The Necessity of Understanding the Levels of Water Safety in Small and Medium Waterways

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1. Foreword

Flood damage is becoming an increasing problem in all regions in recent years, and the severe damage being caused by small and medium-sized waterways that are easily affected by heavy downpours is especially noticeable. In addition to reawakening an awareness of the fact that water maintenance standards for small and medium waterways are still insufficient, this also indicates new aspects of fluctuations in natural conditions, such as increases in the frequency of heavy rain and changes in the way that rain is falling, and societal changes, such as a lowering of our capability to cope with natural disasters brought about by the ageing of society.

Small and medium-sized waterways tend to be relatively longer in comparison with the large rivers that are directly administered by the central government. For example, a first class river system that comes under the administration of a prefecture may be anything up to a length of 77,000km. When considering this in relation to the new aspects mentioned above from a standpoint of protecting the lives and property of local residents, there is no question that placing as much emphasis on small and medium-sized waterways is as important as it is for the large-scale rivers.

On the other hand, the river administrators and the autonomous bodies in charge of local disaster-prevent measures must accept responsibility for working together to establish flood-control policies and crisis management policies that match up with local situations and be effective from both the software and hardware point of views, while at the same time dealing with the various related situations, such as balancing tight financial restrictions and ensuring the safety of not only main and subsidiary waterways, but also the upper and lower reaches of the rivers. However, the truth of the matter is that there is a lack of fundamental information on flow capabilities and other data owing to large lengths of waterways being overlooked when it comes to measurement surveys that gauge longwise and crosswise channels, water levels, flow rates and other elements.

Amidst this background, the National Institute for Land and Infrastructure Management (NILIM) urgently established the NILIM Research Team into Measures for Evaluating the Maintenance of Small and Medium Waterways within the institute and set up a joint project with the River Bureau of the Ministry of Land, Infrastructure and Transport in order to develop a system for evaluating the flow capabilities of small and medium-sized waterways, as is shown in Figure 1, and we also implemented the evaluation of flow capacities in first class rivers spread throughout the entire country and that come under the jurisdiction of prefectural governments in collaboration with various Regional Development Bureaus and other related bodies.

When it comes to evaluating the flows of small and medium-sized waterways, the shortage of fundamental data, as mentioned above, erects a critical barrier. Owing to this, it was decided that instead of the traditional data collection and analytic procedures, we should use an emergency passing grade strategy. In other words, we aimed at developing a consistent method that would be inexpen-

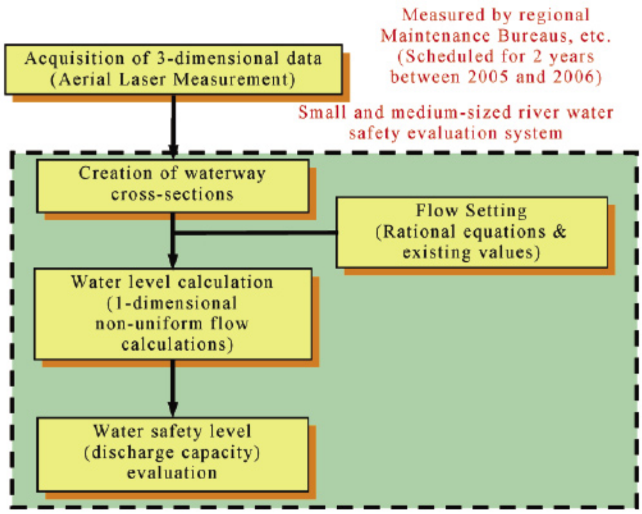

Figure 1 Small & Medium-Sized River Water Safety Evaluation Flow

1. This article has been presented by the group leader under the organization of the team dedicated to its creation, but all of the following team members (including previous members) contributed to its authorship.
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sive, effective and simple as well as being available for practical use within a few years at the most, and that would have the minimum accuracy level required by flood control policy inspections for evaluating the flow capabilities of waterways that stretch to the lengths mentioned above. Details on how this was achieved will be explained later.

The system that was developed, together with all related technical details, is scheduled to be made public for the purpose of promoting the evaluation of flow capabilities in as large a number of small and medium-sized waterways as possible, which will en-able the use of evaluation results once the technical meaning of "passing grade" has been fully compre-hended, and which will enable evaluations to proceed with high scores if and when necessary.

2. Eliminating Blank Areas in Waterway Land Form Data Using Aerial Laser Measurements

(1) Significance of Using Aerial Laser Measurements

It is a sad fact that we have had little success in surveying river channels in small and medium-sized waterways because the areas that can be used for examining flood control policies are restricted to fully-developed areas. In order to solve this problem and eliminate blank areas, we will be using aerial lasers that can easily obtain high-density data on wide geographical areas.

As shown in Figure 2, aerial laser measurement is a technology that acquires three-dimension land form data by shooting laser pulses into the air from an aerial laser scanner mounted in an aircraft, and then analyzes the laser pulses that are bounced back. There are great hopes that three-dimensional data will provide various types of information, including the shape of cross-sectional river channels and floodplains.

This evaluation system complies with the stipu-lations laid out in the Policies for Three-Dimensional River Channel Maps and Basins Using Aerial Laser Measurements proposed by the Ministry of Land, Infrastructure and Transport in June 2005, and satisfies the minimum conditions of 2m pitch for the laser measurement density, which is a prerequisite for the measurement data.

(2) Importance of Filtering when Generating Three-Dimensional Land Form Data

In order to obtain three-dimensional land form data of river channels that can be used for discharge capacity evaluations, it is necessary to remove all of the unnecessary elements that could cause problems during the discharge capacity calculations from the original data from which noise has been eliminated, and create high-density ground data. This process is known as filtering, and the difference between good selections and bad selections in the filtering method for removing the unwanted elements has a huge effect on accuracy.

First of all, the filtering process is run automatically on the original data with a program that targets the entire range of the measurement data in search of the major unwanted elements listed in Table 1, the data after automatic filtering is then compared against the Ortho image and the unwanted elements removed (manual filtering) from the area of the waterways (ground items, such as structures and trees, etc.,) and the high-density ground data is then created.

Table 1 Major Filtering Items (proposed)

Transportation Facilities	Road Facilities, etc.	Road Bridge (length 5m or longer,) Overhead Pass, Pedestrian Overpass
	Railway Facilities	Railway Bridge (length 5m or longer,) Overhead Pass (including overhead monorail lines,) Link-line Bridges
Foliage		Trees Bamboo forests

(3) System for Creating Cross-Sections of River Channels

Using a Triangulated Irregular Network (TIN) model to

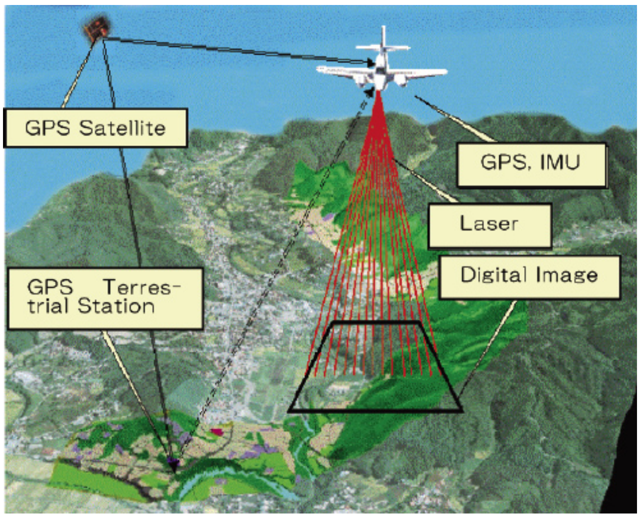

Figure 2 Conceptual Image of Aerial Laser Measurements

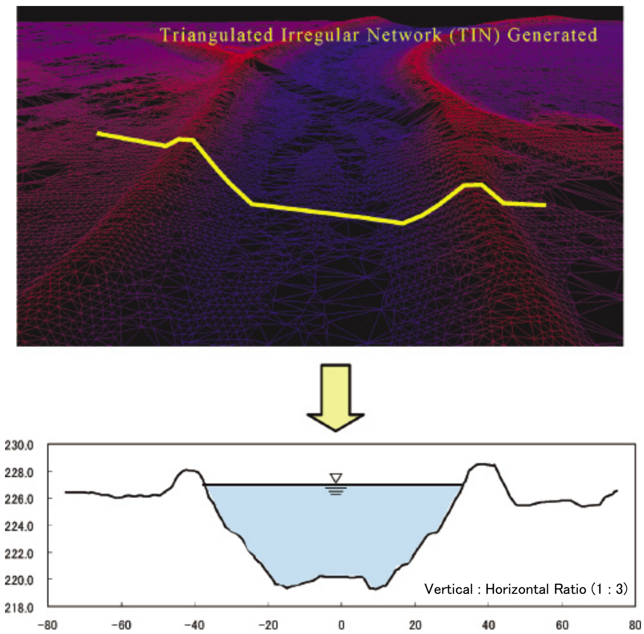

Figure 3 Creation of Cross-Sectional River Channel Maps with TIN Data Evaluation Flow

create cross-sectional maps of river channels concisely and mechanically, we developed a system that automatically acquires the elevation over a random cross-sectional measurement line that cuts across a line that marks the center of the river channel with the Triangulated Irregular Network created from the laser data, as can be seen in Figure 3

(4) Considerations for Improving the Accuracy of Cross-Sectional River Channel Data

Apart from the discrepancies that occur with the aerial laser measurements themselves (reliance is placed on the measurement equipment and measurement implementation conditions, etc., but discrepancies of ±30cm for horizontal accuracy and ±15cm for vertical accuracy generally occurs) when acquiring the cross-sectional maps of river channels mentioned above, it is thought that the following four discrepancies also arise during the process of creating the cross-sectional maps.

- Discrepancies that occur through analyzing blanks in laser data.
- Discrepancies that occur with interpolation from the TIN data.
- Discrepancies that occur with land element fil-tering.
- Discrepancies that occur because water surfaces cannot be measured.

In order to minimize these discrepancies, methods of using mostly winter measurements that are not so badly affected by foliage growth, and carrying out accuracy checks, correction and interpolation with the use of river channel measurement cross-sections when they are available are being considered.

3. Methods of Measuring Flow and Water Levels of Waterways for which no Detailed Waterway Plans are being Investigated

(1) Basic Concept

We have an excellent opportunity to use the results listed in waterway maintenance policies, waterway maintenance plans, overall plans and other documentation that are based on the models required for actual water flow and water level calculations by probable scale and the actual measurement data based on the hydrological parameters that these models use if they are available for the waterways in question. However, there are many cases with small and medium-sized waterways where this information is not available, so the problem of how to measure water flow and water levels when no data on the results of detailed waterway investigations exist is a large one.

Owing to this and in response to the passing grade strategy, we decided to apply simple calculations that that do not rely on the fixed constant identifiers used with actual measurements. In consideration of the fact that detailed investigations will be carried out independently when necessary in the future, we decided that it was necessary to create a foundation for calculating discharge capacities of small and medium-sized waterways at the very least that could be used throughout the entire country on a common basis as quickly as possible.

In more detail, this is a simple method of calculating one-dimensional non-uniform flow with probable scale flow volume calculations acquired with precipitation intensity equations for all areas of the country created through a unified method based on Amedasu rainfall data and rational equations. When dams and other facilities for regulating flood water existed in the area, we applied the maximum amount of flow discharge to the dam discharge data, and intend to reflect the results of this separately.

(2) Precipitation Intensity r

This uses the Amedasu Probable Precipitation Calculation Program developed by the Public Works Research Institute, an independent administrative agency (http://www.pwri.go.jp/jpn/tech_inf/amedas/top.htm). This program creates the following pre-cipitation intensity equation (Fair equation) based on precipitation recorded between 1971 and 2003 in 748 of the approximately 1,300 Meteorological Agency's Amedasu measurement locations positioned throughout the entire country.

$$r_t^T = \frac{bT^m}{(t+a)^n}$$

In this equation r_t^T is the probable amount of rainfall (mm/hr) falling for t number of consecutive hours in the year T, T is the probable year, t is the number of consecutive hours (hr) the rain will fall, and a, b, m, n, are the Fair parameters. The time a flood is likely to occur in the rational equation is applied to t.

(3) Flow Coefficient f and Flood Arrival Time t in the Rational Equation.

The flow coefficient f used in the following rational equation is weighted average of the flow coefficient for each land use region (related to the area of each region,) and 0.7 is set for mountainous areas and 0.9 is set for flat areas in accordance with the Waterway Erosion Prevention Technology Standards. The area of mountainous areas and flat areas are acquired through actual waterway surveys.

$$Q_p = \frac{1}{3.6} frA$$

In this equation Q_p is the flow at the peak of flooding (m^3/s), f is the flow coefficient, r is the precipitation intensity within the time that flooding occurs (mm/h), and A is the area of the flow region (km^2). The method of calculating the time of flood arrival can be made with either the Kraven equation, the Sumiya equation, or the Doken equation whichever is the most suitable.

(4) Calculation of One-Dimensional Non-uniform Flow and Roughness Coefficient n

Although the calculation methods for water levels that can be reflected back on the relative amount of information available on details on river channels, including riverbed materials and foliage within the area of the river, as well as the complex and characteristic flood flows can be applied practically, a large amount of time is required to accumulate this data. Owing to this, in order to make the best possible use of the afore-mentioned aerial laser measurements, the water level calculations from the waterway cross-sectional data explained earlier can be used without modification if a rough coefficient calculated from one-dimensional non-uniform flow calculations that use a single composite rough coefficient in the cross-section is applied to each section. However, as small and medium-sized waterways tend to have many steep slopes, it has been designed so that calculations related to a combination of tranquil flows and rapid flows can also be used if necessary.

In cases like this, the method of applying the rough coefficients that include all necessary elements of the river channels is extremely important. We consequently decided to select 58 rivers for which the rough coefficients are estimated from actual measurements for even small and medium-scale rivers, and analyzed the tendency of the rough coefficients to discover the common denominator for the component rough factor of small and medium-sized rivers, and calculated river levels based on this.

4. Expressing Flood Control Safety (Discharge Capacity,) etc.

By evaluating discharge capacities acquired from the results of the water level calculations indicated in Figure 4, we intend to create flood safety evaluation maps for every river, city, town, village and prefecture similar to those shown in Figures 5 and 6.

We intend to gather together the opinions of each local area and of each regional bureau and river control office in order to examine the thought-processes behind available budgets and local philosophies with regard to the waterways under their jurisdiction for the purpose of creating accurate flood-control evaluations, and this information will then be reflected back onto the processes of determining evaluations for levees and displaying the evaluations in an easy-to-understand way.

5. Conclusion

We are currently dedicated to putting the aerial later measurement system into practical use for each regional bureau in order to measure first-class river system throughout the entire country (109 river systems in total.) By providing all national research agencies with the results of laser measurements as they become available and by using this flood safety evaluation system, we will be able to implement flood safety evaluation of small and medium rivers within a minimal period of time.

Despite the tight fiscal conditions that have been prevalent in recent years, we hope that the results of this study will contribute to enhanced levels of understanding of flood safety in small and medium-sized rivers from an accurate and objective point of view, leading up to a situation in which we can eliminate the risk of flood disasters in areas with small and medium-sized rivers, and implement more effective methods of crisis management through the use of various technologies and unique methods.

River Name	Calculated Length	Probable Scale	Probable Precipitation	Probable Flow	Percentage of Length that Satisfies Discharge Capacities	
					Left Bank	Right Bank
A Waterway, B River	8.6km	1/10	46.7mm/60mins	400m^3/s	78%	85%

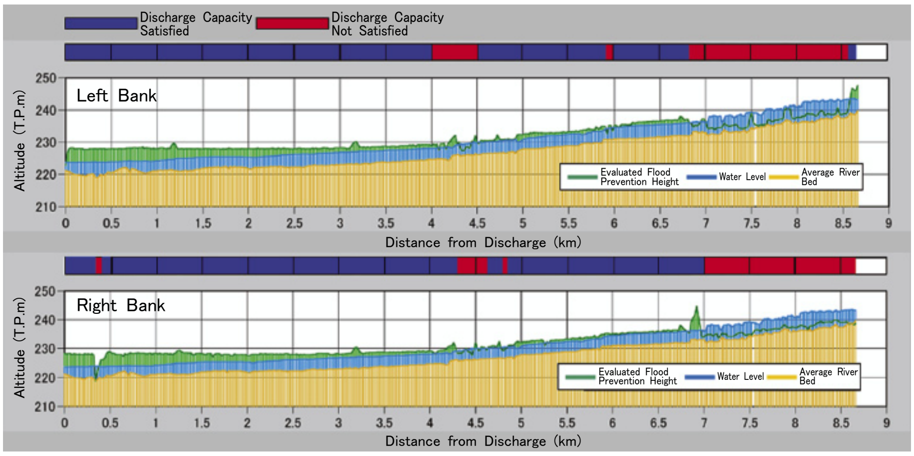

Figure 4 Simulation of the Relationship between Water Level and Evaluated Flood Prevention Height*

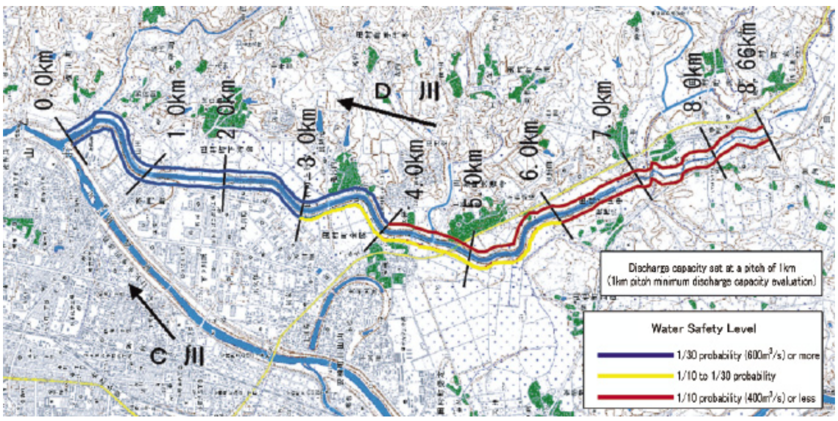

Figure 5 Expressing The Results of Water Safety Evaluations on Waterway Maps*

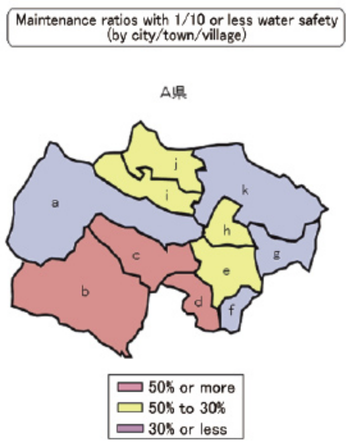

Figure 6 Simulation of Maintenance Conditions for Local Autonomous Bodies

* The images in Figures4 to 6 are only for reference purposes, and are not