Manual for Economic Evaluation of Flood Control Investment (Draft)

April 2005

River Bureau
Ministry of Land, Infrastructure, Transport and Tourism

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0. Introduction

0.1 Basic concept of economic evaluation of flood control investment

The economic evaluation of flood control investment is conducted for the purpose of assessing the economic benefits and cost-effectiveness that resulted from the development of flood control facilities such as levees and dams.

The benefits brought by such improvement include: increase of disposable income by mitigating the direct/indirect damages of flood disasters to human lives and properties, an economic benefit created by improved productivity of land use together with decreased flood disasters, and a feeling of security among people due to the improved flood safety.

Many kinds of economic benefits derived from developing flood control facilities are not easily measured, although such facilities are essential to support socioeconomic activities. In this regard, flood control facilities are different from other infrastructures such as roads whose objective is to enhance the convenience of users.

The flood control facilities exist as a prerequisite of socioeconomic activities. Because the public have difficulties in realizing the effect of flood control facilities, the facilities' effect cannot be measured as market goods.

For example, benefits in association with improved land use productivity are brought not only by developing flood control facilities but also by combination of other infrastructure. Furthermore, because future land use change is hard to predict, measurement of its economic impact is also difficult. Economic benefits of people's sense of safety are also hardly evaluated.

In this regard, benefits of developing flood control facilities only consider a part of possible benefits, that is, a part of benefits of damage prevention (the increase of disposable income created by mitigating direct and indirect property damages due to flood disasters).

Some assumptions are necessary for calculating benefits of damage prevention.
The first assumption is "properties" located within flood hazard areas. Estimation of properties is a precondition for calculating benefits of damage prevention. The properties have been increasing in Japan after the World War II along with the national economy's expansion. Prediction of future assets is crucial, however its practical and reasonable estimation is difficult at this moment. Therefore, we have to assume that the current asset condition continues as it is in the future as well.

The second assumption is "time period" to return to the ordinary socioeconomic condition from flood disaster situation. Even if the direct property damages are the same level, the recovery periods from flood time back to ordinary time vary significantly depending on the victims' incomes and assets and on the economic power and the ratio of affected people in the disaster-hit area. Accordingly, for the purpose of accurate estimation of damage amount, the relationship between the income and economic power of individuals and the total economic damages (sum of direct and indirect damages) in the affected area could be determined theoretically based on the past record of flood disasters. Nevertheless, such data is not available.

Therefore, in order to estimate the minimum amount of disaster damages, the following assumption is also made. Regarding direct damages, damaged properties would recover instantly. Regarding indirect damages, such as business interruption, socioeconomic activities would resume after the minimum days required for the recovery of physical assets.

The third assumption is a “levee breach point.” A location where the levee stops functioning (a breach point or an overtopping point) needs to be estimated for the flood damage calculation,. However, the current levee is the products of historical flood defenses. Moreover, the construction materials inside the levee body cannot be easily identified. Although comparative and qualitative analysis on the levee’s reliability is possible, its absolute reliability cannot be practically available. Accordingly, the levee breach point cannot be identified deterministically. Therefore, such a location should be estimated.

The forth assumption is a “level of flood event,” which causes disasters. Because flood is a natural phenomenon, economic analysis on the single largest flood is not sufficient. Comparison with other rivers and economic evaluation of appropriate design flood level require the probability analysis of flood occurrence.

Estimation of the probability of flood occurrence needs statistical analysis of hydrological data, which is the record of precipitation and river discharge measured in each river basin. Although Japan’s class A river systems set out the target level of 1 in 100 to 200 years, the observation data of precipitation and discharge covers only 40 to 50 years. Such data samples are not large enough for statistical analysis. The probability of flood occurrence might change depending on the future floods. Consequently, the target flood level might change in the future as well.

The fifth assumption is the “base data and damage ratio of properties” applied for calculating the benefits of disaster prevention. Although the property and damage condition differs from one disaster-hit area to another, damage estimation has to use the currently available data and ratio, which may be the average in the nation or in each prefecture.

Economic evaluation of flood control investment calculates the benefits of disaster prevention, that is, the benefits based on the abovementioned five assumptions. However, the evaluation only considers a part of benefits provided by the development of flood control facilities. Furthermore, the people do not recognize the benefits of disaster prevention, while they realize direct economic benefits brought by road development.

In addition, risk premium should be considered in the projects of flood control facilities, which reduce overall risk in the target region. For example, suppose there are two options, one is to suffer a damage of 10 million yen with a probability of once in 50 years, and the other is to expend 200 thousand yen every year to avoid the suffering. People usually prefer the latter option regardless of the fact that the expected values of annual loss are both 200 thousand yen, because the sacrifice by the loss of 10 million yen is 50 times greater than that of 200 thousand yen due to the theory of diminishing marginal utility of incomes. In other words, the difference between these two options explains a risk premium. If the risk premium exists, two solutions are available: evaluation with a lower discount rate than usual investments, or evaluation of larger benefits.

Meanwhile, uncertainty is also inevitable for the cost of flood control facilities. The project period and investment plan of the facilities cannot be precisely predetermined in many cases. A preliminary work process can be estimated, but detailed works and the necessary periods are difficult to predict. Even if the total investment is the same amount, the total cost discounted at the time of project evaluation fluctuates significantly depending on the project implementation period and the distribution of investment. Accordingly, the economic evaluation has to estimate the project period and the investment plan in reference to previous examples of the similar type and scale.

In reality, it is quite difficult to accurately estimate the benefit and cost of flood control facilities as a basis of cost-benefit analysis. Keeping this in mind, economic evaluation of flood control investment should be carried out.

Moreover, the flood control facility is an essential system to assure the safety of citizens in the country. Flood defense is considered as a basic safety function in the category of social infrastructure and plays a similar role of defense and public security. In this regard, a flood control facility should not be assessed from the point of economic efficiency, but should be planned from the point of fairness. The Government has considered the aspect of fairness that provides all citizens with basic safety as well as that of efficiency explained by the cost-benefit analysis. This is why the Government has implemented the flood control projects by examining the balance between upstream and downstream, or left bank and right bank

The Supreme Court Decision in the Daito Flood Disaster case (January 26, 1984) has clarified the above points by ruling that a defect in river administration shall be decided by whether the river administration has an acceptable safety level judging from the general standard and social convention in the rivers of the same type and scale. This judgment clearly shows that the fairness of flood safety level is strongly required in Japan. According to the opinion poll on rivers conducted by the then Prime Minister's Office in September 1996, nearly 80% of respondents acknowledged that the current flood safety targets in large rivers were appropriate. In conclusion, the current flood safety level is acceptable from the viewpoint of social convention.

Furthermore, a flood safety level for preventing recurrent disasters is also necessary, which means another damage will be avoided from the flood event of the same level as a previous large-scale disaster.

As stated several time here, economic assessment under this economic evaluation of flood control investment does not calculate the entire benefits of flood control project, but only regards recovery from negative value to zero as an economic benefit. Additionally, the project requires not only the aspect of economic efficiency but also the aspect of fairness. The project is decided considering the total balance of upstream/downstream and left/right banks. The economic evaluation of flood control investment is one of evaluation indices. Because the evaluation needs to be objective and transparent, the system of this economic evaluation should be continuously upgraded by, for instance, improving the methods of damage ratio calculation and inundation simulation.

0.2 Basic concepts of damages in the economic evaluation of a flood control investment

The flood countermeasures should be deliberated by aiming at all the rivers by assuming individual rivers as one system. Therefore, it can be considered that the corresponding flood pain for prevention is preventable by flood control systems that consist of various flood facilities including levees and dams. Basically, the definition of corresponding flood plain for prevention is limited to areas where the flood water reaches. Nevertheless, it is common to divide it to multiple flood plains depending on the geomorphologic characteristics of flood plains and rivers because there exist some areas not connected together. For this reason, first of all, divining the corresponding flood plain for prevention is conducted taking the characteristics of flood plains and rivers into account, in light of the flood conditions of past event.

The flood plain is currently prevented by the series of levees which protect that from the flood event. Therefore, it is rational to evaluate the safety-level as a series of system per the corresponding flood plain for prevention. In this regard, it has a difficulty for the accurate identification of the soil materials within the levee body because of the nature of levee earlier mentioned as a by-product of history even when attempting to evaluate the levees individually. An absolute evaluation of safety-level is almost impossible, so it is difficult to evaluate the particular levees even if the relative one available. This means that there is no choice but to evaluate the safety-level as a system per the corresponding flood plain for prevention.

For the evaluation, while the height of levee is a significant indicator, the safety-level of levee against the osmosis and the water-hammer should be also evaluated. Thus, the functional evaluation should be conducted including not only the height of levee, but also the functional evaluation. Thus, the functional evaluation should be conducted including not only the height of levee, but also the functional evaluation.

For the method, while there are various ways thinkable, the evaluation is supposed to figure out based on the width of levee body taking the safety against the infiltration of river water into the levee body as one of the basis of judgment, and then to adjust the height of levee by a slide-down operation according to the design cross-section surface.

The safety against water-hammer is supposed to be evaluated depending on the presence of high water channel revetments. The discharge capacity of rivers is to be judged by the non-uniform flow calculation used for river channel plan based on the height of levee that the above mentioned evaluation taken into account. And then the flood damage is supposed to be calculated on a supposition that an overflow flood will breakout at the time when exceeding the discharge capacity at each corresponding flood areas for prevention. The levee failure points are supposed to be evaluated the safety-level as a system per the corresponding flood plain for prevention mentioned above. For that reason, that failures are supposed to occur at those having possibility of worst level of damage per the corresponding flood plain for prevention.

The flood control is typically function-enhanced projects on the premise of facilities system that are the by-products of history, which reinforces the functions of these facilities.
For the functional enhancement, it is common to proceed it with a mid-term goal setting while sequentially keeping the balance of flood safety-level of upstream/downstream and left/right banks. Therefore, for the goal setting of river improvements in the process of operations is based on the premise that the safety-level will be established in light of the balance of the flood control safety-level of upstream/downstream and left/right banks.

1. General review

1.1 Purpose

The purposes of this economic evaluation of a flood control investment are to figure out the effects that available for economic evaluation among those of flood control projects as the benefit generated by the projects. Along with that, it is to evaluate the economic efficiency of corresponding projects by calculating the costs for the implementation of flood control and for maintenance/management of facilities as the cost for the flood control projects, and by comparing them.

This manual (draft) provides standard evaluation methods for these purposes. The figures applied to this evaluation are the nation average, the fundamental figures per prefecture, and the damage ratio. For this reason, an individual evaluation is available without problem even when taking methods and items as well, which out of those supposed to be evaluated in general in this manual (draft)

1.2 Scope

This manual (draft) is possible to develop the suppositions of the improvement period and the investment plan during the operations at the formulation phase of plan. It is adopted to the economic evaluation of a flood control investment that conducted by control projects which being worth of the economic evaluation. To be specific, it is adopted to the discussion about the improvement plan of rivers, the evaluation when adopting new projects for new dams, its re-evaluation, and so on.

1.3 Key definitions

●Flood plains
The areas that enveloped by inundated zones due to flood water in the event that the corresponding river occurs an overflow stream/levee failure.

●Inundation by spill overtopping of a river
In this manual, the inundated event that flooded from a section of excavated river channel.

●Inundation by overtopping
In this manual, the inundated event by levee overtopping.

●Second line levee
The levee structure having a decisive influence on a spatial and temporal spread of flood water among constructions that continuously embanked such as levee and road.

●Flood block
The block of flood areas that are the same in pattern of flood event among a series of flood areas, and divided by river channel section/left and right levee according to a tributary/levee constructed against mountain/second line levee and so on. (While the flood block may vary from the scale, a small scale of corresponding flood flow is adopted to the block.)

●Discharge capacity
In this manual, the capacity which is able to discharge in a certain water level is called “a discharge capacity against the water level” at a corresponding cross-section of river channel. This is calculated using the H-Q formula derived from a hydraulic calculation.

●Non-hazardous discharge
The discharge that confirmed to be a safe flowing available as per the river plan that taking into account the shape of levee, the presence of revetment, and the foundation height of levee failure by left/right bank of river channel cross-section. The water level (a reverse conversion using H-Q formula) against the discharge quantity is called “non-hazardous water level”.

●Non-hazardous discharge of an inundation block

The smallest discharge among the non-hazardous discharges at each point within the flood block is called “a non-hazardless discharge of block”.

●Maximum discharge capacity
In this manual, the discharge capacity at a point of crest height of levee.

●Slide down
The parallel displacement downward to the minimum of a design levee so as to be included to the shape of cross-section of current levee of the corresponding river channel levee.

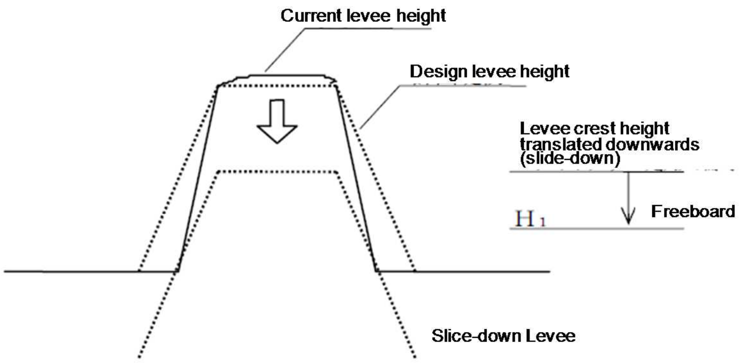


Figure-1.1 Concepts of Slide down Levee

●Benefits
In this manual, the financial amounts that preventable from damages by the improvements of flood facilities.

●Costs
The costs required for the improvement of flood control facilities that necessary for generating benefits mentioned above and for the maintenance.

●Present discount value (present discount price)
Even a case of products (money) being same in value, the value varies depending on the time of receiving (generally, the earlier the receipt, the greater the value).
Based on these theories, a cost-benefit analysis evaluates the benefits and costs as a present value in a unified manner.
For that reason, it is required to convert the future or past value of money to the current one.
When investing the present “C0” (Yen) in a compound interest account (interest rate, “y”),
the present value of “Cn” after “n” years goes “$C0=Cn/(1+\gamma)\ n-1$”
because it goes “$Cn=(1+\gamma)\ n-1\ C0$” after “n” years.
For example, a land cost “C” will reduce the present value according to the years passing by while it should be “C” after “n” years as well if there is no change in the price in the future.

●Social discount rate
The discount rate to derive the present value from future benefits and costs for a unified evaluation (present discount value) when conducting the costs-benefits analysis. The Ministry of Land,

Infrastructure, Transportation and Tourism has specified 4% for all the social discount values that to be applied to the costs-benefits analysis for its public projects. This evaluation is following that for the time being.

●Residual value

(Concepts of residual value)

In theory, it is possible to calculate the residual value of a flood control facility with the following formula. Namely, the residual value is calculated as the net benefit that will be generated if a flood control facility would be placed in service permanently, in theory, beyond the evaluation period (the evaluation period lasts for 50 years following the completion of a flood control facility planned in a project).

$$\sum_{t=T+1}^{\infty} \frac{(B_t - C_t)}{(1+r)^{t-1}}$$

T: the evaluation period, r: social discount rate, B_t: benefits to be generated in year t, C_t: costs in year t

(Detailed explanations of residual value)

・It is generally assumed that the facility constructed in a public work project will keep producing the expected values beyond the evaluation period, if adequate maintenance activities were undertaken for the facility. Therefore when the residual value of a flood control facility is taken into account in the economic evaluation at the end of the evaluation period of a project, the net benefit to be generated beyond the evaluation period should be calculated based on some adequate theoretical ideas and should be reported as the benefit of a project as of the end of the evaluation period.

・However when it is practically difficult to calculate the net benefits to be generated into the remote future beyond the evaluation period, but it is still expected that the residual value of a constructed flood control facility will be too great to ignore, you can calculate its asset value as of the end of the evaluation period and regard it as its residual value[※)1]. If the residual value is calculated in such a manger, you should describe the method used in the report on the economic evaluation.

・It is generally difficult to evaluate the values of nondepreciable assets (i.e., land) as of the end of the evaluation period, their residual values should be calculated based on their acquisition prices.

・If land is developed for construction of a flood control facility by improving the qualities of soils or by reclaiming the foreshore, you should calculate the residual value of such land as of the end of the evaluation period by use of its presumed value as of the end of the evaluation period estimated with reference to its market prince in the base year, while paying due attention to double-count with benefits.

・The residual values of depreciable assets after they have reached their useful life should be decided adequately in advance with, for example, the straight-line method that uses the concepts of asset depreciation of corporate accounting.

・If there were depreciable assets with sufficient values as of the end of the evaluation period because they have not reached their useful life or they are nondepreciable assets, their asset values as of the end of the evaluation period could be regarded as their residual values.

※)1

The methods explained in the above, such as the use of acquisition prices of land or of the concepts of asset depreciation of corporate accounting, are used as alternative ways applied when it is difficult to calculate “the net benefits beyond the evaluation period”.

Source: Technical Guideline on a Cost-Benefit Analysis for Evaluation of a Public Work Project (common principles), complied in June 2009, Ministry of Land, Infrastructure, Transportation and Tourism.

1.4 Fundamental policy of the economic evaluation

In the economic evaluation, the total costs for improvements/ maintenance of a flood control facility and the total benefits (i.e., damage reduction) to be realized by improvement of a flood control facility are discounted at a designated social discount rate to the present and are compared (please refer to Figure 1-1). In a cost benefit analysis, the point in time when the economic evaluation is undertaken should be assumed as the base year of discounting. The costs and benefits keep incurring during the period of improvement works of a flood control facility and the evaluation period which starts immediately after the completion of a flood control facility and lasts for subsequent 50 years. The total costs should be calculated by adding the costs required to improve a flood control facility until its completion to the maintenance costs that will incur for 50 years following the completion of a flood control facility, and by discounting them to the present value. The total benefits should be calculated by summing up expected annual average damage reductions and by discounting their total to the present value.

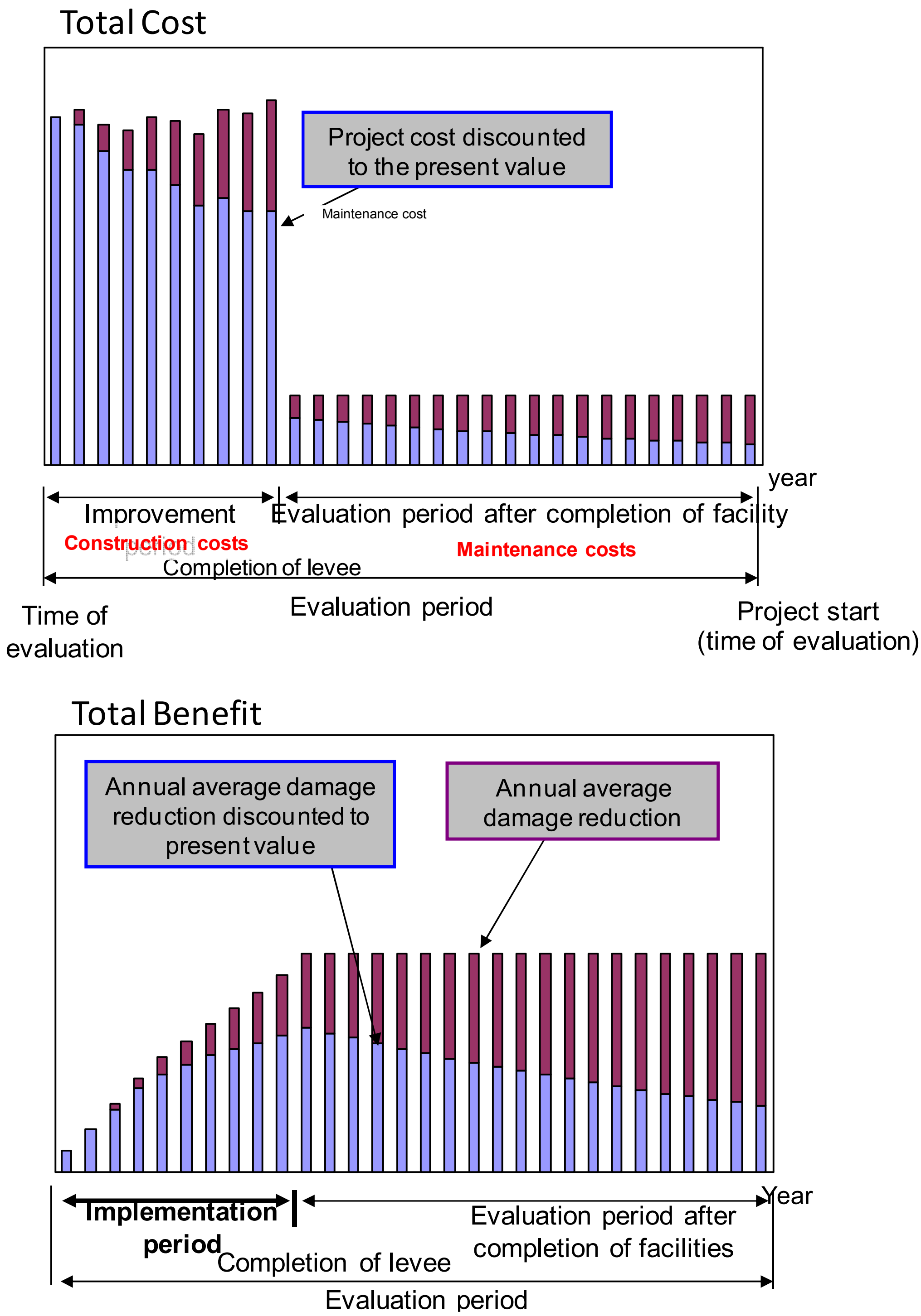


Figure-1.1 Concepts of total cost and total benefit

As is indicated in Figure 1-1, the total costs and total benefits should be calculated, when a river improvement plan is developed and a newly adopted river and/or dam project is evaluated or re-evaluated. In such an evaluation, the benefits to be realized by an investment plan in a flood control facility and by improvements of flood control facilities should be grasped in order of generation. Subsequently the construction costs that will incur every year, maintenance costs and expected annual average damage reduction should be discounted to the present and total benefits/ costs should be calculated.

When the details of an investment plan (construction costs, an improvement period and the allocation of construction costs) are already decided, the calculation of each cost should be made accordingly. But if the details of an investment plan are not decided and only the rough estimate of the construction costs were available, the costs should be calculated based on the probable improvement period and allocation of the construction costs with reference to the records of past similar projects.

Also when a series of flood control projects have been conducted intermittently so as to improve the same river and it is necessary to evaluate them as a series, it may not be adequate in some cases to conduct the economic evaluation based on the current states of a river channel. If that would be the case, the evaluation should be conducted by regarding a string of such past flood control projects for the same river as a series and by tracking back to the point when the states of a river channel seems to be adequate for the economic evaluation.

The followings are the reasons why the evaluation period lasts subsequent 50 years following an improvement period of a flood control facility and the completion of a flood control facility;

●The useful life of a flood control facility have both physical and social aspects. Physical useful life represents the number of years during which the functions of a flood control facility will be maintained. It will vary depending on how the facilities have been maintained adequately. On the other hand, the sense of values and the social demands at the time when a flood control facility was constructed are strongly reflected to social useful life of a flood control facility. As social useful life of a certain flood control facility changes when utilities of the facility change over time, using the social useful life that extends for a longer period of time would be pointless in the economic evaluation.

●Discounting the costs and benefits beyond 50 years following the completion of a flood control facility to the present value is pointless, as the values obtained following the calculation will be almost zero. Therefore, such discounting does not have a greater impact on total costs and total benefits.

●The legal durable periods of fixed assets are designated as a measure developed based on the taxation system of Japan. The legal durable period of a levee is 50 years, while that of a dam is 80 years.

It is very important to conduct the economic evaluation more objectively and reasonably in the future. In this sense, if it were possible to conduct the evaluation uniformly based on certain common conditions (e.g., “Harmless discharge”) other than those described in the above, such conditions should be assumed in the evaluation as far as possible.

1.5 Calculation of total benefits and costs

The procedure to investigate the total costs and benefits of a flood control facility when an economic evaluation of a flood control investment is implemented based on this manual (draft) is show in Fig. 1-2.

From Chapter 2, the method of the economic evaluation will be shown based on its actual procedure, from benefit calculations to cost calculations.

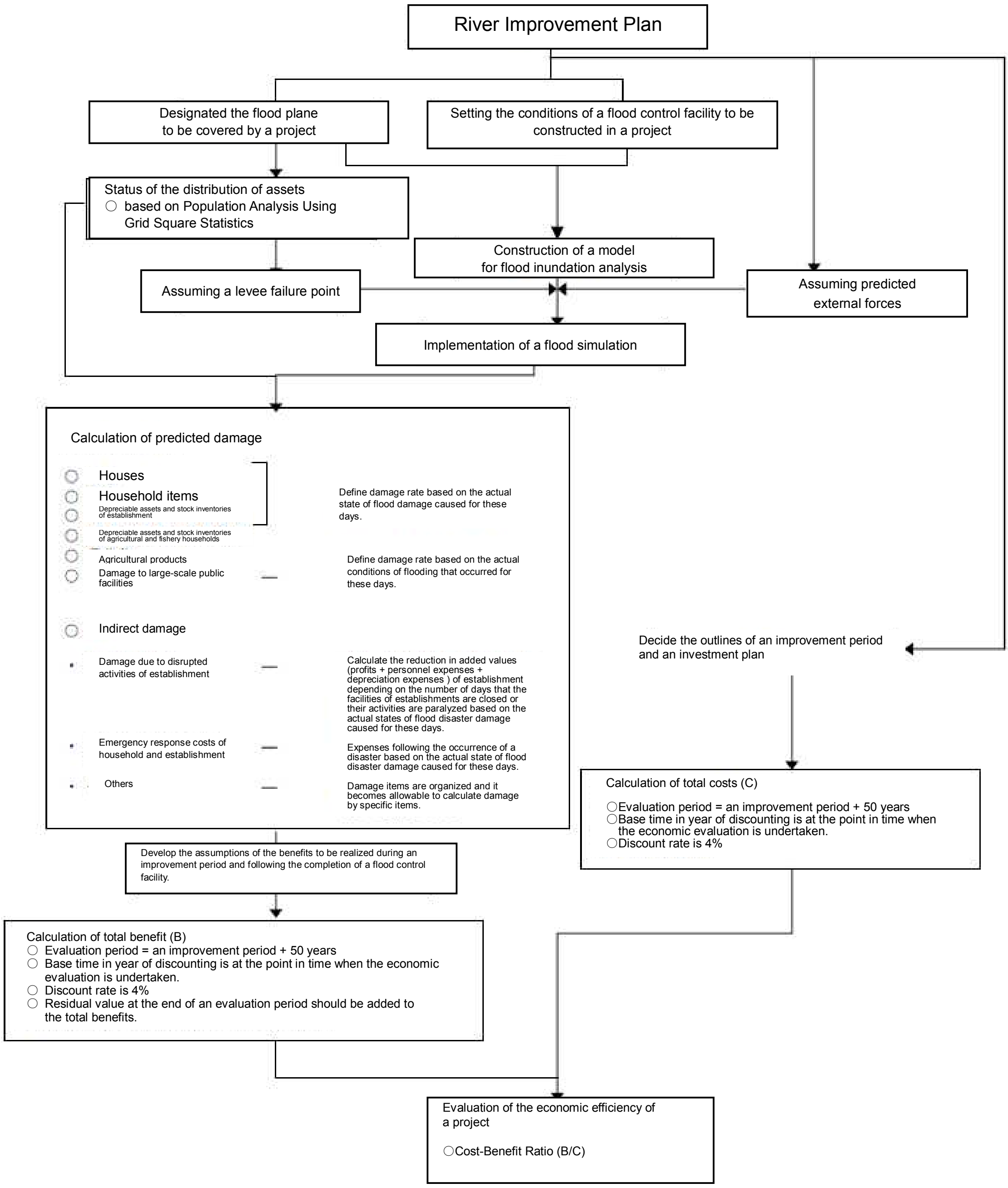


Figure-1.2 Procedures of an economic evaluation of a flood control investment

2. Analyzing the characteristics of a flood plain

2.1 Setting up the characteristics of a flood plain

A flood flow analysis should be conducted based on the current conditions of a flood plain. The structures that will affect the spread of flood water and the flood patterns in a flood plain should be taken into account in the model used for the analysis.

Furthermore, when the structure (e.g., continuous embankment) currently under construction or of which the construction plan is already decided will affect the flood pattern in a flood plain, and their designs are clearly known, they also should be taken into account in a flood flow analysis model.

Also in a large-scale development project such as an industrial park, if the structures explained in the above could be defined clearly in the model used for the analysis, they also should be taken into account in the model or when the values of properties in a flood plain are calculated.

[Explanation]
The calculation of the values of properties in a flood plain (to be explained in Chapter 4) and the construction of a flood flow analysis model should be conducted basically based on the current conditions of a flood plain and along with the following procedures;

(1) A Flood plain to be analyzed

The flood plain to be analyzed should be defined with reference to past research results on Flood Hazard Map, and so that the maximum inundation area in the event of the flood events assumed in the analysis will be the part of a flood plain. In general the boundaries of the maximum inundation areas are decided based on the geomorphologic conditions of a flood plain, but in low-lying areas near an estuary, the boundaries are sometimes decided based on artificial structures such as levees constructed adjacent to a river. Accordingly, the areas that are predicted to be inundated in the event of a flood disaster in the light of the results of past flood simulations, the boundaries of flood plains on Landform Classification Map for Flood Control, design high water level of a river and terrain elevation and so on, they should be regarded as the flood plains to be analyzed.

(2) Conditions of a flood plain assumed in a mode used for a flood flow analysis
It is required to taken into account in a model used for a flood flow analysis continuous embankment structures (i.e., as terrain elevation and a second line levee) and the water ways of small to medium sized rivers that have an influence on the diffusion of flood water. About the geomorphologic conditions and the conditions of the following structures, in principle their current conditions should be taken into account;

●Continuous embedment such as roads
●Water ways of small to medium sized rivers that have an influence on the diffusion of flood water
●Large scale drainage facilities such as pumps

However in the economic evaluation that investigates future damage by flood disasters following the completion of a planned flood control facility, if the future changes in the above mentioned factors can be clearly predicted in a specific manner, it is also required to take them into account in a model used for a flood flow analysis.

(3) Conditions of a flood plain in the calculation of property values

In principle, the calculations of property values should be made for the properties that exist in a flood plain. But when the future growth of properties can be specifically and reasonably predicted based on the large-scale development plan that is already adopted in an urban development project, it can be included in the calculations of property values.

2.2 Researches on properties in a flood plain

The researches on the ground heights, properties and so on in a flood plain should be conducted and the mesh data based on them should be generated.

[Explanation]

Data on ground heights and properties in flood plains (required to conduct a flood simulation and to estimate damage) should be obtained by conducting researches on them (property researches should be discussed later in Chapter 4) and the mesh data based on them should be generated.

(1)**Setting up the data on average ground heights in a flood plain**

Averaging out the ground height data of point sets within mesh or the ground height data at four-corners of mesh generated based on the map for a city planning at a scale of 1:2,500 or National Base Map of Japan (published by Geospatial Information Authority of Japan) should be the standard way to calculate the ground heights of a flood plain. You should try to reproduce the terrain elevations and geomorphologic characteristics of a flood plain as truly as possible by using most updated maps where possible, by ignoring the data that do not represent the terrain elevations of mesh (such as crest height of continuous embankment structures) and by conducting on-site investigations if certain ground height data were not found on a map, if necessary.

Alternatively "Numerical Map Data (Digital Elevation Model (DEM) data, 50m mesh data (elevation)" published by Japan Map Center, Inc. can be used instead of printed maps. But as the mesh point altitudes of "Numerical Map Data" are calculated by interpolating to the data of the printed map at a scale of 1:25,000, precision might be compromised at low-land areas with sparse contour lines or at the boundaries of flood zones due to extreme altitude change. Therefore when the terrain elevation data of "Numerical Map Data" are used, the mash data of a flood plain and areas along a river should be checked with reference to larger-scale maps appropriately.

(2)Calculation of property data

This topic will be discussed later, in Chapter 4.

When the mesh data of the flood plain to be analyzed are generated, it is preferable to ensure in advance the consistencies between the standard regional mesh that are used for "Numerical Map Data (Digital Elevation Model (DEM) data, 50m mesh data (elevation)" and the calculation mesh for a flood simulation (to be discussed later) so that the burdens of damage calculation should be reduced.

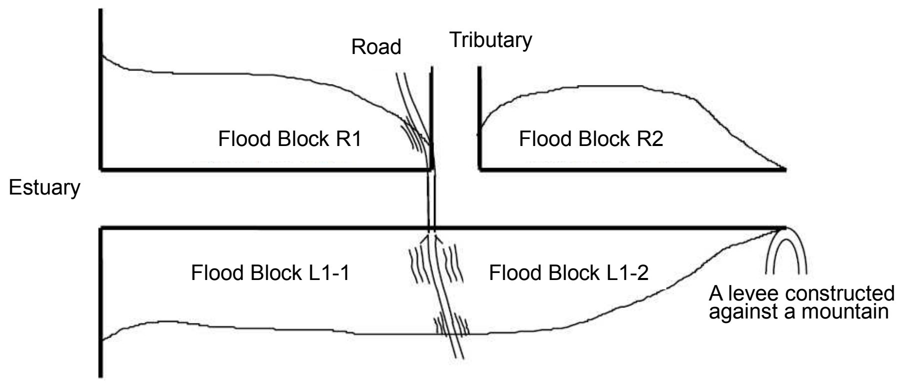
2.3 Analyzing the characteristics of a flood plain

2.3.1 Dividing a flood plain into flood areas

> A flood plain to be analyzed should be divided into several flood areas that shares the same characteristics (i.e., flood block). When it is divided, their differences arising from the difference in catchment scale should be taken into account.

[Explanation]

As is indicated in Figure 2-1, a flood plain which is defended by a group of levees installed on both the right and left banks are divided into inundation blocks. These blocks form the basis when a phased improvement project for a river channel is planned, and are the factors that have an influence on the expected damage to be discussed later. Therefore a flood plain should be divided with caution by taking into account the following points;



(For the reasons why Flood Block L1 is divided into L1-1 and L1-2, please see below ⑤and ⑥.)

Figure-2.1 Dividing a flood plain to be analyzed

① **Flood pattern**

Flood pattern is broadly divided into 3 types depending on the geomorphologic characteristics of a flood plain and the magnitude of a flood event that will occur;

Flow-down type flooding : a flood event that flows down along river side areas.

Reservoir-type flooding : the depth of flood water will increase along with a rise in the water level of a river, but the boundaries of inundation areas won't change significantly.

Diffusion-type flooding : a flood spreading in all directions.

A flood plain should be broadly divided into several flood areas by expected flood pattern (i.e., flood blocks) with reference to geomorphologic characteristics and the results of past inundation analyses, because the characteristics of inundation damage and the methodologies applied to a flood flow analysis will change depending on flood pattern. But in the area that generally shows a reservoir-type flood pattern, a diffusion-type flooding might be caused when a small to a small to medium sized flood event struck the area. When the flood patter in a certain flood block is determined, it should be done qualitatively.

②**Left and right banks of the channels to be analyzed**

The flood areas that are divided by their flood pattern should be further sub-divided vertically into the left and right banks by assuming the river to be analyzed is the boundary between them.

③**A tributary that flows into a main river**

When a flood plain is divided by a tributary levee and a flood pattern will change from there, the tributary levee should be treated as the borderlines of blood blocks.

④**Levees constructed against mountains**

When a flood area is divided by a levee constructed against a mountain, the levee should be treated as the borderline of blood blocks.

⑤**Subdividing a flood block by scale of flooding and levee failure point**

When a large scale flood disaster strikes a certain flood block, it will be inundated from the upper reach to the down reach. But as is indicated in Fiture-2.2, in the event of a small to medium scale flood disaster, the flood block may be further subdivided by its geomorphologic factors. If that would be the case, each area subdivided should be treated as a flood block.

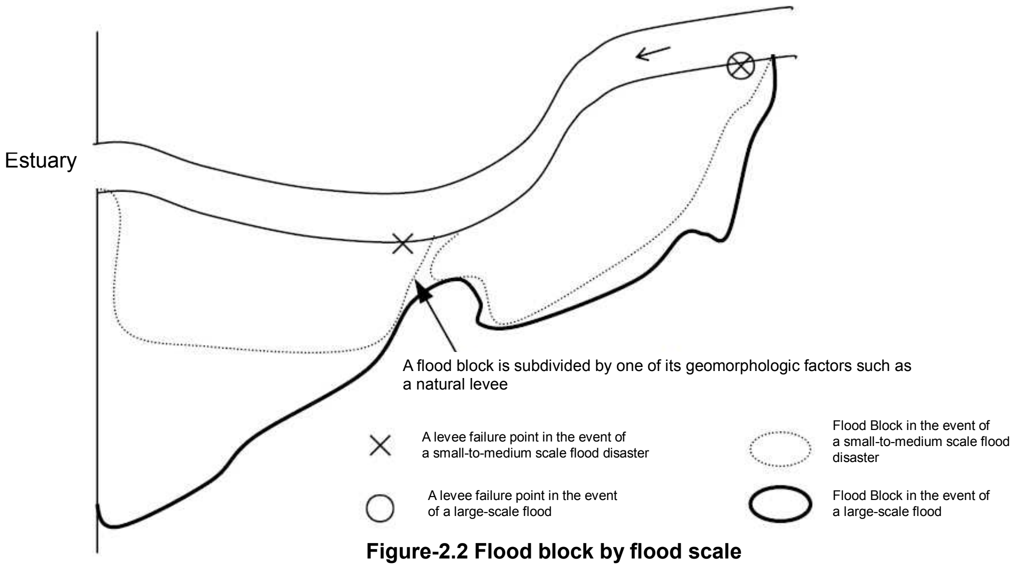


Figure-2.2 Flood block by flood scale

⑥**Structures (e.g., continuous embankment) dividing a flood plain**

As is the case with the above ⑤, when a flood block is subdivided by a small to medium sized river or a continuous embankment structure (acting as a second line levee), each area subdivided should be treated as a flood block (please refer to Figure-2.2).

⑦**Experience of flood disasters**

When a flood plain adjacent to a river with records of large-scale river flooding is divided into blood blocks, it should be done with reference to various factors including the boundaries of the areas inundated during past flood disasters.

2.3.2 Assessment of flow capacity

> The flow capacities on the both left and right banks of the channel to be analyzed should be calculated first. Subsequently, the harmless discharge in each flood block should be defined as the peak discharge that won't cause flood inundation and its probability should be calculated. In addition, the maximum discharge capacity at each point on the left and right banks of the channel should be calculated.

[Explanation]

In each flood block, it should be assumed that levee failures / inundation will occur when river discharge exceeds the harmless discharge of each flood block. Furthermore, when flood water flows down at each point of a river and it exceed the maximum discharge capacity at each point of a river, it should be assumed that flood water will overflow. In the following sections, the methods to calculate harmless discharge and the maximum capacity of low will be explained.

(1) Timing to calculate flow capacity (conditions of a river channel to be analyzed)

Flow capacities should be calculated based on the conditions of a river channel when a flood control project is initiated and when a planned flood control facility is completed. The reason to calculate the flow capacities at the point in time when a planned flood control facility is completed as well as when a flood control project is initiated is, for evaluating the effects of a flood control project by comparing flood damage inflicted before and after project.

However when a series of flood control projects have been conducted intermittently so as to improve the same river and it is necessary to evaluate them as a series, it may not be adequate in some cases to conduct the economic evaluation based on the current states of a river channel. If that would be the case, the evaluation should be conducted by regarding a string of such past flood control projects for the same river as a series. You can trace back to the point when it seems to be suitable to implement the economic evaluation and can conduct the economic evaluation based on the conditions of a river channel at that point.

(2) Conditions to assess flow capacities

①Method of a hydraulic analysis

Flow capacities should be calculated by means of a hydraulic analysis which is also used in the river channel plans which is subject to the economic evaluation so as to ensure the consistencies with them. At present in a river channel plan for a larger river channel, the flow capacities of a larger river is evaluated by means of a varied flow calculation (hereinafter referred to as" quasi 2D flow calculation") that takes into account vegetation. Therefore basically in the economic evaluation, the flow capacities of a larger river should be evaluated by means of quasi 2D flow calculation.

② Hydraulic conditions

The conditions for calculating flow capacities based on the current states of a river channel used in a river channel plan should be used as the hydraulic conditions for judgment of the flow capacities of the current states of a river channel in the economic evaluation. In specific, the consistency with a river channel plan should be ensured in terms of the extent of dead water zones such as downstream end water level, coefficient of roughness and vegetation, boundary mixing coefficient, the dam-up caused by structures such as bridges, the rise in water level due to sand banks, small-scale wand waves and a curved river, and the rise in water level due to confluence with a tributary.

Furthermore, the hydraulic conditions of a river channel following the completion of a planned flood control facility must be consistent with those of a river channel plan.

(3) **Expressing in H-Q formula**

By use of the above mentioned hydraulic analysis and hydraulic conditions, the water level (H) by scale of river discharge(Q) should be calculated, and the water level and river discharge curve (i.e., H-Q formula) such as $Q=a(H+b)^2$ should be constructed. Allocation of river water should be determined based on planned allocation rates of river water.

(4) **Assessment of harmless discharge**

The crest height of each cross-section of the river channel to be evaluated is translated downwards (slide-down, please refer to Figure-2.3). Subsequently, H_1 is calculate by subtracting design freeboard from the crest height, and then the flow capacity at H_1 (i.e., Q_1) is calculated with H-Q formula. H_0 is whichever is the higher of the ground height of a landside area or that of high water bed (i.e., the bed height of a breached levee, please refer to Figure-2.4). The flow capacity at H_0 should also be calculated with H-Q formula.

When the construction of low or high water channel revetments or the implementation of the countermeasures against water leakage is planned in a river channel plan but has been not implemented yet, each of such circumstance should be taken into account adequately when Q_1(discounted flow) is calculated. Whichever is the larger of discounted Q_1 or Q_0 should be regarded as the minimum flow capacity of a cross-section. By organizing the minimum flow capacity at each point of a river vertically, a flow capacity chart (Figure- 2.5) is prepared. The minimum flow capacity of each block in the chart should be regarded as the harmless discharge of each block.

However if it were not adequate to evaluate the economic efficiencies of a project based on the current states of a river channel, you can trace back to the point when it seems to be suitable to implement the economic evaluation. Basically such a river channel must be evaluated by means of the same methods. However as it is hard to believe that the unimproved levee has the capabilities to let the volumes of river water designed based on its crest height flow down a river with safety (and steadily), Q_0 (flow capacity) at H_0 can be used in place of a quasi-harmless discharge(please refer to Figure-2.4).

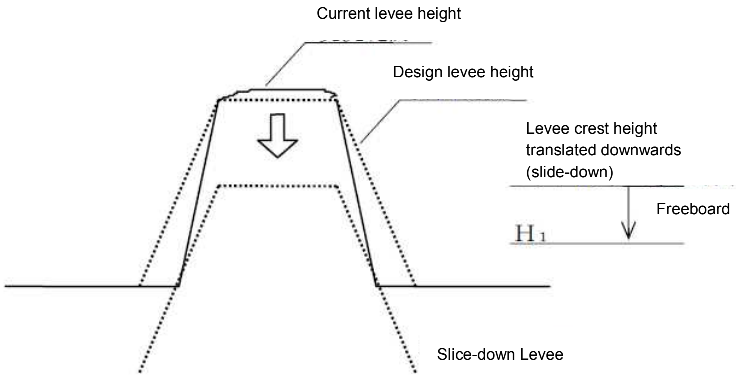


Figure-2.3 Slide-down

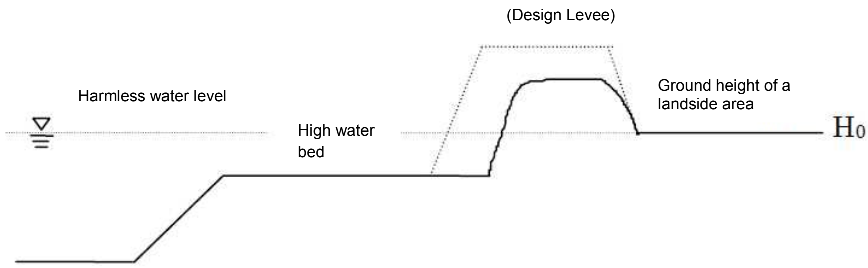


Figure-2.4 Method to evaluate levee that has not been improved yet in the definition of harmless discharge

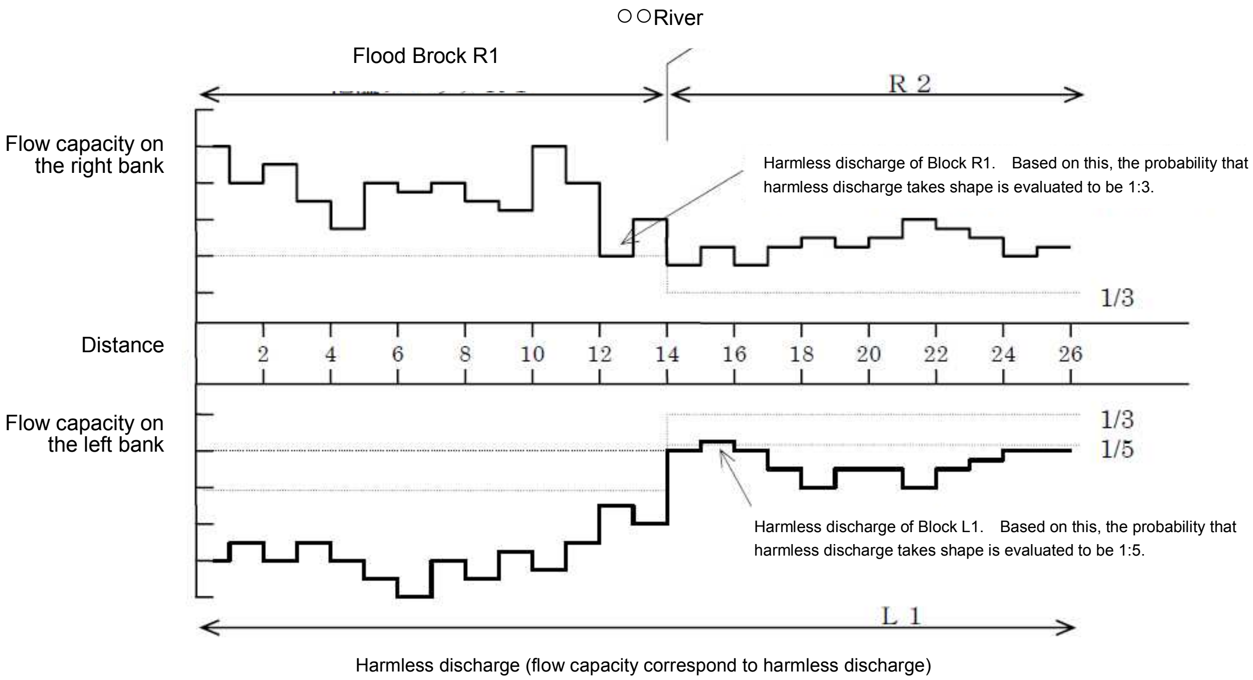


Figure-2.5 Flow capacities of both the right and the left banks

(5) Assessment of the maximum capacity of low

The maximum discharge capacity is defined as the limit of river discharge that does not cause an overflow event. The maximum capacities of flow on the left and right banks of a river of each cross-section (Figure-2.6) should be the flow capacities at the crest heights of levees (When the maximum discharge capacity is calculated, the crest height of a levee should not be translated downwards (or slid down)). The maximum discharge capacity should be calculated with the above mentioned H-Q formula.

(6) Point to be noted

In the above mentioned calculation of flow capacity, when flow capacity is significantly overestimated or underestimated due to the effects of structures (e.g., weirs), the water level and river discharge curve (i.e., H-Q formula) should not be constructed automatically based on the results of a hydraulic analysis. Where necessary, some adequate consideration should be used by adjusting H-Q formula or by excluding the point from levee failure points (to be explained later) by taking into account the hydraulic characteristics of the reach to be evaluated so that an adequate evaluation on flow capacities will be conducted.

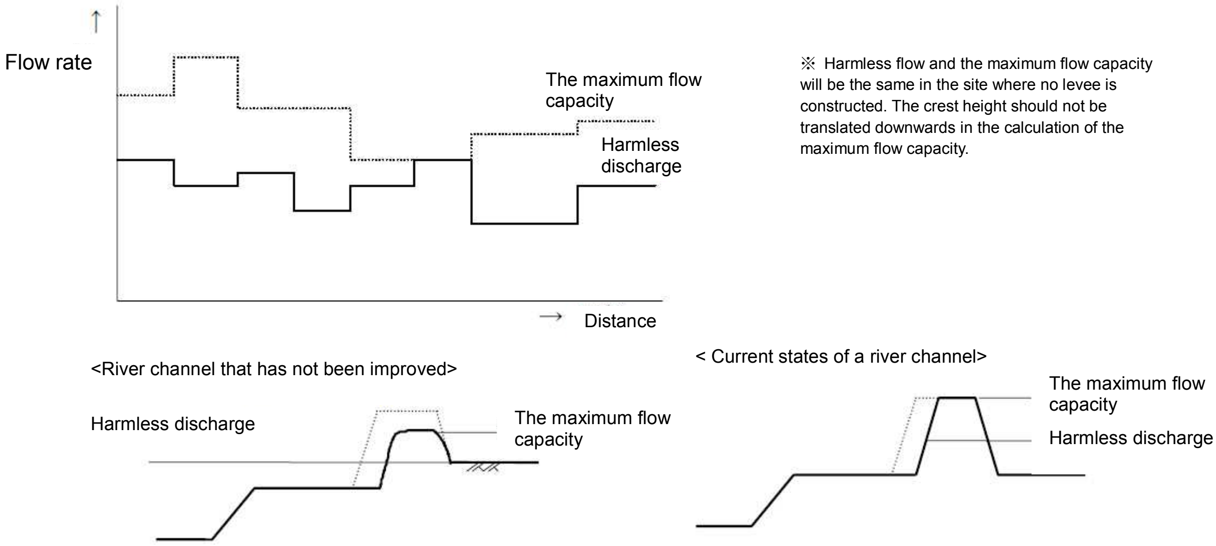


Figure-2.6 Calculation of the maximum flow capacity

2.3.3 Setting up levee failure points

One levee failure point should be assigned in each flood block.

[Explanation]

It is often difficult to specify possible levee failure point, because levees were constructed under various historical circumstances and it is often difficult to specify the soil materials used for their bodies, and the duration of a specific flood event and so on are probability events which cannot be treated in a deterministic manner. Furthermore by taking into account the point that it is a series of levees that controls flood disasters in a flood block, it should be assumed in a flood block where a series of flood phenomena are considered to be a single event that levee failures may be caused at any point (cross-section) if river discharge exceeds “the harmless discharge of the flood block”. However even though it would not be easy to specify levee failure points in advance, it is still necessary to assume levee failure points when you try to estimate expected damage caused by the flooding of the river channel to be improved. So you should take into account the circumstances in a plan where the anticipated damage shall be stretched to the maximum and shall designate a single point where the largest damage will be inflicted as “a levee failure point” of a flood block.

When you try to select a “levee failure point”, you should select a “levee failure point” where “the largest damage” will be inflicted based on Flood Hazard Map with reference to the following past research results.

●Researches on the important point for controlling floods
●Remains of cofferdams and river bed (based on Landform Classification Map for Flood Control)
●Erosion due to overflow scour (the same above)
●Alluvial fan
●Confluence of tributaries
●Points where crossings are installed

In addition, the following points should be taken into account;
●points where harmless discharge is relatively small
(i.e., greater risks of a levee failure due to overtopping)

●The points where difference in height between calculated water levels and the bed height of a breached levee is large (i.e., massive flood discharge)

3. Flood simulation

3.1 Basic concepts of Flood simulation

A flood simulation should be undertaken by scale of river discharge and by flood block. If there were a specific point with insufficient flow capacity in the upper reach area, the possibilities of overtopping (or overflow) at such point should be taken into account in the simulation.

[Explanation]

1. Cases of flood simulations

A flood simulation should be undertaken by scale of river discharge and by flood block. When tributaries are taken into account, the simulation should be undertaken in the same manner, by scale of the discharge of each tributary and for the all flood blocks that will be affected when tributaries are flooded.

A Levee failure point in each simulation case should be the point assigned to the flood block to be analyzed (therefore, the number of levee failure points should be one in each simulation case). The amount of damage at a levee failure point should be regarded as the amount of damage in the flood block at a certain level of discharge. If both main river flooding and tributary flooding are anticipated in the same flood block, whichever is greater in damage should be regarded as the damage in the flood block (Figure-3.1 and Figure-3.2).

2. Important points to note when a flood simulation is carried out

The points to be noted so as to reproduce inundation phenomena as truly as possible and to analyze the conditions of flooding that will inflict the largest damage are as follows;

●Flooding from the points with insufficient flow capacities

An overflow event (spill-over topping) will occur at the points in the upper reach areas when river discharge at such points exceeds the maximum discharge capacity.

●Decreased river discharge following overtopping (or spill overtopping)

When levees are overtopped at the upper stream, the river discharge that flows to the lower stream will decrease depending on the magnitude of total flood discharge. Even when it is anticipated that flood water will eventually return to a river, the reduced river discharge at the lower stream should still be taken into account.

●Flood events to be evaluated

When the scales of flooding assumed in the designs of a flood control facility differ between the upper/downstream of a river and/or main/branch rivers or, there is a need to change the scale of the flooding assumed in the designs of a flood control facility, you should deal with the situations by changing such scales by flood block (Figure-3.1 and Figure-3.2).

(Example)

As is indicated in Figure-3.1, when the amount of damage of the tributary in flood block 3 is larger than that of a main river, you should take into account the damage of the tributary and can calculate the total damage *D* as follows;

D = Total maximum damage
$=d_{1H} + d_{2H}$ (← caused by the breaches at the main river)
$+d_{3S}$ (← caused by the breaches at the tributary) (i.e., $d_{3S} > d_{3H}$)

The index notation (1, 2, 3) shown in the above formula represent each flood block, while H and S represent flooding at the main river and at its branch river respectively.

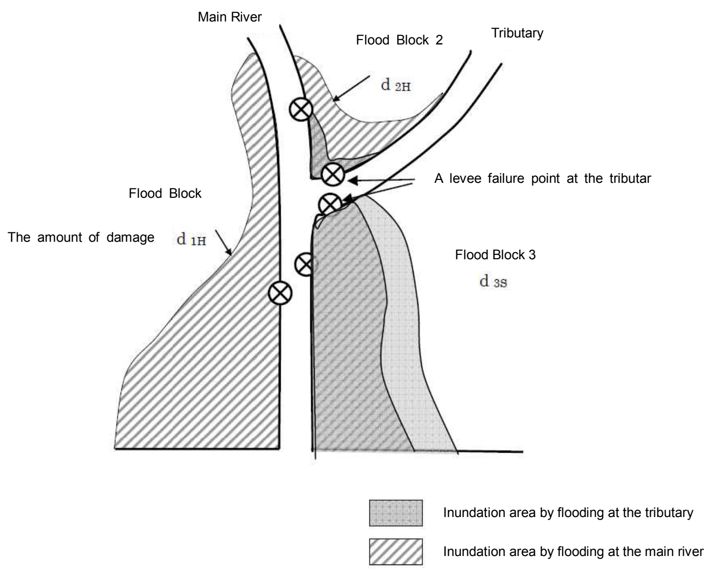


Figure-3.1 Damage caused by flooding at a tributary and a main

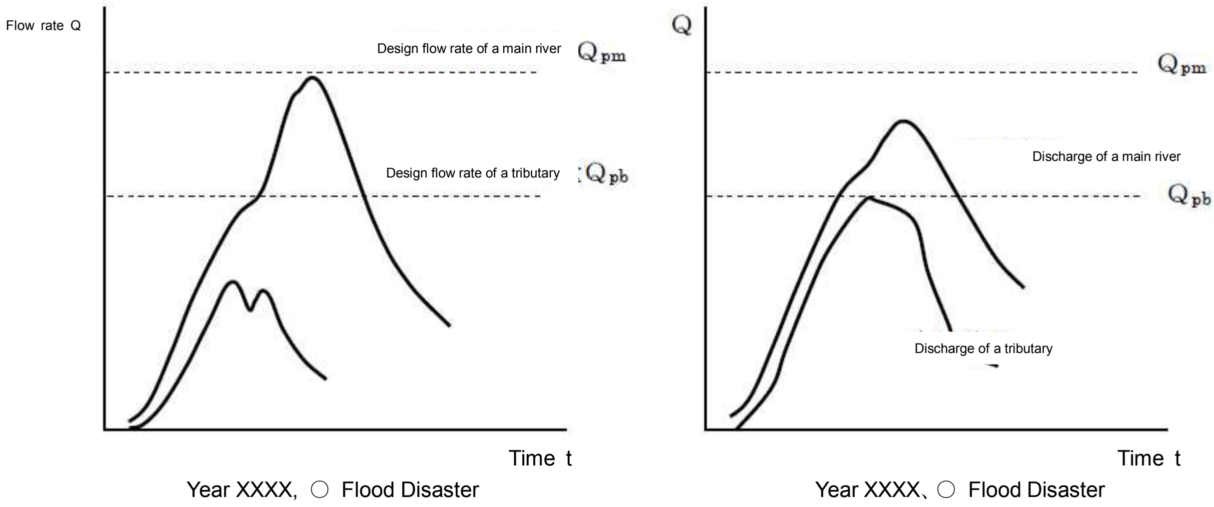
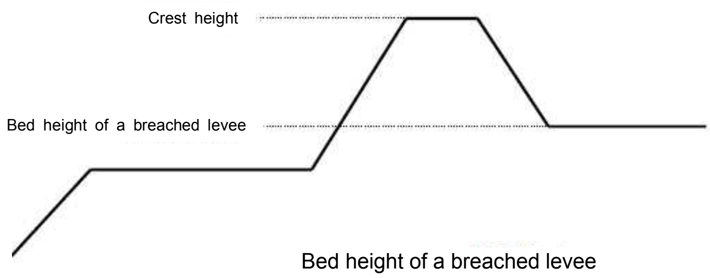


Figure-3.2 The example where the scale of a flood disaster assumed in a project is different between a main river and its tributary

3. Possibility that levees will breach and anticipated level of river discharge following a levee breach

Levees may breach when river discharge in a specific flood block exceeds its harmless discharge, but in reality, a levee breach does not occur when the discharge of a river does not reach the bed height of a breached levee

Therefore it is required to compare the harmless discharge and the river discharge that reaches the bed height of a breached levee of each flood block (calculated in the previous section), with each level of discharge of a river so as to make sure the possibility of a levee failure at each level.
(Note: the river discharge that reaches the bed height of a breached levee (please refer to page 32) should be regarded as the discharge at the bed height of a breached levee).



Bed height of a breached levee

(Example)
When flow rate is 2,000(㎥/s),

Flow rate > block harmless discharge (1,500(㎥/s))
※there is a possibility that a levee might breach.

Flow rate > Flow rate at the bed height of a breached levee (1,000(㎥/s))
※It is assumed that a levee will breach.

Therefore it should be assumed that a levee will breach at the levee failure point.

(When any of the above two theories are proved, there is no possibility that a levee will breach and you should not assume that a levee failure will occur.)

3.2 Developing the conditions of a flood inundation

3.2.1 Conditions of a flood event

You should develop about 6 cases of flood hydrographs based on the following conditions; the scale of flood discharge is greater than harmless discharge, the maximum scale of flood discharge is the design flood discharge, and the probabilities of flooding vary at each base point*.

[Explanation]

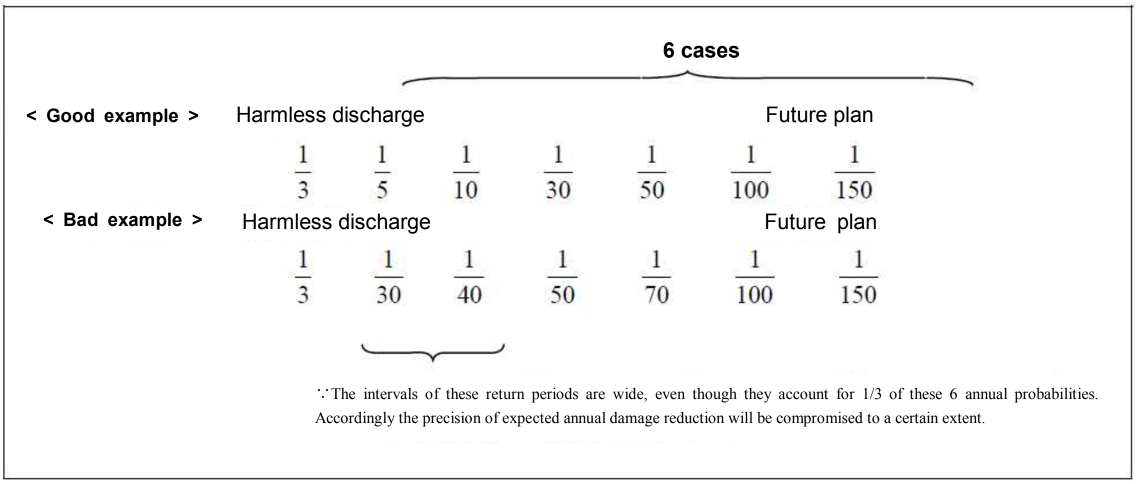
Out of several different conditions of a flood event, about 6 cases of flood hydrographs (i.e., the scales of flood discharges. They are greater than harmless discharge and the maximum scale of flood discharge is the design flood discharge) should be developed.

When the probabilities of such flood discharges are calculated, you should make sure if their intervals (interval probabilities) were constant so as to ensure that they will not hinder estimation of annual average damages (to be discussed later).

Flood hydrograph shall be constructed based on the representative food events selected during the discussion on baseline water stage and by taking into account the following matters;

●Design flood scales of a flood administration facility
●Some of the renowned flood damage that was inflicted as recently as possible
●Flood events whose damage is expected to be greater due to their larger total flood discharge

The probabilities of the flood discharges should be evaluated at each base point. But when the hydrograph of main rivers and those of its tributaries are constructed separately, the probabilities at important points along its tributaries should be used for the evaluation.



In principle, flood hydrograph is used in a flood simulation, but it is allowable to use only peak runoff in the mountainous reaches that shows the flow-down type of a flood pattern. The precipitation records used for flood hydrograph by probability should be adjusted so that they will fit into certain probabilities by means of the methods adopted in the discussion of baseline water stage (i.e., probabilities of river discharge, probabilities of rainfall) and the flood hydrograph by probability should be constructed with a runoff calculation

However when a series of flood control projects have been conducted intermittently so as to improve the same river and it is necessary to evaluate them as a series, it may not be adequate in some cases to conduct the economic evaluation based on the current states of a river channel. If that would be the case, the evaluation should be conducted by regarding a string of such past flood control projects for the same river as a series. You can trace back to the point when it seems to be suitable to implement the economic evaluation and can conduct the economic evaluation based on the conditions of a river channel at that point. In such an occasion, a run off calculation should be conducted based on the conditions of a flood control facility at that point. If the evaluation should be made based on the current states of a river channel at the start of a project or those when a planned flood control facility is completed, a run of calculation should be conducted by taking into account the levels of flood control at that point (such as a dam). Adjustments should be made based on the current operation rules when the evaluation should be made based on the current states of a river channel, or the planned operation rules when the evaluation should be made based on the future states of a river channel following the completion of a planed flood control facility.

* Base point
The point based on which data the scale of design external forces (the probabilities of hydrologic events) are decided in the flood prevention zone which is the most important area to a river system. One base point should be assigned to each river system. The point that is located above or in the neighborhood of the flood prevention zone such as an urban district which is the most important to a river system should be designated as the base point to a river system with due regard to demography, asset distribution, geomorphology and flood patter of the flood area to which the point belongs. Moreover, the points where the sufficient amount of data on water level, river discharge and so on can be obtained should be selected as base points.

Source: Handbook for estimating high water discharge (proposal), announced in July 2007, Japan Institute of Country-ology and Engineering

3.2.2 Flood discharge

Flood discharge at each levee failure point in each flood block should be calculated by scale. The possibilities that a flood event may occur at the upstream area of a river (overtopping or overflow) should be taken into account.

[Explanation]

1**. Procedure of the calculation**

Overflow discharge and levee-breach discharge in a flood simulation should be calculated according to the following procedure;

① **Overflow discharge and levee-breach discharge**

Overflow discharge and levee-breach discharge should be calculated based on the relationships among the water levels at an overtopped point /a levee failure point, the water level at landside areas, and the bed height of a failed levee.

②Water levels

In order to ensure the consistency with a river improvement plan, water levels should be calculated by means of the before mentioned quasi 2D flow calculation (i.e., H-Q formula) based on the river discharge calculated by a varied flow calculation. Water levels should be used only for judging the possibilities of overtopping and a levee breach, and for calculating overtopping discharge and levee-breach discharge. This calculation should be regarded as a separate calculation from the varied flow calculation which is used to calculate water surface profile following overtopping and a levee breach.

② River flood routing

Overflow discharge and levee-breach discharge should be treated as lateral overflow, and reduced flow volume at the downstream should be taken into account in these discharges. When overflow discharge and levee-breach discharge will run through a flood plain and will return to a river channel by way of tributaries or through the sites where no levee are constructed, these points should be taken into account in a varied flow calculation.

In the above calculations, it is necessary to conduct a varied flow calculation and a flood analysis in an integrated manner except for the case when flood discharge is determined only by the water level of a river. If the calculations based on existing models are conducted separately, it is desirable to refine existing models so that calculations for a river channel and those for a flood plain will be conducted interchangeably.

2. Method of a flood simulation

Figure-3.3 shows the procedure (i.e., a flow chart) of a flood flow analysis mentioned in the above.

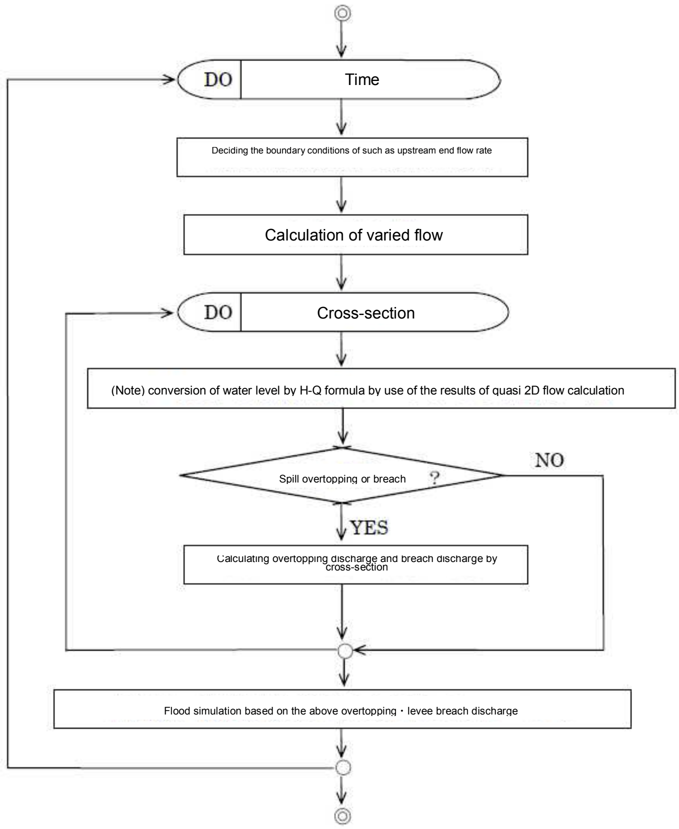


Figure-3.3 Outline of the procedure of a flood simulation

(Note) This is done for estimating most plausible water level with a varied flow calculation on the basis of ever-changing flow rate distribution and the flow rate calculated in a river channel plan. Therefore considerations must be used such as excluding the tidally affected area for which it is difficult to develop H-Q formulae from levee failure points.

3. **Setting conditions for calculations**

Conditions for calculations (such as breach sections) should be configured according to the following procedure with reference to "Manual for an Flood Simulation (Draft)" (published by Public Work Research Institution, Ministry of Land, Infrastructure, Transportation and Tourism, February 1996).

① **Width overtopped**

The width overtopped from levee crest at a levee failure point should be whichever is smaller; width breached to be explained in ② below, or the distance from the crest to the breach point caused by flood flow right under the levee.

② **Width breached**

When the data on breach sections are available from past disaster events, you should refer to them. But if there weren't such data, you should decide first if the breach point were the vicinity of a confluence or not. And then, breach width y (m) should be calculated based on river width X (m) with the following formulae.

If some explanations are added to "the vicinity of a confluence", it is the case when the width of a tributary that has not a little impact if it flows into a main river at a confluence is more than 30% of the width of its main river or the size of its influence intervals are about twice in width of a main river to both the upstream and downstream directions from a confluence.

●a breach point is the vicinity of a confluence: $y = 2.0 \times (\log_{10x})^{3.8}+77$
●a breach point is not the vicinity of a confluence: $y = 1.6 \times (\log_{10x})^{3.8}+62$

③ **Bed height of a breached levee**

It is assumed that a levee will be torn down to its footing (or foundation). Either the ground height in a landside areas or the height of high water bed, whichever is larger, should be regarded as the bed height of a breached levee at the location where a levee is constructed.

④ **Progress of a levee breach with time**

When a levee starts breaching, about one over twice (y/2) of a final breach width is considered to collapse instantly. Within the next one hour, the width will expand to a final breach width. The rate to expand the chasm during this period should be regarded as constant. The bed height of a failed levee will be reached to the bed height of the above ③ instantly.

⑤ **How facilities should be treated in a flood analysis model**

The facilities that may have some impacts on flood phenomena should be taken into account in the models used for inundation analyses as far as possible based on the judgment by technical experts. The following points should also be taken into account;

●Embankment --- "embankment of which the ground height is 50% higher than that of the average ground height" should be taken into account in a model. Specifically, levees, second line levee (including open levee), railway, main traffic road and other embankments.

Embankments are placed on the calculation mesh used for a flood simulation so that it will traverse the boundaries of calculation meshes. Therefore embankments will be arranged like a staircase in calculation mesh, when they are viewed as a plane.

●Pump --- Pumps should be taken into account based on their actual operation rules. But if it were difficult to obtain actual operation rules, hypothetical operation rules should be prepared (i.e., pumps will start draining out water at its maximum capacity at the onset of an inundation).

●Sluice --- Please use the formula suggested by Public Work Research Institution, Ministry of Land, Infrastructure, Transportation and Tourism in below section ⑥ (3))

●Culvert --- The same formula with that for a sluice should be applied.

●Water channel --- It would be ideal to use the varied flow models that exclude inertial terms so as to reproduce the behavior of flood water within a water channel as truly as possible. But when changes in river discharge over time are limited, it is possible to use simpler computation models based on the judgment by specialists. As is the case with embankment explained in the above, a water channel is placed along the boundaries of calculation meth in a flood simulation. If you take into account too much smaller-sized channels, the calculation may become unstable. So attentions should be paid to the selections of channels to be taken into account.

●Sewage --- If they are taken into account, it would be desirous to apply the calculation method which is the same with that for a water channel.

⑥ **Overflow discharge and outflow from facilities**

When overflow discharge is calculated, the overflow discharge formula which is considered to be adequate based on the relationship between the alignment of a river and the water-course in the event of flooding at the sites expected to be overflowed should be used.

Since the calculation by use of an overflow discharge formula completely disregards the balance with the discharges of a river channel, overflow discharge may be overestimated in the calculation. Therefore, it is required to make sure that overflow discharge Q_B is smaller than the flow volume Q_D which is greater than the discharges at the bed height of a breached levee. When Q_B is larger than Q_D, you should make some adjustments by assuming for example, Q_B is equal to Q_D. When the water level behind levees (landside) is higher than the water level of a river, it should be assumed that flood water will reflux from landside areas to a river.

(1) **Front overflow**

The formula developed by Mr. Homma should be applied for calculation of front overflow.

Mr. Homma's formula:

Complete overflow ($h_2/h_1<2/3$) $$Q = 0.35 \times h_1\sqrt{2gh_1} \times B$$

Submerged overflow ($h_2/h_1 \geqq 2/3$) $$Q = 0.91 \times h_2\sqrt{2g(h_1 - h_2)} \times B$$

h_1 and h_2 are the water depth measured from the bed height of a breached levee. Higher figure in value should be h_1, while lower figure in value should be h_2.

(2) **Side overflow**

Overflow discharge should be calculated with the following formula.

Flow volume calculated by use of Mr. Honma's formula is represented by Q_0. When the bed slope of a river is I, inundation flow Q is expressed as follows. Please be noted that the unit of "cos" in the parenthesis is "degree".

●Inundation discharge following levee breach Q

$I > 1/1580$ $$Q/Q_0 = (0.14 + 0.19 \times \log_{10}(1/I)) * \cos(48 - 15 \times \log_{10}(1/I))$$

$1/1580 \geqq I > 1/33600$ $$Q/Q_0 = 0.14 + 0.19 \times \log_{10}(1/I)$$

$1/33600 \geqq I$ $$Q/Q_0 = 1$$

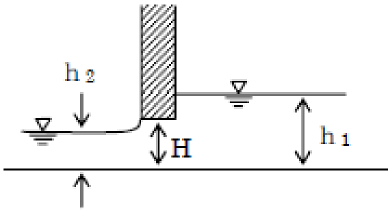
●Overflow discharge following spill overtopping Q

$I > 1/12000$ $$Q/Q_0 = \cos(155 - 38 \times \log_{10}(1/I))$$

$1/12000 \geqq I$ $$Q/Q_0 = 1$$

(3) **Discharges from Sluice and Culvert**

The discharges should be calculated by the formula suggested by Public Work Research Institute, Ministry of Land, Infrastructure, Transportation and Tourism. The heights of a sluice and a culvert are represented by H and their widths are represented by B. The water depths measured from the bed heights of an outlet is represented by h_1 (deeper) and h_2 (shallower).



Submerged outflow: $H_2 \geqq H$ $\quad Q = CBH\sqrt{2g(h_1 - h_2)}$, $C=0.75$

Subsurface flow: $h_2 < H$ and $h_1 \geqq 3/2H$ $\quad Q = CBH\sqrt{2gh_1}$, $C=0.51$

Free outflow: $h_2 < H$ and $h_1 < 3/2H$ $\quad Q = CBh_2\sqrt{2g(h_1 - h_2)}$, $C=0.79$

In the case of Free Outflow and $h_1 / h_2 \geqq 3/2$, $h_2 = 2/3\ h_1$ instead of $h_1 / h_2 \geqq 3/2$.

⑦Degree of roughness

Degree of roughness should be judged comprehensively based on the results calculated in a computation model and the status of land use in watershed, and historical flood data. You can refer to the method described in "Manual for Flood Simulation (Draft)" that expresses degree of roughness by the function of water depth and the occupancy rates of buildings.

⑧Setting the interval between calculations

The interval between calculations should be decided by taking into account time required for each calculation to the extent that the results of these calculations are stabilized.

When the water channels which run through a flood plain are taken into account in these calculations, sufficient attentions should be paid to its handling, because if small channels were taken into account, the results of these calculations may become unstable.

3.3 Implementation of a flood flow analysis

A flood flow analysis should be undertaken on condition of the before mentioned flood discharges. Inundation areas and inundation depths will be calculated in the analysis.

[Explanation]

The standard method to calculate flood discharges is Quasi 2^{nd} varied flow calculation conducted in mesh. When it is inadequate to use such a calculation method in the light of the terrain conditions in a flood plain, you may use other method. When mesh data are generated, the consistency must be ensured with the mesh data on properties (i.e., numerical map data and national land numerical information). The basic mesh length should be set at the scale of 1:25,000. But if you can compromise precision of calculations and can use larger scale mesh, or if the scale of mesh is set at the scale of 1:25,000 and the enormous number of mesh grid cells are generated and it becomes difficult to conduct practical calculations, you can use mesh at 1:50,000 scale instead.

However to do so, you need to verify the following points;

From the view point that "an embankment of which ground height is higher than average ground height by 50cm" should be taken into consideration in a model, the differences in ground heights in mesh due to slopes should be limed to up to 50cm. In this case, this restriction can be expressed in the following formula;

You should define $\triangle X$ as well as $\triangle t$ in consideration of the restriction of calculation time required for calculations and stability of calculations. Their ($\triangle X$,$\triangle t$) validity should be examined with the following formula;

$$\Delta z = I \times \Delta x \leq 0.5m$$

$$\Delta x > 10\sqrt{A}$$

$$\Delta t \leq \Delta x / 25$$

$\triangle X$: longitude of mesh(m), $\triangle t$: time interval of calculation (second), A: square meters of inundation block(k m^3), $\triangle Z$: average difference in ground elevation (m) between meshes, I: slope

3.4 Calculation of damage by a flood event

> Damage by a flood event should be calculated based on the mesh data on properties/ geomorphology and the inundation depth obtained in a flood flow analysis.

[Explanation]

Flood damage of each mesh is calculated based on the mesh data (on ground height, properties and slopes) and the inundation depth obtained in a flood flow analysis. By totaling damage of each mesh, flood damage in a flood plain can be calculated by probability. Furthermore annual average damage reduction can be calculated by multiplying the damage calculated in the above by a flood event with the probability of flood events (this calculation method will be further discussed in Calculation of Benefits in Chapter 4).

4. Cost-benefit analysis

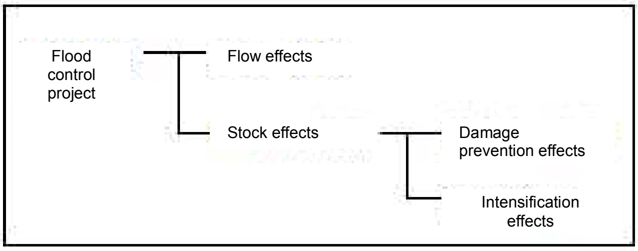
4.1 Benefit to be assessed in the economic evaluation

> The effects to prevent flood damage should be taken into account as benefits in the economic evaluation.

[Explanation]

The economic effects brought by the implementation of flood control projects are divided into two parts; stock effects (e.g., effects to prevent damage to properties in a flood plain) and flow effects (e.g., the effects brought by implementation of a project). The stock effects include direct/ indirect effects to prevent flood inundation damage and intensification effects due to intensification of land use as a result of improvement of flood control reliability.

But at present, it is not always possible to quantify all damage prevention benefits. It is even more difficult technically to quantify intensification benefits brought by the improvements of water control facilities. In addition, it would be arduous to make an assessment on intensification benefits alone completely separately from the effects to prevent damage.



Conventionally, direct damage to general assets has been calculated based on their fair values. But in most cases following a flood event, people tend to repurchase houses and assets so as to resume their lives again in the affected area. In the light of this, direct flood damage should be calculated based on the re-procurement costs that are close to actual direct flood damage and people actually pay.

In this manual (draft), out of direct/ indirect damage by a flood inundation listed in Table 4-1, at present the damage prevention effects that can be assessed economically are evaluated as benefits. When it is expected that benefits will be generated by a flood control facility under improvement in a certain project, the benefits generated during an improvement period should be understood in a chronological order and the improvement period of a flood control facility should be taken into account in the economic evaluation.

When a levee improvement project is implemented, improvements will be typically carried out in the order shown in Graph 4-1. The effects of levee improvements will be generated gradually as investments are made in a levee even during an improvement period.

However in the case of improvement projects for dams, the expected effects will be generated only after their completion and from the stage where the dams are expected to start producing effects (e.g., in their initial impoundment stage) .

As is mentioned in the above, it is important that the benefits produced by improvements of water control facilities under construction are assessed in a chronological order and to conduct an evaluation adequately.

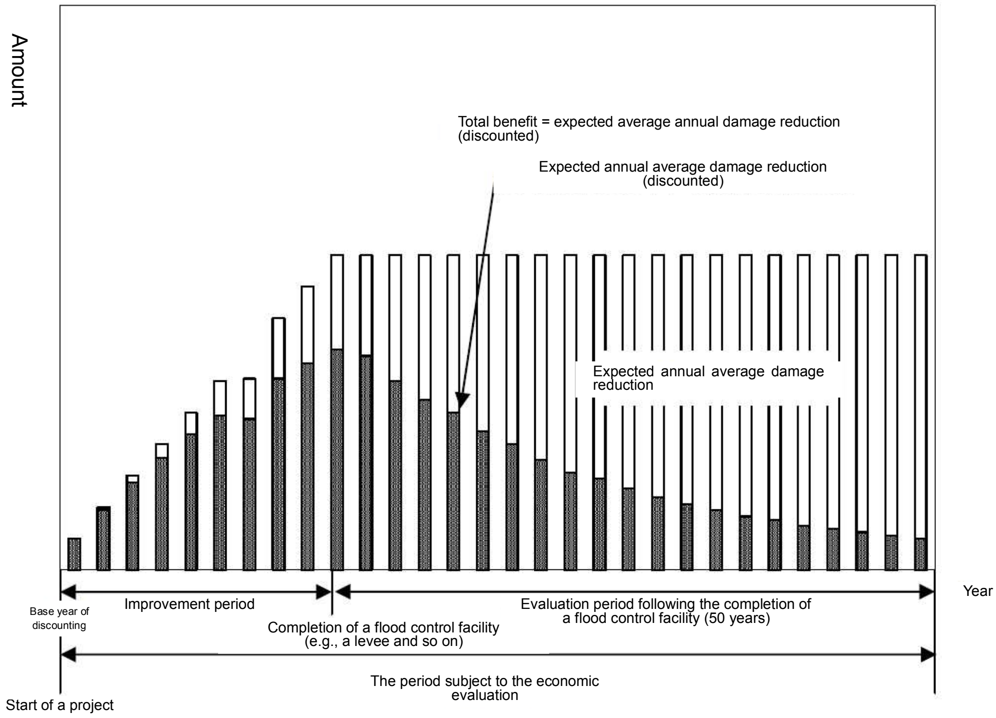
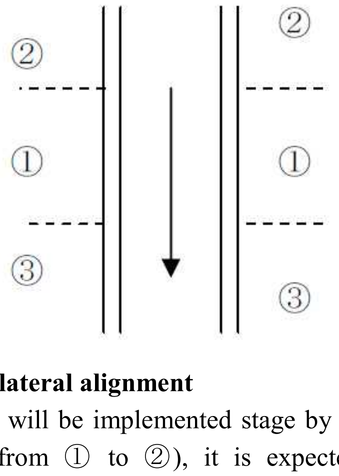


Figure-4.1 Generation of levee's benefits

【Improvements of levees】

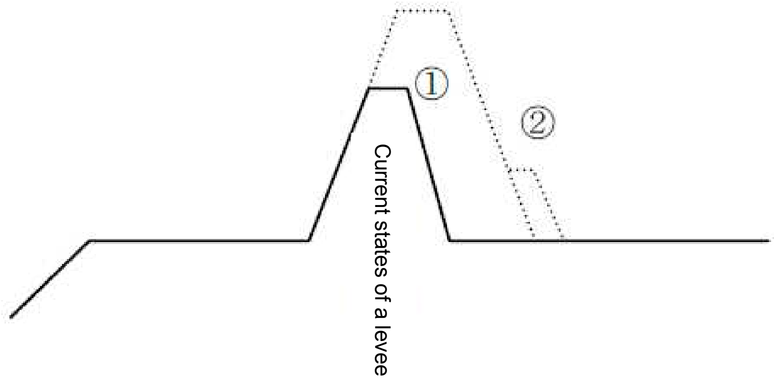
●Phased construction works in a vertical alignment

When improvement works of levees will be implemented stage by stage in a vertical direction along a river and the works are planned to be initiated from an high risk area (e.g., in the order of Reach ①→ Reach ②→ Reach ③. Please refer to the below figure), it is expected that the effects brought by the improvement works will be generated following the completion of works in one reach. It shouldn't be assumed that the effects won't be generated until the works scheduled for all of the three reaches are completed.



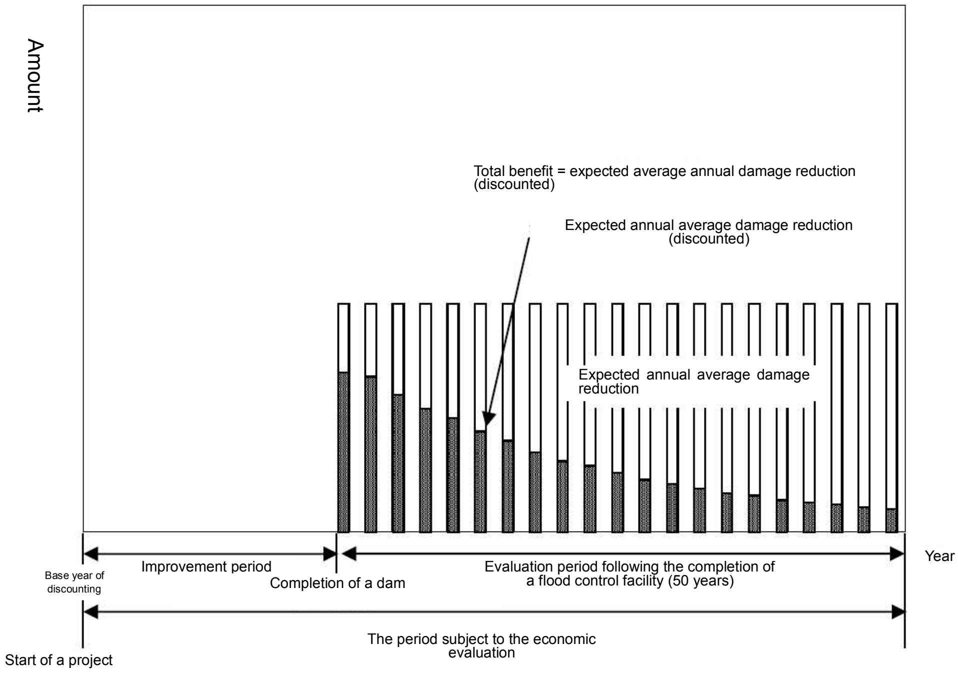
●Phased construction work in a lateral alignment

When an levee improvement work will be implemented stage by stage in a lateral direction of a river (such as levee widening works from ① to ②), it is expected that the effects brought by the improvement work will be generated each time following the completion of ① or ②. It shouldn't be assumed that the effect won't be generated until the works scheduled in the two stages are completed.



【Dams】

In the case of an improvement project for a dam, its expected effects will be generated only after its completion and from the stage where the dams will start producing effects.



On the other hand, in this manual (draft), when the benefits of a flood control project are evaluated, the evaluation should be made on the assumption that the current conditions of properties won't change basically in the future. But if it is possible to calculate the future growth of properties in a flood susceptible area in a specific and rational manner, you can include such properties when the values of properties in a flood susceptible area are calculated and can evaluate the benefits of a flood control project.

It also will be required to make an assumption on time necessary to resume normal socio economic activities following flooding.

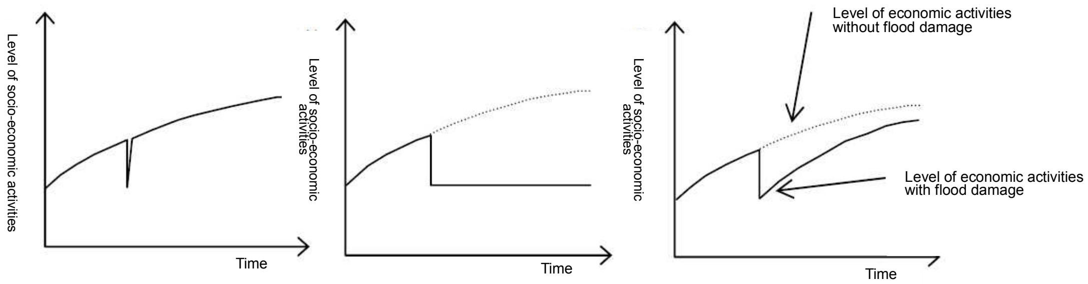


Figure-4.3 Time required to resume normal socio-economic activities following a flood disaster

As is indicated in Figure-4.3, even when the total sum of direct flood damage to properties is the same, time required to return to normal socio-economic activities following a flood event greatly differ among areas depending on the level of incomes or properties of people affected, the characteristics of the area affected (e.g., its economic power, urban area or rural area) and the percentage of people affected in an affected region. Therefore if you try to calculate the exact amount of flood damage, it can be considered to review the examples of past flood damage and to use them so as to draw on the co-relations between personal incomes/ economic powers in affected area and total damage (the total sum of direct and indirect flood damage) . But such data do not necessarily exist.

Due to the above reason, in this manual (draft), out of the idea that we should calculate the lowest possible amount of damage caused by a flood disaster so as not to overestimate such damage, there would be no choice but assuming that direct damage to properties will be recovered in a moment, direct damage including damage due to disrupted activities at business establishments will be recovered physically within the minimum required number of days, and the business resume its normal course of socio-economic activities following the minimum required number of day.

However, the discussions on the relationship between socio-economic activities by people/ in a region and flood disaster should be continued.

About other benefits that will be discussed in section 4.6, when they are quantifiable based on the research results on individual rivers, it shall not be precluded to include them as the benefits in the economic evaluation. But it is still required to make sure that their inclusion won't cause double evaluation.

Table-4.1 Stock effects generated by a flood control project

Category					Contents of effects (damage)
Damage prevention benefits	Direct damage	Effects to reduce damage to properties	Damage to general assets	Residential buildings and business establishments	Damage to residential buildings and business establishments
				Residential properties	Inundation damage to furniture and cars
				Depreciable assets at business establishments	Inundation damage to depreciable properties excluding land and buildings, out of fixed properties at business establishments
				Inventory assets at business establishments	Inundation damage to inventory assets at business establishments
				Depreciable assets of agriculture and fishery households	Inundation damage to depreciable properties excluding land and buildings, out of fixed properties of agriculture and fishery households
				Inventory assets of agriculture and fishery households	Inundation damage to inventory assets of agriculture and fishery households
			Damage to agricultural products		Inundation damage to agricultural products
			Damage to large-scale public works		Inundation damage to large-scale public work facilities, public service offices, farmland and agricultural facilities
		Effect to prevent damage to human			Loss of lives
	Indirect damage	Effect to prevent damage to ordinary activities	Damage due to disrupted activities	Household economy	Damage caused by disrupted house works and leisure activities in normal times by a disaster at inundated houses.
				Business establishments	Damage caused by interrupted and/or terminated productions at flooded manufacturing activities due to disasters (reduced production level)
				Public and public interest services	Damage caused by interrupted and/or terminated public or public interest services due to a disaster event
		Effect to prevent aftermath damage	Emergency response costs	Household economy	Damage caused due to ex-post disaster activities such as cleaning up disaster wastes and additional payments for procurement of some alternative products such as safe drinking water and etc. at flooded houses
				Business establishments	The same damage with that of household economy
				Public and public interest services	Generally the same damage with that of household economy in addition to the interest rates of ex-post disaster emergency loans extended by municipalities and disaster relief money
			Ripple-off damage due to traffic disruption	Road, railway, airport and harbor	Ripple-off damage spread around affected areas and neighborhood due to traffic disruption including road, railway and etc.
			Ripple-off damage due to suspension of	Electricity, water, gas,	Ripple-off damage spread around affected areas and neighborhood caused by suspension of lifeline services

			lifeline services	communications and etc.	including electricity, gas, water and etc.
			Ripple-off damage due to disrupted activities of business establishments		Ripple-off damage spread around affected areas and neighborhood due to reduced production levels at nearby manufacturing factories because of short supply of half finished products as well as termination of services by public and public interest institutions
		Effect to prevent psychological damage	Damage accompanying business interruption		Psychological stress due to damage to properties
			Damage accompanying interrupted normal activities		Psychological stress due to damage to normal activities
			Damage accompanying damage to human bodies		Psychological stress due to damage to human bodies
			Damage accompanying aftermath damage		Psychological stress due to ex-post cleaning works
			Damage accompanying ripple-off damage		Psychological stress due to ripple-off damage
		Risk premium			Psychological stress due to anxiety about affecting again
Intensification benefits					Land price hike due improvements of flood control reliabilities

※ Damage prevention effects described in the above are not all and there exist other damage prevention effects including damage due to flooded an underground shopping mall (damage rates and damage unit prices of the matters in the shaded boxes ▭ in the above are clarified in this manual (draft))

4.1.1 Properties that may be damaged directly by a flood event

The properties that may be damaged directly by a flood event;

- ●Buildings
- ●Residential properties
- ●Depreciable assets and assets in inventory (business establishments)
- ●Depreciable assets and assets in inventory (agriculture and fishery households)
- ●Agricultural products
- ●Large-scale public facilities

[Explanation]

In this manual, the properties that will suffer from direct inundation damage include the followings;

① Buildings
Residential buildings and business establishments

② Residential properties
Furniture, electrical appliances, clothing, automobiles and etc.

③ Depreciable assets and assets in inventory (the businesses)
Depreciable assets and inventory assets at business establishments (e.g., machine tools, office equipment and etc.).

④ Depreciable assets and assets in inventory (agriculture and fishery households)
Production facilities and inventories (e.g., agricultural equipment and etc.)

(The properties in the above ①～④ are called “General Assets”)

⑤ Agricultural products
Paddy field rice and the crops produced during a flood season.

⑥ Large scale public facilities

Large scale public facilities (road, bridges sewages and city facilities)

Utility facilities (facilities related to electric power supply, gas distribution, water supply, railway, communications (e.g., telephone) and etc.)

Agricultural facilities including farmland, waterway and etc.

4.1.2 Properties that may be damaged indirectly by a flood event

Out of the indirect damage that will be rippled out from direct damage, those that can be evaluated economically should be taken into account in the economic evaluation.

[Explanation]

It is difficult to grasp the whole picture of ripple-off damage by a flood event, because it spreads out both inside and outside of an inundation area, and will vary depending on the characteristics of the river flooded, socio-economic activities in the areas inundated and the magnitude of inundation. Furthermore, the methodology to quantify the amount of indirect damage has not been established both rationally and economically for all such damage items.

Therefore for the time being in this manual (draft), out of indirect damage caused by a flood event, following those that can be inferred economically and statistically should be grasped as indirect damage and should be evaluated in the economic evaluation. But if it is possible to establish the rational methodologies to quantify the other indirect damage that objectively reflect the characteristics of a river, such indirect damage can be included in the economic evaluation as benefits.

●Losses due to disrupted activities at business establishments

●Emergency response costs (household)

●Emergency response costs (the businesses)

4.2 Investigation of property data

The baselines required calculating flood damage (e.g., properties and the number of households/ office workers in a flood area) should be calculated per calculation mesh in a flood simulation.

[Explanation]

(1) Properties to be evaluated

The baselines related to the following properties should be investigated.

●Residential building (floor area)

●Residential properties (the number of households)

●Depreciable assets and inventory assets at business establishments (the number of workers)

●Depreciable assets and inventory assets for agriculture and fishery households (the number of agriculture and fishery households)

●Agricultural products (Square meters of rice and crop fields)

(2) Baselines to be investigated

The baselines should be investigated by use of Statistical Maps on Grid Square Basis (prepared by Statistics Bureau of Japan) per calculation mesh used in a flood simulation (in principle, 1:25,000).

●Population・the number of households (Statistical Maps on Grid Square Basis･･･National Population

Census by Statistic Bureau)

●The number of workers by industrial classification (Statistical Maps on Grid Square Basis･･･Establishment and Enterprise Census)

●The number of agriculture and fishery households (Statistical Maps on Grid Square Basis･･･National Population Census by Statistic Bureau)

●Total floor area (the mesh data developed by Japan Construction Information Center Foundation)

●Square meters of rice and crop fields (maps or numerical maps (1/10 subdivision of standard mesh) (by Japan Construction Information Center Foundation and so on)

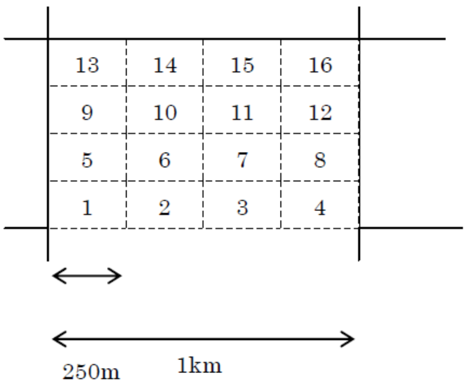
(2) Dividing proportionally into 1:25,000 mesh

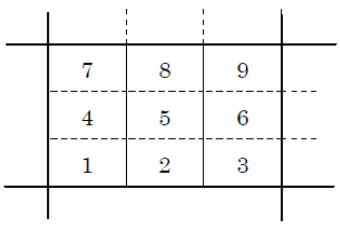
When 1:100,000 mesh cell grids are proportionally divided into 1:25,000 mesh, it should be done based of the ratio of residential areas and so on.

When the population, the number of households and workers and the number of agriculture and fishery households in 1:25,000 mesh are *pi* (i=1,2,･･･,16), those data in 1:100,000 mesh is P and the residential area in 1:25,000 mesh is *ai*, *pi* should be calculated with the following formula.

$$p_i = P \times \frac{a_i}{\sum_{i=1}^{16} a_i}$$

The total floor area data is produced based on 1:10,000 mesh. The mesh boundaries in 1:25,000 scale do not fit into those of 1:10,000 mesh. It should be assumed that property densities should be uniform in the mesh that are not covered in 1:25,000 mesh.





Namely when α_i represents total floor area based on 1:10,000 mesh and *i* represents the numbers assigned to each mesh in the above figure, the total floor area in 1:25,000 mesh should be as follows;

$$\alpha = (\alpha_1 + \alpha_2 + \alpha_4 + \alpha_5) + (\alpha_3 + \alpha_6 + \alpha_7 + \alpha_8) \times \frac{1}{2} + \alpha_9 \times \frac{1}{4}$$

When investigating the baselines, you can use the above mentioned 1:100,000 mesh data as well as 1:10,000 mesh data produced by Japan Construction Information Center Foundation based on the following national statistics.

●1995 National Population Census
●1996 Establishment and Enterprise Census (base figure: its 1995 census)

4.2.1 Residential buildings

The values of residential buildings should be calculated by multiplying total floor area by the appraised value of a residential house (㎡).

[Explanation]

The asset values of residential buildings should be calculated by multiplying total floor area (㎡) by the assessed values of a residential buildings classified by prefecture (for these appraised values, please see Table 1 in the Appendix attached at the end of this manual).

Total floor area × appraised value of a residential buildings classified by prefecture (㎡)

If the total floor area were basically calculated by multiplying the number of households by average floor area per household, the floor areas per business establishment won't be included in the calculation and the total floor area will be underestimated. Therefore the total square area in the 1:10,000 mesh data prepared by Japan Construction Information Center Foundation which is developed based on Reports on Preliminary Investigation on the Prices of Fixed Assets (Ministry of Internal Affairs and Communications) and so on should be used for the calculation.

4.2.2 Residential properties

The values of residential properties should be calculated by multiplying the number of households by the appraised values of residential properties per household.

[Explanation]

The values of residential properties should be calculated by multiplying the number of households by appraised values of residential properties per household (for these appraised values, please see Table 1 in the Appendix attached at the end of this manual).

The number of households ×appraised values of residential properties per household

(Note)
The number of households to be used for this calculation should be cited from data classification: " The number of general households【Statistic figures, not designated as officially secret】(Data No.185)" found in "Households by type of household" of Statistical Maps on Grid Square Basis･･･National Population Census by Statistic Bureau.

4.2.3 Depreciable assets・inventory assets (business establishments)

The values of depreciable assets and inventory assets at business establishments should be calculated by multiplying the number of workers (based on industry classification) by the appraised values of depreciable assets / inventory assets per employee based on industry classification.

[Explanation]

The values of depreciable assets and inventory assets at business establishments should be calculated by multiplying the number of workers (based on industry classification) by the appraised values of depreciable assets/ inventory assets per worker (based on industry classification) (for these values, please see Table 3 in the Appendix attached at the end of this manual). When the categories of "Establishment and Enterprise Census" and the middle categories of "Japan Standardized Industry Classification" are not consistent, the large categories of these statistics should be used for this calculation.

The number of workers×appraised values of depreciable assets/ inventory assets per employee

In this calculation, the number of workers by the industry classification of Establishment Mesh Census should be used. The industry classification and their data no. are shown in the table below;

Large industry category	Establishment Mesh Census	
	Industry Classification	Data No. (No. of Workers)
D. Mines	Mine	8
E. Construction	Construction	11
F. Manufacture	Manufacture	14
G. Distribution of Electricity, Gas, Energy and Water	Distribution of Electricity, Gas, Energy and Water	89
H. Transportation, Communications	Transportation, Communications	92
I. Wholesale, Retail	Wholesale, Retail, restaurant	95
J. Finance, Insurance	Finance, Insurance	149
K. Real Estate	Real Estate	152
L. Other services	Other services	155
M. Public Interests	Public Interests (which are not included any of the other categories)	227

(Note: Data No. in the above table are those used in 1991 Establishment Mesh Census.)

4.2.4 Depreciable assets・Inventory assets (agriculture and fishery households)

The values of depreciable assets and inventory assets of agriculture and fishery households should be calculated by multiplying the number of agriculture and fisher households by the appraised values of depreciable assets / inventory assets per such household.

[Explanation]

The values of depreciable assets and inventory assets for agriculture and fishery households should be calculated by multiplying the number of agriculture and fishery households by the appraised values of depreciable assets/ inventory assets per such household.

The number of agriculture and fishery households
×appraised values of depreciable assets/inventory assets per such household

Since these evaluation units are national average, if it is possible to reasonably reflect regional characteristics to the depreciable assets / inventory assets of agriculture and fishery households by use of certain unit prices, you can use them in this calculation. The total sum of "the number of agriculture and forestry households" (Data No. 205) as well as "the combined number of agriculture/ fishery/ forestry households and non-agriculture/ non-fishery/ non-forestry households" (Data No. 206) in the data classification of "Private Households by Economic Type of Household" of the National Census Map on Grid Square Basis should be used for the above calculation.

4.2.5 Agricultural products

The asset values of agricultural products are calculated by multiplying paddy and crop filed areas (㎡) by annual average yields and agricultural price.

[Explanation]

The asset values of agricultural products should be calculated by multiplying paddy / crop field areas (㎡) by annual average yields per unit area (for paddy field, please see Table 5 in the Appendix attached at the end of this manual. For crop filed, they will differ depending on regional circumstances) and agricultural prices per crop yield unit (for the prices, please see Table 6 attached in the Appendix at the end of this manual).

Paddy/Crop fields (㎡)×Annual average yields×Agricultural prices

When the asset values of agricultural products are calculated based on the assets values of representative commodities, they should be calculated by multiplying the average appraised values of such commodities per unit crop filed area (㎡) " *c"* by mesh crop field area "*c"* (㎡, 1,000 JPY/a) based on the statistical references compiled by prefectural / municipal governments so as to calculate the average asset values of representative commodities during a flood season yielded in the flood areas to be protected by a flood control project.

$$c = \Sigma p_i \cdot x_i / \Sigma A_i$$

i: types of crops produced during a flood season, *p*: price (1,000JPY/*t*), *x*: crop yields(*t*), *a*: crop field planted (㎡, *a*)

4.3. Calculation of direct damages

Direct damage to general assets and agricultural products should be calculated by multiplying their asset values by their damage rates defined by inundation depth. The direct damage to large scale public facilities should be calculated based on the ratio between direct damage to such facilities and that to general assets.

[Explanation]

Direct damage to general assets and agricultural products should be calculated by use of damage rates at the maximum inundation depth of each mesh.

Direct damage to large scale public facilities (large scale public facilities, public utility facilities and farmland/ agricultural facilities) should be calculated by use of the ratio between past direct damage to large scale public facilities and past direct damage to general assets.

Hereinafter, direct damage to large scale public facilities should be calculated by asset class shown in 4.1.1.

4.3.1 Direct damages to residential buildings

Direct damage to residential buildings should be calculated by multiplying their asset values adjusted by their distribution of floor numbers within mesh by damage rates defined by inundation depth.

[Explanation]

Direct damage to residential buildings should be calculated by multiplying their asset values calculated in 4.2.1 and adjusted by their distribution of floor numbers within mesh by damage rates in Table-4.2.

Adjusted asset values of residential buildings × damage rates

Table-4.2 Damage rates by inundation depth

Inundation depth / Ground slope	Under the floor level	Above the floor level					Sediment deposit (above the floor level)	
		Less than 50cm	50～90	100 ～ 199	200～299	More than 300cm	Less than 50cm	More than 50cm
A Group	0. 032	0. 092	0. 119	0. 266	0. 580	0. 834	0. 43	0. 785
B Group	0. 044	0. 126	0. 176	0. 343	0. 647	0. 870		
C Group	0. 050	0. 144	0. 205	0. 382	0. 681	0. 888		

A: less than 1/1,000, B] 1/1,000, C: more than 1/500

(Note): 1. These damage rates are calculated by use of the results of " Fact-Finding Survey on Flood Damage" (from 1993 to 1996) (But about sediment deposit, conventional damage rates are used.)
2. Partial destruction of residential buildings is also taken into account in these figures.

(1) Things to be noted when damage rates are applied

1) Deciding the 1st floor elevation

The 1st floor elevation of each building should be decided by taking into account the characteristics of respective residential buildings and business establishments. In general, so as to ensure the consistency with Construction Standard Act of Japan and other related regulations, when the flood water depth in calculation mesh reaches more than 45cm in a flood analysis, it should be assumed that greater damage will be inflicted to household properties by inundation above the floor level.

2) Ground slope

By taking into account the difference in fluid dynamics of flood water, different damage rates should be applied depending on the conditions of ground slopes. Ground slopes should be decided per mesh based on the geomorphologic characteristics of a flood area and the average ground height of mesh. If you try to generate ground slopes automatically per mesh based on the differences in ground heights in adjacent meshes, the ground slopes generated might be extremely different from those in adjacent meshes. If the ground slopes generated did not represent the actual geomorphology of the area, some additional operations will be required such as averaging broader extent.

(2) Things to be noted when the asset values of residential buildings are adjusted

When the mesh water depth where apartments or condominiums are located is below the floor level, people in the residential rooms on or above the 2nd floor of apartments or condominiums will not suffer from flood damage. Therefore, some required adjustments should be made accordingly.

When such adjustments are made, it is desirable to use the average number of floors of the buildings located in a certain mesh and to decide the buildings that will be damaged directly by a flood event. As inundation depth is 3 meters high in most of the cases, if you decide to disregard the residential rooms on and above the 3rd floor, it is possible to make adjustments such as the followings.

The asset values of business establishments must be adjusted by the number of floors.

<One example to adjust the asset values of residential building that will be damaged directly by a flood event>

$P = P_o \times \gamma$

P_o represents the asset values of residential buildings per mesh and γ represents correction factor. When the average number of floors of residential buildings in a certain mesh is f,

When $f<3$, $\gamma = 1.0$
When $f \geqq 3$, $\gamma = 2 / f$

The average number of floors of residential buildings can be decided based on local conditions by the following measures.

Method for using mesh data
National Census Maps on Grid Square Basis includes the data on the number of household dwellings by building floor. When these data are used, a certain compromise should be made if appropriate, but if you assume for example that only the residential rooms on the 1st and 2nd floor will suffer from flood damage, you can calculate correction factor γ .

<Reference>
When some statistical indices are used
The research undertaken by Japan Construction Information Center Foundation in the past reports the relationship between the average number of building floors (f) in a specific area and the density of population/ employees can be expressed as $f \fallingdotseq f(\mathrm{m}) \fallingdotseq a+b \cdot m$. When ($f$) can be estimated with such a simplified method, it can be used.

4.3.2 Direct damage to residential properties

Direct damage to residential properties should be calculated by multiplying their asset values adjusted by the distribution of floor numbers within mesh by damage rates defined by inundation depth.

[Explanation]
Direct damage to residential properties should be calculated by multiplying their asset values calculated in the above 4.2.2 and adjusted by the distribution of floor numbers within mesh by damage rates in Table-4.3.

Adjusted asset values of residential properties ×damage rates

For the things to be noted when damage rates are applied and the asset values are adjusted, please refer to 4.3.1.

Table-4.3 Damage rates by inundation depth

Inundation depth	Under the floor level	Above the floor level					Sediment deposit (above the floor level)	
		Less than 50cm	50～99	100～199	200～299	More than 300cm	Less than 50cm	More than 50cm
Damage rates	0. 021	0. 145	0. 326	0. 508	0. 928	0. 991	0. 50	0. 845

(Note) These damage rates are calculated based on "Fact-Finding Survey on Flood Damage" (from 1993 to 1996) (But about sediment deposit (above the floor level), conventional damage rates are used.)

4.3.3 Direct damage to depreciable assets and inventory assets at business establishments

Direct damage to depreciable assets and inventory assets at business establishments should be calculated by multiplying their asset values adjusted by the distribution of floor numbers within mesh by damage rates defined by inundation depth.

[Explanation]

Direct damage to depreciable assets and inventory assets at business establishments should be calculated by multiplying their asset values calculated in the above 4.2.3 and adjusted by the distribution of floor numbers within mesh by damage rates in Tabel-4.4.

For the things to be noted when the damage rates are applied and the asset values are adjusted, please refer to 4.3.1.

Table-4.4 Damage rates by inundation depth

Inundation depth / Assets	Under the floor level	Above the floor level					Sediment deposit (above the floor level)	
		Less than 50cm	50～99	100～199	200～299	More than 300cm	Less than 50cm	More than 50cm
Depreciable assets	0. 099	0. 232	0. 453	0. 789	0. 966	0. 995	0. 54	0. 815
Inventory assets	0. 056	0. 128	0. 267	0. 586	0. 897	0. 982	0. 48	0. 780

(Note) These damage rates are calculated by use of the results of "Fact-Finding Survey on Flood Damage" (from 1993 to 1996) (But about sediment deposit (above the floor level), conventional damage rates are used.)

4.3.4 Direct damage to depreciable assets and inventory assets of agriculture and fishery

Direct damage to depreciable assets and inventory assets of agriculture and fishery households should be calculated by multiplying their asset values by damage rates defined by inundation depth.

[Explanation]

Direct damage to depreciable assets and inventory assets of agriculture and fishery households should be calculated by multiplying their asset values which are calculated in the above 4.2.4 by damage rates shown in Table-4.5.

When the damage rates are applied, please refer to the items described in 4.3.1.

Table-4.5 Damage rates by inundation depth

Inundation depth	Under the floor level	Above the floor level					Sediment deposit (above the floor level)	
		Less than 50cm	50～99	100～199	200～299	More than 300cm	Less than 50cm	More than 50cm
Depreciable assets	0. 0	0. 156	0. 237	0. 297	0. 651	0. 698	0. 370	0. 725
Inventory assets	0. 0	0. 199	0. 370	0. 491	0. 767	0. 831	0. 580	0. 845

4.3.5. Direct damages to agricultural products

Direct damage to agricultural products should be calculated by multiplying their asset values by damage rates defined by inundation depth and the number of days inundated.

[Explanation]

Direct damage to agricultural products should be calculated by multiplying their asset values calculated in the above 4.2.5 by damage rates defined by inundation depth and the number of days inundated.

Asset values of agricultural products × damage rates

In principle damage to agricultural products should be calculated based on the actual agricultural outputs in the area.

So as to use the damage rates reflecting the actual conditions of local farming management as far as possible, damage rates should be defined based on the researches on the real situations of damage to agricultural products caused by recent flood events and the relationship between the inundation depth and damage to agricultural products, by taking into accounting the status of planting of flood-susceptible seeds (the agricultural products grown from such seeds would lose their values as products, if they were inundated (damage rate: 100%)) and the status of planting flood-resistant seeds.

If such farming conditions were unknown because of no significant flood events for these days, damage rates in Table-4.6 can be used for the calculation.

The number of days inundated should be calculated based on the reduction rates in inundation depth, the geomorphologic characteristics and past experience in flooding with reference to the results of inundation analyses. When it seems to be impossible to define every variety of agricultural products planted, their average per field can be applied for the calculation.

Table-4.6 Damage rates by inundation depth

Type of crops	Items	Overhead flooding/ inundation depth												Buried field in sediment		
	Overhead flooding/ inundation depth	Less than 0.5m				0.5～0.99m				More than1.0m				Sediment deposit depth from the surface of the earth		
	# of days inundated	1~2	3~4	5~6	More than 7	1~2	3~4	5~6	More than 7	1~2	3~4	5~6	More than 7	Less than 0.5m	0.5～0.99m	More than 1.0 m
Paddy field	Rice plant	21	30	36	50	24	44	50	71	37	54	64	74	70	100	100
Crop Field	Rice Plant	20	34	47	60	31	40	50	60	44	60	72	82			
	Sweet potatoes	11	30	50	50	27	40	75	88	38	63	95	100			
	Chinese cabbage	42	50	70	83	58	70	83	97	47	75	100	100			
	Cultivated crops	19	33	46	59	20	44	48	75	44	38	71	84			
	Root crops	32	46	59	62	43	57	100	100	73	87	100	100			
	Gurds	22	30	42	56	31	38	51	100	40	50	63	100			
	Pea seedling	23	41	54	67	30	44	60	73	40	50	68	81			
	Crop field average	27	42	54	67	35	48	67	74	51	67	81	91	68	81	100

(Note)

1."Cultivated crops" include Welsh onion, spinach and so on. "Root crops" include Japanese radish, dasheen, great burdock and carrot. "Gourds" include cucumber, Oriental melon and water melon. "Pea seedlings" include adzuki bean, soya bean, peanut, onion and so on.

2. The damage due to buried paddy/ crop fields in sediment deposit is inflicted when paddy/ crop fields are buried in sediment deposits brought by flood water. Therefore in the case of "sediment flow", its damage rate should be corrected based on actual circumstances.

4.3.6 Direct damage to large-scale public facilities

Direct damage to large-scale public facilities is calculated by multiplying damage to general assets by the ratio between past damage to large-scale public facilities and that to general assets.

[Explanation]

Direct damage to large-scale public facilities is calculated by multiplying damage to general assets (the total sum of damage calculated from 4.3.1 to 4.3.4) by the ratio between past damage to large-scale public facilities and that to general assets (please refer to Table-4.7)

Damage to general assets × the ratio between damage to large-scale public facilities and that to general assets

Table-4.7 The ratio between damage to large-scale public facilities and that to general assets (%)

Facilities	Roads	Bridges	Sewage system	Urban facilities	Public interests	Farmland	Agricultural facilities	Sub-total
Damage rates	61. 6	3. 7	0. 4	0. 2	8. 6	29. 1	65. 8	**169. 4**

(Note) The major flood events that inflicted nation-wide flood damage were selected from "Statistics on Flood Damage" issued over the past 10 years (from 1987 to 1996) and then, their flood damage was calculated as national average based on "Statistics on Flood Damage" and statistic references released by the Ministry of Agriculture, Forestry and Fishery.

However, if you tried to calculate direct damage to large-scale public facilities in large cities by multiplying damage to general assets (national average) by the ratio between past damage to large-scale facilities (national average) to that to general assets (national average), the damage will be overestimated. Therefore, the calculation should be made based on the ratios of past damage to large-scale public facilities to that to general assets in the cities or similar regions that can be cited from "Statistics on Flood Damage".

There might be different opinions if damage to river administration facilities should be included in that to large-scale public facilities or not.

①The benefits of a flood control project are expected to be generated by reducing flood damage to general assets (such as residential building) and roads by improving flood control facilities. In this manual (draft), it is assumed that the flood control facilities will maintain their functionality over the next 50 years following the improvements (i.e., during the 50-years evaluation period) and the damage prevention benefits will be generated during the period, every year, without fail.

②If you decided to include damage to river administration facilities to large-scale public facilities, the underlying assumptions of the above ① will change. Therefore, when the damage prevention benefits are calculated, reduced functionality of the flood control facilities should be taken into account.

Due to the above issues, this manual uses the amount of damage to large-scale public facilities (169.4%) except for that to river administration facilities.

But further discussion shall be required on this point.

4.4 Calculation of indirect damage

Out of indirect flood damage, only the indirect damage items that can be evaluated economically should be assessed in the economic evaluation.

[Explanation]

Out of the indirect damages addressed in Table-4.1 "Stock effects generated by a flood control project", those that can be evaluated economically are as follows;

●Damage caused by disrupted activities at business establishments
●Damage caused by emergency response costs (households)
●Damage caused by emergency response costs (the businesses)

4.4.1 Damage caused by disrupted activities at business establishments

Damage due to disrupted activities at business establishments should be calculated by multiplying the number of workers by the total number of days lost due to disrupted activities at business establishments / business stagnation and added value per worker per day.

[Explanation]

Damage due to disrupted activities at business establishments by industry classification (D) should be calculated by multiplying the number of workers shown in the large categories (of Japan Standardized Industry Classification) by the total number of days lost due to disrupted activities at business establishments / business stagnation, and added value per worker per day (for the added value, please refer to Table 7 in the appendix attached at the end of this manual). Subsequently, the total sum of (D) can be obtained by adding them up.

As the activities at business establishments will be affected not only by if the establishments will be inundated or not, but also by if the region where the establishments are located will be inundated or not, the adjustments described in 4.3.3 should not be applied.

$$D_i = M_i \times (n_0 + n_1 / 2) \times p_i$$

i: the large categories (of Japan Standardized Industry Classification), *M*: number of workers, *p*: added value (JPY/(worker・day), n_o, n_1: the number of days lost due to disrupted activities at business establishments and stagnation respectively, by inundation depth.

(Note) The large categories (of Japan Standardized Industry Classification (revised in October 1993))

D. Mining, E. Construction, F. Manufacturing, G. Distribution of Electricity, Gas, Energy and Water, H. Transportation・Communications, I. Wholesale・Retail, J-M. Other services・Others

Table-4.8 The number of days when activities of establishments are disrupted and stagnated

Inundation depth	Under the floor level	Above the floor level				
		Less than 50cm	50 ～ 99	100～199	200～299	More than 300cm
The number of days disrupted	3.0	4.4	6.3	10.3	16.8	22.6
The number of days suspended	6.0	8.8	12.6	20.6	33.6	45.2

(Note) Based on “Questionnaire Survey on Flood Damage” undertaken to conduct a survey on the flood disasters caused in 1995 and 1996.

4.4.2 Emergency response costs (households)

Emergency response costs of households for ex-post cleanup works and alternative activities by family members should be calculated by multiplying the number of households by the estimated compensations for ex-post cleanup works.

[Explanation]

(1) **Compensations for ex-post cleanup works**

The emergency response costs (i.e., compensations) for ex-post cleanup works (such as the restoration of flood damage at each household) should be calculated by multiplying the number of households by the estimated compensations for ex-post cleanup works at general households (per day) (please refer to Table 8 in the appendix attached at the end of this manual), and the total number of days required for the cleanup works (by inundation depth, please refer to Table-4.9).

Ex-post cleaning up and tidying up works undertaken at general households mainly consist of various restorations of flood damage to residential properties. But by taking into accounts the cleanup works around residential areas and the activities by associations of condominium residents, the adjustments discussed in the above 4.3.1 should not be applied to this calculation.

The number of households ×Estimated compensations for cleanup works ×Total number of days required for cleanup

Most of the policies of non-life insurance products stipulate that the cost required for dismantlement and removal of inundated residential buildings shall be about 10% of the costs required to newly construct them. Based on this assumption, when it is anticipated that residential buildings will be destroyed totally or partially by flooding, it is possible to assume that the compensations for ex-post cleanup works will be about 10% of the asset values of the residential buildings affected by a flood disaster.

Table-4.9. The total number of days required for ex-post cleanup works

Inundation depth	Under the floor level	Above the floor level				
		Less than 50cm	50～99 cm	100～199cm	200～299cm	More than 300 cm
The number of days	4.0	7.5	13.3	26.1	42.4	50.1

(Note) Based on “Questionnaire Survey and Flood Damage” undertaken to conduct a survey on the flood disasters caused in 1995 and 1996.

(2) **Household expenses for alternative activities**

The Emergency response costs of households for alternative activities (i.e., costs for purchasing drinking water and conducting alternative activities for commutation) should be calculated by multiplying the number of households by the unit price of expense burden for alternative activities (by inundation depth, please refer to Table-4.10)

Table-4.10 Unit price of expense burden for alternative activities (unit:1,000JPY/ a household)

Inundation depth	Under the floor level	Above the floor level				
		Less than 50cm	50 ～99cm	100～199cm	200～299cm	More than 300 cm
Unit price	82.5	147.6	206.5	275.9	326.1	343.3

(Note) based on “Questionnaire Survey on Flood Damage” undertaken to conduct a survey on the flood disasters caused in 1995 and 1996.

4.4.3 Emergency response costs (the businesses)

The emergency response costs for alternative activities should be calculated by multiplying the number of business establishments by the unit price of expense burdens for alternative activities.

[Explanation]

The emergency response costs for alternative activities should be calculated by multiplying the number of business establishments by the unit price of expense burdens for alternative activities (by inundation depth, please refer to Table-4.11).

Table-4.11 Unit price of expense burdens for alternative activities
(unit: 1,000JPY/ per establishment)

Inundation depth	Under the floor level	Above the floor level				
		Less than 50cm	50～99cm	100～199cm	200～299cm	More than 300cm
Unit price	470	925	1, 714	3, 726	6, 556	6, 619

(Note) Based on "Questionnaire Survey on Flood Damage" undertaken to conduct a survey on the flood disasters caused in 1995 and 1996.

(Reference) Compensations for ex-post cleanup works

It can be imagined that the workers who work at ordinary business establishments will be assigned to ex-post clean up works following a flood event. But in this case, the added values generated by the cleanup works will be offset by the payment for the cleanup works (the compensation for the added value). As the damage caused by disrupted activities at business establishments / business stagnation during the cleanup works are calculated separately as the losses due to disrupted activities at business establishments, the compensations for the cleanup works at business establishments are not calculated in this manual so as to avoid double evaluation.

4.5 Calculation of benefits

The total benefits during the period subject to the economic evaluation should be calculated by adding the benefits that are the difference in damage between with- and without-project conditions to the residual values of a flood control facility as of the end of the period subject to the economic evaluation.

[Explanation]

In principle, when a river improvement plan is developed and a newly adopted river and/or dam project is evaluated/ re-evaluated, the economic efficiencies of these projects should be assessed based on the current conditions of the river channel to be improved.

However when a series of flood control projects have been conducted intermittently so as to improve the same river and it is necessary to evaluate them as a series, it may not be adequate in some cases to conduct the economic evaluation based on the current states of a river channel. If that would be the case, the evaluation should be conducted by regarding a string of such past flood control projects for the same river as a series. You can trace back to the point when it seems to be suitable to implement the economic evaluation and can conduct the economic evaluation based on the conditions of a river channel at that point.

The total benefits of a flood control project should be obtained by calculating the damage (as benefits) to be prevented by implementation of a project based on the difference in damage between with- and without- project conditions (please refer to Figure-4.4) and by adding it to the residual values of a flood control facility as of the end of the period subject to the economic evaluation.

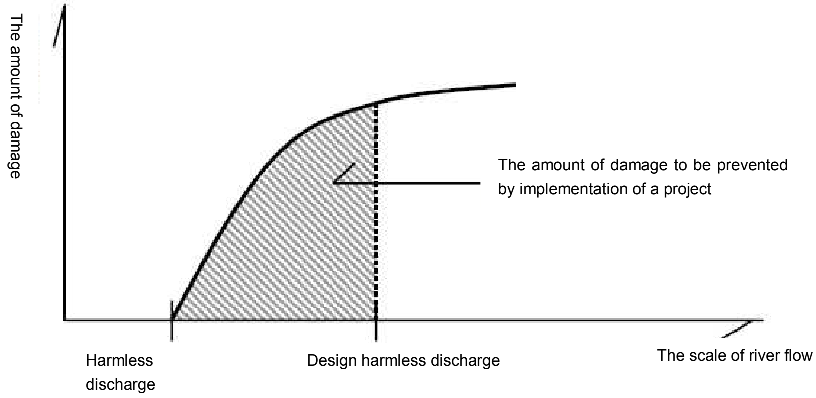


Figure-4.4 Benefits of a flood control project

4.5.1 Expected annual average damage reduction

> Expected annual average damage reduction should be calculated by aggregating the annual average damage (by scale of river flow) obtained by multiplying the amount of damage reduction by occurrence probabilities of flood events.

[Explanation]

Expected annual average damage reduction should be calculated by aggregating the annual average damage (by scale of river flow) obtained by multiplying the amount of damage reduction (by scale of river flow) by occurrence probabilities of flood events (by scale of river flow) (please refer to Table-4-12).

Table-4.12 Table for calculation of expected annual average damage reduction

Scale of river flow	Annual average exceedance probability	The amount of damage ①Without project conditions	②With project conditions	③The amount of damage reduction (①-②)	Average damage by reach	Probabilities by reach	Annual average damage	Aggregated annual average damage = Expected annual average damage reduction
Q_0	N_0			$D_0(=0)$	$\frac{D_0+D_1}{2}$	N_0-N_1	$d_1=(N_0-N_1)\times\frac{D_0+D_1}{2}$	d_1
Q_1	N_1			D_1	$\frac{D_1+D_2}{2}$	N_1-N_2	$d_2=(N_1-N_2)\times\frac{D_1+D_2}{2}$	d_1+d_2
Q_2	N_2			D_2	⋮	⋮	⋮	⋮
⋮				⋮	$\frac{D_{m-1}+D_m}{2}$	N_m-N_{m+1}	$d_m=(N_{m-1}-N_m)\times\frac{D_{m-1}+D_m}{2}$	$d_1+d_2+\cdots+d_m$
Q_m	N_m			D_m				

4.5.2 Calculation of the benefits generated during an improvement period

> When it is expected that benefits will be generated by improvements of a flood control facility during an improvement period, the benefits should be evaluated adequately so as to conduct the economic evaluation that takes into account an improvement period of a flood control facility.

[Explanation]

When an investment plan (i.e., construction costs, an improvement period and allocation of project costs) is already specified, the benefits to be generated in an improvement project should be calculated adequately on the basis of such a plan.

At the stage of project cost estimation, the benefits should be calculated based on an expected improvement period that are temporarily determined with reference to those of past similar projects.

4.5.3 Total benefits generated during the period subject to the economic evaluation

The total benefits should be calculated by adding the total sum of the benefits generated during the period subject to the economic evaluation, and the residual values of a flood control facility as of the end of the period subject to the economic evaluation.

[Explanation]

(1)Total sum of the benefits discounted to the prices when the economic evaluation is conducted and generated every year throughout the period subject to the economic evaluation.

$$B = \sum_{t=0}^{S+49} \frac{b_t}{(1+r)^t}$$

B_t: annual benefits generated in year t, r: discount rate (i.e., 0.04), S:an improvement period (year)

(2) Residual values discounted to the prices when the economic evaluation is conducted.
The residual values of a flood control facility as of the end of the period subject to the economic evaluation should be calculated along with the following procedures;

1) River channels
●Levees and low flow channels which are not structures (C^1_{S+50})

$$C^1_{S+50} = \frac{\sum_{t=0}^{S-1} c^1_t}{(1+r)^{S+49}}$$

C^1_{S+50} : construction costs to be incurred every year except for costs of land, compensation costs, indirect costs and miscellaneous costs for construction
r: discount rate (i.e., 0.04)

(Note) It is assumed that the functionality of a flood control facility won't decrease, if it were adequately maintained. Therefore, it is also assumed that the asset values of a flood control facility won't decrease until the end of the period subject to the economic evaluation.

●Structures such as revetments (C^2_{S+50})

$$C^2_{S+50} = \frac{0.1 \times \sum_{t=0}^{S-1} c^2_t}{(1+r)^{S+49}}$$

C^2_{S+50} : construction costs to be incurred every year except for costs of land, compensation costs, indirect costs and miscellaneous costs for construction
r:discount rate (i.e., 0.04)

(Note) In this manual (draft), it is assumed that the residual value of a flood control facility as of the end of the period subject to the economic evaluation will be 10% of total project cost.

2) Dams (D_{S+50})

$$D_{S+50} = 0.9(1-\frac{50}{80}) \times \frac{\sum_{t=0}^{S-1} d_t}{(1+r)^{S+49}} + 0.1\frac{\sum_{t=0}^{S-1} d_t}{(1+r)^{S+49}}$$

dt : construction costs to be incurred every year except for costs of land, compensation costs, indirect costs and miscellaneous costs for construction.
r:discount rate (i.e., 0.04)

(Note) Dams should be depreciated by the straight line method for their legal durable period.

3) Costs of land (K_{s+50})

$$K_{S+50} = \frac{\sum_{t=0}^{S-1} k_t}{(1+r)^{S+49}}$$

k_t : the costs of land that will incur every year,   r: discount rate (i.e., 0.04)

4.6 Other benefits

If the following benefits are quantifiable in the economic evaluation on individual rivers, they should be evaluated as the benefits of a project.   But attentions are required not to conduct double evaluation.

- ●Interrupted house works in normal times
- ●Emergency response costs borne by the government and prefectural / municipal governments
- ●Rippled-off damage due to traffic disruption
- ●Rippled-off damage due to termination of lifeline services
- ●Rippled-off damage to business establishment located in the surrounding areas of an affected area due to disrupted activities of affected businesses
- ●Damages to human bodies such as loss of lives
- ●Damages to underground commercial malls
- ●Risk premium
- ●Intensification benefits

[Explanation]

As was mentioned in 4.1, out of the direct and indirect damage caused by flooding, only the effects to prevent currently economically quantifiable damage are evaluated as benefits in this manual (draft). Accordingly, there still exist the benefits that haven't been quantified and the evaluation of intensification benefits has never been conducted.

About the benefits listed in the above box, if they were quantifiable in the economic evaluation on individual rivers, it is not precluded to evaluate them as the benefits of a project in the economic evaluation.   But attentions are required not to conduct double evaluation.

If possible, we should try to take into account these benefits in a benefit calculation of the economic evaluation in the future based on the experience with such evaluations and advancement of evaluation techniques. By doing so, further improvements will be pursued.

Other underlying concepts of benefits and the points to be kept in mind in the economic evaluation are as follows;

4.6.1 Disrupted house works in normal times

The effects to prevent the disruption of household activities in normal times (including house works and leisure activities) can be evaluated as the benefits of a project.

[Explanation]

(1) It becomes difficult for affected households to continue their ordinary lives because they need to relocate their affected household properties to safe places and to cleanup disaster waste or to tidy things up ex-post. They temporarily lose their ordinary life styles. Accordingly, the effects to prevent such damage can be considered as one of the benefits generated by flood control.

(2) In the past investigation, the value of people's ordinary life is represented by the sum total of their production value and consumption value. To decide the production value, it is required to find first out the number of hours dedicated for ex-post house works and then, find out the unit price of the work hour with reference to a by-occupation wage list. The consumption value is the household expenditures for leisure activities. Finally, the damage caused by disrupted ordinary house works is calculated by multiplying these per-day unit prices by the number of days affected (defined by inundation depth) .

(3)However it is difficult at present to establish these unit prices because the number of the cases investigated is still small. In addition to that, there still remains a room for discussion on the methodology applied to define the values when we consider house works as production. That is why the standard methods for calculation of such values are not shown in this manual.

4.6.2 Emergency response costs borne by the national government and prefectural / municipal governments

The emergency response costs borne by the national government and prefectural / municipal governments can be evaluated as benefits.

[Explanation]

(1) The emergency expenses borne by the national government and prefectural / municipal governments include the interests of various emergency loans, disaster relief money and the expenses required for disposal of disaster wastes/ ex-post cleanup activities. Also, if the tax rate and the premiums of national pensions are temporarily reduced, these represent the decrease in the revenues of the national government and prefectural / municipal governments, even though the national government and prefectural/ municipal governments do not make any payments for them.

(2) It is possible to find out the actual amount of the emergency response costs (or damage), if the national government and prefectural/ municipal governments conduct researches based on related reference materials or through interviews following a flood disaster. But as a lot of works will be required for such efforts and the actual amount of emergency response costs (or damage) will vary depending on the socio-economic characteristics of affected areas and the magnitude of a flood disaster, it is difficult to establish their standardized unit prices right at this point.

4.6.3 Ripple-off damage caused by traffic disruption

The ripple-off damage caused by road traffic disruption can be evaluated as benefits.

[Explanation]

(1) If roads and railways are inundated or are damaged due to the hydraulic actions of water stream, the road traffic in affected areas will be disrupted and damage will be inflicted in the neighboring areas.

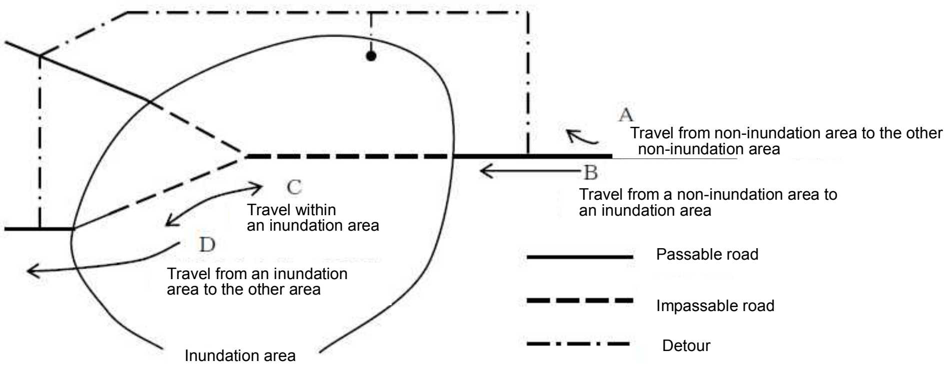
(2) Theoretically, it can be considered to evaluate the additional costs incurred by making a detour as damage.

(3)The method to calculate the amount of damage caused by detours is shown in the Manual for Cost-Benefit Analyses on Roads (draft). If the volume of detour traffic could be estimated based on the volume of traffic in normal times in a flood area, the damage caused by detours can be calculated by the method. The period to close roads can be determined based on the number of days inundated with reference to the past records of traffic disruptions in an affected flood plain during past flood disaster events.

The amount of damage = time-loss + distance-loss

Time-loss = ΣΣ時 (リンク 車種) basic unit of time value × (time requires for detouring × the number of cars - normal travel time before flooding × the number of cars)

Distance-loss = ΣΣ時 (リンク 車種) (basic unit of driving costs for detouring × detoured distance × the number of cars – basic unit of driving costs in normal times × driving distance in normal time × the number of cars)



[The volume of traffic is divided into the above A～D. It is required to take into account the above A and B in these calculations so as to avoid double evaluation with that for damage caused by disrupted activities of establishment.

Fiture-4.5

(4) The damage to the businesses in an inundation area caused by traffic disruptions is calculated separately in the evaluation of the indirect damage caused by disrupted activities at business establishments. Accordingly the traffic volume of the businesses affected by traffic disruptions must be excluded from the total traffic volume determined based on Road Traffic Census and so on, in order to avoid double evaluation.

(5) In addition to road traffics, it can be further considered to evaluate as damage the additional travel costs incurred due to inundated public facilities such as airports.

4.6.4 Ripple-off damage caused by the suspension of lifeline services

The ripple-off damage caused by the suspension of lifeline services such as electricity and gas can be evaluated as benefits.

[Explanation]

(1) When lifeline services such as distribution of electric power, gas and so on are temporarily suspended due to flooding, flood damage will spread to near-by areas. It is difficult to develop the method for calculation of such ripple-off damage which is applicable nation-wide, because conditions may vary among inundation areas, such as how many companies providing lifeline services are located in an inundation area or how far their back-up systems are deployed.

(2)When these losses are evaluated through the interviews with public utility companies by area, attentions are required to avoid double evaluation with the indirect damage caused by disrupted activities at business establishments. (If material damage is evaluated also through such interviews, attentions are required to avoid double evaluation with the indirect damage to large-scale public facilities.)

4.6.5 Ripple-off damage to business establishments in neighboring areas due to disrupted activities at affected business establishments

The ripple-off damage caused by decrease in the production level at near-by business establishments due to disrupted activities at affected business establishments.

[Explanation]

(1)There might be the cases when the activities of certain businesses are disrupted due to flooding, and their partners located in neighboring areas may also be forced to stop their business activities.

(2) ①To begin with, the cost-effectiveness analyses undertaken in the economic evaluation assume the whole society as a perfect market. From the view points of the national economy, such secondary ripple-off damage will be offset by the productions of other areas and should not be included in the benefits of flood control. But there is another opinion on this. ②If you look at the actual status of flood damage, it can be assumed that such secondary ripple-off effects are generated for a relatively short period of time within an limited area. Accordingly, if the extent of such ripple-off effects can be limited to a basin or a certain prefecture, it will be allowable to evaluate them as the benefits of flood control.

(3) Therefore, only when there is an affected company that produces special products that can be produced only in an affected area and cannot be replaced by the products manufactured in other areas, the ripple-off damage caused by disrupted activities at business establishments can be evaluated as a damage prevention benefit in the economic evaluation. Even when that is not the case, the information on the ripple-off damage would be able to be used as a piece of information which is useful when a flood control project is conducted.

(4)In specific, the method combining Inter-Industry Relation Table and Linear Programming Method might be applied for the evaluation. But due to some issues of Inter-Industry Relation Table including the assumption that the businesses classified in the same industry classification have no business connections, the resultant damage calculated with this method will be by far underestimated as compared with the realities of the situations of such damage.

(5) But if a large-scale flood event occurs, the input-output relationships across various industries will change and the efforts extended to conduct the analyses based on industry related models may become useless. Accordingly, it is required to pay an attention to such possibilities.

4.6.6 Damage to human bodies including loss of lives

The effects to prevent loss of lives and psychological damage can be evaluated as benefits.

[Explanation]

(1) Damage to human bodies can be roughly calculated by means of such as the Hoffman's method to evaluate lost benefits. But as death tall is influenced by some natural factors (such as time when a flood event occurs) and social factors (such as the issuance of an evaluation warning), it is difficult to estimate such damage.

(2) Researches on the psychological damage caused by disasters were conducted in the past, but the data obtained in such researches were unstable on the one hand, and hold the issue of double evaluation with other types of damage items, on the other hand.

4.6.7 Damage to underground malls

In the area where underground malls are actively developed, the damage caused by the inundation of underground malls can be evaluated as benefits by use of the damage rates that take into account the characteristics of the area such as geomorphology.

[Explanation]

(1) If the damage rages that are conventionally used were applied for calculation of the damage to properties kept in underground malls, the damage will be by far underestimated. Accordingly, it is necessary to develop the damage rates that take into account the characteristics of an area such as geomorphology.

(2) As the mesh data used for this calculation are treated as the 2D data that combines the data of above-the ground areas and those of underground malls, attention is required to handle such data so as to avoid double-counting.

4.6.8 Risk Premium

The effects that prevent devastating flood events can be evaluated as benefits.

[Explanation]

A flood control project has the effects not only to prevent physical damage and damage to human bodies, but also to dispel uneasiness felt in some uncertainties that "if a flood event occurs, we may suffer from enormous damage". For instance in general, residents make due efforts so as to alleviate their anxieties over the possibilities that they may be affected by a disaster event in the future by installing watertight doors or purchasing non-life insurance. If the improvements of flood control facilities can alleviate such residents' anxieties, such effects generated by the improvements of flood control facilities should be converted to monetary terms and should be evaluated as benefits of a project, in addition to expected amount of damage reduction. Risk premium represents the monetized values of residents' anxieties over the possibilities that they may be affected by a flood disaster in the future.

The following two methods may be used to evaluate risk premiums as benefits;
①Applying lower discount rate than those for other public work projects
②Increasing expected damage reduction proportionally in a certain rate.

(1) It is determined that the social discount rate applicable to all cost-effectiveness analyses of the public work projects directly managed by the Ministry of Land, Transportation, Infrastructure and Tourism be 4%. Therefore, it would be difficult to apply a lower-than-4% discount rate only for flood control investments.

(2) So as to prepare for extra expenditures or the flood damage worth more than the expenditures actually incurred for a predicted flood disaster, the expected amount of damage reduction is increased at a certain rate. It can be considered to increase the expected amount of damage reduction proportionally by applying the magnifying power ε used by non-life insurance companies that is calculated using the ratio of premium income to premium payment (i.e., the mark up ratio of insurers) that takes into account insurance subscription rate. But careful discussions will be required on the detailed data of non-life insurance companies required to obtain magnifying power ε and on the damage items to increase proportionally by means of the magnifying power ε .

(Reference)
Professor Yukio Noguchi, Research Center for Advanced Science and Technology, The University of Tokyo told during the seminar on economy held on March 1982;

1) "When it is expected that a certain project will reduce some risks (or will remove risks entirely) in a system including certain risks, such a project should be evaluated with lower discount rate than the expected marginal efficiency which is applied to more general investments. "

2) "The benefits generated in "critical conditions" should be evaluated by use of the so-called "shadow prices" that are higher than general market prices."

3) Furthermore, in addition to the before mentioned project for levees, there are the public investments in which this sort of treatments are justified. They are disaster prevention projects including forest conservation・flood control dam construction projects, a damage preservation forest project, a storm surge protection project and a countermeasure against an earthquake disaster. The common characteristic of these projects is that they bring about effects when economic activities as a whole are depressed (i.e., in a critical condition).

4.6.9 Intensification benefits

When the market prices of land go up due to changes in land use following improvements of flood control reliabilities, such price hikes can be evaluated as intensification benefits.

[Explanation]

(1)In addition to the before mentioned damage prevention benefits, increase in the market prices of land due to changes in land use can be evaluated as intensification benefits by estimating a land use model based on the relationship between the reliabilities of flood control and the status of land use.

(2)Intensification of land use is one of the original goals of a flood control project along with prevention of disaster damage. Theoretically, the present values of damage to be avoided in the future by implementation of a flood control project are reflected in the increases in the market prices of land, which are the base when intensification benefits are calculated. Therefore, the evaluation of intensification benefits could be double counting with disaster prevention benefits.

(3)When the land that was formerly designated as urbanization control area and was left to dilapidation or used only for farming becomes available for construction of houses as an urbanized area because reliabilities of flood control are enhanced by implementation of a flood control project, it would be possible to evaluate the increases in the market prices of such land as benefits. In this case, such benefits can be evaluated not only based on the increases in the market prices of such land, but also as damage prevention benefits in consideration of the future conditions of properties.

5. Calculation of costs

5.1 Costs to be evaluated

The costs of a flood control investment consist of the construction costs required from the start of a flood control project to the completion of a planned flood control facility, and the maintenance costs incurred during the period subject to the economic evaluation.

[Explanation]

In principle, when a river improvement plan is developed and a newly adopted river and/or dam project is evaluated/ re-evaluated, the economic efficiencies of these projects should be assessed based on the current conditions of the river channel to be improved. Therefore, the costs of a flood control investment consist of the future costs that will be spent to complete a planned flood control facility (the construction costs of a planned flood control facility, costs of land and compensation costs) and the maintenance costs that will be spent during the period subject to the economic evaluation (for the next 50 years following the completion of a planned flood control facility) (please refer to Figure-5.1 and 5.2).

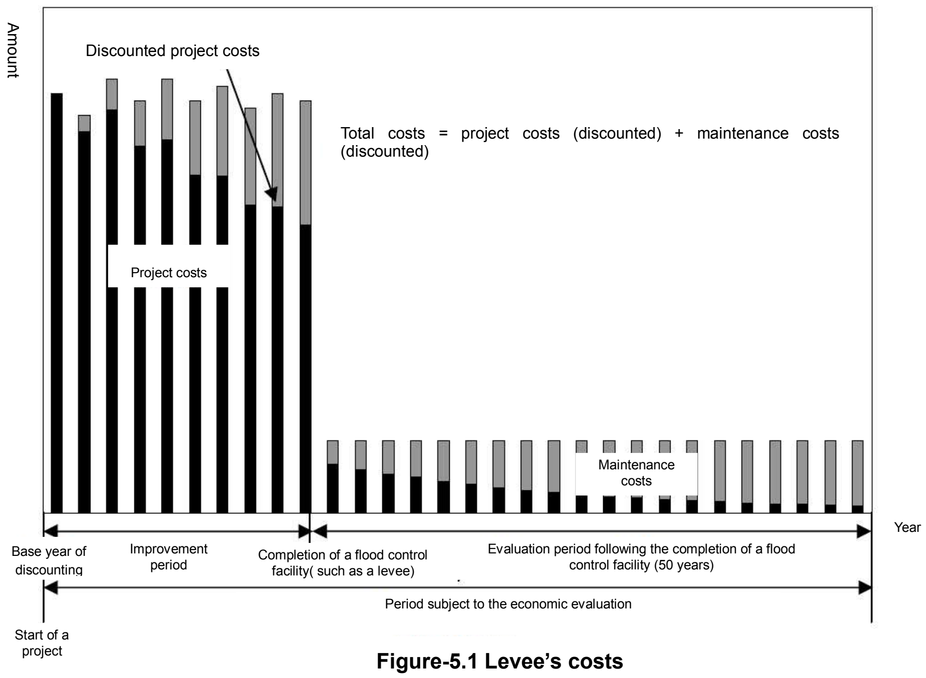


Figure-5.1 Levee's costs

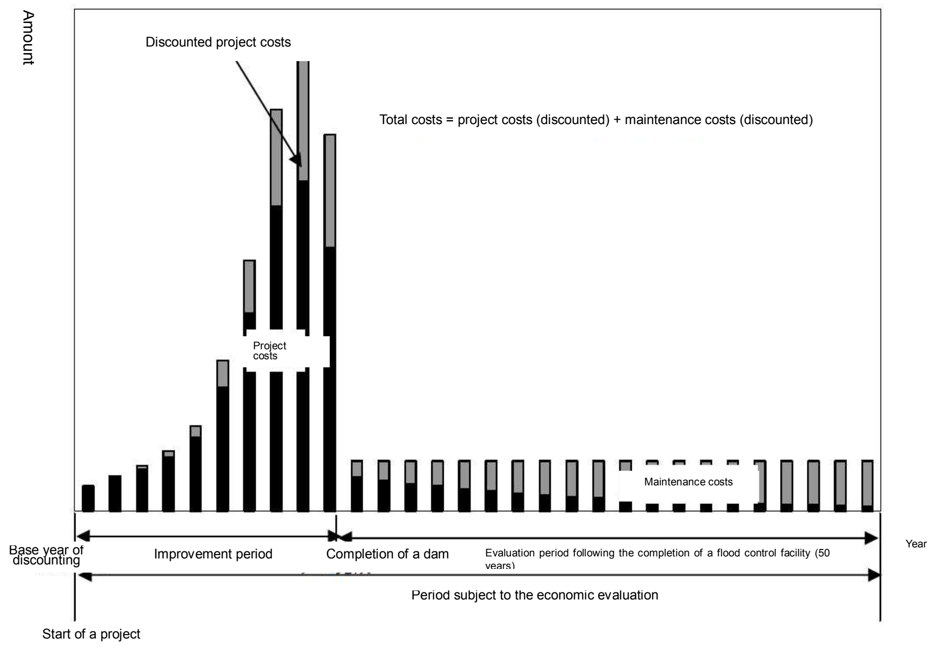


Figure-5.2 Dam's costs

However when a series of flood control projects have been conducted intermittently so as to improve the same river and it is necessary to evaluate them as a series, it may not be adequate in some cases to conduct the economic evaluation based on the current states of a river channel. If that would be the case, the evaluation should be conducted by regarding a string of such past flood control projects for the same river as a series. You can trace back to the point when it seems to be suitable to implement the economic evaluation and can conduct the economic evaluation based on the conditions of the river channel at that point.

In this case, the investments that have already made should be reviewed based on the records of past project' costs and should be discounted to the price when an evaluation is conducted.

5.2 Calculation of the costs incurred during an improvement period

So as to conduct the economic evaluation that takes into account the costs which will incur during an improvement period of a flood control facility, it is necessary to roughly decide a project period and an investment plan.

[Explanation]

When a specific investment plan (construction costs, an improvement period and the allocation of construction costs) are already decided, the calculation of each cost should be made accordingly.

However if it were not decided and only rough estimates of its construction costs were decided, an improvement period and the allocation of construction costs should be roughly decided with reference to past similar projects and then, the costs should be calculated.

5.3 Construction costs

In the evaluation to assess the current conditions of a river channel which is conducted at the start of a flood control project, the quantity of each work necessary to complete a planned flood control facility should be decided first, and the costs for these works should be estimated.

[Explanation]

As the costs of a flood control investment, the sum total of the costs for primary construction works, ancillary construction works (the costs borne by a river administrator), costs of land, compensation costs, indirect costs and miscellaneous costs should be calculated.

5.3.1 The cost for primary construction works

The construction costs directly related to the improvement of a flood control facility (costs for primary construction works) should be calculated by multiplying the quantity of construction works by its unit price.

[Explanation]

●The amount of necessary soil for embankment, for backward displacement of an embankment and for raising the height of an embankment should be calculated first. And then the costs for their primary construction works should be calculated by multiplying them by direct construction costs (per unit volume) calculated separately.

●About the costs for bank revetment works, the construction area should be calculated first. And then, the costs for its primary construction works should be calculated by multiplying them by direct construction costs (per unit volume) calculated separately.

●About the costs for river-bed excavation, the amount of soil to be excavated from the river-bed should be calculated first. And then, the cost for its primary construction works should be calculated by multiplying them by direct construction costs (per unit volume) calculated separately. When the unit price is decided, the costs to carry excavated soil out and the costs for its disposal should be taken into account.

●About the costs for construction of a multi-purpose dam, the costs for its primary construction works should be calculated by multiplying the approximate amount of project costs by the percentage of the cost burden to be assigned to a flood control project that is calculated in a sample calculation of a project cost allocation.

●About the costs for construction of a detention reservoir, the costs for embankment and moat should be calculated based on the above methods. The costs for sluicing outlets should be calculated with the methods described below.

●About the construction of a discharge channel, the costs for embankment and moat should be calculated based on the above method.

5.3.2 Costs for ancillary works

The construction costs accompanying the improvements of a flood control facility (costs for ancillary works) should be calculated by multiplying the number of sites requiring such works by unit price or the total length of such sites and unit price.

[Explanation]

Only the costs borne by a river administrator should be totaled. When it is not appropriate to assume that all the costs for ancillary works will be paid only by a river administrator, the costs that are not considered to be borne by a river administrator should be excluded from the total.

●The number of sites requiring replacement works should be calculated first by road bridge, railroad bridge and aqueduct bridge. Then, the cost for such ancillary works should be calculated by multiplying them by a renovation cost per site.
●First, the number of sites of weirs, sluice and sluice pipe requiring renovation should be calculated. And then, the cost for such ancillary works should be calculated by multiplying them by a cost per site.

●The number of sites requiring the construction or renovation of a water lifting/ drainage facility should be calculated first. For a waterway, the total length of a waterway requiring renovation of a water lifting/ drainage facility should also be calculated in advance. Then, the costs for such ancillary works should be calculated by multiplying them by a cost per unit length.

●The length (or area) of a road requiring replacement should be calculated first. And then, the cost for such ancillary works should be calculated by multiplying them by a cost per unit length.

●Out of the ancillary works that are not described in the above, costs of the types of ancillary works which are essential to ensure the preciseness of cost calculation should be estimated by site and by type of work.

5.3.3 Costs for land

The costs for land should be calculated by multiplying the size of land required for a project by its market price.

[Explanation]
The size of land required for improvements of a flood control facility should be calculated first. And then, the costs for land should be calculated by multiplying it by its market price.

5.3.4 Compensation costs

The compensation costs for relocation and so on should be calculated based on their recent examples.

[Explanation]
The unit prices of a compensation costs should be calculated first based on their recent examples. And then the compensation costs for relocation and so on should be calculated by multiplying them by the quantity to be compensated.

5.3.5 Indirect costs

The indirect costs should be 30% of the sum total of primary work costs and ancillary work costs.

[Explanation]
The indirect costs should be calculated to be 30% of the sum total of primary work costs and ancillary work costs. If there are separate figures that are specific and reflect the current status of individual rivers, it is also possible to use them for calculation of indirect costs.

5.3.6 Miscellaneous construction costs

The miscellaneous construction costs should be calculated to be 20% of the sum total of primary construction costs, ancillary construction costs, costs for land, compensation costs and indirect costs.

[Explanation]

The miscellaneous construction costs should be calculated to be 20% of the sum total of primary construction costs, ancillary construction costs, costs for land, compensation costs and indirect costs. If there were separate figures that are specific and reflect the current status of individual rivers, it will be also possible to use them for calculation of miscellaneous construction costs.

5.4 Maintenance costs

The maintenance costs that will incur during the period subject to the economic evaluation are divided into two parts; fixed cost that will incur every year during the period and one-time/ regular costs such as costs for replacement of machinery. When the maintenance costs are calculated, these two parts should be calculated separately.

[Explanation]

●In principle, the maintenance costs should be estimated for the next 50 years following the completion of a planned water control facility. They are divided into two parts; fixed maintenance costs that will incur every year such as costs for weeding, and one-time/ regular maintenance costs such as costs for operation of a pump and periodical (e.g., every 10 years) replacement costs of equipment.

●When it is difficult to conduct the above calculations, you can calculate the ratio of construction costs to maintenance coasts based on past project records. By use of this ratio, you can estimate the maintenance costs of a project which will incur steadily for the next 50 years.

5.5 Total costs

The total costs should be the sum total of project costs and maintenance costs.

[Explanation]

The total costs for a flood control project should the sum total of its project costs and maintenance costs which are discounted to the price when an evaluation is conducted.

$$C = \sum_{t=0}^{S-1} \frac{c_t}{(1+r)^t} + \sum_{t=S}^{S+49} \frac{m + M_t}{(1+r)^t}$$

S: an improvement period, C_t: project costs that will incur every year, m: maintenance costs that will incur steadily every year, M_t: maintenance costs that will incur unexpectedly or regularly, r: discount rate (should be 0.04)

6. Evaluation of economic efficiency

6.1 Costs and benefits to be compared

In the economic evaluation for flood control investments, total costs should be compared with the benefits to be generated in proportion to investments (i.e., costs) made.

[Explanation]

For instance as you can see in Figure-6.1, a single flood block is divided into 4 parts, and each part has its own levee. C_1-C_4 projects are planned for each levee..

The flood damage when the levee constructed in each part is independently breached and inundated is represented by B_1-B_4. The status when the evaluation of a river improvement plan and the evaluation/ re-evaluation of a project for rivers and dams are undertaken is represented by $\Sigma B_i / \Sigma C_i$ (B_i and C_i are limited to the ranges on which the effects of a project (or benefits) have some impacts.)

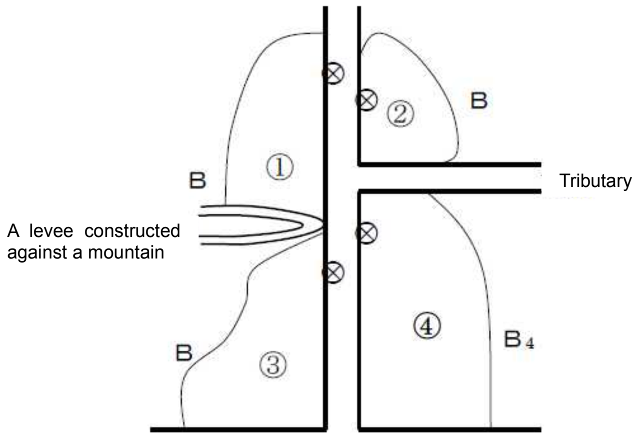


Figure-6.1 Costs and Benefits to be compared

Calculations on flooding should be undertaken by setting one levee failure point to each part. And then, a cost-effectiveness analysis should be conducted by comparing the total costs and the total benefits obtained from the calculations. Here is the reason in doing so;

①In an actual flood control project, a flood control facility is improved so that the facility will be able to endure basic design floods in each flood block. Therefore, so as to ensure the consistency between cost and benefit, applying the above calculation methods to a cost-effectiveness analysis is adequate.

②One opinion says that the benefits of a flood control project shouldn't be just the sum total of benefits generated in each flood block and they should be weighted by inundation area, because it is quite rate that a flood event occurs in each inundation block simultaneously. But since a flood event is a natural phenomenon, it is difficult to specify the probability of a levee failure (Further discussion would be required in the future on this point).

6.2. Methods to review the results

A series of discussions should be orderly described in the formats attached at the end of this manual.

[Explanation]

A series of evaluation results should be orderly described in the formats attached at the end of this manual. These forms are developed so that the processes, conditions and results of a series of discussions shall be examined and archived for future use and it is not necessary to stick to the details of each format. Where necessary, you can change the layout, style or items included in these formats. In principle, the data and calculation methods used for a cost-benefit analysis should be disclosed.

6.3 Evaluation indices

In principle, the economic efficiency of a specific project should be evaluated in cost-benefit analyses. Their Net Present Value should also be calculated in the analyses.

[Explanation]

The evaluation indices used in a cost-benefit analysis generally include Cost Benefit Ratio, Net Present Value and economic internal rate of return. In principle in a cost-benefit analysis, Cost Benefit Ratio (B/C) should be calculated, but as reference, net present value should also be calculated. It is not precluded to calculate economic internal rate of return in this manual (draft).

Table-6.1 Major economic indices of a cost-benefit analysis and their features

Indices for the evaluation	Definitions	Features
NPV: Net Present Value	$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^{t-1}}$	• Possible to compare the size of net benefits generated by implementation of a project. • Will be influenced by the social discount rate applied.
CBR: Cost Benefit Ratio ※hereinafter referred to as "B/C"	$\frac{\sum_{t=1}^{n} B_t /(1+i)^{t-1}}{\sum_{t=1}^{n} C_t /(1+i)^{t-1}}$	• Possible to compare the efficiency of the investments of a project by comparing the size of benefit per investment. • Will be influenced by the social discount rate applied. • When this economic index is used for comparing project alternatives, it should be carefully considered if each cost items (operating cost, maintenance cost and so on) should be evaluated as benefit or as cost.
EIRR: Economic Internal Rate of Return	$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i_0)^{t-1}} = 0$ i_0 can be describe in the above formula.	• Possible to judge the efficiency of the investments of a project by comparing it with the social discount rate applied. • Won't be influenced by the social discount rate applied. applied.

N: the period subject to the economic evaluation, B_t: benefits generated year $_t$, C_t: benefits generated in year $_t$
i: social discount rate