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Development of the New Inspection Method on Scour Condition Around Existing Bridge Foundations

by

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ABSTRACT

In the past, investigation on the scour condition around bridge foundations in Japan has been conducted by the traditional method which is to measure a depth from water surface to streambed by using a standing bar on a boat. However, it has been difficult to measure the precise depth through this method. Then, PWRI has newly developed such the method that depth is measured by a radio-controlled boat with an acoustic analysis device and a personal computer analyzing data collected in combination with its location. According to the method, ups and downs of streambed around a pier can be two-dimensionally and precisely measured. The method based on the relatively simple principle for survey of the progressive condition at streambed during floods has also been developed.

1. INTRODUCTION

There has been a large amount of bridge stock in Japan as roads improvement has advanced positively. We should keep bridges in good condition for a long period in the future, which means that the operation and maintenance for bridges will become more important.

There are many kinds of causes such as major earthquake, floods scouring, ground movement and the others in terms of main damage of bridge foundations in Japan. We can point out that floods scouring is distinguished among these factors causing bridge failures or severe damages, and the most common cause which requires the repair or strengthening of bridge foundations is also from floods scouring. Consequently, it is absolutely necessary to investigate the scour condition as early and accurate as possible and to estimate the soundness of bridges in terms of keeping bridge foundations in good condition. The problem is, however, that it is generally hard to make a cost-effective investigation since scours occur under water.

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In this paper, the authors present current situation of scour investigation and innovative investigation techniques and monitoring equipments for scour developed by Public Works Research Institute (PWRI).

2. CURRENT INVESTIGATION FOR SCOUR

Scour investigation currently used for bridge foundations is shown in Photos 1 and 2 indicating a primitive technique in a manner using sounding poles or staffs to measure a streambed depth from a footing or a boat above water surface. This technique is not only in poor degree of accuracy, but also a dangerous work by itself. In the case that detailed investigation under water is required a visual inspection by divers is used together as shown in Photo 3. However, the combined method has a problem such that (1) investigations are hard and dangerous if flow velocity is so fast, and (2) they generally take much time and cost.

In order to solve these problems we should develop innovative techniques with safety and readiness for investigating scour condition

3. TECHNIQUES FOR INNOVATIVE SCOUR INVESTIGATION

First, the authors selected some sensors which were highly possible devices to be able to precisely measure the location of streambed as shown in Table 1, and then conducted applicability testings in advance of development of techniques for innovative scour investigation.

The result of applicability testings is shown in Table 2. Based on the result, we chose a fathometer instrument which can surely measure the location of streambed and require no professional knowledge on the interpretation of data collected. As the methods to investigate the location of streambed through sensors we decided to choose the following two techniques:

(1) a technique for wider investigation around piers

(2) a technique for simplified narrower investigation limited to vicinity of piers

With regard to an instrument of moving and holding a sensor, the former is the technique using a radio-controlled boat with a sensor and the latter, on the other hand, is the technique using a sounding rod with a sensor at its edge from a bridge deck.

3.1 Technique using RC boat

This technique consists of hardware and software for data storage and image processing as shown in Figure 1. The radio-controlled boat (hereafter RC boat) is

1.5 m long, 0.8 m wide and 20 kgf weight and is a hydrospace screw type using a gasoline engine (Photo 4).

The digital fathometer instrument and a telemeter which transmits to a receiver mounted near river by radio are on the boat. A laser-type total station is installed at the bank of a river and follows up the location of the RC boat (Photo 5). The data of the water depth and location of the RC boat are input automatically into a personal computer (PC) on which a trail figure usually is mapped out. Consequently, we can measure a wider range around piers.

When the data of the water depth and its location are input there may happen some troubles such as electronic noises due to unknown reasons and/or tracing errors of the RC boat, although these are repairable at an editorial stage. The investigation result shows us precise streambed condition around bridge piers using processing through PC, and the furthermore can draw figures of a two-dimensional contour line and a birds-eye view as shown in Figures 2 and 3.

We can conduct wider investigation of streambed condition around piers and estimate the soundness of bridge foundations against scour based on the location of piers and streambed conditions using these techniques.

3.2 Technique from bridge deck

This technique is to measure through a supersonic sensor mounted on the edge of a sounding rod from pavement of a bridge deck or an inspection scaffold on a bridge inspection vehicle and to investigate a limited area around piers different from RC boat investigation for wide area.

In the case of selecting devices we considered that they should be with a compact and light weight instrument and capability to deal promptly with investigation since the work is conducted from the bridge deck or the inspection scaffold on the bridge inspection vehicle. Furthermore, we tried to find configuration of streambed easily with display of an investigation result on a monitor screen with color image.

A brief introduction of a supersonic sensor (or a color-imaged sonar) which is selected based on the applicability testing is as follows.

Figures 4 and 5 shows an outline of the color-imaged sonar. First, a sonar head attached to the edge of a sounding rod is brought down from the bridge deck or the inspection scaffold on the bridge inspection vehicle until about 1 m under water, and then we can measure through going into a 360-degree roll of the sonar head.

An example of streambed profile displayed on the monitor screen is shown in Photo 6. By reason that the color-imaged sonar can measure one topographic profile only in every measurement, the investigation should be conducted measuring streambed conditions around piers using rotating the sonar around horizontally in every 30 degrees. If there may be dead angles due to pier's location we should measure with the location of a sonar moving. This system can draw a birds-eye view compiled by the software of image processing for RC boat technique. In the case of focusing on limited area of near pier the color-imaged sonar can collect more condensed data than other techniques.

4. SCOUR MONITORING EQUIPMENT

It becomes possible to precisely investigate scour conditions of streambed around bridge piers using two techniques above. However, these investigation techniques are useful only for normal flow condition and are useless in the case of a rapid current during floods condition causing scour. Furthermore, nobody can measure a maximum scour depth through investigation during normal floods condition since scour holes can be filled back with secondary sediments after floods. On this context, the authors developed another device which can measure degradation of streambed even during floods and also the maximum scour depth eliminated the effect of secondary sediments, and conducted its applicability-proved testing as well.

Figures 6 and 7 show outlines of two techniques indicating investigation manners at the testing as follows:

(a)Ring type
First, a supporting pipe is driven into streambed and then a ring with magnet are attached to the outside of the pipe on the streambed. The ring also can slide to the bottom as the level of streambed degrades downward due to scour. Maximum scour depth can be investigated through measuring a location of the ring using a movable magnet sensor inside the pipe.

(b) Electromagnetic type
A supporting pipe is driven into streambed and then sensors which can perceive the existence of magnet are attached to the inside of the pipe while magnets are arranged outside. If the magnets are destroyed by a flood, the sensor can recognize their location lost. The measured time-depending variation figure indicates the maximum scour depth.

With regard to scour monitoring equipments (Ring type and Electromagnetic type), it is necessary to confirm movability of sensing element, maintainability and reliability since they should be installed under water for a long period. Accordingly, applicability testings in laboratories were first conducted, and then they were installed at in situ bridge piers constructed near the center of stream after small improvements based on the testing. The investigation result on degradation conditions of streambed during flood are shown in Figure 8, which indicate that the progressive condition of the rapid streambed degradation more prompt than expected and deeply accumulated secondary sediments can be observed.

5. CONCLUDING REMARKS

In this paper, the authors propose several kinds of investigation techniques based on the office survey related to existing technologies and in situ applicability testing in order to develop techniques with safety and readiness for investigating scour conditions around bridge foundations.

All bridges in every country have the possibility of the occurrences of scour damages while there are many countries in which we don't need to pay attention to the effect of major earthquakes in bridge design unlike Japan or America in the world. The authors wish that investigation techniques and monitoring equipments proposed by them are put to practical use and to contribute to the cost-effective operation and maintenance for bridge foundations.

REFERENCES

1. M. Okoshi & J. Fukui, Present state of investigation technique for scouring, The Foundation Engineering & Equipment, pp19-21, vol.29, No.9, 2001.9.
2. Cooperative research report on development of measurement & diagnoses technique for bridge substructures, Public Works Research Institute, No.157, 1997.1.

Photo 1 - Conventional investigation technique for scour from a footing

Photo 2 - Conventional investigation technique for scour from a boat

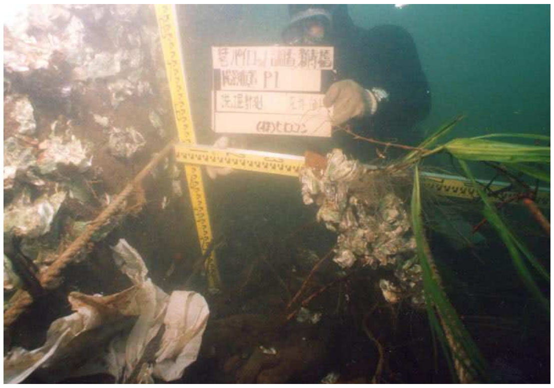

Photo 3 - Scour investigation technique by divers

Photo 4 - Outline of investigation using a RC boat

Photo 5 - Measurement of RC boat’s location by total station

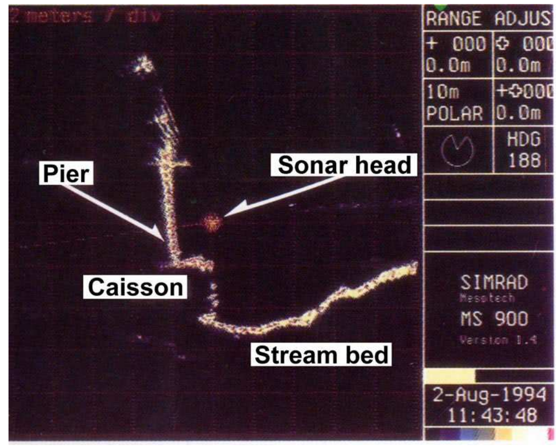

Photo 6 - Streambed profile measured by color-imaged sonar

Table 1 - Conventional Sensors

Principle	Sensor
Supersonic	Fathometer
Acoustic wave	Acoustic exploration
Electromagnetic wave	Underground radar
Non-confrontational	Electric exploration
Elastic wave	Seismic exploration
Resistance	Sounding
Magnetism	Magnetic logging
Light	Underwater camera

Table 2 - Applicability Testing

Sensor	Advantage	Disadvantage
Supersonic	• can measure the distance to streambed immediately. • can repair data destroyed easily	shall be moved because the sensor can measure forward only.
Underwater camera	Visual inspection of structural members underwater and streambed condition	Scope is limited. Result depends on the turbidity of a river.
Acoustic wave	can investigate the secondary sedimentation layer and geological structure.	Energy damping becomes large in the certain river condition.
Elastic wave	(ditto)	(ditto)
Electromagnetic waves	(ditto)	(ditto) Impossibility at a tidal area

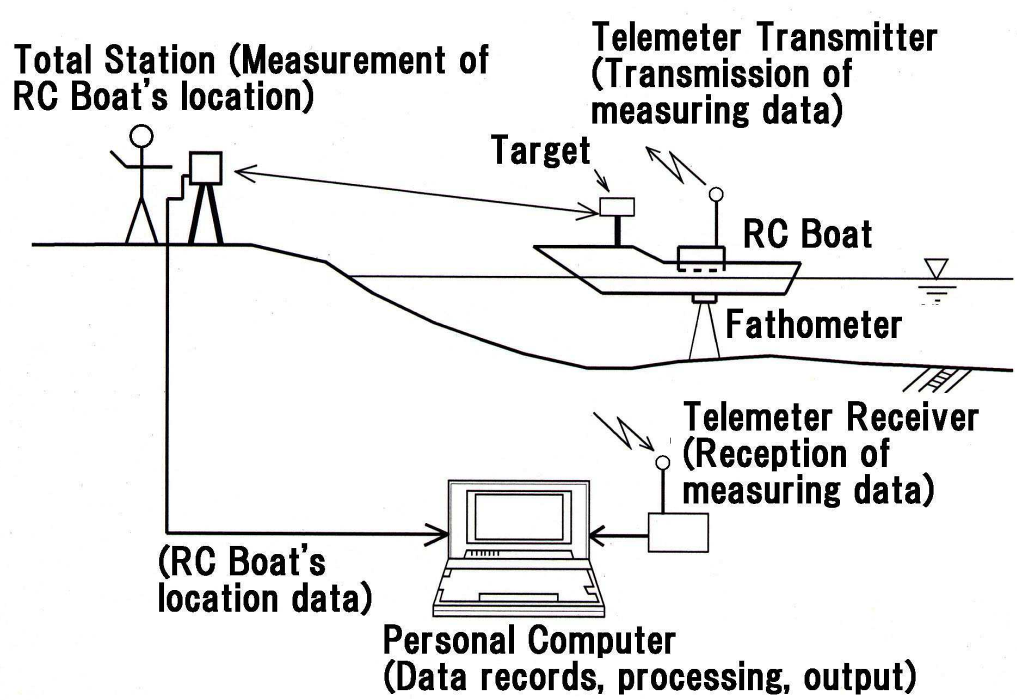

Fig. 1 - Outline of RC boat system

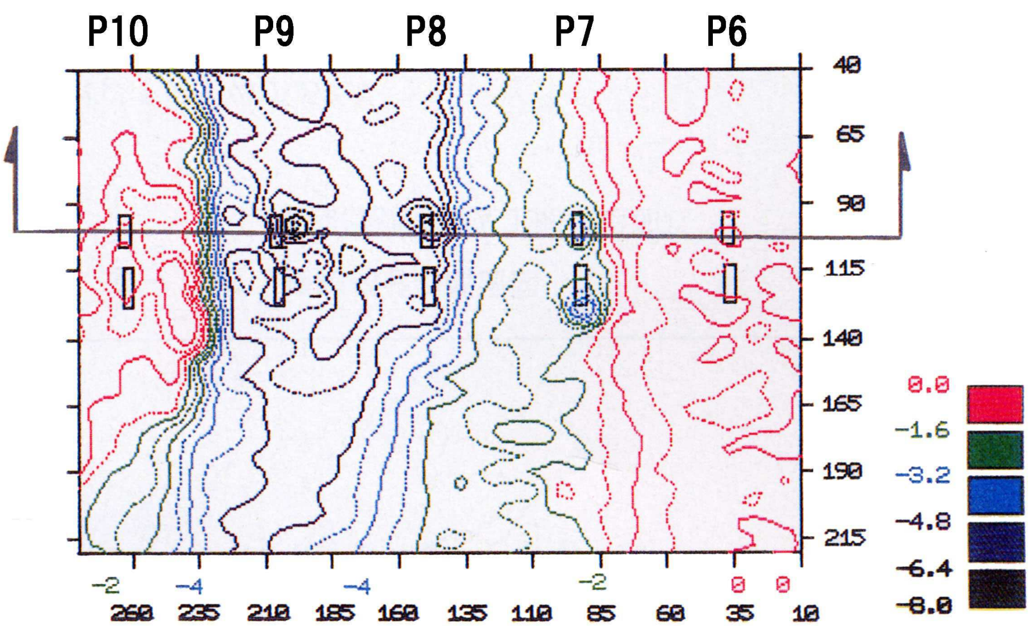

Fig. 2 - Two-dimensional contour line

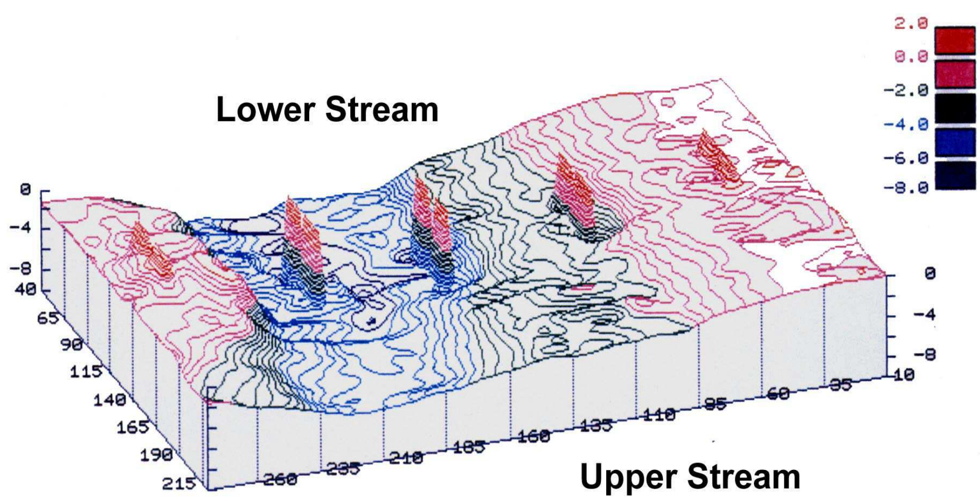

Fig. 3 - Birds-eye view of streambed
(three-dimensional contour line)

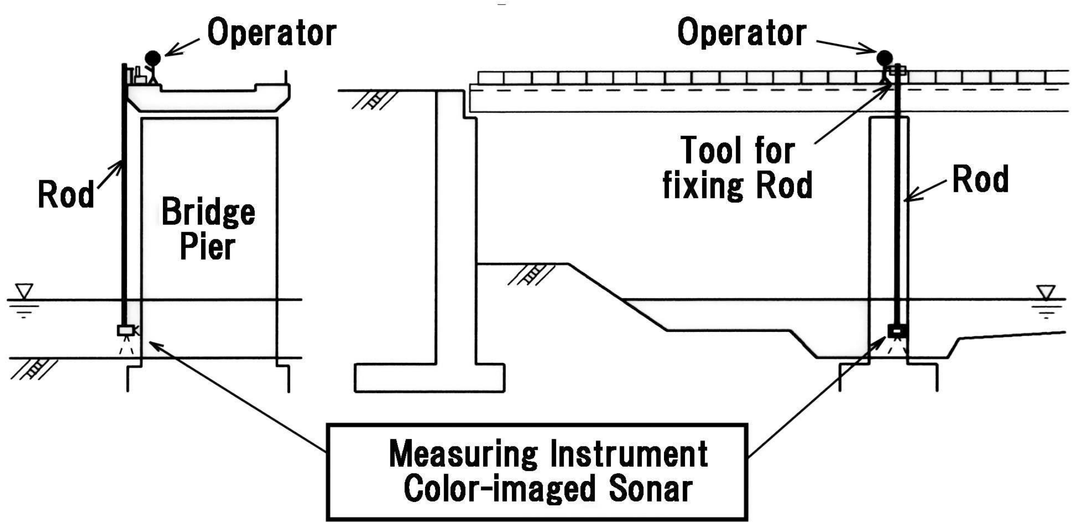

Fig. 4 - Outline of the Color-imaged sonar

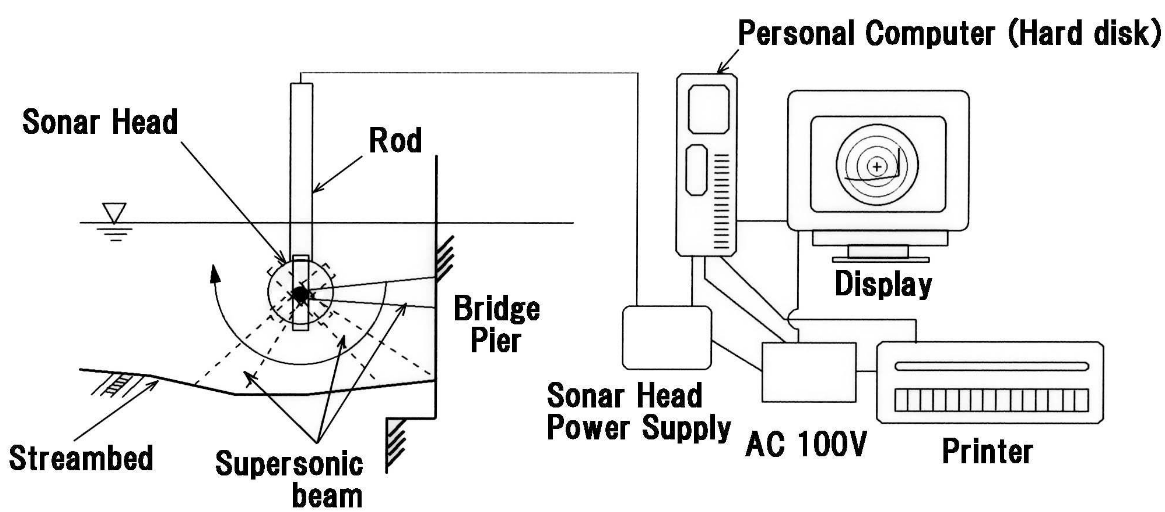

Fig. 5 - Outline of the Color-imaged sonar

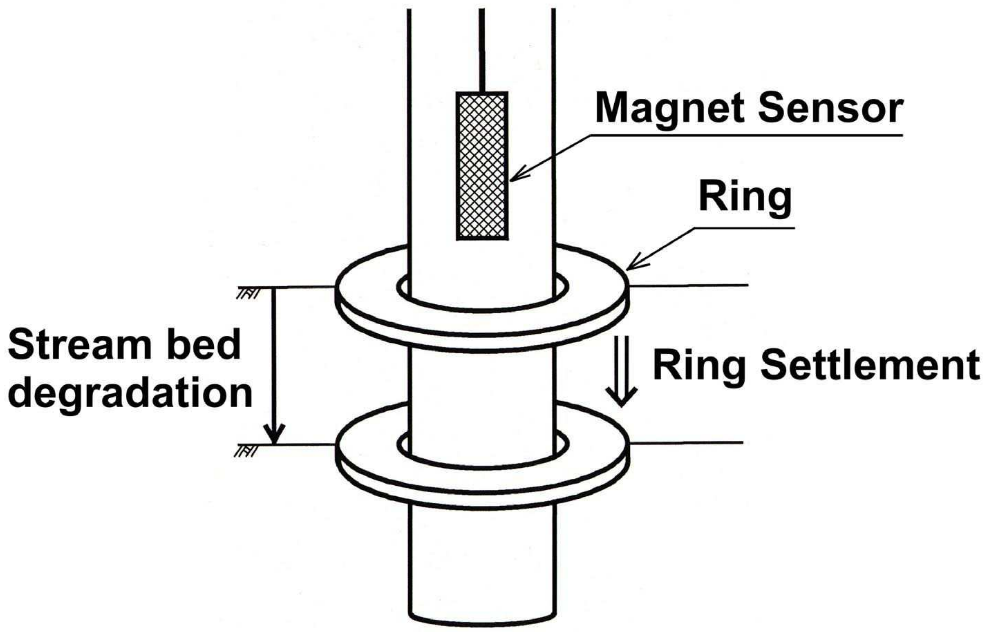

Fig. 6 - Outline of ring type equipment

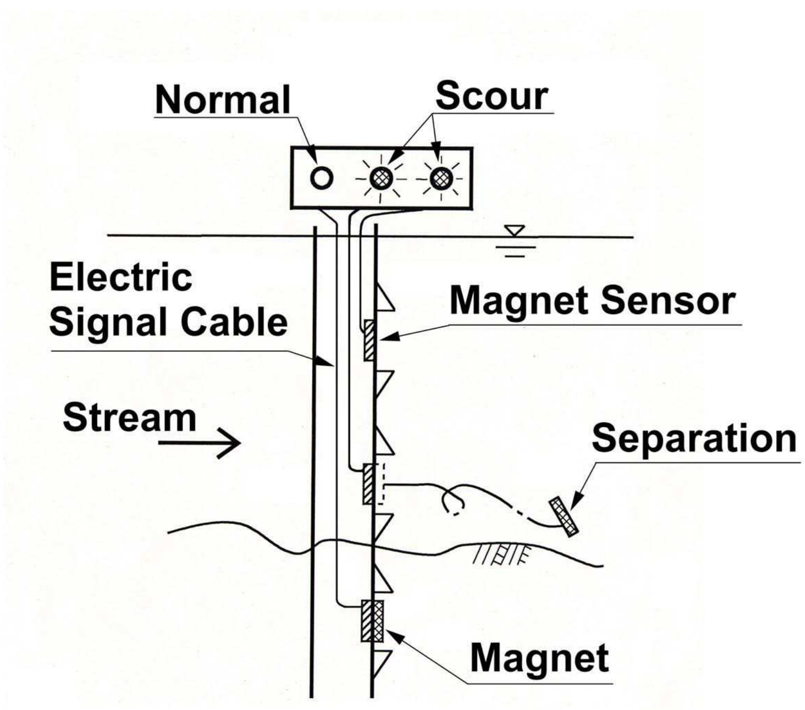

Fig. 7 - Outline of electromagnetic type equipment

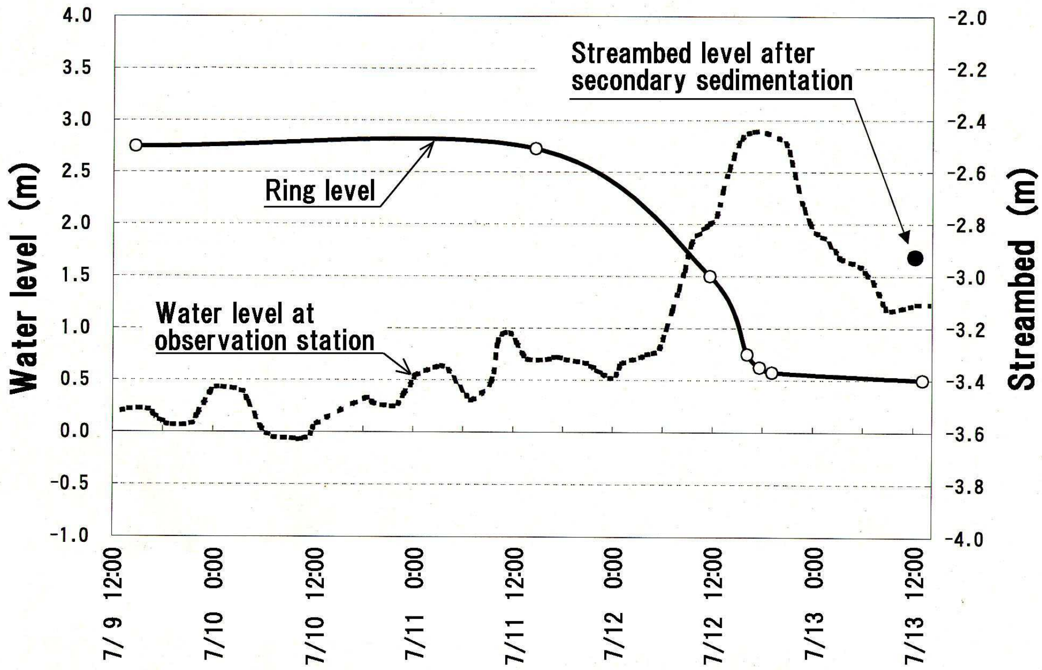

Fig. 8 - Degradation conditions of streambed