(1) Preliminary Survey

For cases in which so much time has passed after inundation that no flood marks remain:

1) On the map, identify the place names recorded in past newspapers and literature, and estimate the approximate extent of inundation on the basis of topographic features.
2) Interview elderly residents in the pertinent areas, to collect information on the extent and depth of inundation.

(2) Identification of Flood Marks

When identifying flood-level marks:

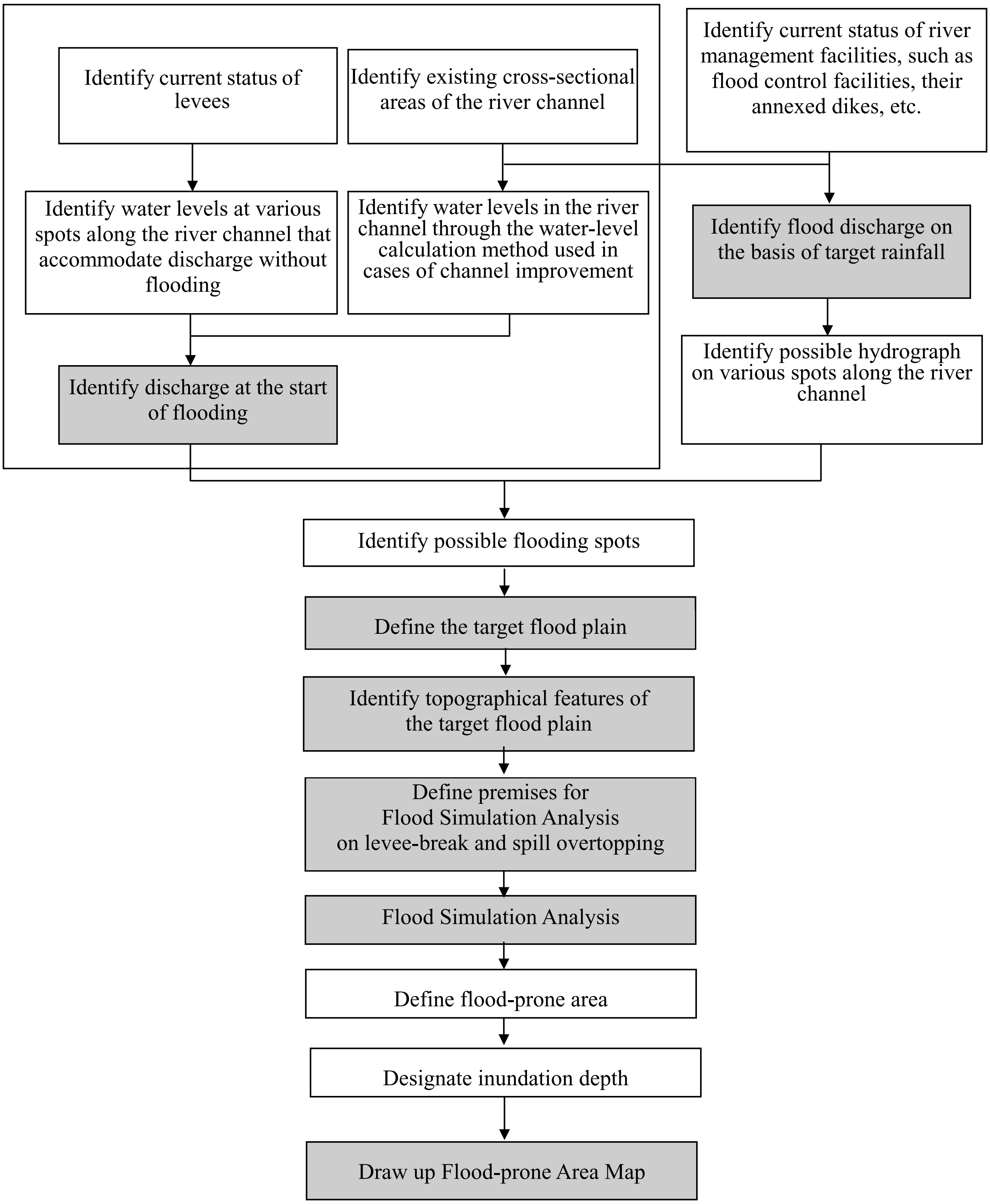
1) Identify the mark levels as soon as possible after the flood reaches its peak.
2) Specify the flood marks, preferably based on mud marks.
   Mud marks fade out in the meantime, or disappear within a short time, particularly after rain. Even if they do not disappear, they might be worked into a lower level by rain.
3) In cases of specifying the marks based on trash, look carefully and extensively around the spots beforehand, and exclude those trash levels unusually lower than the surrounding ones.
   Trash often slides down by its own weight, or might otherwise be moved unnaturally, such as by wind. Mud marks seem to offer more accurate marks than trash. Draw up a proper level-line, connecting the reasonable marks, and define its level by surveying.
4) Compare the mark levels with the peak flood levels recorded at the nearby water-level stations, if any, in order to verify them.
5) Sampling of flood marks in the flow direction shall be done at intervals of 50-100 m in a straight river channel, preferably ensuring the collection of at least one set of reliable data from both sides of the channel.

(3) Drawing-up of Historical Inundation Map

Draw up a map of past inundation, integrating all relevant data collected, that is, the surveyed flood marks, topographically classified feature maps, and estimated inundated area maps through interviews with elderly residents, etc.

8.4 Drawing-up of Flood-prone Area Map
(Cases in which Flood Simulation Analysis is possible)

For cases in which Flood Simulation Analysis is possible, Flood-prone Area Maps are to be drawn up and used as basic information for producing Flood Hazard Maps.



Example of Flood-prone Area Map

Source: The Kurobe River Flood-prone Area Map

(1) Defining the Target Flood Plain

A pertinent flood simulation model is to be set up, based on the conditions of the current flood plain.

1) Target flood plain

Define the target flood plain on the basis of estimated flooded area maps from past inundation records, so as to include possible inundation areas by the target flooding, particularly the maximum extent of inundation areas corresponding to the respective assumed levee-break spots.

In lowland areas near the river mouth, the inundation area may be delimited by artificial structures such as levees of a neighboring river, and so forth.

2) Defining the flood plain for the simulation model

In order to accurately estimate the inundation depth of a flood, it is necessary to identify factors such as topographic features, existing continuous banking structures, e.g. roads or railways, and dikes of small- or medium-sized rivers, which affect the overflowing water.

(2) Identification of Ground Level and Land-use Pattern in the Target Flood Plain

To ensure the accuracy of topographic conditions, identify the ground levels in the target flood plain, and define them by 50-m meshes (commonly used in Japan). It is desirable to coordinate these meshes with 250-m flood-simulation meshes (commonly used in Japan), as described later.

1) Identification of averaged ground level

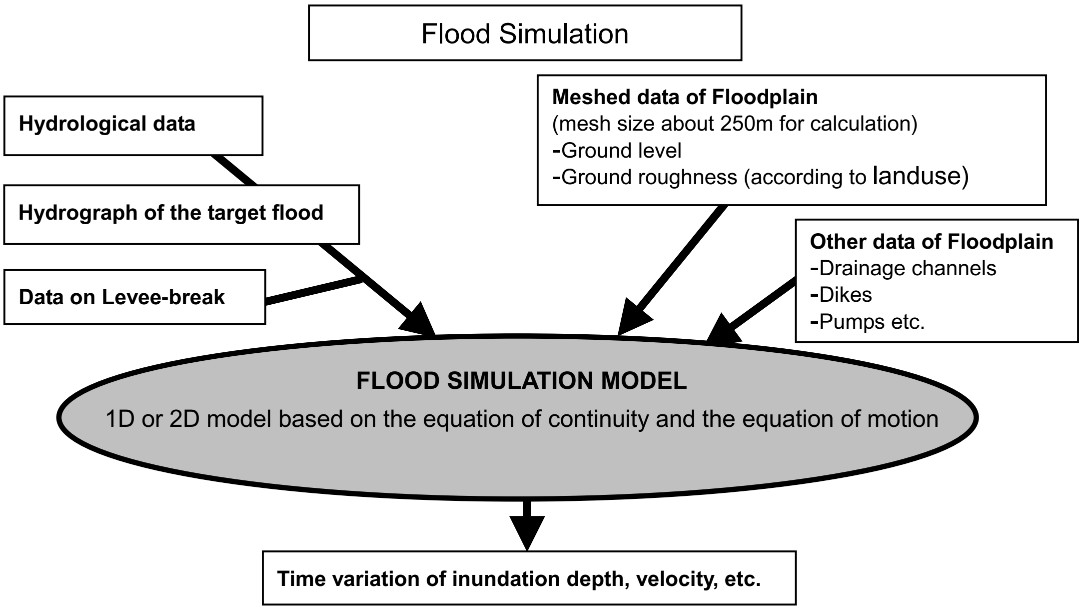
Identification of ground levels is done by specifying the averaged ground level at the center and the four corners of the respective 50-m meshes by using a large-scale urban planning map of 1/2,500 (commonly used in Japan) or the “National Land Base Map,” published by the National Geographical Survey Institute.

Supplementary field surveys shall be conducted, as needed, in order to represent all topographic features as accurately as possible. "Numerical Elevation Map of 50-m Meshes," published by the Japan Map Center, may be used in Japan for base maps.

2) Identification of current land-use patterns and tenement rate for roughness coefficient
It is necessary to define the roughness of the flood plain for simulation analysis. Survey and define the current land-use patterns and tenement rate thereof.

(3) Defining the Premises for Flood Simulation Analysis by Levee-break and Spill Overtopping

1) Identification of premises for flooding due to levee-break, discharge capacity of river channel and flooding-start discharge
Identify the possible flooding spots on the levees, and successively possible flooding-start water levels for the respective spots, taking into consideration the current status of protection and maintenance for the existing river channel.
Here, it shall be assumed that levees break when the channel discharge exceeds water levels of those that could possibly start flooding for the respective dangerous spots.
The water levels shall be specified taking into consideration the levee height and current status of protection works against leakage, filtration, and erosion for the respective spots.
In principle, those levels shall be estimated by means of the same analysis method as that for river channel planning.



Refer to the following notes for defining the flooding-start discharge due to levee-break:

a) River channel
The river channel for estimating the flooding-start discharge shall be the existing channel.

b) Assumption in estimating flooding-start discharge
The flooding-start discharge due to levee-break shall be estimated by the same hydraulic analysis method as that for river channel planning. Currently, in cases of planning large river channels, the non-uniform flow analysis (quasi-two-dimensional non-uniform flow analysis) is widely used, taking into consideration the existing trees and shrubs.

c) Establishment of H-Q correlation formula
Using the above-mentioned analysis method, estimate the respective water levels "H" corresponding to the respective discharge "Q" in the current river channel, and establish the H-Q correlation formula in such a form as:

$Q = a(H + b)^2$

d) Estimation of flooding-start discharge

For the respective cross sections of the river channel, define “Hj” as the design high-water level (HWL) for the reach where the levee is completed. Similarly, define the marginal water level, at which the river water could barely be accommodated in the channel without spill, for the reach where the levees are not yet completed. Estimate the respective discharge “Qj”, which corresponds to respective “Hj” through the H-Q formula to obtain the flooding-start discharge. It shall be assumed that flooding due to levee-break would start at a specific water level, just exceeding the “Hj” for the embanked reach. Similarly, the flooding due to spill would start at another specific water level, just exceeding the land-level in the flood plain for the non-embanked reach.

The level “Hj” for the non-embanked reach shall be appropriately specified, taking into consideration the current cross sections of the levees, and their protection against infiltration, leakage and erosion.

2) Defining possible flooding spots

It is necessary to estimate the maximum inundation depth of the flood plain, due to flooding at overall dangerous spots. Define the minimum number of flooding spots where levee-breaks bring about the maximum equal extent of inundation, wherever the target flood discharge respectively attains the flooding-start discharge for all possible levee-break spots.

(4) Flood Simulation

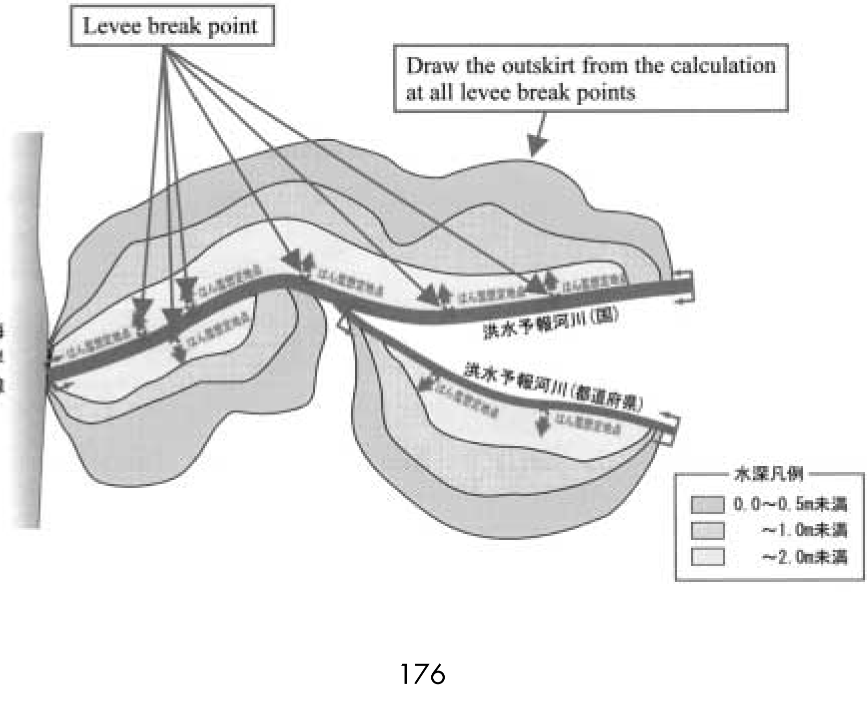
1) Basic concept of simulation analysis

a) Flood wave

The flood wave to be used in the flood simulation shall be specified on the basis of the target rainfall through the same runoff analysis method as that for river channel planning.

b) Flood simulation cases

The flood simulation shall be repeated the same number of times as that of possible flooding spots, as described above. Use only one flooding spot for each case, so that the respective maximum damage (maximum inundation depth) in the flood plain shall be estimated in correspondence to each possible flooding spot.



c) Precautions in flood simulation

i) Spill overtopping and flooding in upstream areas

The discharge hydrograph to be given at a possible flooding spot shall be the one that generates the maximum peak discharge for the respective possible flooding spots in the river channel.

For cases in which spill overtopping or flooding occurs upstream of the possible flooding spots, and the flooded water does not return to the channel (namely, diffusion-type flood), a modified discharge hydrograph is to be given for the respective possible flooding spots, taking into account the reduction of river discharge due to the aforesaid overflow.

ii) Dams and flood control channels

Runoff calculation shall be conducted, taking into account the effect of the existing flood control dams and channels, when designating the target possible flood plain. The inflow from drainage pump-stations, located upstream of the possible flooding spots, is likely to be incorporated as well.

2) Setting-up of conditions for simulation analysis

a) Analysis method of flooding discharge

i) Flooding discharge

The flooding discharge shall be estimated on the basis of the relationship between the river water level at the possible flooding spots, the water level within the protected land behind the levees and the threshold level of the levee-break spots.

ii) River water level

For consistency with river channel planning, the river water level shall be estimated on the basis of the discharge obtained by the unsteady flow analysis for the channel, following the H-Q formula through the same water-level analysis method as that for river channel planning.

iii) Determination of flooding discharge

The flooding discharge due to levee-break shall be dealt with as the transverse outflow across the possible flooding spots.

It is necessary to concurrently conduct both the unsteady flow analysis for the channel and the flood simulation analysis for the plain, with the exception of cases in which the flooding discharge is inevitably determined only by the river water level.

- Floodplain

[Equation of Continuity]

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

[Equations of Motion]

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}(uM)+\frac{\partial}{\partial y}(vM)=-gh\frac{\partial H}{\partial x}-\frac{gn^2u\sqrt{u^2+v^2}}{h^{1/3}}$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}(uN)+\frac{\partial}{\partial y}(vN)=-gh\frac{\partial H}{\partial x}-\frac{gn^2v\sqrt{u^2+v^2}}{h^{1/3}}$$

where,

u, v : velocity in the x and y directions

M, N : flow flux per unit width in the x and y directions($M=uh$, $N=vh$)

h : water depth

H : water level

n : equivalent roughness coefficient (considering drag force by buildings)

- River channel

[Equation of Continuity] $$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q$$

[Equations of Motion] $$\frac{1}{gA}\frac{\partial Q}{\partial t}+\frac{1}{gA}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+\frac{n^2|Q|Q}{A^2R^{4/3}}=0$$

where,

Q :discharge H : water level
A : cross sectional area q : lateral flow
R : hydraulics radius

These partial differential equations are discretized by an explicit finite difference scheme, and solved numerically.

b) Defining of conditions for analysis

i) Spill overtopping extent
The spill overtopping range across the levee at the possible flooding spots shall be either the levee-break extent stated below, or the integrated extent up to the successive levee-break spot immediately downstream, whichever is smaller.

ii) Levee-break extent
The pattern of levee-break shall be defined by referring to past break records, if available. If not, estimate the levee break extent "y(m)", based on the river width " x(m)", through the formula as shown below, whether the levee-break spot is in the vicinity of the confluence or not. Here, "the vicinity of the confluence" means that the effects of the confluence shall not be ignored, the width of the tributary is greater than 30% of the width of the main river, and the extent thus affected would be around twice the width of the main river, upstream as well as downstream of the confluence.
-In the vicinity of the confluence : $y = 2.0 \times (\log_{10}x)^{3.8} + 77$
-Not in the vicinity of the confluence : $y = 1.6 \times (\log_{10}x)^{3.8} + 62$

iii) Threshold level of levee-break spots
The levee is assumed to break down to its threshold level of the spot, which shall be either the ground level of the protected land or the level of the high-water channel, whichever is higher.

iv) Levee-break progress in time
The levee is assumed to immediately break to half of the final break extent "y/2", simultaneously collapse to the aforesaid threshold level, and break to the full extent within one hour. The break is assumed to proceed at a fixed rate.

v) Facilities to affect flooding discharge
The structural facilities that are likely to affect flooding discharge shall be incorporated into the flood simulation model, to the degree that is possible.

-Embankments: If the relative height from the averaged ground level is 50 cm or greater, incorporate the embankments into the model. These are continuous dikes, railroads, highways or other bankings.
-Waterways: If the flooding is such that it surmounts the dike height of small- or medium-size rivers in the flood plain, the waterways are assumed to be full of water as if there are continuous embankments.