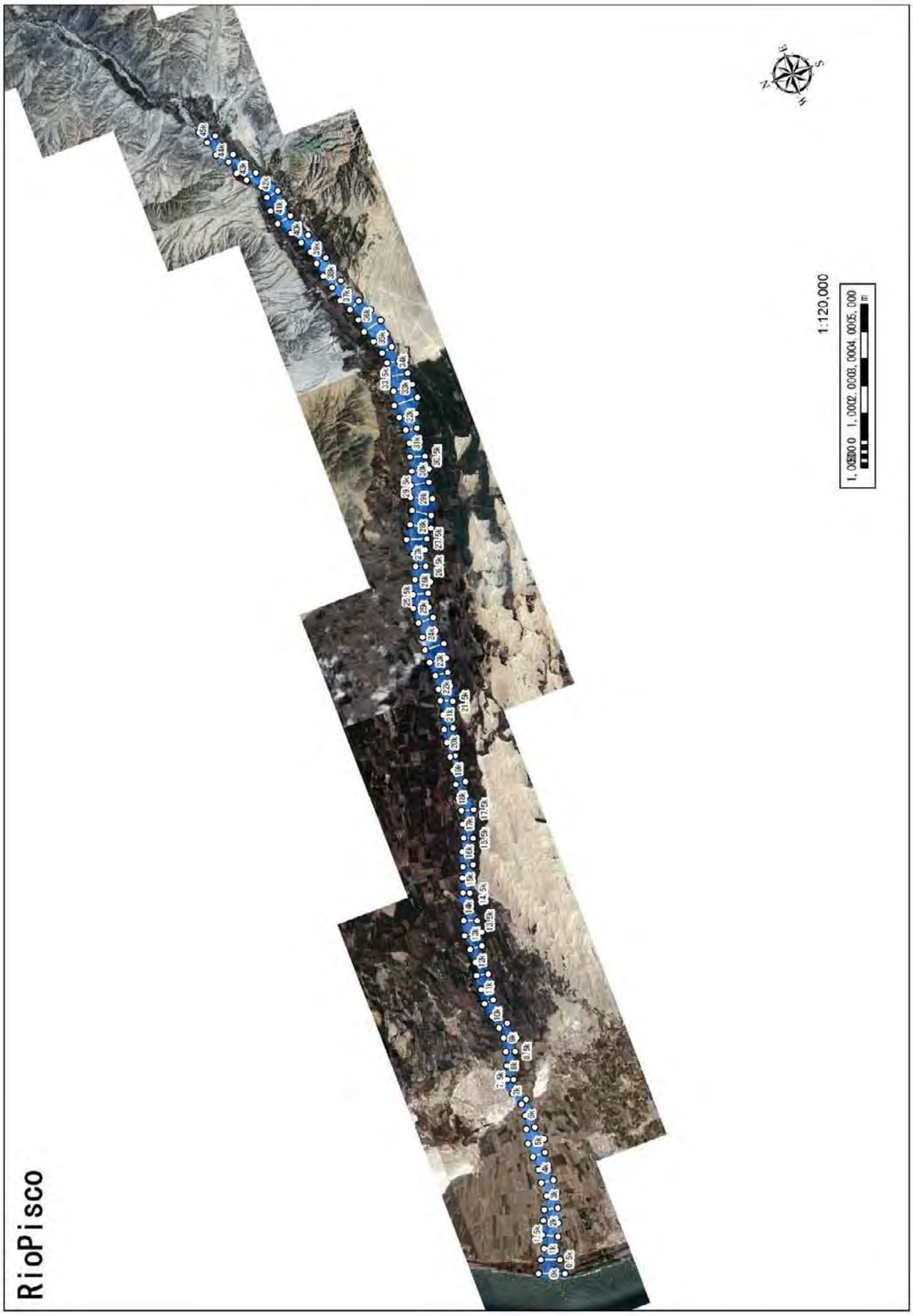


Figure 1.11 **Satellite Image of Pisco River (by Google Earth)**

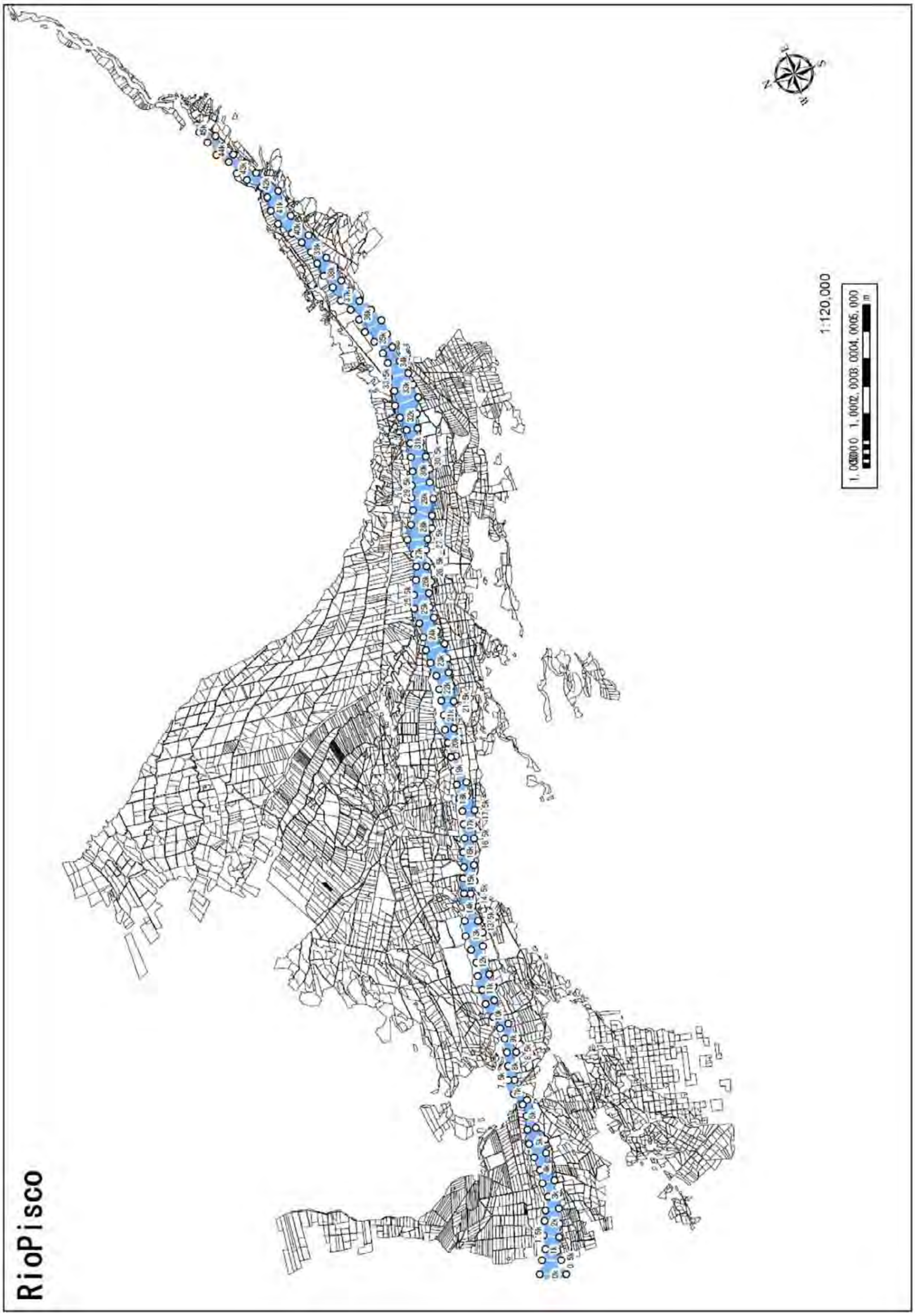


Figure 1.12 **Land Use Map of Pisco River**

(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.

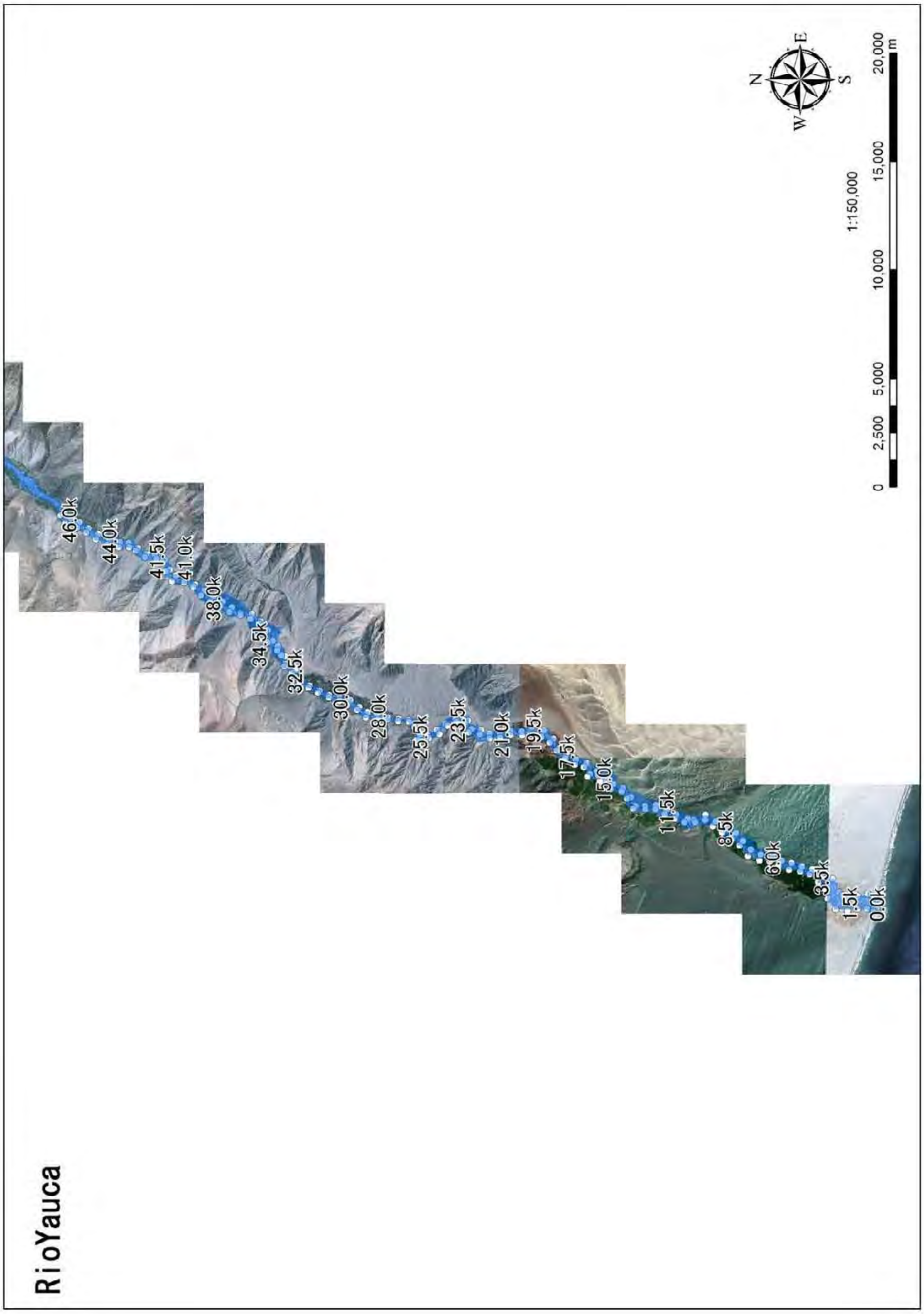


Figure 1.13 **Satellite Image of Yauca River (by Google Earth)**

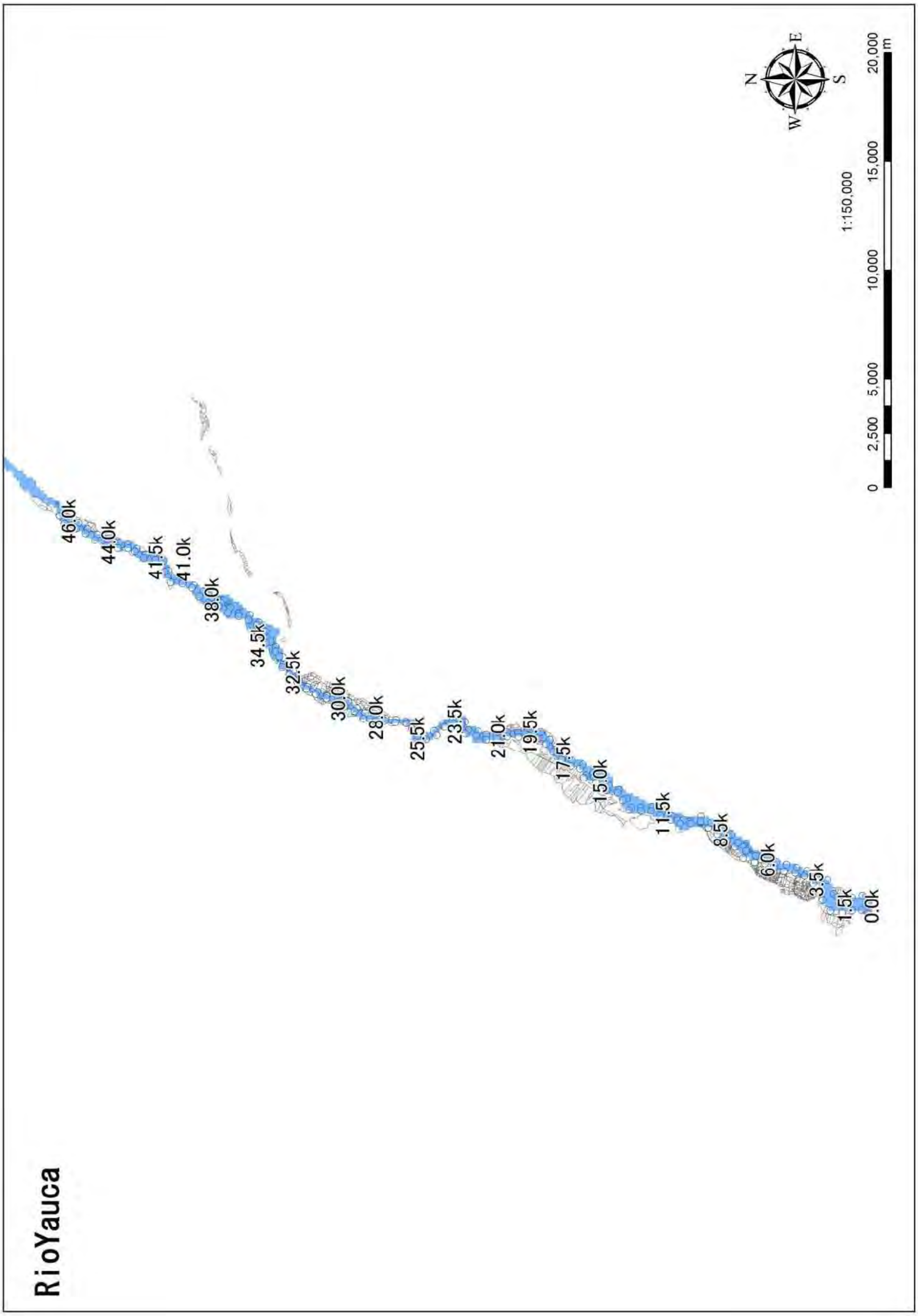


Figure 1.14 **Land Use Map of Yauca River**

(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)**

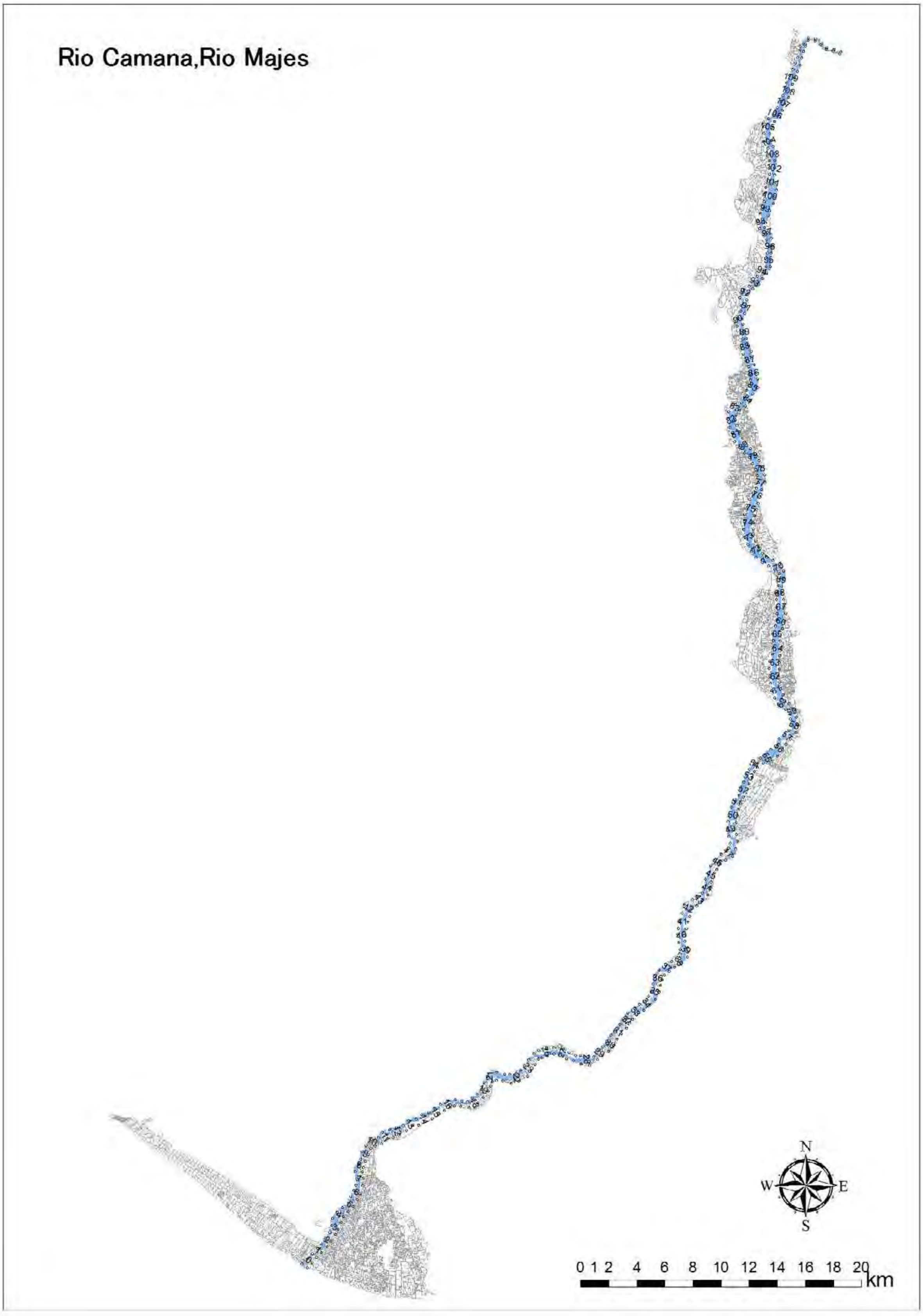


Figure 1.16 **Land Use Map of Majes-Camana River**

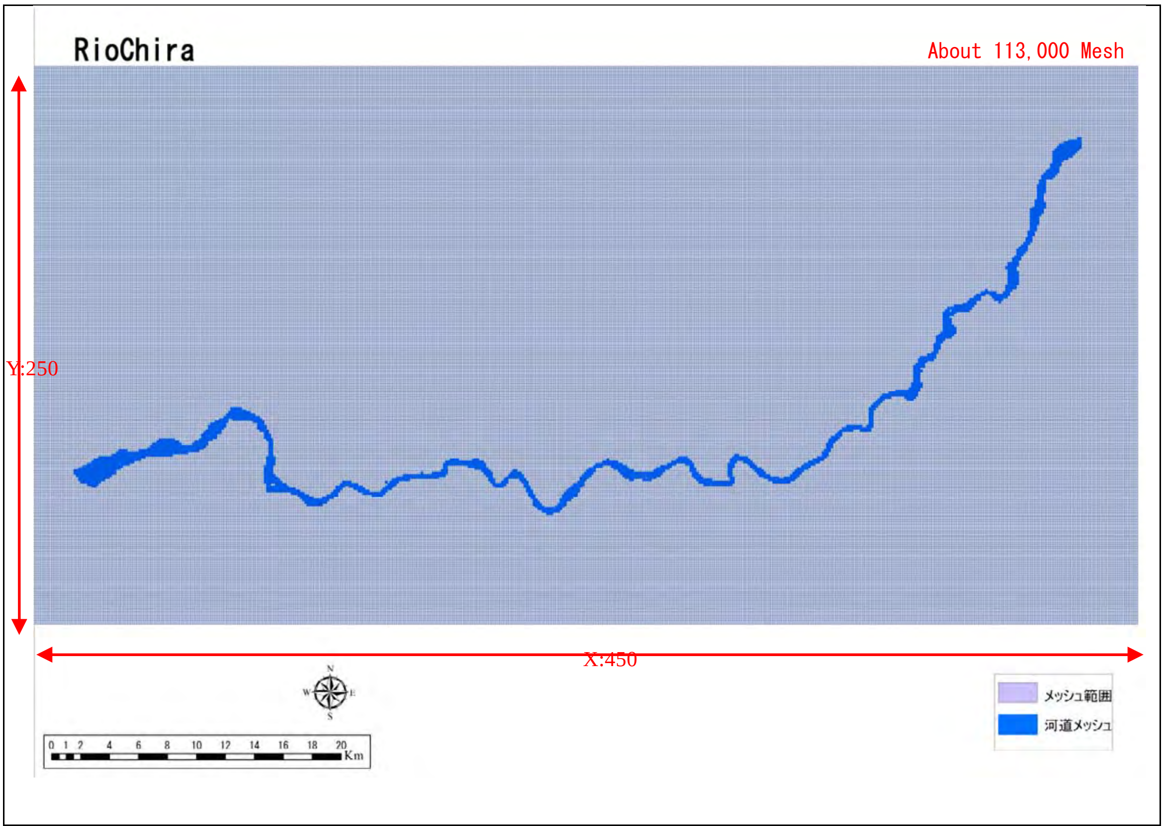
1.2.2 Setup of the Calculation Condition

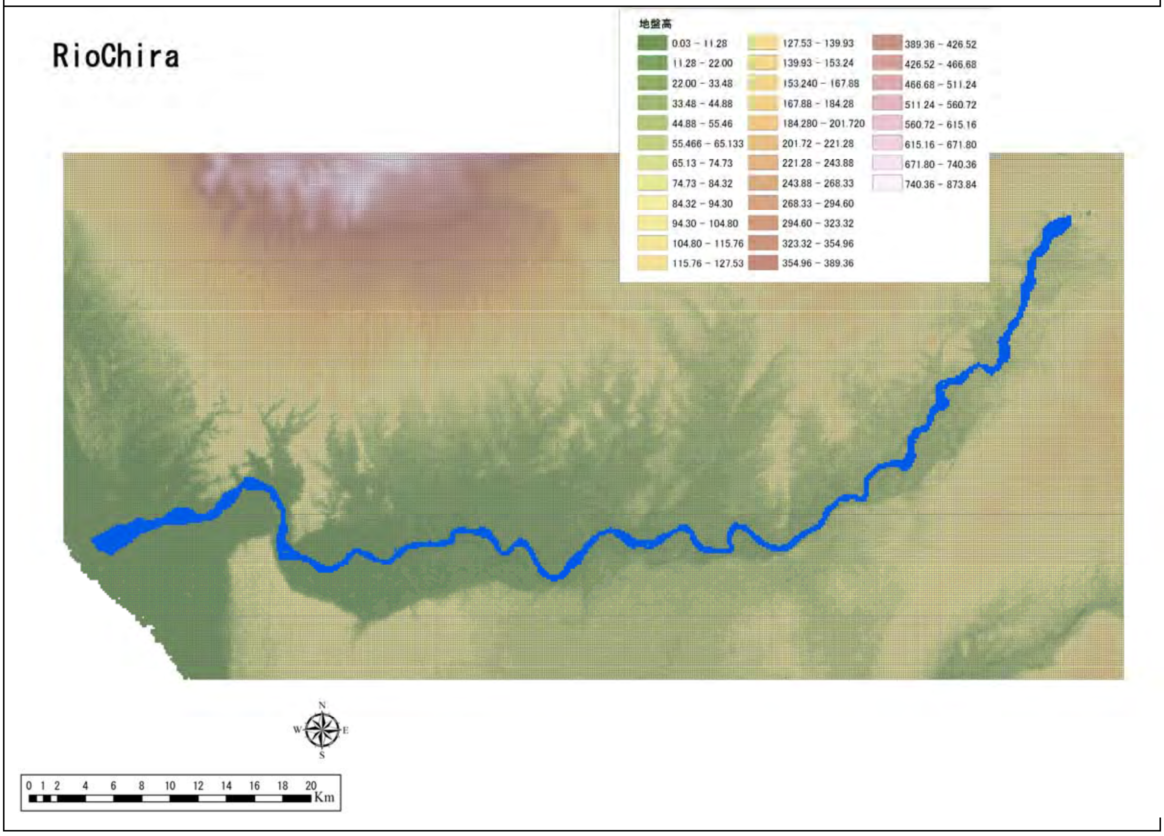
The calculation conditions and the model outline of the inundation analysis for each river are shown from the next page.

(1) Chira River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 450, y: 250)	About 113,000 meshes
		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
	Structure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
		Drainage condition	No drainage	No setup
Channel Model	Channel	Section for Modeling	Downstream: river mouth part, Upstream: 99.5 km	0 - 99.5 km
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		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
Flood Condition	Basic Condition	Computation time	Setup according to external force (hydrograph of upstream end)	About 90 hours
		Computation interval	Δt 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. 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	No setup
		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

(2) Chira River (Model Outline)

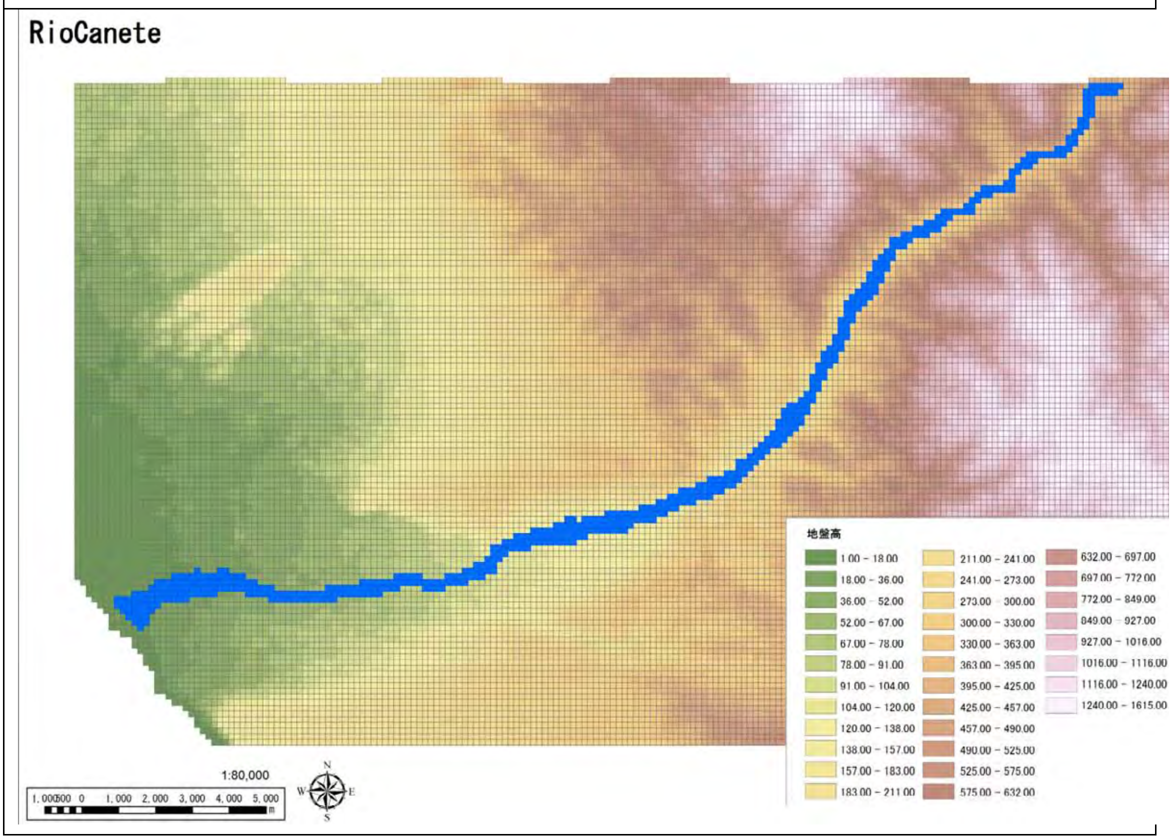




(3) Canete River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 202, y: 120)	About 24,000 meshes
		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
	Structure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	Not setup
		Drainage condition	No drainage	Not setup
Channel Model	Channel	Section for Modeling	Downstream: river mouth part, Upstream: 32.5 km	0 – 32.5 km
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 32.5 km
		Downstream Boundary condition	Setup of uniform flow water level in downstream cross section (I=1/550)	Uniform flow depth I=1/550
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional-non-uniform-flow calculation
Flood Condition	Basic Condit	Computation time	Setup according to external force (hydrograph of upstream end)	About 24 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. 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	No setup
		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	River bed gradient at the maximum river bed depth: about 1/100 or less	Setup as 1/100

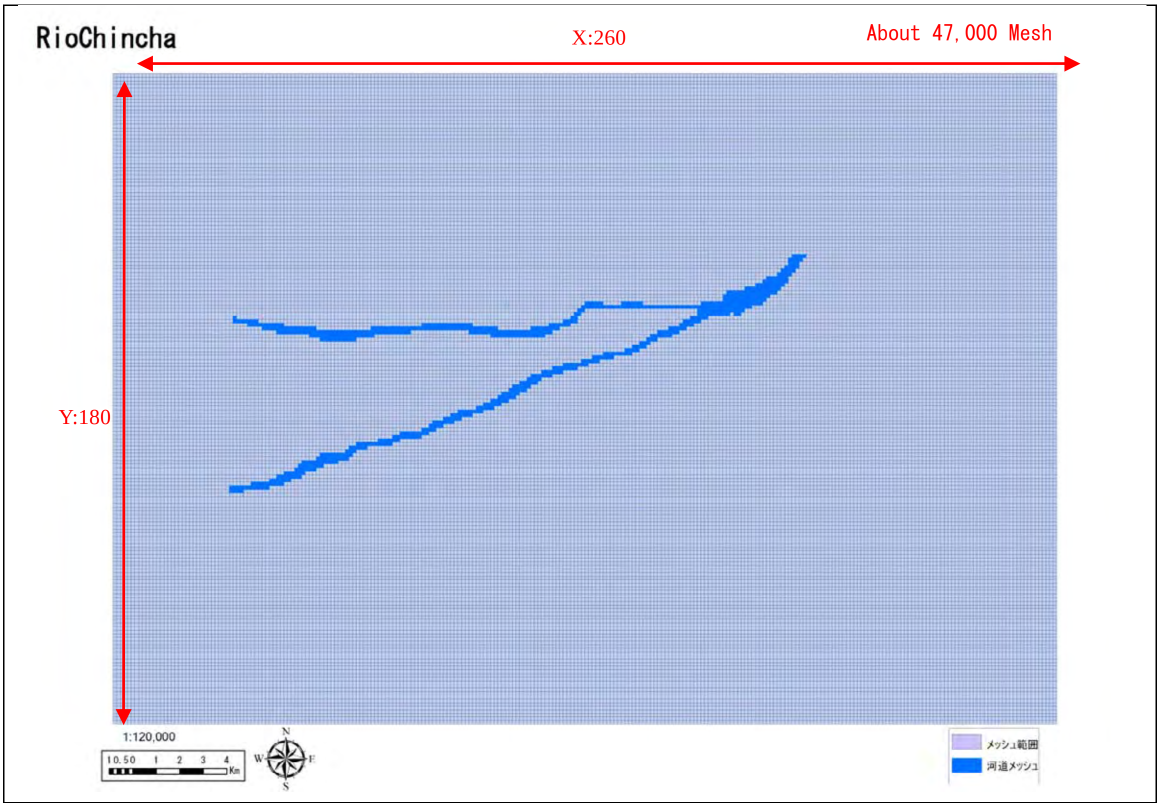
(4) Canete River (Model Outline)

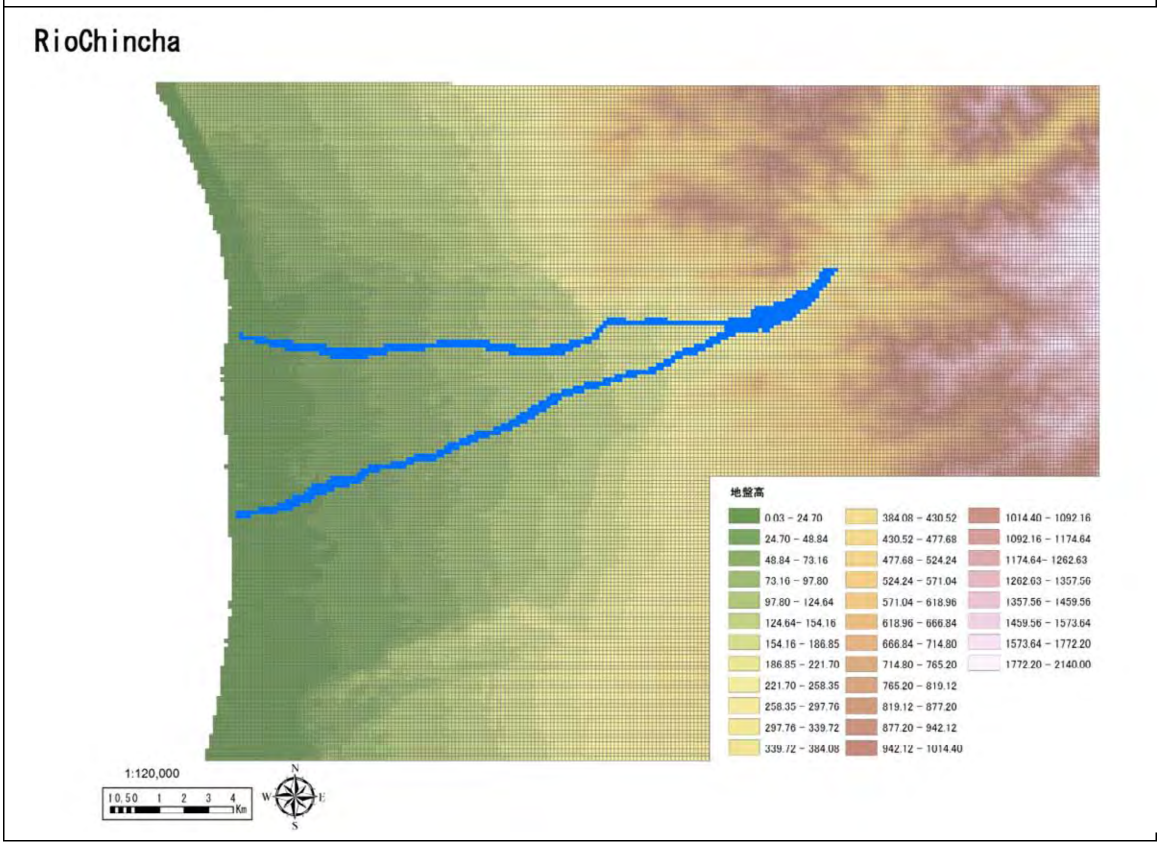


(5) Chincha River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 260, y: 180)	About 47,000 meshes
		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
	Structure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
		Drainage condition	No drainage	No setup
Channel Model	Channel	Section for Modeling	Downstream: river mouth part, Upstream: 25.0 km	0 – 25.0 km
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		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
Flood Condition	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. 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	No setup
		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)

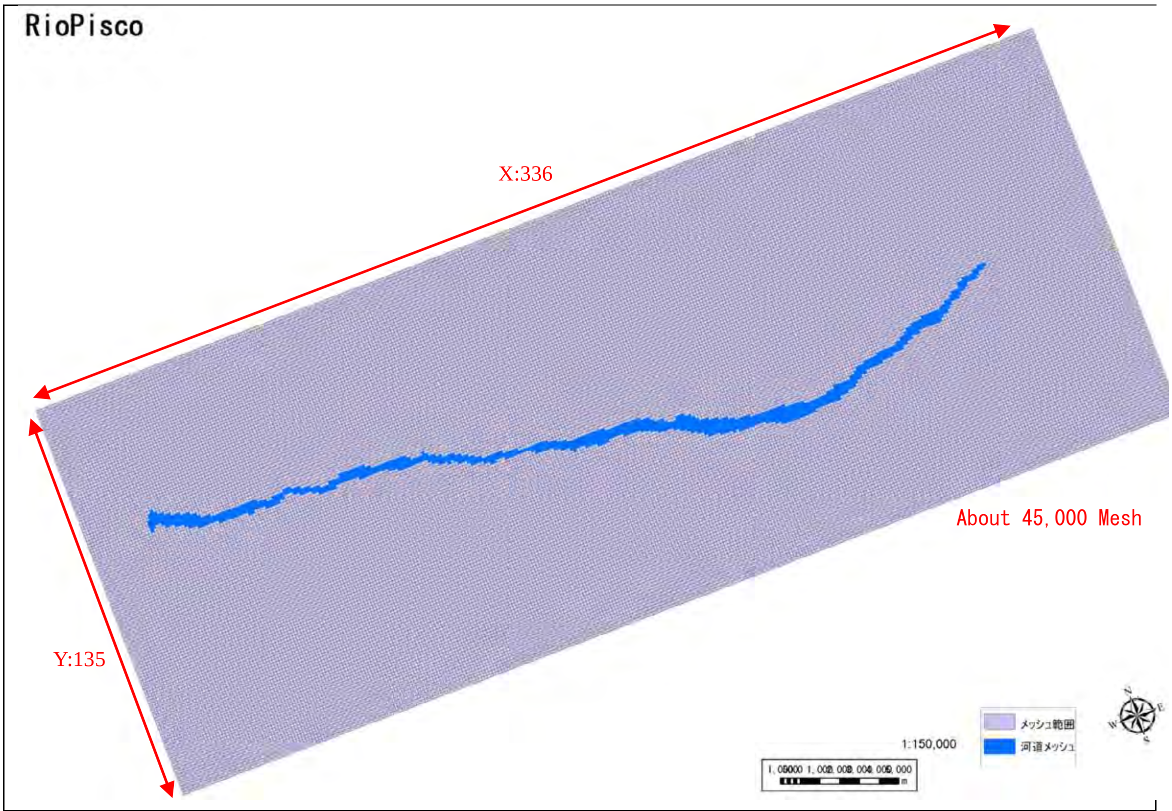


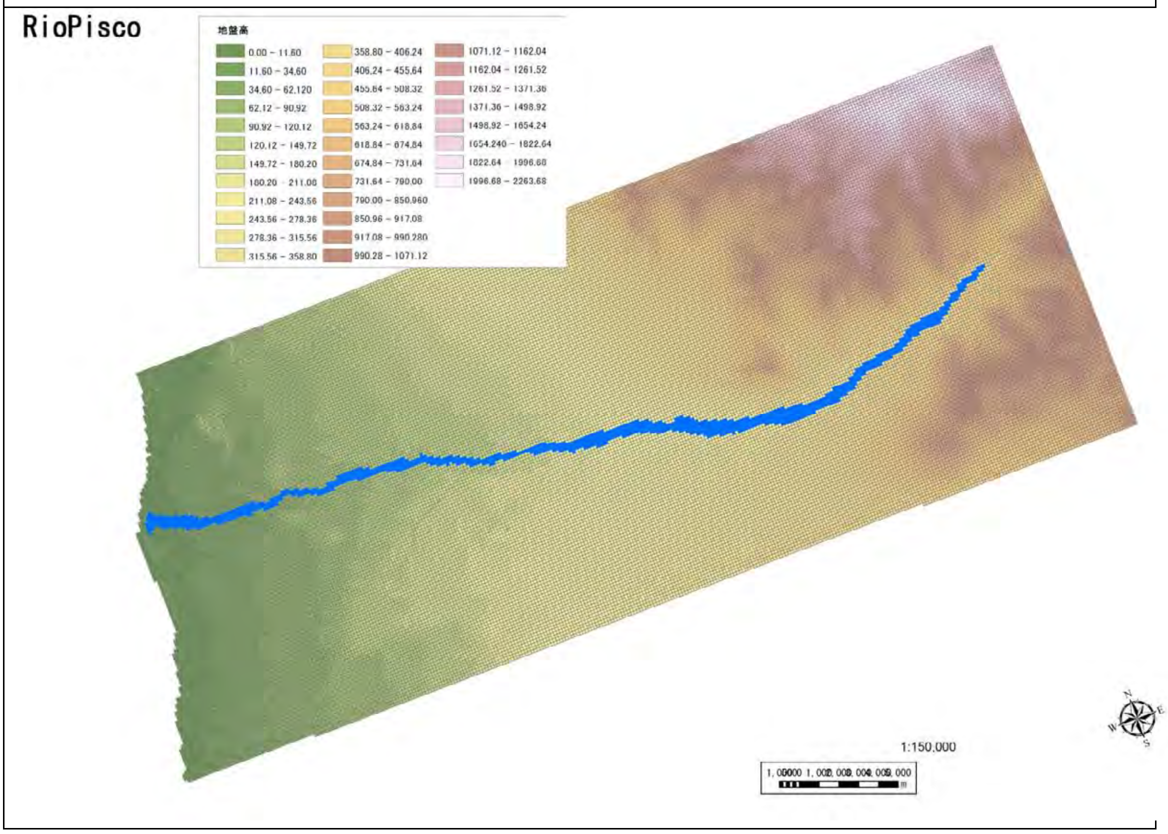


(7) Pisco River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 336, y: 135)	About 45,000 meshes
		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
	Stru ctur	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
		Drainage condition	No drainage	No setup
Channel Model	Chann el	Section for Modeling	Downstream: river mouth part, Upstream: 45.0 km	0 – 45.0 km
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		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
		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
Flood Condition	Basic Condit	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. 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	No setup
		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.	Set-up as 1/200

(8) Pisco River (Model Outline)

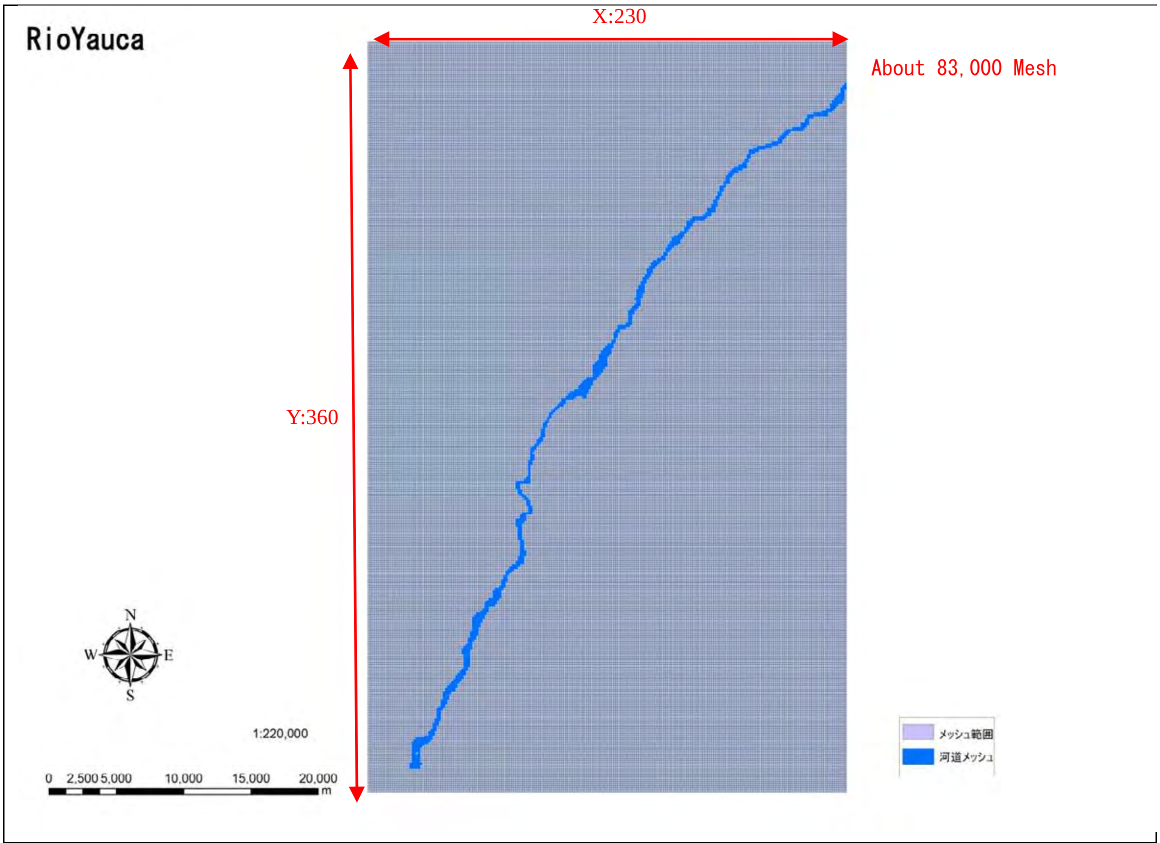


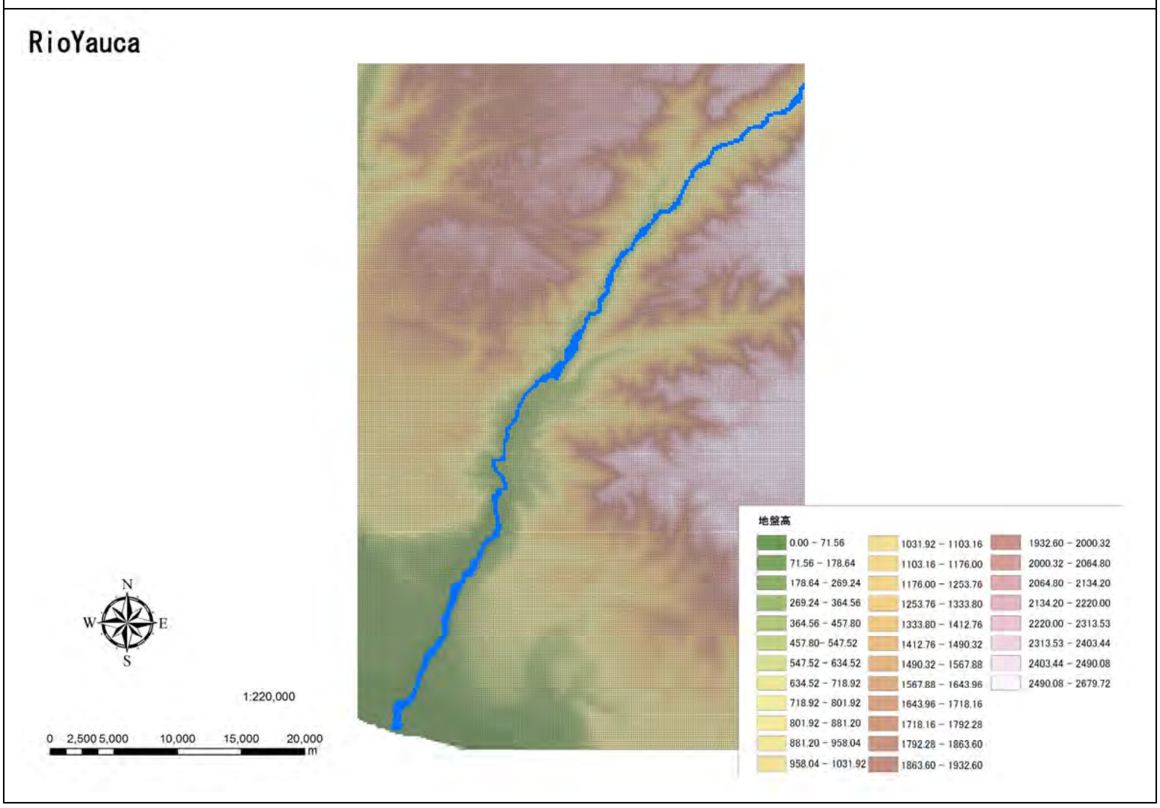


(9) Yauca River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 230, y: 360)	About 83,000 meshes
		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
	Structure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
		Drainage condition	No drainage	No setup
Channel Model	Channel	Section for Modeling	Downstream: river mouth part, Upstream: 46.0 km	0 – 46.0 km
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		Upstream boundary condition	As boundary condition, the discharge hydrograph is set up at the end of upstream of model area	Upstream end: 46.0 km
		Downstream Boundary condition	Setup of uniform flow water level in downstream cross section (I=1/550)	Uniform flow depth I=1/1500
		H-Q equation	Setup by result of one dimensional non-uniform flow calculation	One-dimensional-non-uniform-flow calculation
Flood Condition	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	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 Rivers” in Japan	No setup
		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 place
		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: 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 mark.	Setup as 1/250, 1/150

(10) Yauca River (Model Outline)

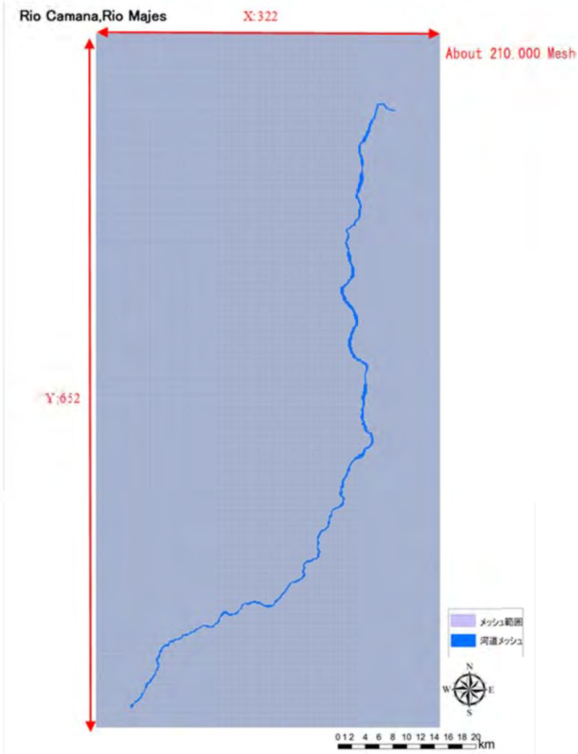


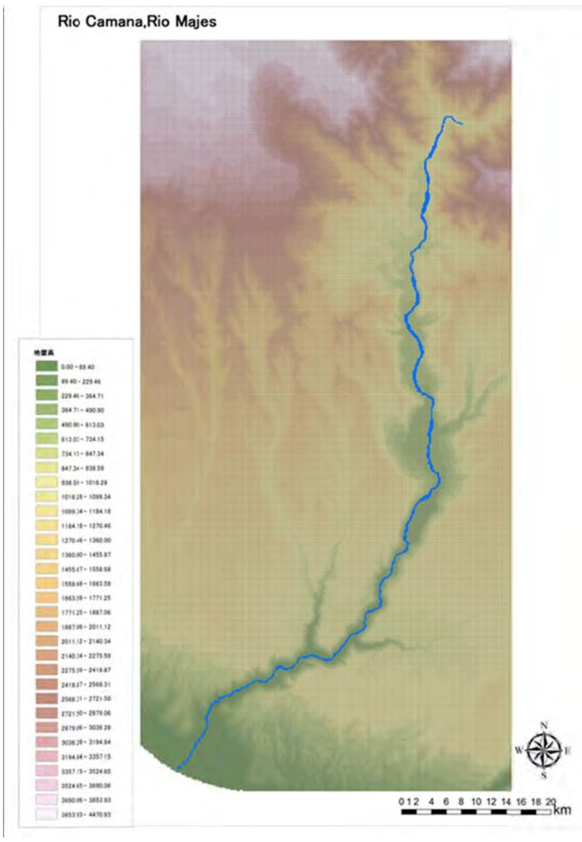


(11) Majes-Camana River (Calculation Condition)

Item			Condition for Inundation Model	Rio Chira
Inundation Model	Flood Plain	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
		Inundation Model area	Inundation flow spreading area from channel (x: 322, y: 653)	About 210,000 meshes
		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
	Structure	Continuous embankment structure	Set up of open mouth condition in main roads, rail ways, culverts, etc.	No setup
		Drainage condition	No drainage	No setup
Channel Model	Channel	Section for Modeling	Downstream: river mouth part, Upstream: 115.0 km	0-40.0 km (Camana river), 40.0-115.0 km (Majes river)
		Channel data	Channel section survey in this project	Survey in 2010
		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
	Condition	Floods	Setup hydrographs by the results of HEC-HMS	HEC-HMS
		Discharge Distribution	No inflow from the tributaries	No setup
		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
		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
Flood Condition	Basic Condition	Computation time	Setup according to external force (hydrograph of upstream end)	About 20 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. 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	No setup
		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 place
		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	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 2.1 **Peak Discharge to Each Probable Flood Scale (Chira River)**

	(
2	890.00
5	1,727.00
1	2,276.00
2	2,995.00
5	3,540.00
100	4,058.00

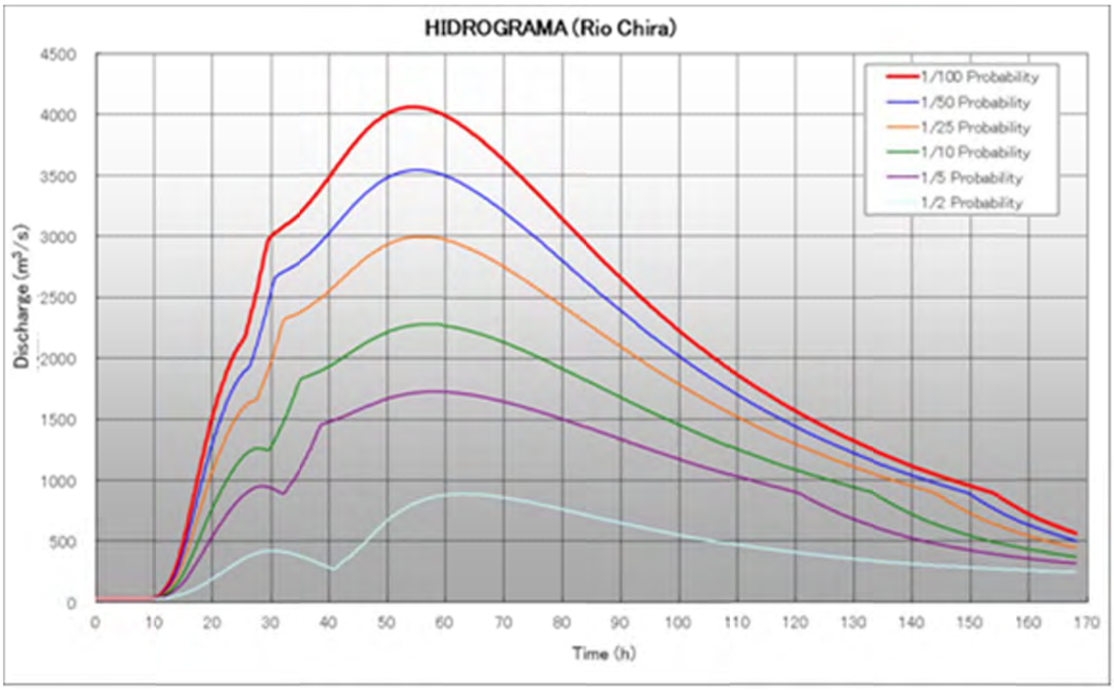


Figure 2.1 **Probable Flood Hydrographs (Chira River)**

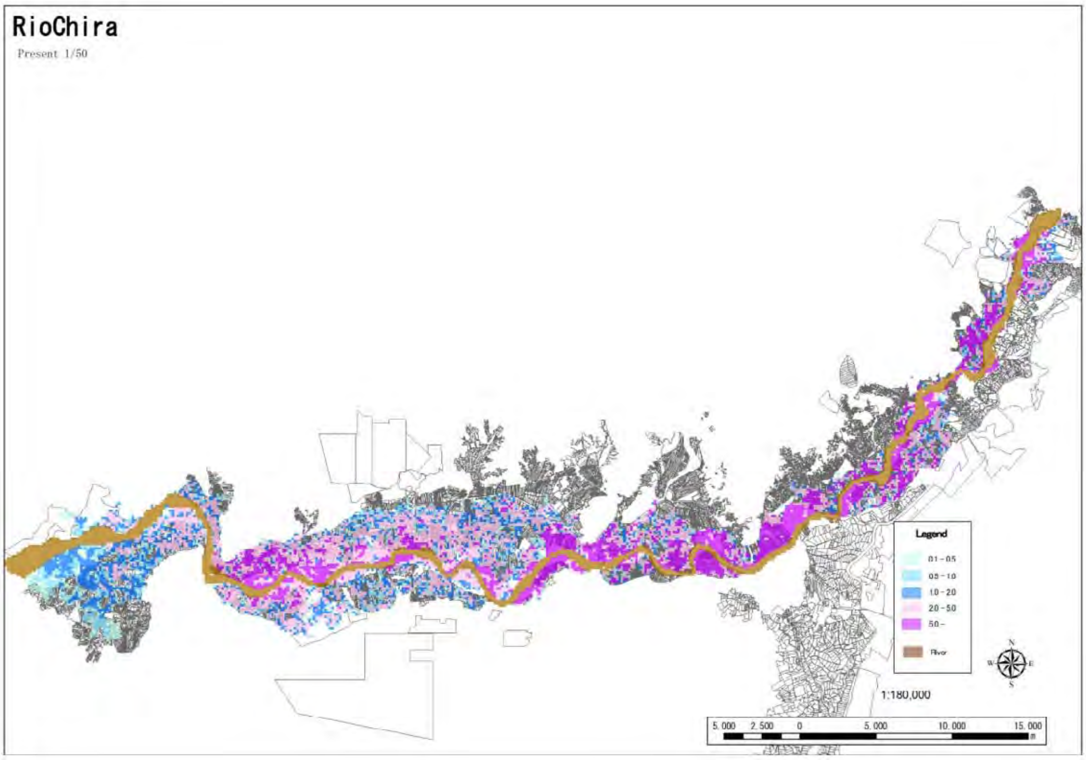
(2) Result of Inundation Analysis (without case)

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

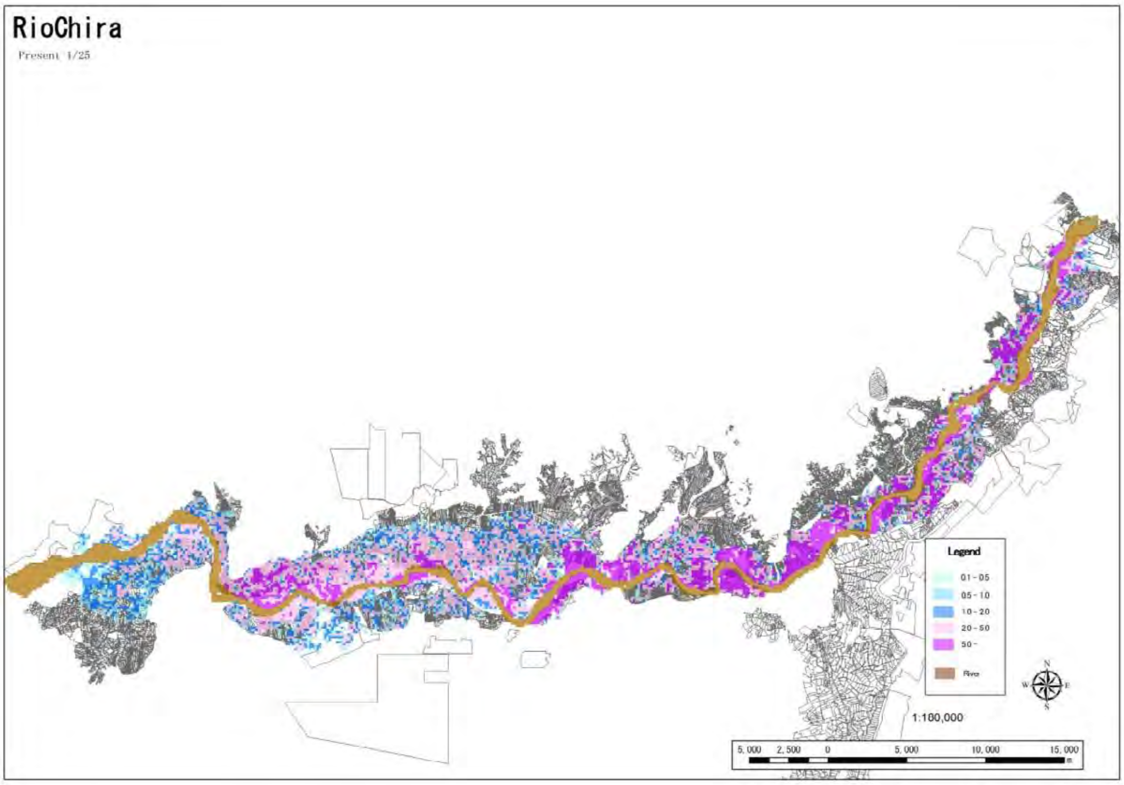
Table 2.2 **Inundation area for each Probable Flood Scale in Chira River (Without case)**

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
Chira	6,233	14,024.3	7,340	16,515.0	8,661	19,487.3	9,589	21,575.3

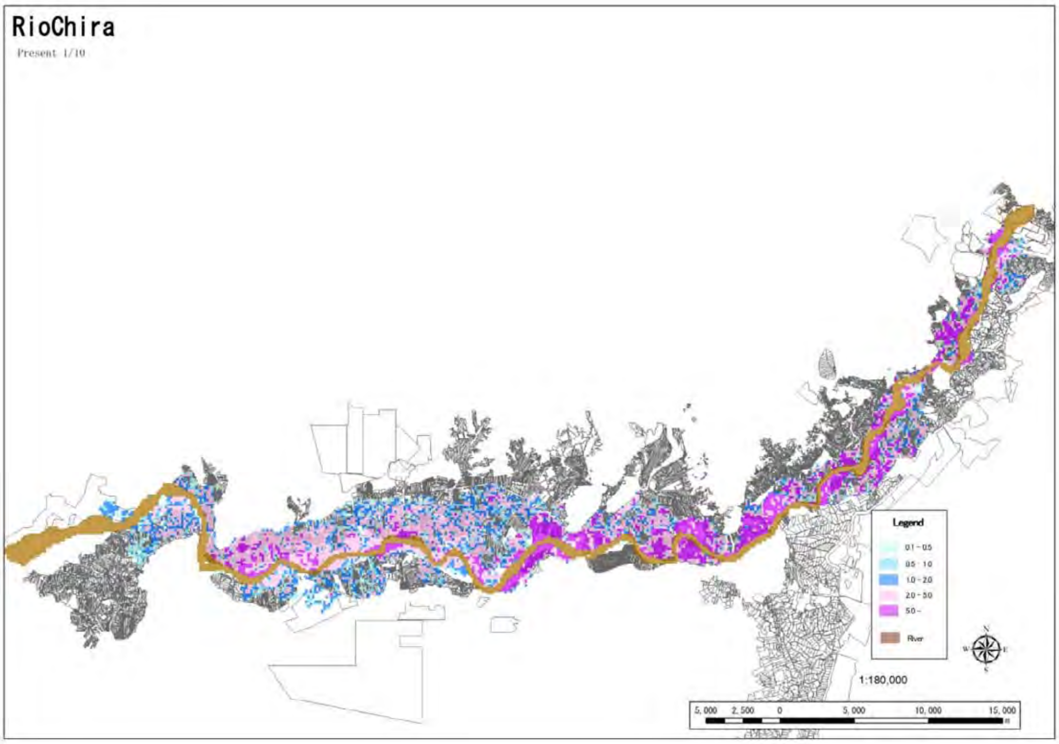
Chira River（1/50 Year Probable Flood） Without Case



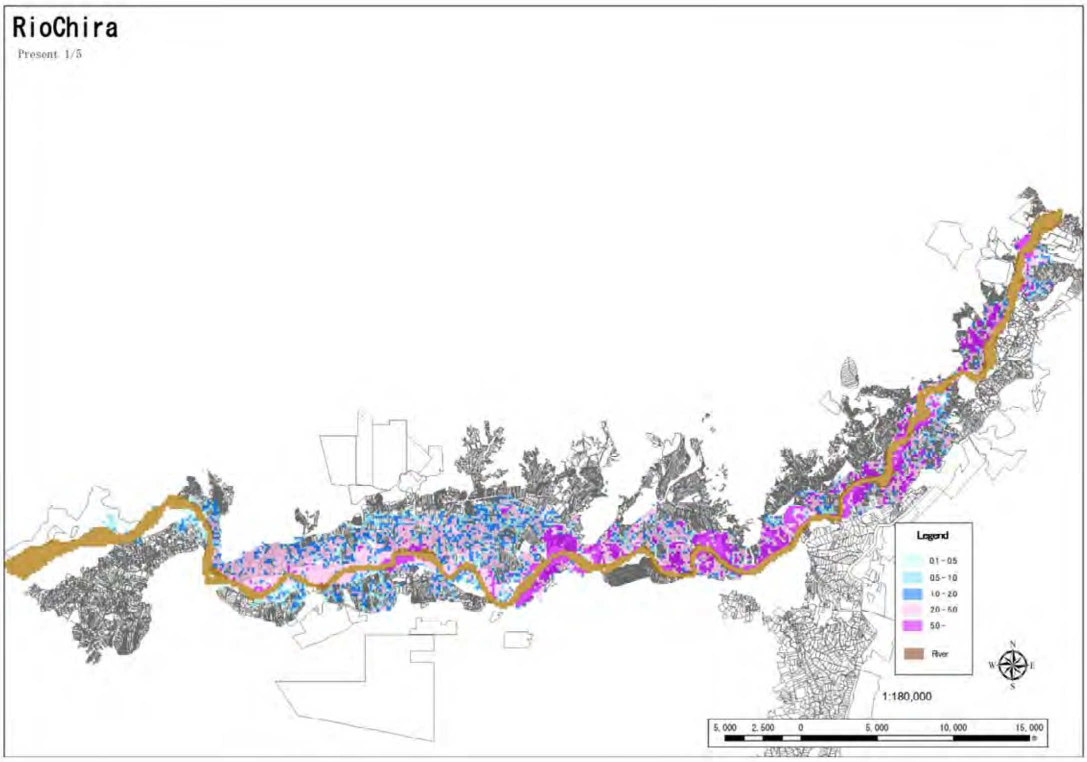
Chira River（1/25 Year Probable Flood） Without Case



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***.

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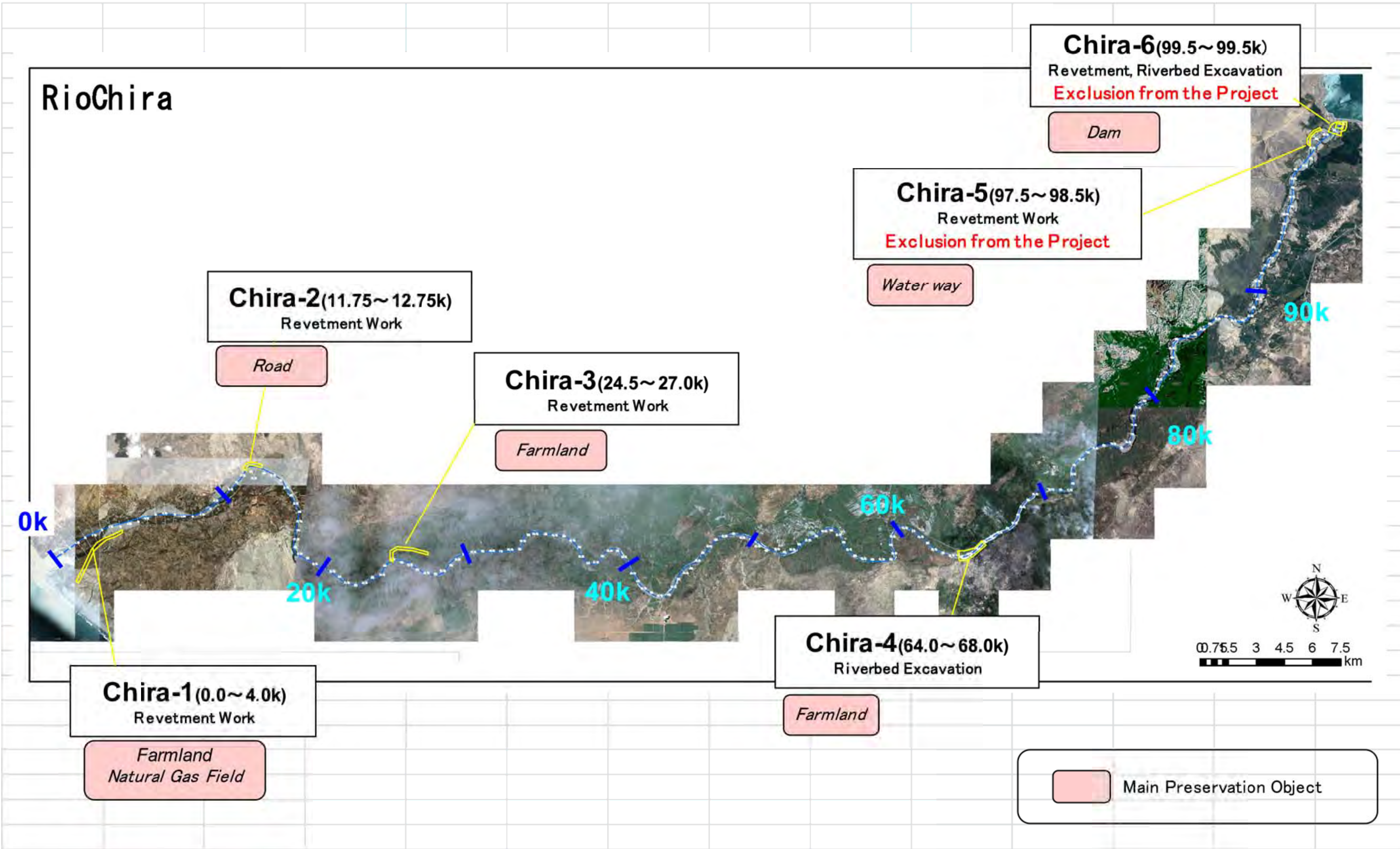


Figure 2.2 **Locations for Flood Mitigation Measures in Chira River**

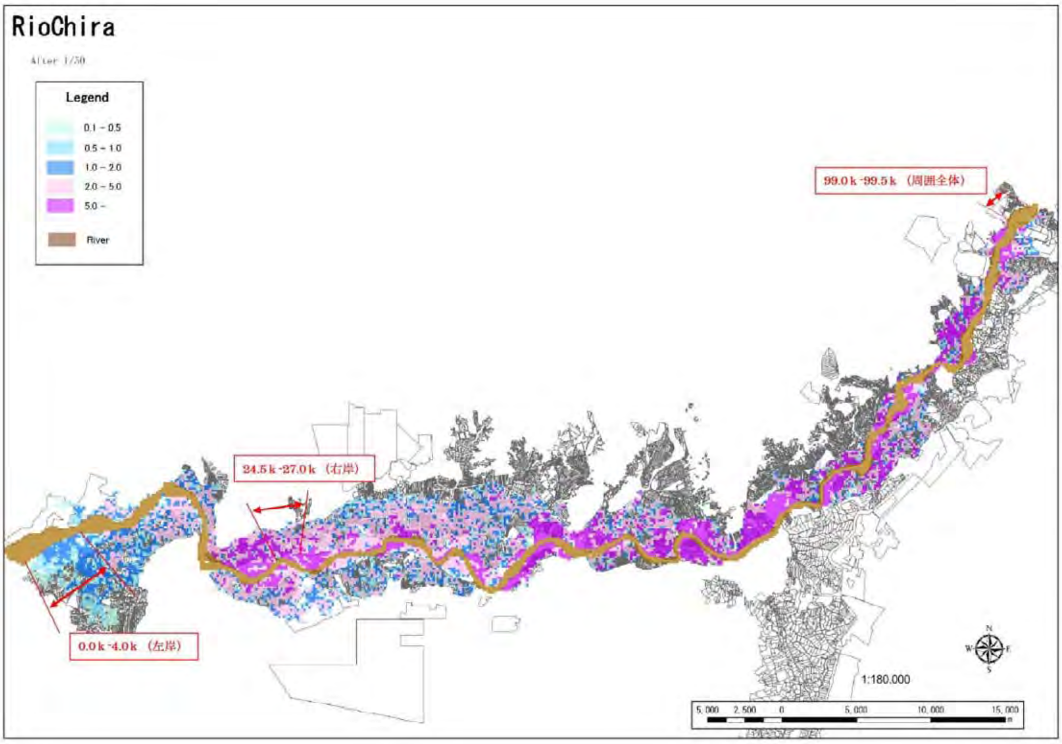
(4) Result of Inundation Analysis for each Probable Flood (with case)

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

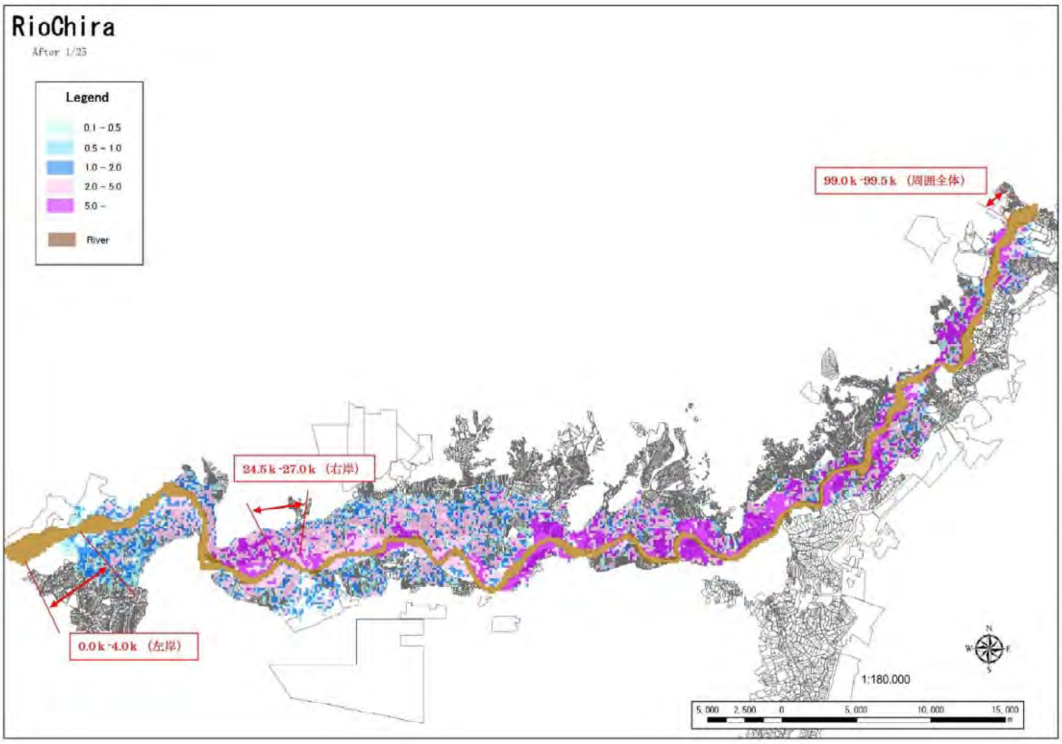
Table 2.3 **Inundation Area for each Probable Flood Scale in Chira River With case)**

With Case	1/5		1/10		1/25		1/50	
	No. of Mesh	ha	No. of Mesh	ha	No. of Mesh	ha	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

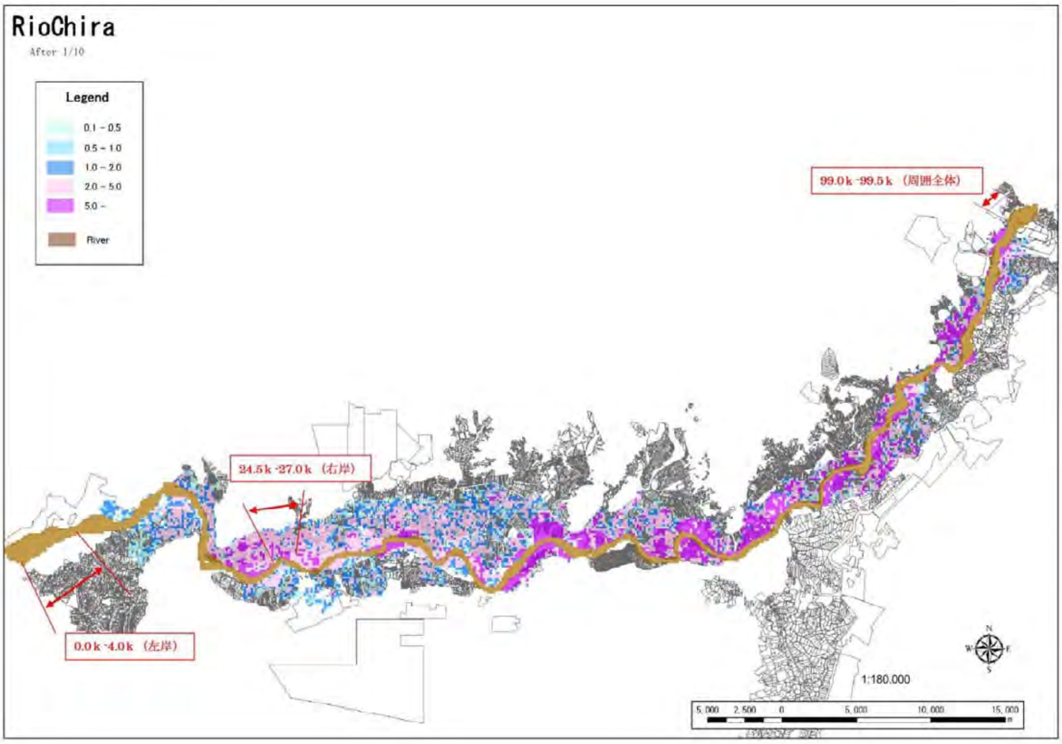
Chira River（1/50 Year Probable Flood） With Case



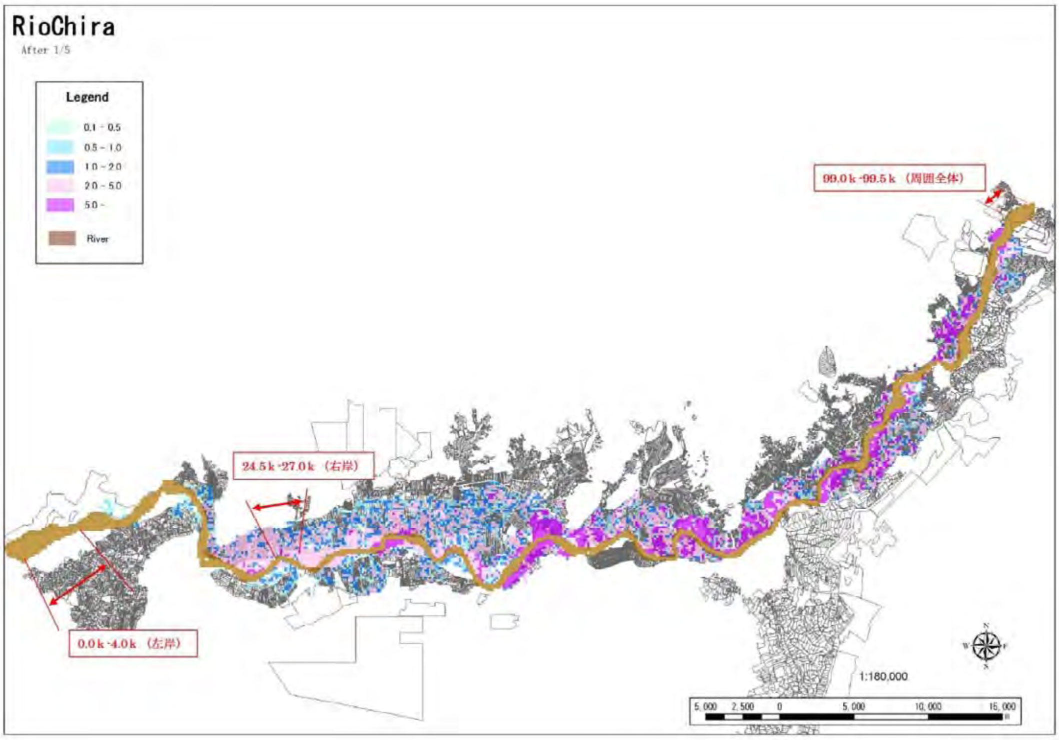
Chira River（1/25 Year Probable Flood） With Case



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

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.

Table 2.4 **Peak Discharge to Each Probable Flood Scale (Canete River)**

Return Period	Q (M3/S)
2	331
5	407
10	822
25	1496
50	2175
100	2751

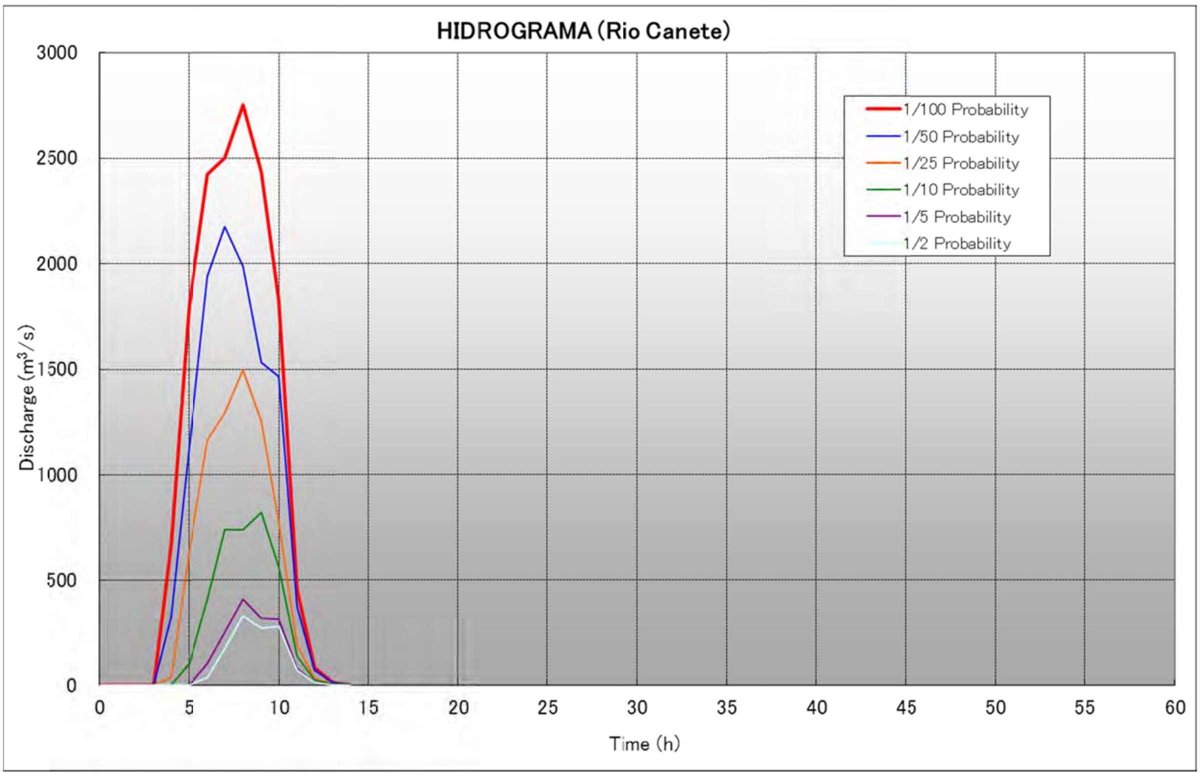


Figure 2.3 **Probable Flood Hydrographs (Canete River)**

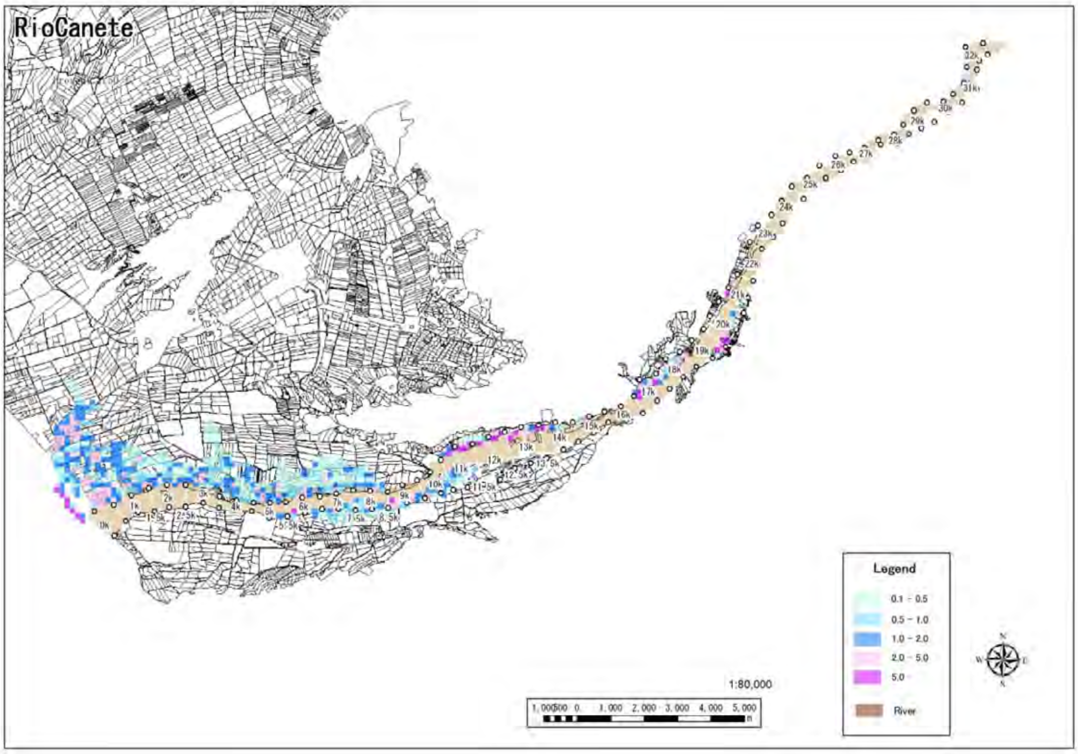
(2) Result of Inundation Analysis (without case)

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

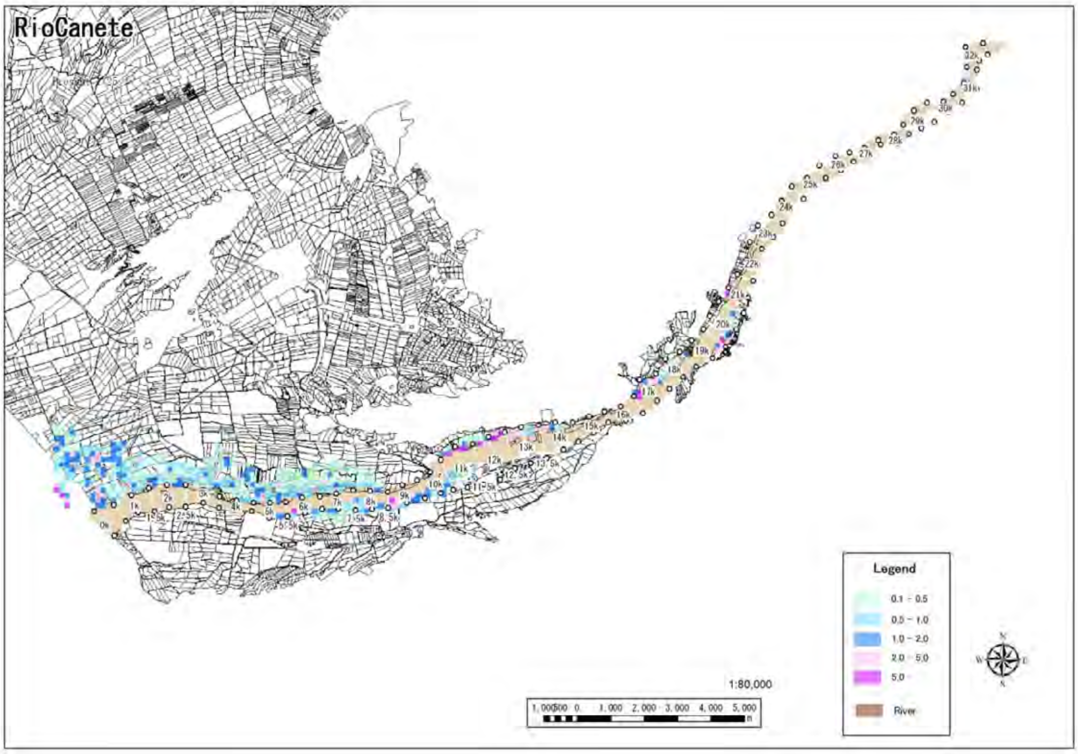
Table 2.5 **Inundation Area for each Probable Flood Scale in Chanete River (Without case)**

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

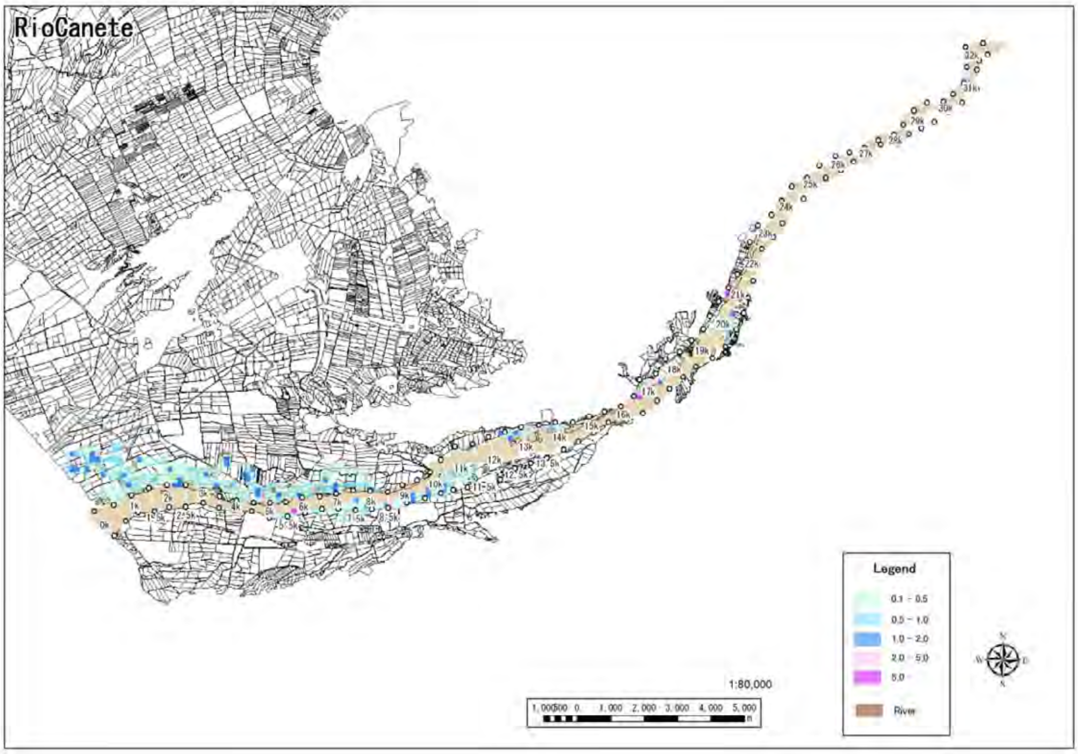
Canete River (1/50 Year Probable Flood) Without Case



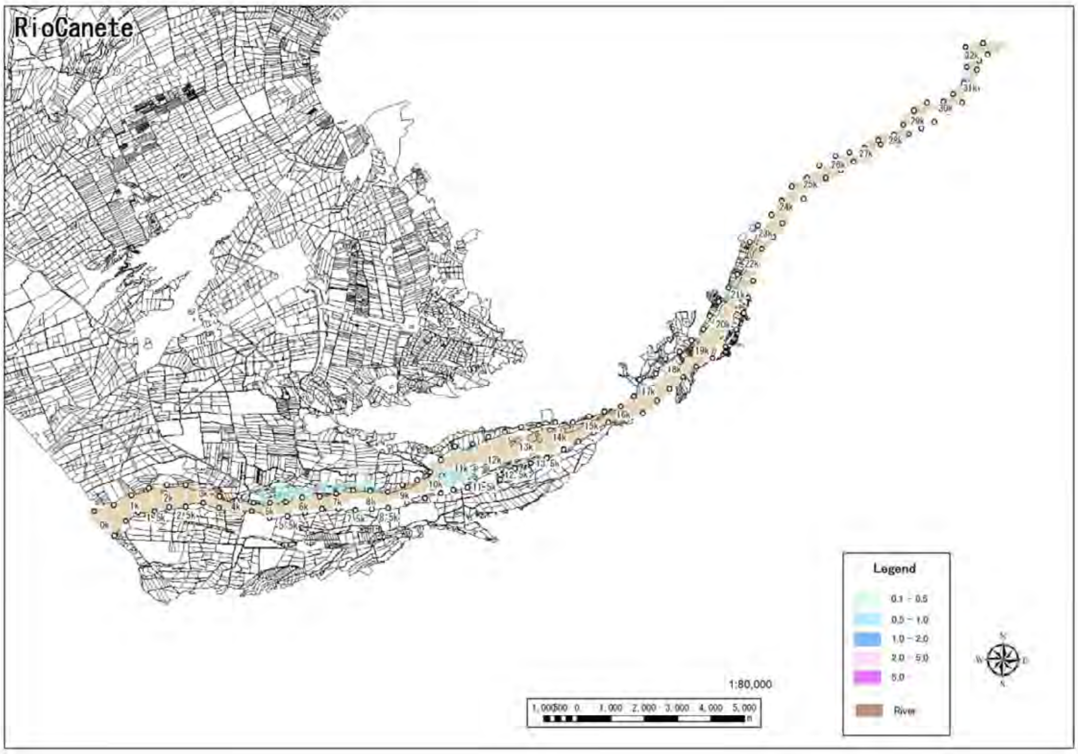
Canete River（1/25 Year Probable Flood）Without Case



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***.

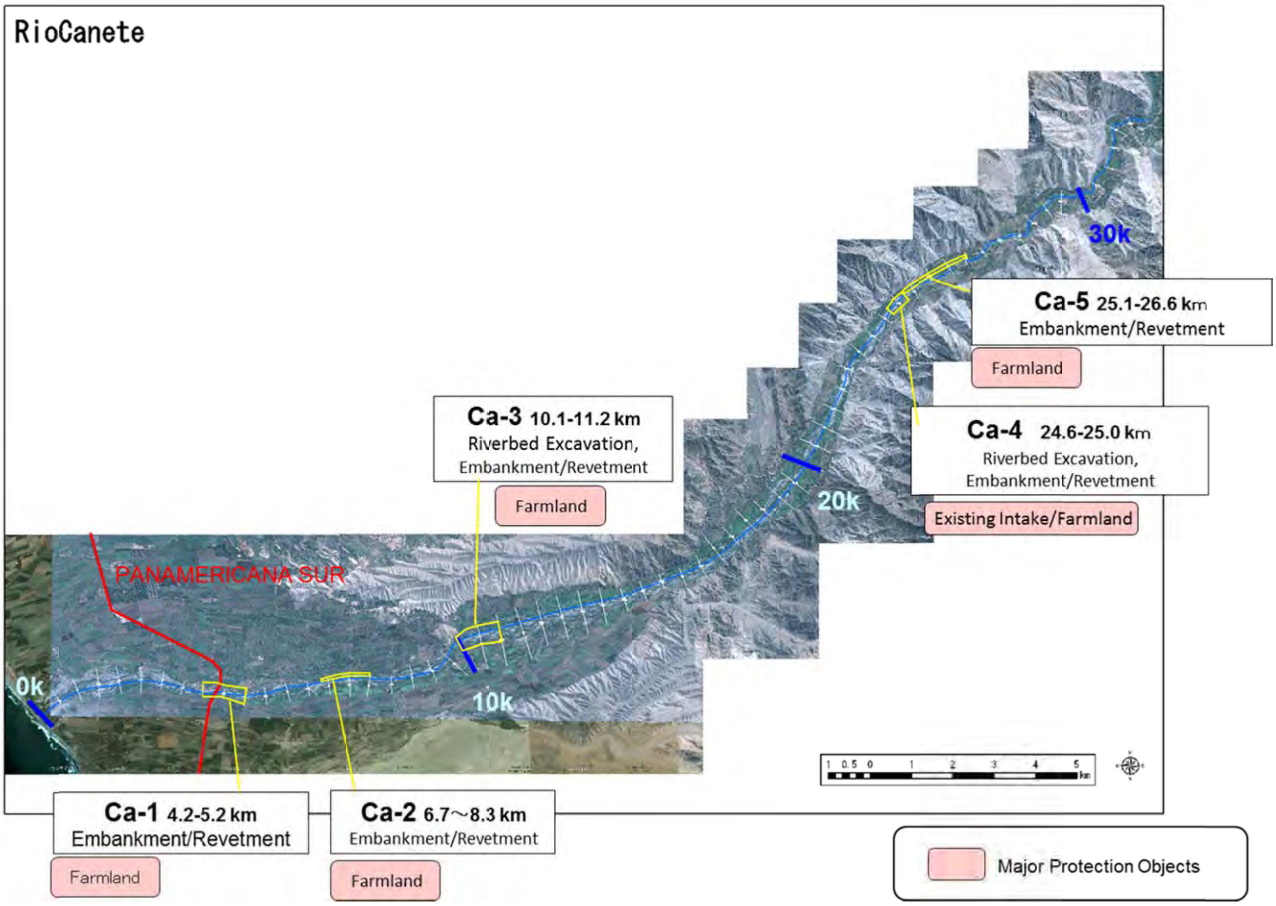


Figure 2.4 **Locations for Flood Mitigation Measures in Canete River**

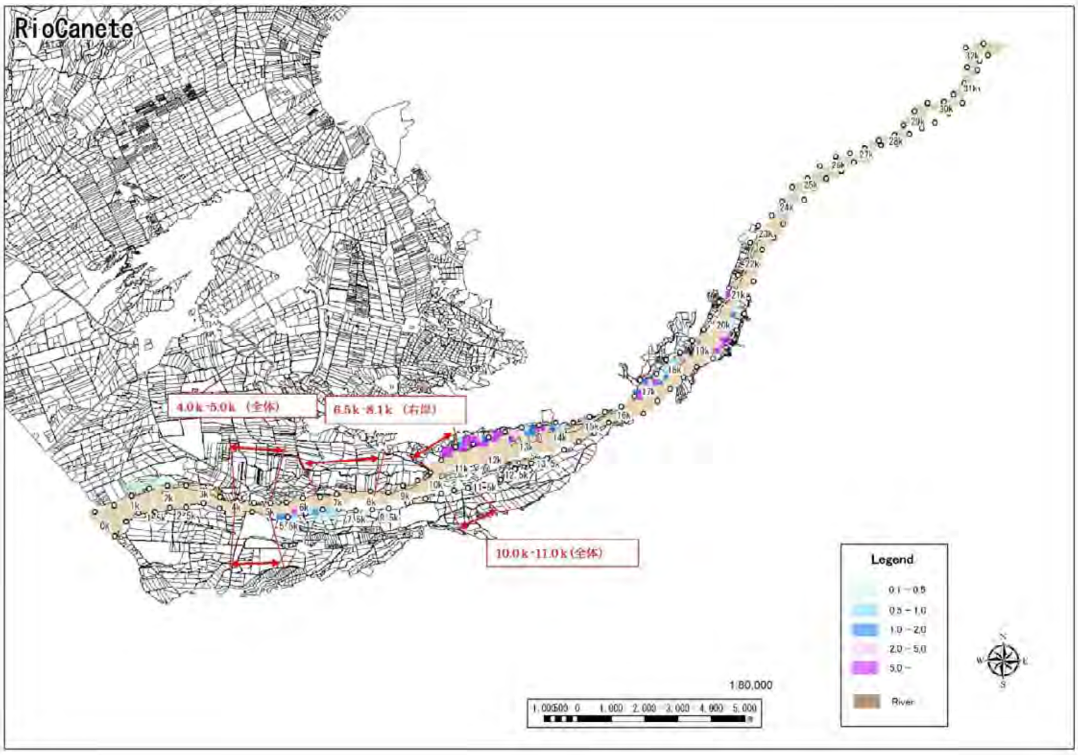
(4) Result of Inundation Analysis for each Probable Flood (with case)

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

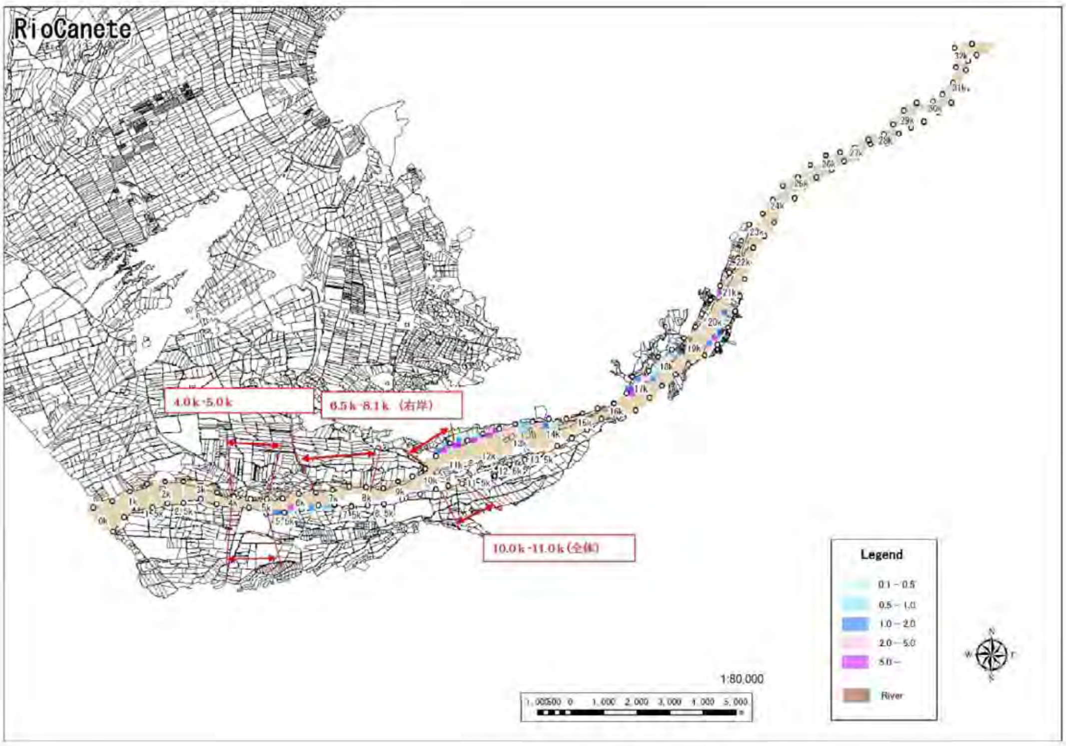
Table 2.6 **Inundation area for each Probable Flood Scale in Canete River (with case)**

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

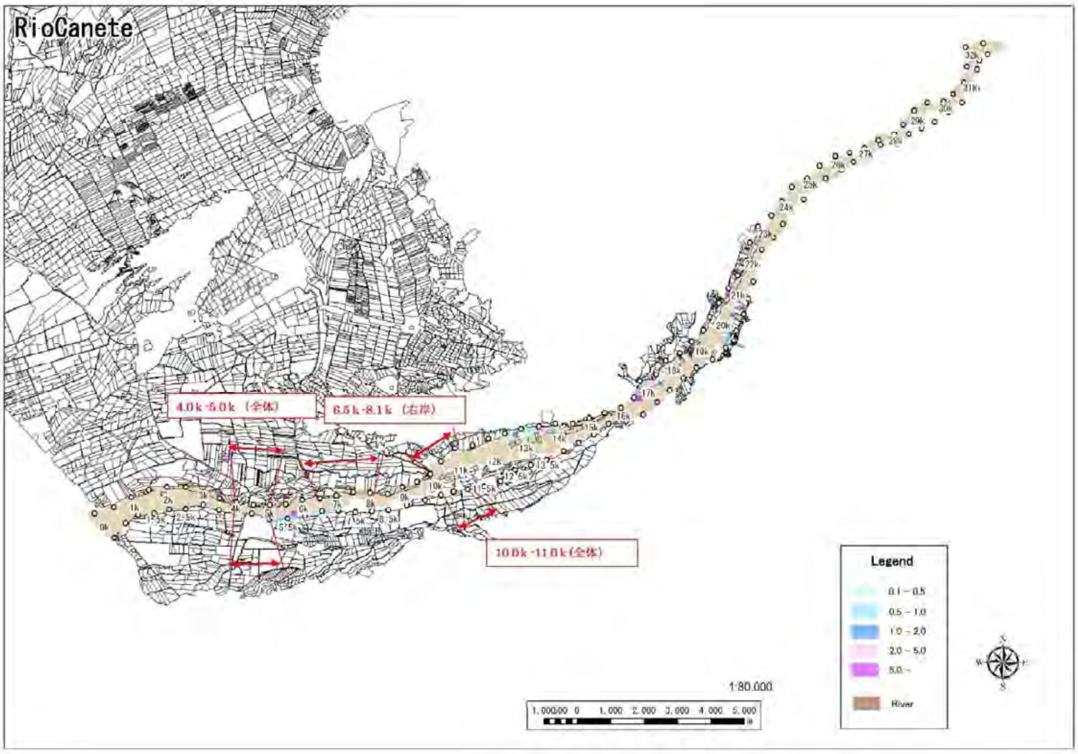
Canete River (1/50 Year Probable Flood) With Case



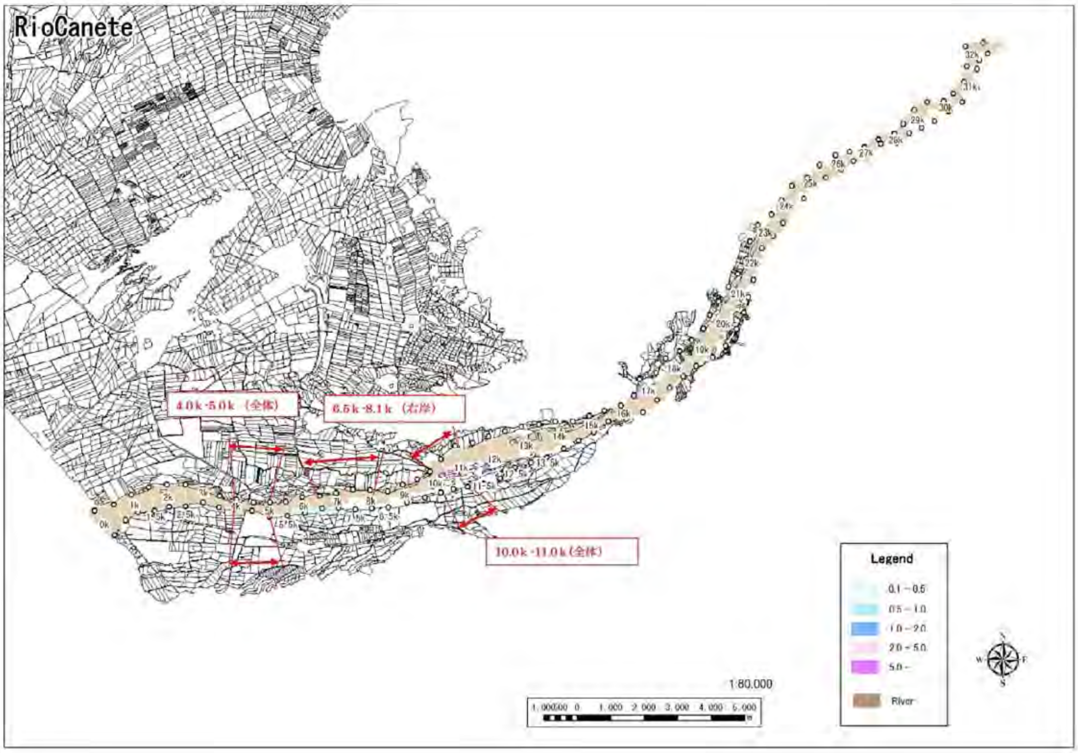
Canete River (1/25 Year Probable Flood) With Case



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 2.7 **Peak Discharge to Each Probable Flood Scale (Chincha River)**

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

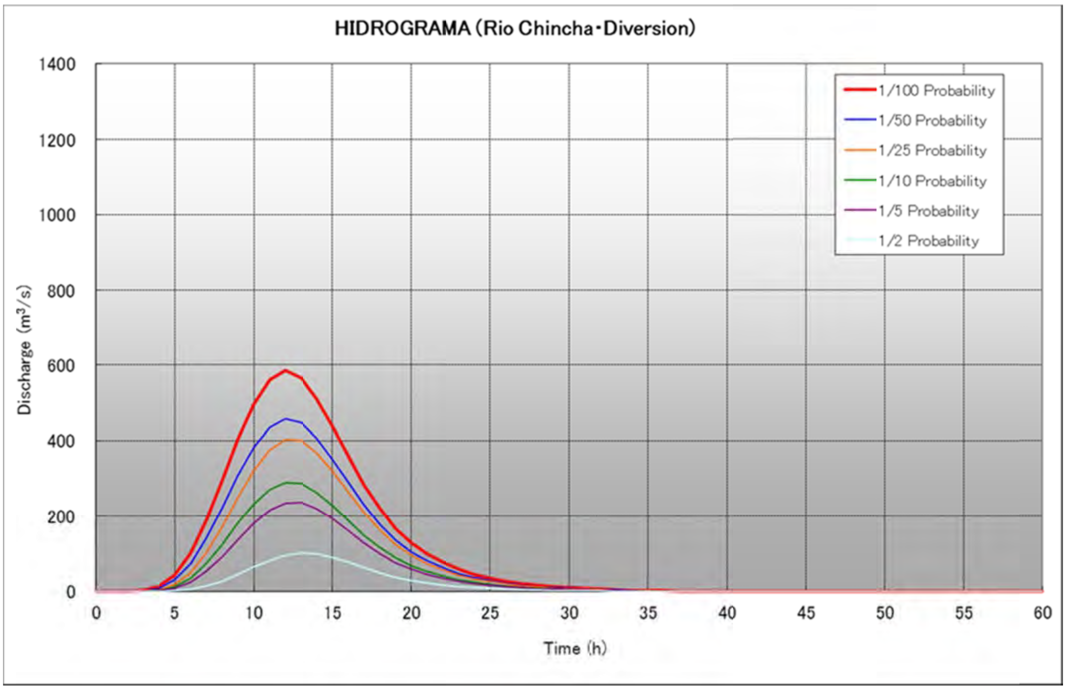


Figure 2.5 **Probable Flood Hydrographs (Chincha River)**

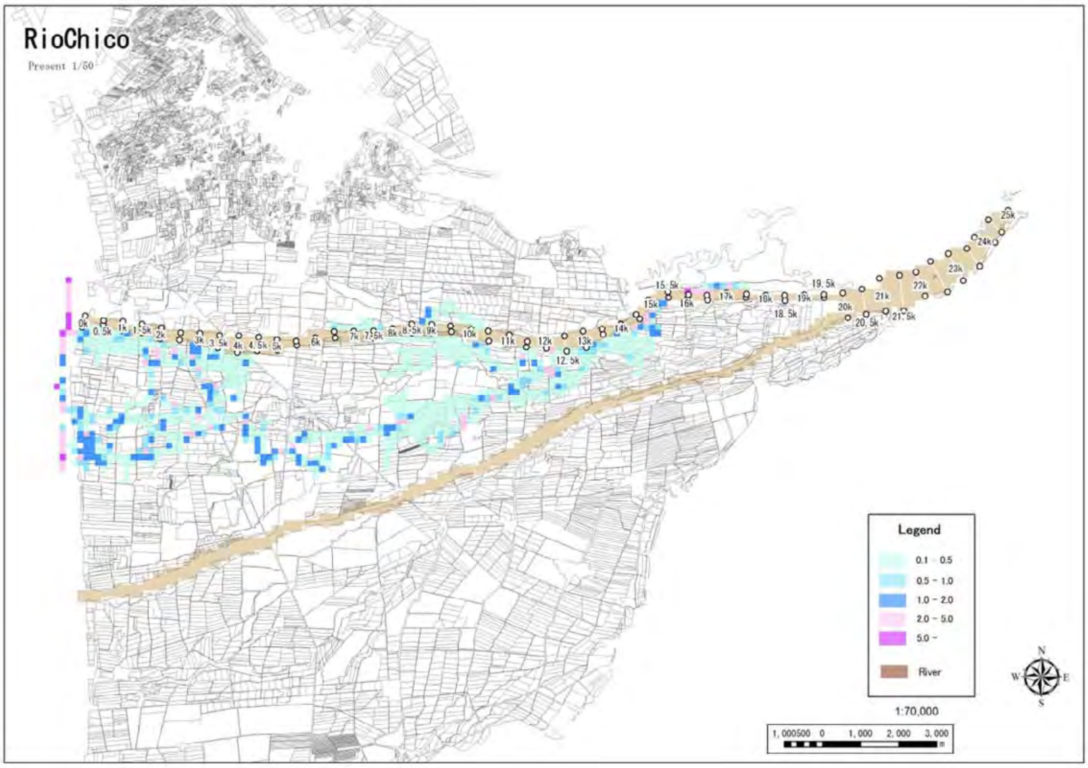
(2) Result of Inundation Analysis (without case)

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

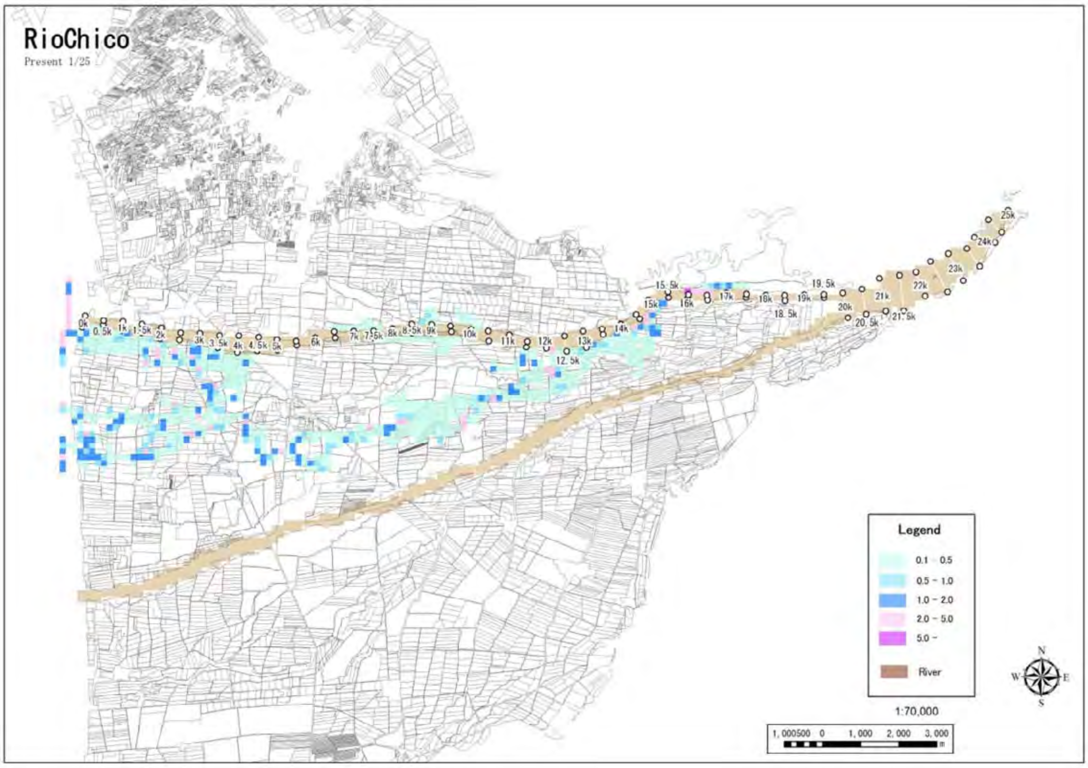
Table 2.8 **Inundation area for each Probable Flood Scale in Chincha River (Without case)**

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
Chincha	①Chico	270	607.5	293	659.3	714	1,606.5	827	1,860.8
	②Matagente	249	560.3	265	596.3	498	1,120.5	587	1,320.8
	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

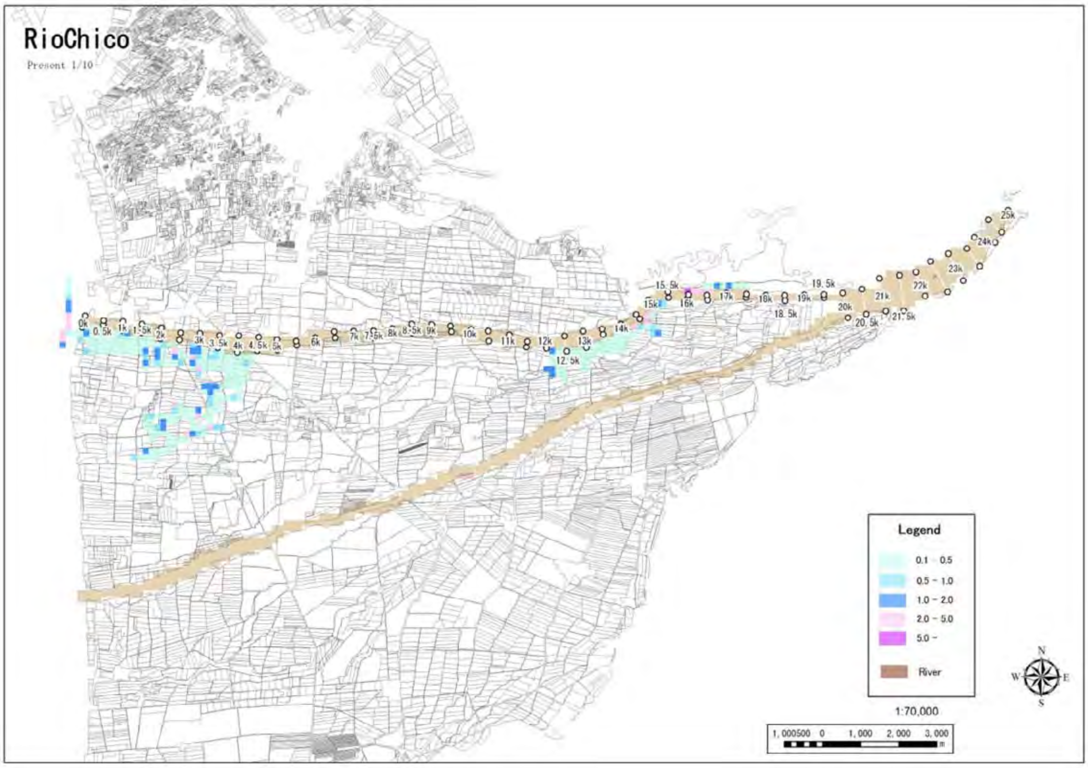
Chincha (Chico) River (1/50 Year Probable Flood) Without Case



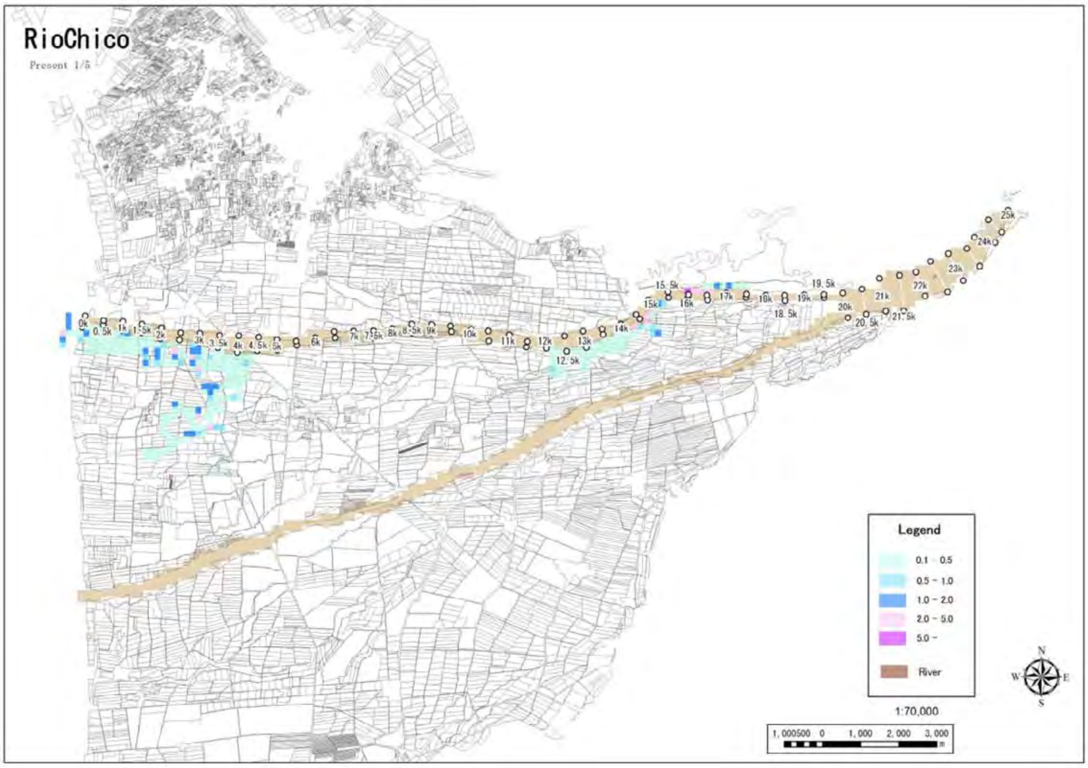
Chincha (Chico) River (1/25 Year Probable Flood) Without Case



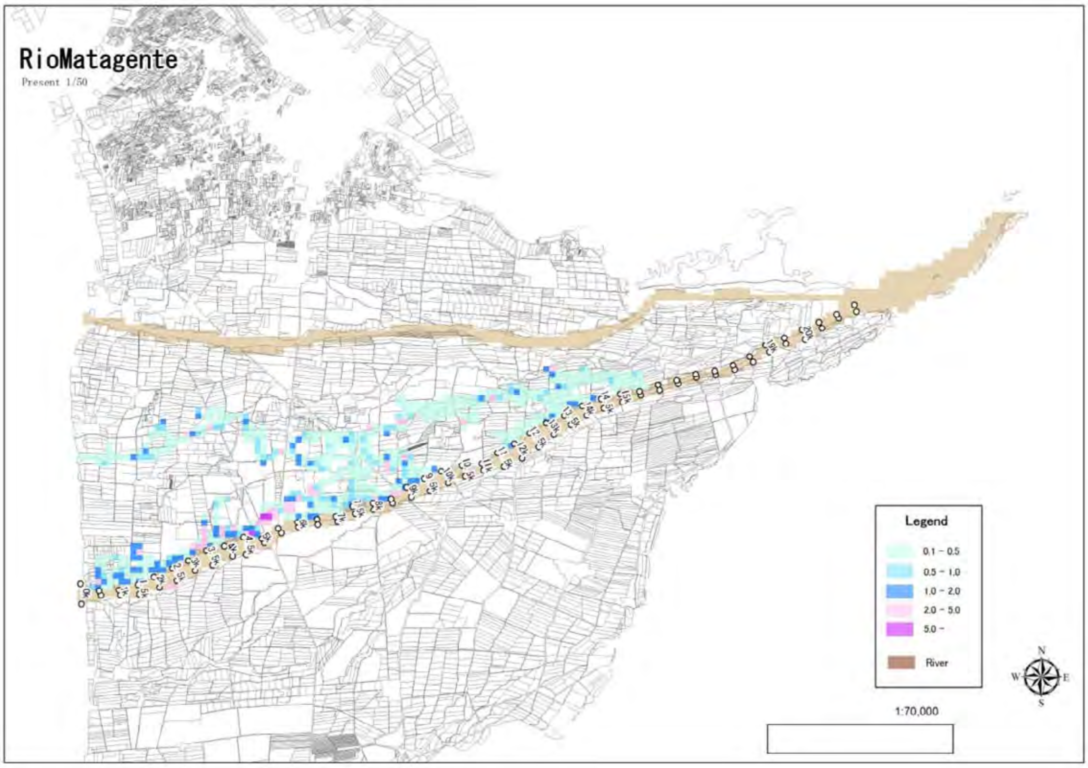
Chincha (Chico) River (1/10 Year Probable Flood) Without Case



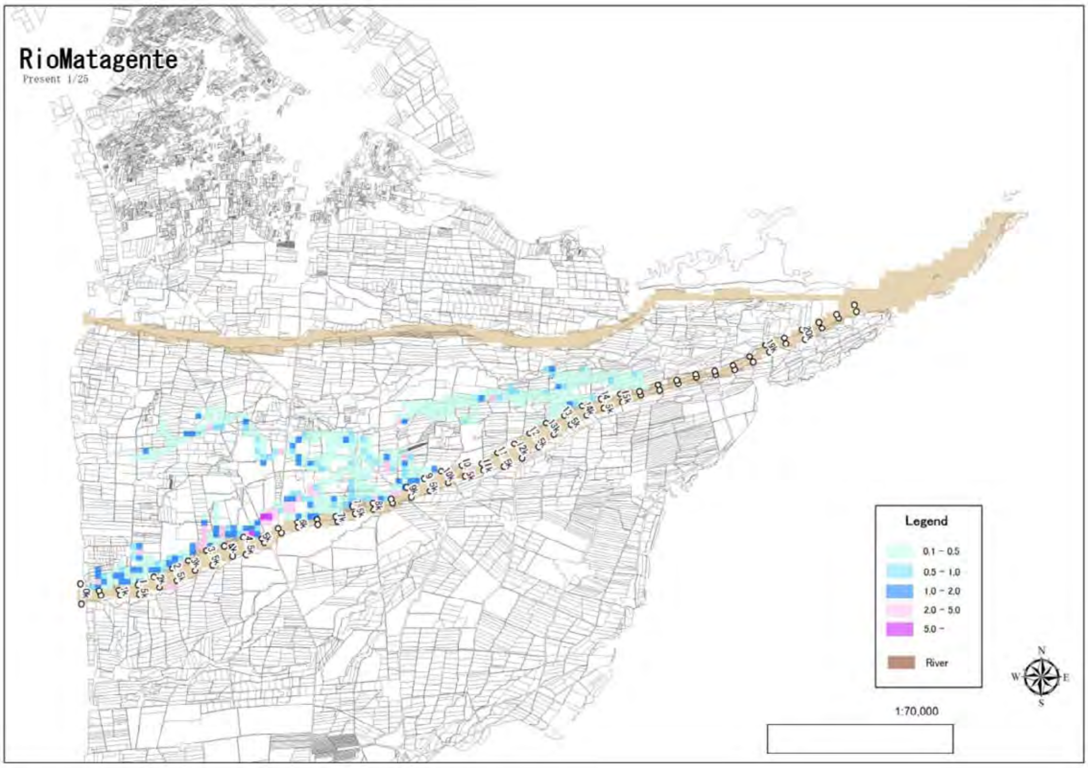
Chincha (Chico) River (1/5 Year Probable Flood) Without Case



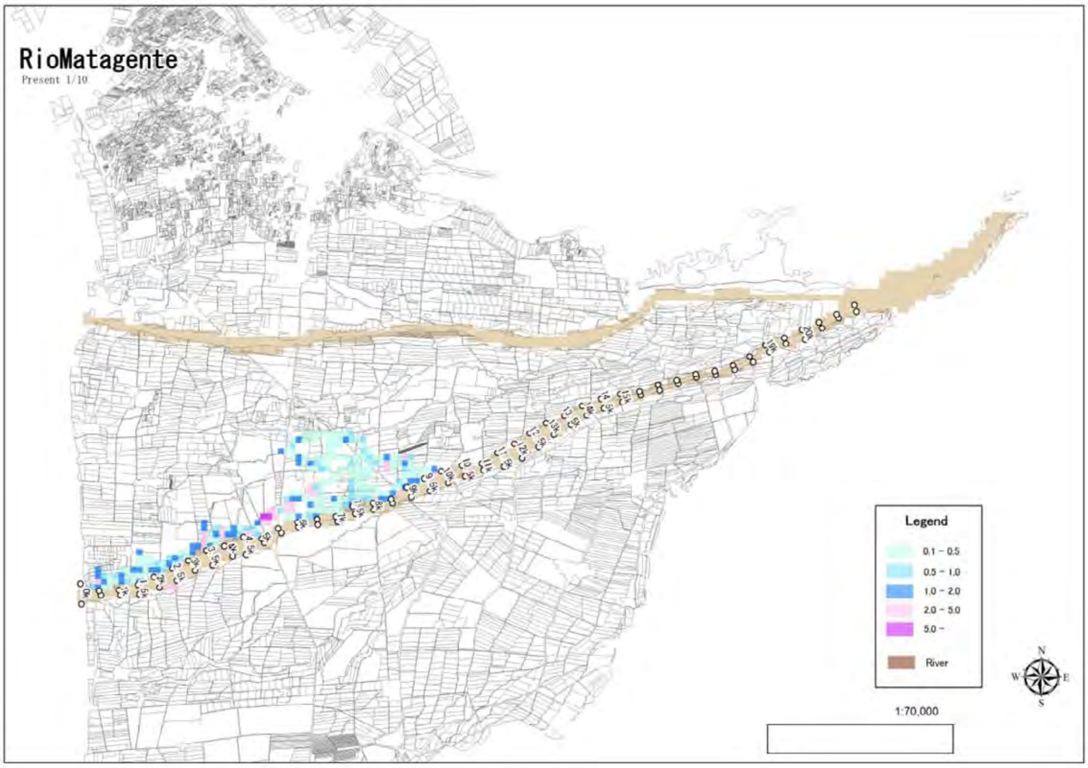
Chincha (Matagente) River (1/50 Year Probable Flood) Without Case



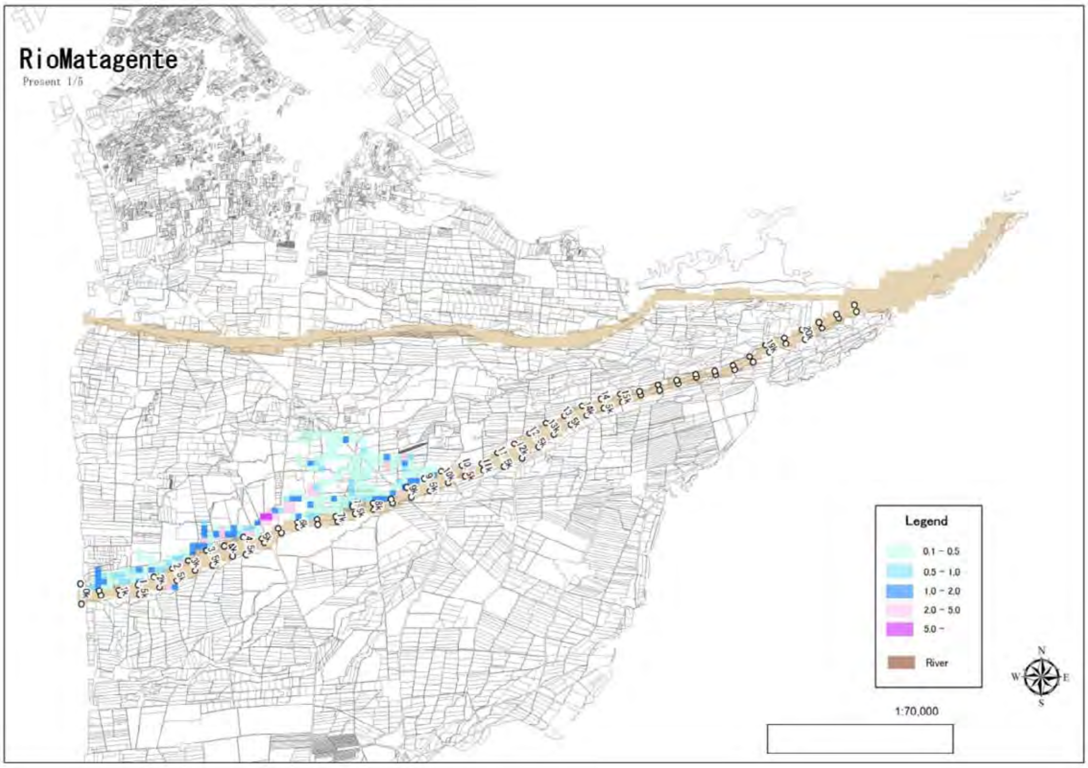
Chincha (Matagente) River (1/25 Year Probable Flood) Without Case



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



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



(3) Flood Mitigation Measures

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***.

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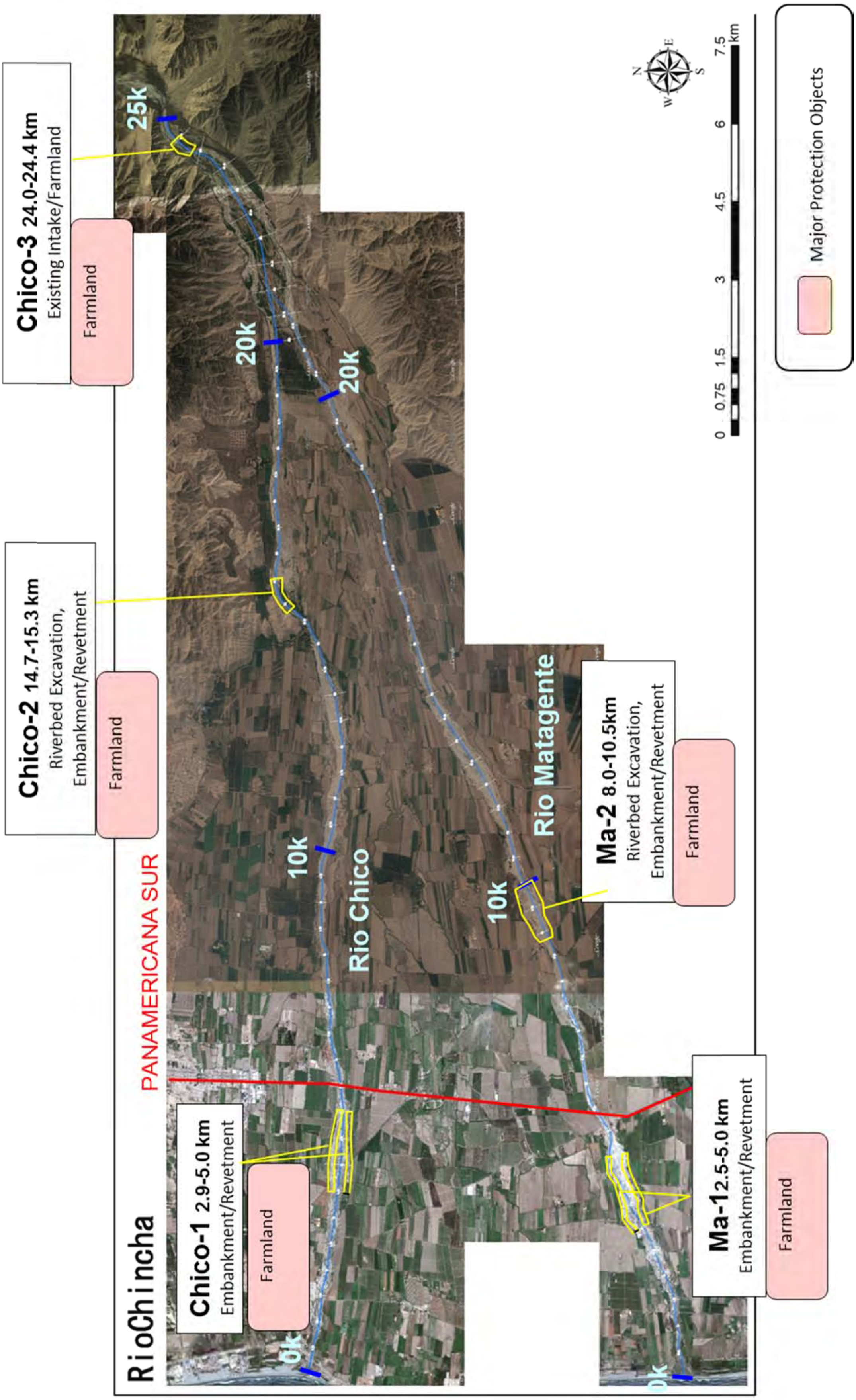


Figure 2.6 **Locations for Flood Mitigation Measures in Chincha River**

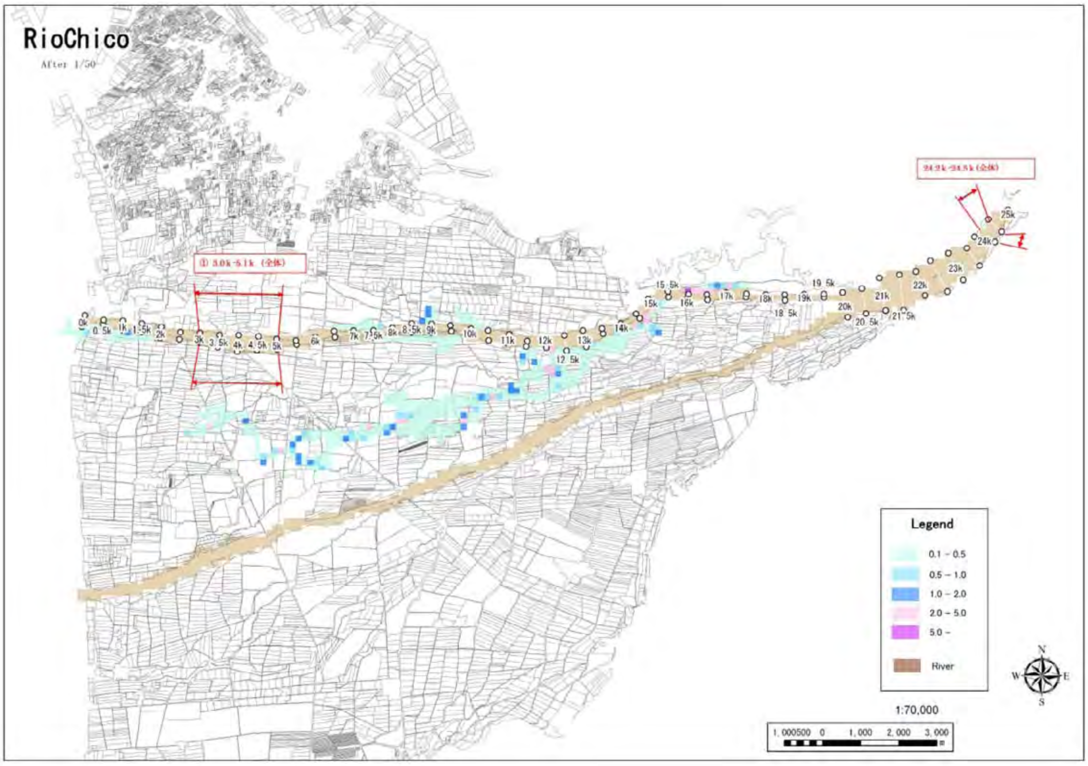
(4) Result of Flood Analysis According to each Probable Flood Scale (with case)

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

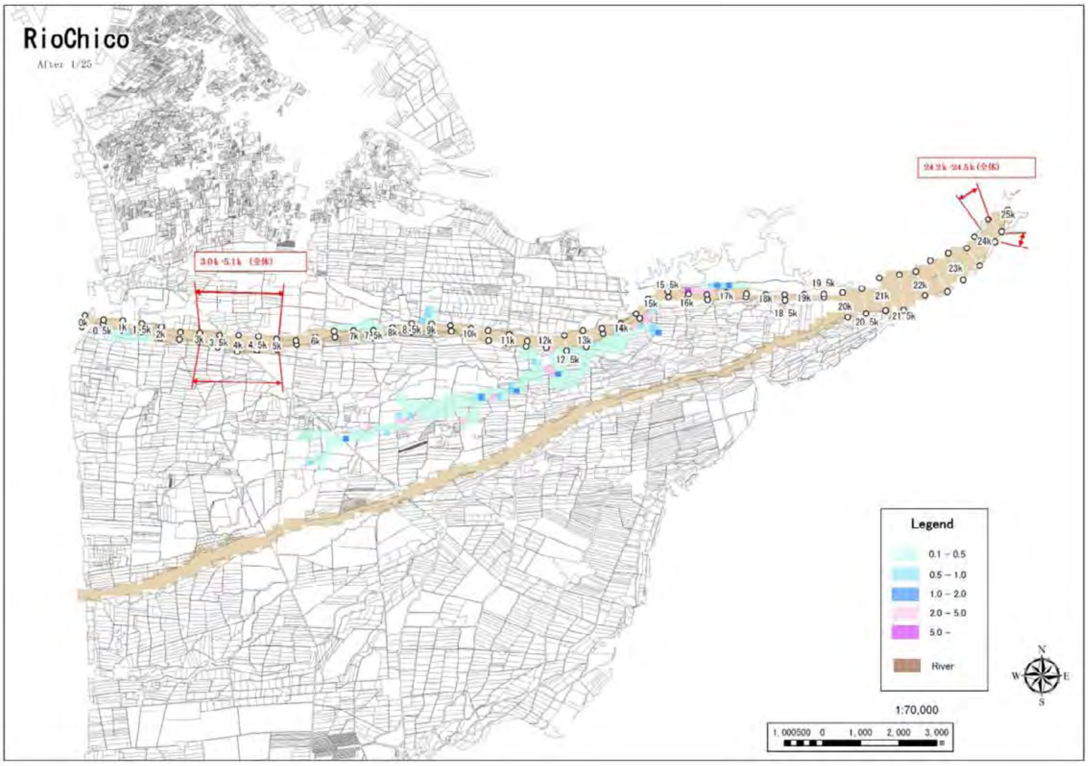
Table 2.9 **Inundation area for each Probable Flood Scale in Chincha (With case)**

With 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
Chincha	①Chico	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

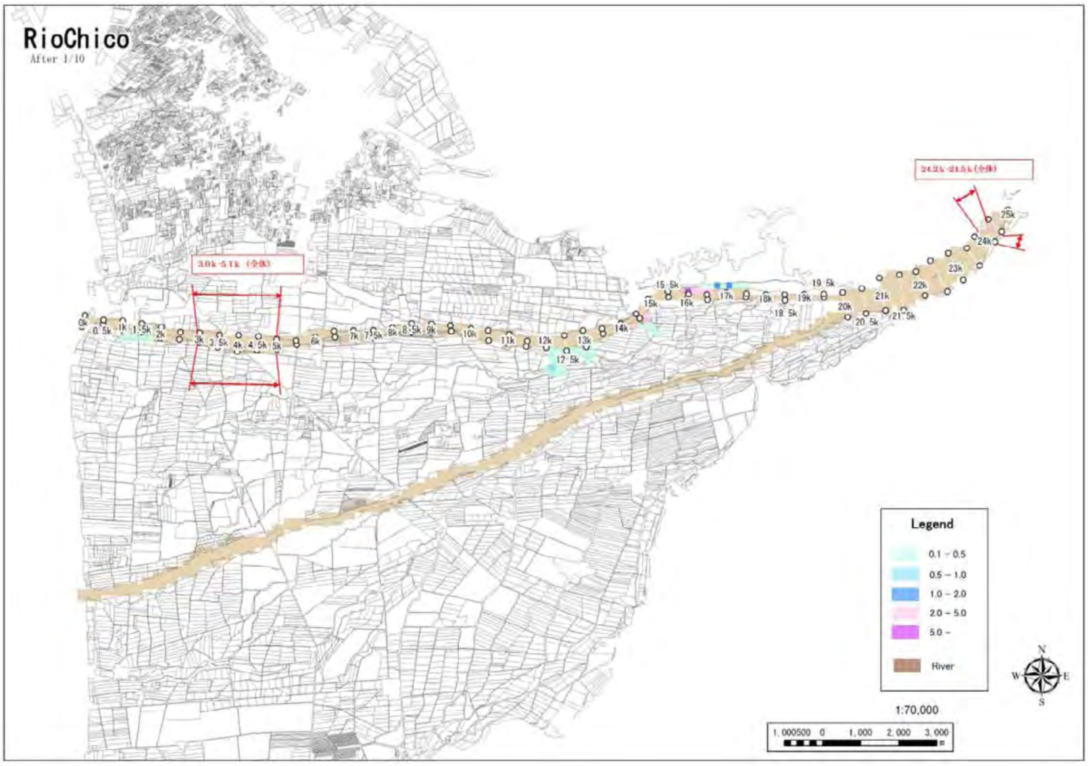
Chincha (Chico) River (1/50 Year Probable Flood) With Case



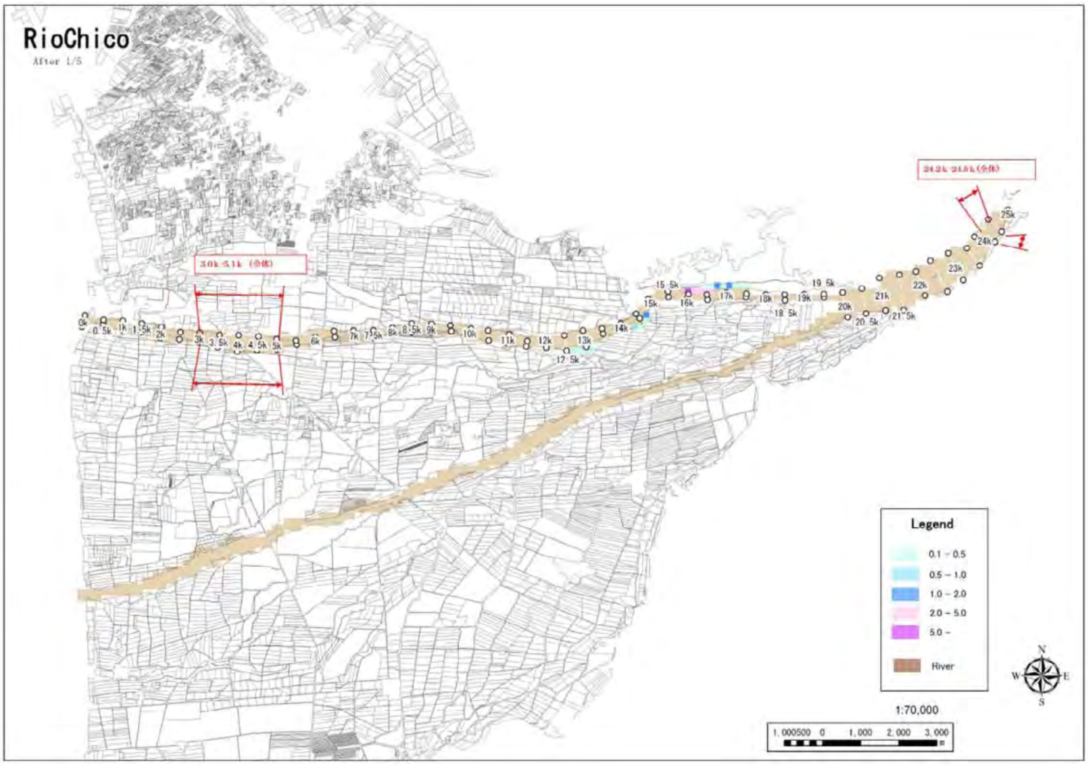
Chincha (Chico) River (1/25 Year Probable Flood) With Case



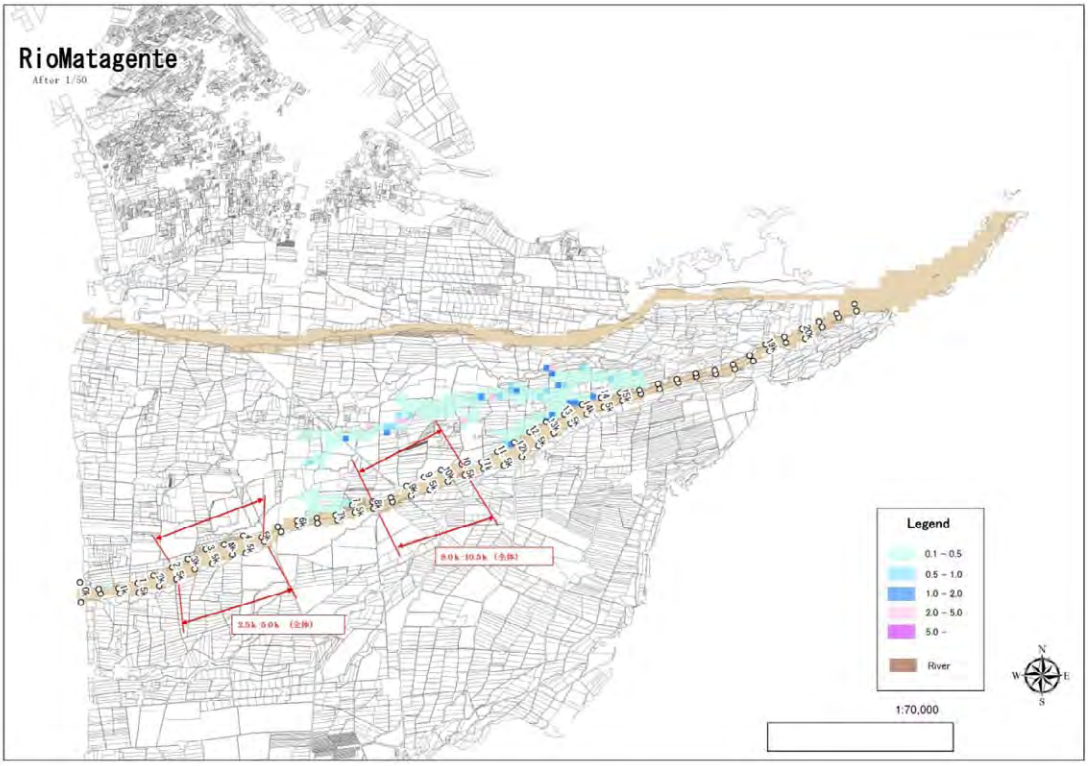
Chincha (Chico) River (1/10 Year Probable Flood) With Case



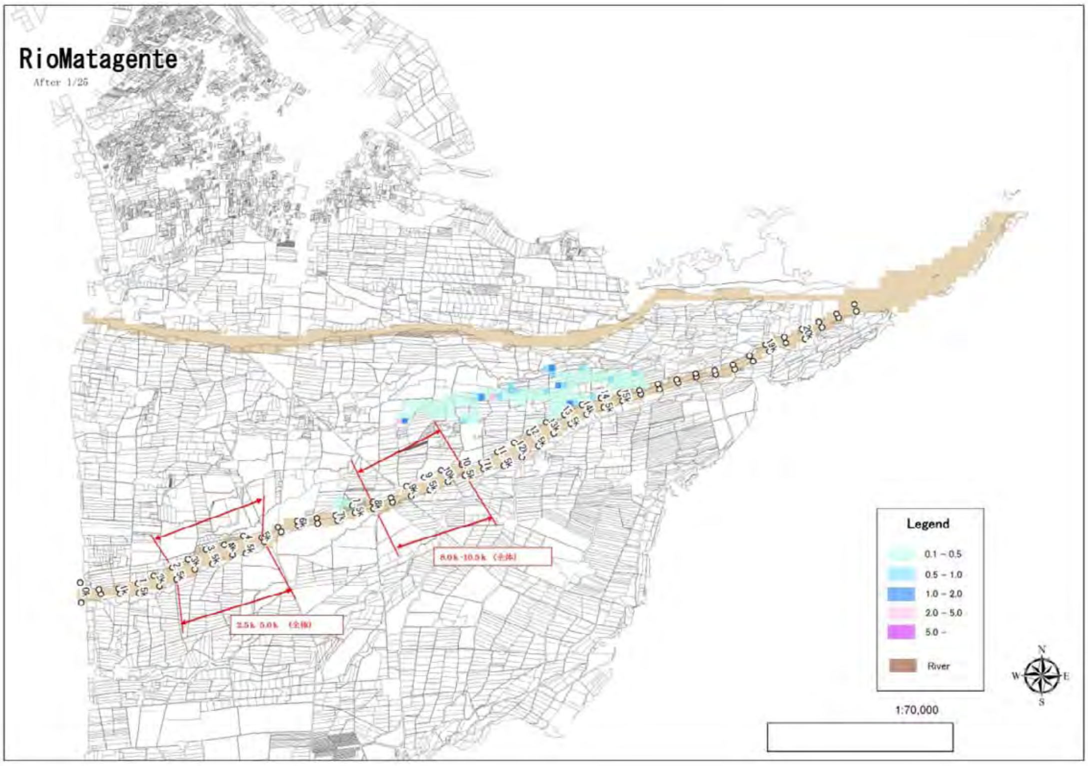
Chincha (Chico) River (1/5 Year Probable Flood) With Case



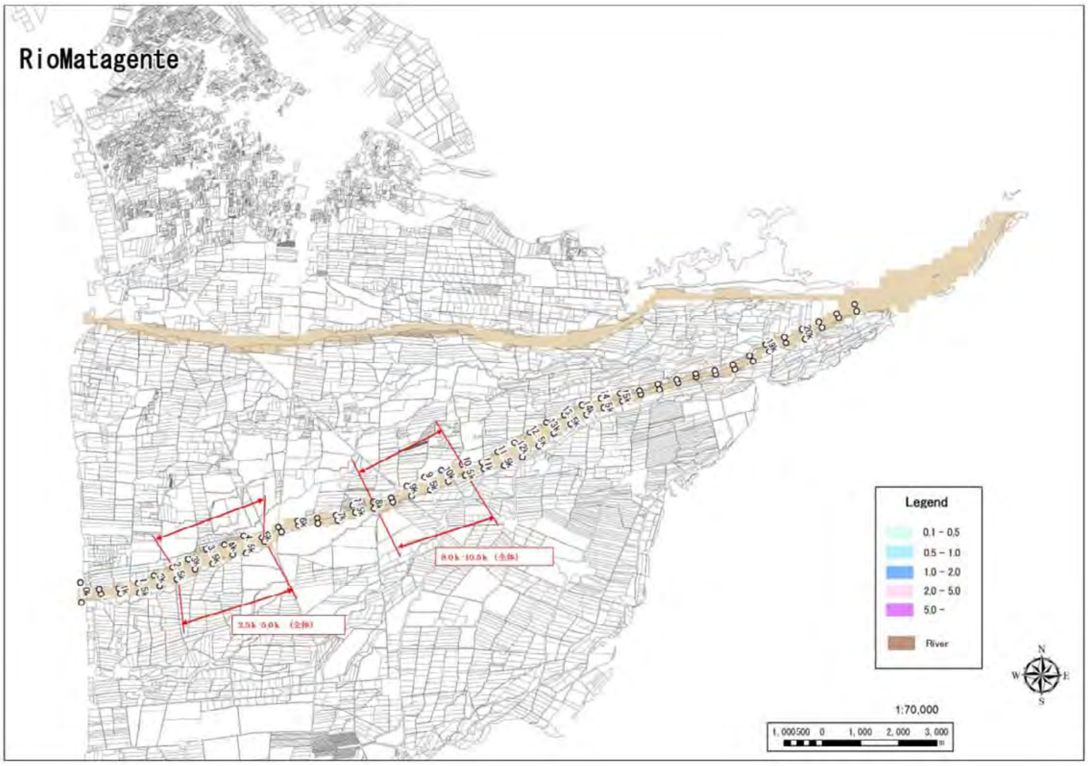
Chincha (Matagente) River (1/50 Year Probable Flood) With Case



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