RA2020-3-II

RAILWAY ACCIDENT INVESTIGATION REPORT

Train Derailment Accident between Shibukawa Station and Shikishima Station, Joetsu Line, East Japan Railway Company

July 30, 2020

The objective of the investigation in this report conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby contributing to prevent future accidents and to reduce damage. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairperson
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese report shall prevail in the interpretation of the report.

Railway Accident Investigation Report

Railway operater:	East Japan Railway Company
Accident type:	Train derailment
Date and time:	At about 22:53, June 28, 2019
Location:	Around 98,246 m from Omiya station, between Shibukawa station and Shikishima Station, double track, Joetsu Line, Shibukawa City, Gunma Prefecture

July 6, 2020

Adopted by the Railway Committee, the Japan Transport Safety Board

Chairperson	TAKEDA Nobuo
Member	OKUMURA Fuminao, Chair
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SYNOPSIS

<SUMMARY>

On June 28, 2019, the 757M train, composed of 4 vehicles and started from Takasaki Station bound for Minakami station of the Joetsu Line of East Japan Railway Company, departed from Shibukawa Station on schedule at 22:51.

While the train driver was operating the train between Shibukawa station and Shikishima station at a velocity of about 76 km/h, he found the fallen trees on the track in front of him, therefore, he immediately operated the emergency brake, but the train collided with dirt and sand including the fallen trees that had flowed into the track and stopped.

The first axle of the front bogie of the first vehicle of the train derailed to left.

About 80 passengers and two crew members, *i.e.*, driver and conductor, were onboard the train, and one passenger was injured.

<PROBABLE CAUSES>

It is highly probable that the accident was that the train derailed caused as collided with dirt and sand including fallen trees that flowed into the track due to the collapse of the slope along the railway.

It is likely that the collapse of the slope was caused by that the slope became unstable due to the increased water content of the surface soil, as the fallen leaves, etc., had accumulated in the waterway laid in upper part of the collapsed slope, which hindered the water flow function of the waterway, and the water overflowing from this area was discharged as concentrated to the slope.

CONTENTS

Attached Materials

1. PROCESS AND PROGRESS OF THE RAILWAY ACCIDENT INVESTIGATION

1.1. Summary of the Railway Accident

On June 28, 2019, the 757M train, composed of 4 vehicles and started from Takasaki Station bound for Minakami station of the Joetsu Line of East Japan Railway Company, departed from Shibukawa Station on schedule at 22:51.

While the train driver was operating the train between Shibukawa station and Shikishima station at a velocity of about 76 km/h, he found the fallen trees on the track in front of him, therefore, he immediately operated the emergency brake, but the train collided with dirt and sand including the fallen trees that had flowed into the track and stopped.

The first axle of the front bogie of the first vehicle of the train derailed to left, *hereinafter, front, rear, left and right are based on the traveling direction of the train, and the vehicles are counted from the front*.

About 80 passengers and two crew members, *i.e.*, driver and conductor, were onboard the train, and one passenger was injured.

1.2. Outline of the Railway Accident Investigation

1.2.1. Organization of the Investigation

On June 29, 2019, the Japan Transport Safety Board designated the chief investigator and one other railway accident investigator in charge of investigating the accident.

The Kanto District Transport Bureau dispatched its staffs to the accident site to support the investigation of the accident.

1.2.2. Implementation of the Investigation

June 29 and 30, 2019	Site investigation, vehicle investigation and hearing statements.
February 12 and 13, 2020	Site investigation

1.2.3. Comments from Parties Relevant to the Causes

Comments were invited from the parties relevant to the probable causes.

2. FACTUAL INFORMATION

2.1. Process of the Train Operation

2.1.1. Statements of the Train Crews

The outline of the process to the accident is as follows, according to the statements of the driver and the conductor of the outbound local 757M train started from Takasaki station to Minakami station of the Joetsu Line of the East Japan Railway Company, *hereinafter referred to as "the driver", "the conductor", "the train", "the company", respectively*.

(1) The driver

I boarded on the train from Takasaki station, at 74,740 m from Omiya station,

hereinafter "from Omiya station" is omitted, where was the starting station. At Takasaki station, I prepared for operation such as to check the train indicators, brake test, etc., but there was no abnormality. In addition, it was not raining, and no operation control was issued for the route of operation.

The train departed from Shibukawa station, at 95,880 m, on schedule at 22:51. The train passed the speed limit section, speed limit was 75 km/h or slower, in the left curve beyond the bridge across the Tone River, by repeating the operation of coasting and powering[*1], by adjusting the velocity so as not to exceed the speed limit. After that, after confirmed that the proceed signal was displayed in the block signal when passing the planted position of the signal calling sign, it was confirmed that there was a fallen tree in the track about 50 m ahead from the train, so I applied the emergency brake immediately, but the train collided with it.

At the time of the collision, I felt the sound as "boom" and shaking, and I could see the splashed mud adhering to the window in front of the driver's seat. After that, until the train stopped, there was a tremor as driving automobiles on a gravel road and a sound and shake as dragging trees involved under floor of the vehicle, but I did not feel that the train was derailed.

After the train had stopped, I first informed to the conductor by a dedicated telephone that the train had collided with fallen trees on the track and stopped, and then reported the same contents to the train dispatcher using the train radio. The train dispatcher communicated me that the train dispatcher would make arrangements to suspend trains running on adjacent track. In addition, because I was instructed to lower the current collector, *i.e.*, pantograph, I operated the pantograph lowering button in the driving desk, but it was not lowered, so I reported to the train dispatcher that I could not lower it. When I checked the value of the air pressure of the main air reservoir in the instruments in the driving desk, it showed "0".

After got the permission to get off the train from the train dispatcher, I got off and inspected the vehicle and railway tracks. As a result, the first axle of the front bogie of the 1st vehicle derailed to left, so I reported the derailment to the train dispatcher.

Subsequently, when I checked the vicinity of the place where the fallen trees were found in the track, the slope on the adjacent track, the up track, side had been collapsed, and the dirt and sand on the collapsed slope flowed into the track. In addition, a large amount of water was continuously flowing from the collapsed slope, and a large amount of mud was deposited and spread between the slope and the railway track.

After that, the passengers were disembarked by me and the rushed rescue staffs and guided to the arranged buses.

*1 *"Powering" means accelerating a train.*

(2) The conductor

I boarded the train from Takasaki Station, the starting station. At Takasaki station, I made preparations for operation such as setting the destination display, etc., but there was

no abnormality. The train departed from the station on schedule.

The train also departed from Shibukawa station on schedule. Since there is a left curve ahead of the accident site, when the train tried to decelerate and pass around the accident site, there was a sudden deceleration as if the emergency brake was operated. The sudden deceleration continued for a few seconds, and I heard the sound as the train colliding with something just before it stopped. From the time the train suddenly slowed down till to the time it stopped, there was no feeling that the conductor's cabin shook vertically and horizontally, and I did not feel as the train was derailed.

After the train stopped, I turned on the headlight and checked backward of the train from the conductor's cabin. As a result, no obstacles were found in or around the track.

Immediately, the driver contacted me by the dedicated telephone and asked, "the train has collided with a fallen tree, but can you see something in backward of the train?", so I answered, "I can't find any obstacle in particular." The driver replied, "I will contact the train dispatcher right now".

After that, I announced the passengers using the public announcing device that the train might have collided with the fallen trees and stopped, and if there were any injured passengers, they were asked to report to the conductor, but nothing was reported.

About 30 minutes after the accident occurred, the station staffs of Shibukawa Station arrived, after that, the passengers were disembarked and guided to the arranged buses.

2.1.2. Records of Operating Status, etc.

The train is equipped with the event recorder that records information such as the speed, time, and brake operation position of the train before and after the driver operates the emergency brake.

According to the records of the device, the manual service brake was operated at 22:53:23.9 while the train was running at a speed of 76 km/h, and the manual emergency brake was operated at 22:53:25.0, and the stop of the train was detected at 22:53:37.5.

In addition, the time information is corrected to the actual time, but the speed information is not corrected, so there may be some error inherent in it.

2.1.3. Information on the Operating Status of the Train

At about 21:49, about 64 minutes before the train, *i.e.*, the outbound train, had passed around the accident site, the inbound 758M train passed around the accident site, and at about 22:09, about 44 minutes before the train, the outbound 755M train passed around the accident site.

According to the company, among total four train drivers and conductors for the both trains, the conductor of the inbound 758M train felt uneasy because it was raining heavily while running in around the accident site, but all four crews did not feel any abnormality.

[Refer to Attached Figures 1 and 2]

2.2. Death, Missing and Injuries of the Persons

Among about 80 passengers and two crew members, *i.e.*, driver and conductor, boarded on the

train, one passenger was slightly injured. According to the company, there were no reports of injuries from passengers on the day of the accident, but the next day, a passenger reported as was injured.

2.3. Information on the Railway Facilities and the Vehicles, etc.

2.3.1. Information on the Accident Site

(1) Topographical and geological conditions in the accident site and surrounding

According to the investigation conducted by the company after the accident, the summary of topographical and geological conditions in the accident site and surroundings were as follows.

The accident site is about 2 km apart in northeast from Shibukawa station, and is located on the boundary between the ridge at the western foot of Mt. Akagi and the river terrace formed by the Tone River. The track is laid in north and south so as to run parallel to the Tone River, with the right side, east side, of the track on the mountain side and the left side of the track on the river side.

Regarding the geology in the accident site and surroundings, according to the surface layer geological map, *i.e.*, the 1/200,000 basic land classification survey and the land conservation basic survey, Gunma Prefecture, the vicinity of the accident site is located on the boundary between river sediments and volcanic sediments. According to the observations of the accident site, the lower part of the collapsed slope is the river sediment, *i.e.*, the layer mainly composed of rocks with rounded corners, and the upper part is the volcanic sediment, *i.e.*, mainly a layer of loam[*2], and is presumed that the topsoil with a thickness of about 1 m covered on top of these layers.

*2 *"Loam" is the soil that is a mixture of sand and clay.*

(2) Track shape and operating velocity

The track shape in around the accident site is the left curve, *i.e.*, circular curve, with the radius of 400 m from 97,241 m to 97,717 m, and 65 m before and after the circular curve is the transition curves[*3], and the straight track from 97,782 m to 98,301 m. Also, from 96,799 m to 101,946 m is the 10 ‰[*4] upgrade track. The inflowing place of dirt and sand, in around 98,246 m, is in the straight and the 10 ‰ upgrade track section.

The maximum operating velocity of the train between Shibukawa station and Shikishima station is 100 km/h, and the speed limit in the left curve with a radius of 400m before the accident site is 75 km/h.

*3 *"Transition curve" is a special track shape provided between a straight line and a circular curve, or between two curves to facilitate the running of the vehicle.*

*4 *"‰, per mil" is a rate per thousand. Here, it is used as a unit for indicating the degree of gradient, and indicates the height difference with respect to a horizontal distance of 1,000 m.*

(3) Derailed status

The front head of the first vehicle of the train stopped at around 98,440 m, and the first axle of the front bogie of the 1st vehicle had been derailed to left.

The bottom of the gear unit case had been contacted with left rail near the derailed first

axle, and the snowplow had been contacted with right rail, and left and right wheels of the first axle were not in contact with the ballasts, etc., of the track and the flange of left wheel had been contacted with the leaf spring of the rail fastening device.

(4) Situation of the collapsed slope and earth and sand, etc., flowed into railway track

According to the company, the situation of the collapsed slope, *hereinafter referred to as "the collapsed slope"*, on right side of the track at the inflowing place of dirt and sand was as follows.

(i) The slope had been managed as the cutting*5 including the collapsed slope, and there is no protective work on the collapsed slope. The slope protection work has been implemented in a part of the slope by the dry stone pitching*6 with split stones.

(ii) The collapse spanned a slope length of about 15 m, a maximum depth of about 2 m, and a width of about 5 to 8 m, and the amount of dirt and sand was about 18 m^3. The gradient on the collapsed surface was about 30° to 40° from lower part to middle part of the slope, and about 45° to 50° on the upper part of the slope.

(iii) The area from lower part to middle part of the collapsed slope is the company's site, but the area from that area to the upper part is outside the company's site, and the collapse occurs in a location that covers both the company's site and the area outside the company's site.

In addition, when the condition of the dirt and sand that flowed into the track was checked in the site investigation after the accident, a retaining wall with a height of about 1.3 m was installed at the lower part of the slope near the collapsed place, but the collapsed dirt and sand etc., overcame it and flowed into the track. The up track of the inflowing place of dirt and sand, centered in around 98,246 m, was covered by the fallen trees including logged woods and earth and sand for about 12 m in the direction of the track, and up to the position of about 0.6 m in height from the top surface of the rail, and the down track was covered for about 6m in the direction of the track, and up to the height of the top surface of rail, respectively. Besides, in the site investigation after the accident, there were no traces of spring water, etc., in the collapsed surface.

On the track in the section about 100 m from the inflowing place of dirt and sand to the train stopped position, *i.e.*, rear of the 4th vehicle, several timbers, including those with a length of about 150 cm and a diameter of about 15 cm, and stones with the largest one was about 50 cm in length, about 30 cm in width, and about 15 cm in height, had been scattered.

*5 *"Cutting" means that the cut surface from the original ground surface becomes the slope surface or the roadbed as it is.*

*6 *"Dry stone pitching" is the lining up crushed stones without hardening with mortars.*

(5) Situation of the upper part of the collapsed slope

On the upper shoulder of the collapsed slope, the village road*7 with a width of about 1.0 m, *hereinafter referred to as "the village road",* is laid, and a waterway with a width of about 300 mm and a depth of about 300 mm, *hereinafter referred to as "the waterway"*, is installed in parallel with the village road.

According to the company, the situation at the upper part of the collapsed slope confirmed by four staffs charged in the facility of the company who arrived at the site at around 01:50 on June 29, the next day of the accident, was as follows.

(i) Overflow occurs near the collapsed slope position of the waterway, and the overflowing water flows across the village road in a continuous flow path shape with a width of about 500 mm and a height of about 5 mm and flows into the collapsed slope.

(ii) At the overflow point of the waterway, sediments such as fallen leaves, twigs and dirt and sand etc., that completely blocked the ditch of the waterway in amount and density, had existed along the waterway for about 200 mm in the direction of the water flow.

According to the company, a small amount of water was also flowing to the lower part of the collapsed slope, and if the water overflows from the waterway as it is, there is a risk that the collapsed area of the slope will expand. When the sediments near the overflow point of the waterway were removed, the water flow function of the waterway was restored and the overflow was resolved, and the running water seen at the bottom of the collapsed slope stopped.

When the condition of the upper part of the collapsed slope was checked in the site investigation after the accident, there were no abnormalities such as the damage to the waterway structure near the overflow point that could hinder the water flow function. In addition, there was the trace that water flowed from the waterway to the collapsed slope on the village road in the upper part of the collapsed slope.

[Refer to Attached Figures 2 to 7]

*7 *A "village road" is a road to which the Road Act, i.e., Article 180 of the 1952 Law, does not apply, and is owned and managed by the local governments such as municipalities and used for public use by the local residents, i.e., the Non-statutory public property.*

2.3.2. Information on the Railway Facilities

(1) Outline of the route

The track in around the accident site is a double track and electrified section with a gauge of 1,067 mm.

(2) Track structure

A ballast track is laid in around the accident site, and the 50 kg N rails are laid. The type of the used sleepers was the PC sleepers, 39 sleepers were laid per 25 m, and the type of ballast is crushed stones and the thickness is 200 mm or more.

Regarding the track inspections, the track irregularity inspection and the sleeper inspection, etc., are conducted once a year based on the "Railway Facility Implementation Standards", which the company has notified the Kanto District Transport Bureau, according to the "Ministerial Ordinance Providing for the Technological Standards for Railways", Ministry of Land, Infrastructure, Transport and Tourism, Ordinance No.151, 2001, *hereinafter referred to as the "Ministerial Ordinance for Technical Standards"*.

No abnormality was found in the latest inspection record of the track in around the accident site conducted before the accident. In addition, all measured results of the track

irregularity in around the accident site conducted by the company after the accident occurred were within the maintenance standard values.

(3) Information on the slope management

The surrounding civil engineering structures including the collapsed slope are mainly composed of the earthwork facilities, *hereinafter referred to as "the earthwork facilities",* such as cut surface, protective works, *i.e.*, stone-covered works, earth retaining walls, etc.

Regarding the inspection of the earthwork facilities, the company should carry out periodic inspections, *i.e.*, usual general inspections, once every two years in the "Civil Engineering Facility Implementation Standards" which the company notified the Kanto District Transport Bureau, based on the Ministerial Ordinance for Technical Standards. In this inspection, the visual inspection is mainly performed based on the "General Inspection Manual for Civil Engineering Structures, etc." established by the company, and when the earthwork facilities is targeted, the soundness shall judge based on the results of the investigation on the type, degree, and progress, etc., regarding of the deformation cracks, subsidence, and swelling[*8], etc., according to the soundness judgment classification shown in Table 1, and measures shall be taken according to the judgment. According to the company, the area outside the company's site in the upper part of the collapsed slope was also inspected by including the range where visual check can be implemented.

The latest periodic inspection, *i.e.*, usual general inspection, for the earthwork facilities was conducted in November 2017, and the soundness was judged as "S", *i.e.*, healthy.

Table 1. Soundness judgment classification [extracted from the general inspection manual for civil engineering structures, etc.]

Health		*State of structure*
A		*Those that threaten or may threaten the safety of driving, the safety of passengers and the public, and the normal operation of trains.*
	AA	*Those that require urgent measures due to changes that threaten driving safety, safety of passengers and the public, and ensuring normal train operation.*
	A1	*Those whose performance is declining due to ongoing deformation, etc., or those whose performance may be lost due to heavy rain, flood, earthquake, etc.*
	A2	*Deformation, etc. that may reduce the performance of the structure in the future*
B		*Those with deformations that may become soundness A in the future*
C		*Those with minor deformation etc.*
S		*Healthy*

In addition, the section including the collapsed slope is designated as the section to be inspected for a rock fall based on the "rock fall inspection manual" established by the company, in order to grasp the changes in the environment along the railway track and the deformations and abnormalities caused by new rock falls, and the visual inspection is conducted in the period of once every two years added to the usual general inspection, and the inspection results are judged, and measures shall be taken according to the judgment.

The latest inspection for the section was carried out in December 2017, and the inspection result was judged as "C", *i.e.*, no change. In the inspections so far, unstable loose rock[*9], etc., that may cause rock fall in the future at the collapsed slopes in the section have not been found.

*8 *"swelling" is a type of deformation of the slope, and means that the middle abdomen of the slope bulges in a convex shape.*

*9 *"Loose rock" refers to a rock mass that is in an unstable state on a bedrock slope, separated from the bedrock that is the ground due to the propagation of cracks.*

(4) Track patrol before the accident

Regarding the track patrols, the "track facility implementation standards" stipulate that it should be conducted by walking or by boarding train based on the frequency according to the railway track class, and the Joetsu Line is patrolled once every four weeks. According to the company, this track patrol is carried out to grasp the status of maintenance of the track, the presence or absence of obstacles against the structure gauge, environmental changes along the track, etc., and it is visually confirmed from the railway track including the slopes along the track.

The latest track patrol for the vicinity of the accident site was carried out on foot on April 4, 2019, and boarded on the train on April 18, 2019, May 16 and June 12, 2019. According to those records, there was no abnormality at the location of the collapsed slope.

(5) Others

(i) According to the reports of the company, there is no record showing that a disaster, etc., has occurred in the collapsed slope since the company was established in 1987.

(ii) No equipment is installed near the collapsed slope to detect the occurrence of disasters including collapse of earth and sand.

(iii) Lighting equipment managed by the company is not installed in around the accident site.

2.3.3. Information on the Vehicles

(1) Outline of the vehicles

The major specifications of the vehicles are as follows. Figure 1 shows the outline of the train and the derailed axle.

Vehicles in the trainset 4 vehicles

Vehicle type DC train, electrified with 1,500V

Capacity and tare[*10]

	Ku Mo Ha 211-3009	Mo Ha 210-3009	Sa Ha 211-3020	Ku Ha 210-3009
Capacity	142 persons	158 persons	156 persons	132 persons
Tare	36.2 t	34.5 t	23.5 t	26.5 t

Maximum dimensions 19,570 mm × 2,950 mm × 3,670 mm

*10 *[Unit conversion] 1t = 1,000kg (weight), 1kg (weight): 1kgf, 1kgf: 9.8N*

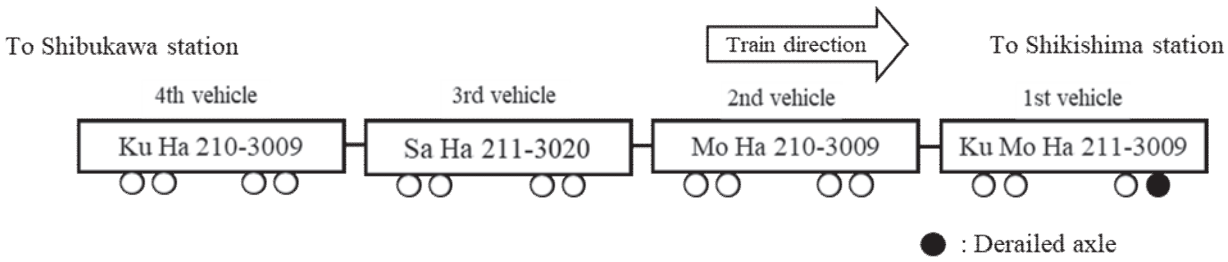


Figure 1. Outline of the train

(2) Periodic inspection, etc.

Regarding the inspection of the vehicles of the train, the "Electric Railcar Maintenance Implementation Standards", which the company has notified the Kanto District Transport Bureau based on the Ministerial Ordinance for Technical Standards, requires to carry out periodic inspection, etc., of the type according to the used status of the vehicles. The most recent periodic inspections before the accident of the train were the daily inspection*11 on June 26, 2019, the regular inspection*12 on June 12, 2019, and the critical parts inspection*13 on October 30, 2017, respectively, and there were no abnormalities in those records. In addition, in the vehicle investigation conducted after the accident, there were no abnormalities other than the parts that were considered to have been damaged by the accident.

*11 *"Daily inspection" is the inspection of trains in the company, to supplement and replace consumables and to inspect the condition and operation of the power generators, etc., for every period not exceeding 10 days from the start of operation.*

*12 *"Regular inspection" is the periodic inspection conducted in thecompany, to inspect the status of the power generator, etc., in a state of on-condition, for every period not exceeding 90 days.*

*13 *"Important parts inspection" is the periodic inspection in the company, and the major parts of the important equipment is removed or the main part is dismantled to perform inspection in detail every 48 months or a period not exceeding 500,000 km, whichever is shorter.*

2.4. Information on the Damages and Traces in the Railway Facilities and the Vehicles

2.4.1. Damages and Traces in the Railway Facilities *[Refer to Attached Figure 8]*

(1) Damaged status of the railway facilities

As described in 2.3.1 (4), dirt and sand flowed into the track from the collapsed part, and trees and stones were scattered on the track from the inflowing place of the dirt and sand to the stopped position of the train, rear of the 4th vehicle. The other status was as follows.

(i) There were two consecutive damages, considered as caused by being contacted by the wheel flange, in the direction of travel on the head of the bolts of the rail fastening devices on the outside of left rail of the down track in around 98,251 m.

(ii) There were intermittent traces, considered as caused by being scratched by the wheel flanges, on the leaf springs of the rail fastening devices on outside of left rail from around 98,252 m to around 98,440 m.

(iii) A part of the PC sleepers in around 98,262 m and in around 98,340 m were damaged.

(iv) The cable protection covers in around 98,340 m and in around 98,365 m were

damaged.

(2) Traces of derailment

No running traces by the wheel flanges leading to derailment were found on the top surface of the rail before and after the inflowing place of earth and sand.

2.4.2. Status of Damages and Traces of Vehicles *[Refer to Attached Figure 9]*

The statuses of major damages in each vehicle are as follows. In particular, dirt and sand, etc., adhered, and many damaged parts were found on the equipment and wheel treads, in the underfloor of the 1st and 2nd vehicles.

(i) Ku Mo Ha 211-3009, the 1st vehicle

The front skirt damaged, the front snowplow broken and damaged, the gear unit case, *i.e.*, the oil level gauge, damaged, the stroke adjuster rod support plate in each front and rear bogie bent and damaged, the ladder for climb up and down bent and damaged, the ATS onboard device damaged, the circuit breaker box, the traction motor isolator box, the auxiliary resistor box and the main resistor box, were bent and damaged, etc.

(ii) Mo Ha 210-3009, the 2nd vehicle

Each cock of the 2nd main air reservoir and the supply air reservoir were damaged, the stroke adjuster rod support plate in each front and rear bogie bent and damaged, the ladder for climb up and down bent and damaged, lower part of the traction motor damaged, etc.

(iii) Sa Ha 211-3020, the 3rd vehicle

The brake disc damaged, etc.

(iv) Ku Ha 210-3009, the 4th vehicle

The snowplow bent and damaged.

2.5. Information on the Train Crews

driver was 31 years old male, having the following licenses.

Class A electric railcar driver's license issued on September 12, 2011.

Class A internal combustion rolling stock driver's license issued on November 2, 2016.

The conductor was 28 years old male.

2.6. Information on the Handling Operation, etc.

2.6.1. Operation Control and Disaster Security during Rainfall

According to the "Disaster Security Standards for Railway Tracks, Regulations" and "Guidelines for Operation Control for Rainfall, Conventional Lines", of the company stipulated to implement operation controls and disaster security during rainfall, *hereinafter referred to as "the operation control, etc."*, based on the effective rainfall[*14], which is calculated based on the precipitation observed by the rain gauges installed along the railway track at about 10 km intervals as a standard. The operation control, etc., was categorized in 3 categories, *i.e.*, the caution, the speed control, and the operation suspension, and the procedures shown in Table 2 are performed according to the standard value of the effective rainfall, *i.e.*, standard value to be

issued, determined for each track section where the operation control, etc., is applied for each category. In addition, stipulated to designate a "predetermined security section" to perform the inspection, etc., during disaster security, for the section including the areas where there is a high possibility of a disaster.

Table 2 Categories and measures for the operation control, etc.

Category	*Measure*	
	Operation control	*Security*
Caution	-	*When reached the standard value to be issued, call the security guards and guard the predetermined security section by a track inspection car, etc. at a cycle of 3 to 4 hours.*
Speed control	*When reached the standard value to be issued, limit the velocity of the train to the specified value.*	*Guard the predetermined security section with a track inspection car, etc. at a cycle of 3 to 4 hours, guard the entire section by the train in a cycle of approximately 2 hours.*
Operation suspension	*When reached the standard value to be issued, suspend the train operation.*	*Guard the whole section by the track inspection cars as much as possible.*

The operation control, etc., for the sections including the vicinity of the accident site are performed according to the effective rainfall based on the observations of the rain gauges installed in Shikishima Station, about 4 km north of the accident site, and Yagihara Station, about 5 km south of the accident site, *hereinafter referred to as "the Shikishima and Yagihara effective rainfall"*.

According to the report of the company, none of short tern index[*15], medium term index[*16] and long term index[*17] of the Shikishima and Yagihara effective rainfall, from 00:00 to 23:00 on June 28, 2019, had reached the standard values for the operation controls, etc., determined by the company. As a side note, according to the company, the track section including the vicinity of the accident site is not designated as a "predetermined security section" to be inspected during disaster security.

[Refer to Attached Figure 10]

*14 *"Effective rainfall" is one of the rainfall indexes showing the risk of collapse of slopes, etc. with respect to rainfall, and is a method to express by accumulating rainfall while reducing the residual effect of the past rainfall over time.*

*15 *"Short term index" means the effective rainfall value with a half-life time of 1.5 hours.*

*16 *"Medium term index" means the effective rainfall value with a half-life time of 6 hours.*

*17 *"Long term index" refers to the effective rainfall value with a half-life time of 24 hours.*

2.6.2. Information on the Measures of the Train Protection

The handling operation by the crew members when it becomes necessary to stop the related trains hastily due to the derailment, the overturning of the train, or the track abnormality, etc., the "implementation standards on operation handling", that company notified the Kanto District Transport Bureau based on the Ministerial Ordinance for Technical Standards, stipulated to implement train protection[*18] by display the stop signal promptly using a vehicle fusee and a train protection radio device when a vehicle is equipped with them and are ready for use. In addition, the "manual of handling operation in abnormal situation, driver edition", which the company has made known to its drivers, describes the content prescribed the essentials on the handling in the abnormal situation indicating *"when there is a risk to hinder the adjacent track, implement train protection without hesitation"*, in addition to the precise methods and procedures, etc., for handling this manual.

The fusee for the vehicle is installed on the ceiling of the driver's cab, and the fusee part is exposed to outside from the roof of the vehicle. Since the handle is connected with the operating device, the fusee can be ignited by pulling this handle from the driver's cab with full power by about 2 cm and stop the approaching train by showing the fusee signal, *i.e.*, stop signal, by the flame. Once the handle was pulled, the spring force returned the handle to its original position, but the ignited status was maintained.

In addition, an actuator with a push button of the train protection radio device is equipped at the position on right side of the driver's desk, and by pressing that button, a warning signal, *i.e.*, stop signal, is issued to the driver of the other approaching trains to stop their trains. The button of the actuator is covered with a cover with a notch called as the cracker plate, and when the button is pressed, the cover breaks, so that it is possible to judge that the operation has been performed.

In the vehicle investigation after the accident, the cracker plate of the protection radio actuator was not cracked. In addition, the company's inspection after the accident revealed no evidence of ignition of the fusee tube of the fusee for the vehicle.

According to the company, a part of the train radio call records between the driver and the transport dispatcher, started at about 22:54:41 after the train stopped, *hereinafter referred to as "the train radio call records"* are as shown in Table 3. According to these records, the driver was asked by the train radio from a dispatcher charged in radio communication among three train dispatchers in charge of the Joetsu Line, *hereinafter referred to as "the train dispatcher charged in radio"*, regarding the kilometerage of the stop position of the train, and the hindered track section, and replied as the kilometerage of the stopped position of the train as 98.3 km, and the hindering track as "up track and down track of Joetsu Line" including the adjacent up track not only the down track on which the train was running. In addition, according to the train radio call records that started at about 23:01:40, the train dispatcher charged in radio instructed the driver to wait as it is, because they are making arrangements to suspend the other train operation from entering in the hindered track section including the adjacent track, and in response to this, the driver responded as understood.

Table 3 Train radio call records, started at about 22:54:41

Caller	Call record content
Train dispatcher charged in radio	Please give me the train number and the running track section.
driver	I am a driver of the 757M train stopping between Shibukawa and Shikishima stations. I just collided with the fallen trees while driving.
Train dispatcher charged in radio	757M driver, please tell me the stopped kilometerage, and the hindering track section.
driver	The kilometerage is 98.3 km, and the hindering track section is the Joetsu up track and down track, over.
Train dispatcher charged in radio	Then, the kilometerage is 98.3 km, and the hindering track section is the Joetsu up track and down track, over.
driver	Yes, that's right, over.
Train dispatcher charged in radio	Please wait.

In the operation status record of the centralized traffic control device before and after the occurrence of the accident, from 22:50 to 22:59, among the train dispatchers, a staff charged in the input work, *hereinafter referred to as "train dispatcher charged in input"*, has displayed the stop signals in the starting signals of the Joetsu Line, in the signal devices in the premises of Shibukawa Station and Numata Station by manual remote operation in the centralized traffic control system[*19], and the times of the operations to suspend departure of trains were recorded as 22:55:33 and 22:55:46, respectively.

*18 *"Train protection" is the measures to urgently stop other trains so that they do not approach the hindered place by displaying a stop signal with a fusee, etc., when the train operation is hindered.*

*19 *"Centralized Traffic Control System" is a train control method or a device that enables remote control of a large number of signal equipment such as the signals at each station, where is a controlled station, in a wide range from one place, i.e., the central control center.*

2.7. Information on Weather, etc.

2.7.1. Weather on the Day of the Accident

According to the information of the Japan Meteorological Agency, the weather condition in Maebashi on June 28, was "cloudy, with occasional rain" from 06:00 to 18:00, and "rain, occasionally cloudy and sometimes accompanied by lightning" from 18:00 to 06:00 of the next day. In addition, at the time of the occurrence of the accident, the Maebashi District Meteorological Observatory issued the advisories for a heavy fog and a lightning in Shibukawa City, where the accident site is located, and the advisories for a heavy rain and a flood had been issued in addition to the advisories for a heavy fog and a lightening, in Maebashi City.

2.7.2. Hourly Precipitation, Daily Precipitation

According to the records of the Japan Meteorological Agency Maebashi Regional Meteorological Observatory, *hereinafter referred to as "the AMeDAS Maebashi"*, located in about 15 km south of the accident site, and the Japan Meteorological Agency Numata Regional Meteorological Observatory, *hereinafter referred to as "the AMeDAS Numata"*, located in about 15 km north of the accident site, the daily precipitations in June, 2019, and the hourly precipitations of June 28, 2019 were as shown in Figures 2 and 3, respectively. According to these figures, the hourly precipitation of 14 mm that was the maximum on the accident day was recorded at AMeDAS Maebashi from 21:00 to 22:00 on June 28.

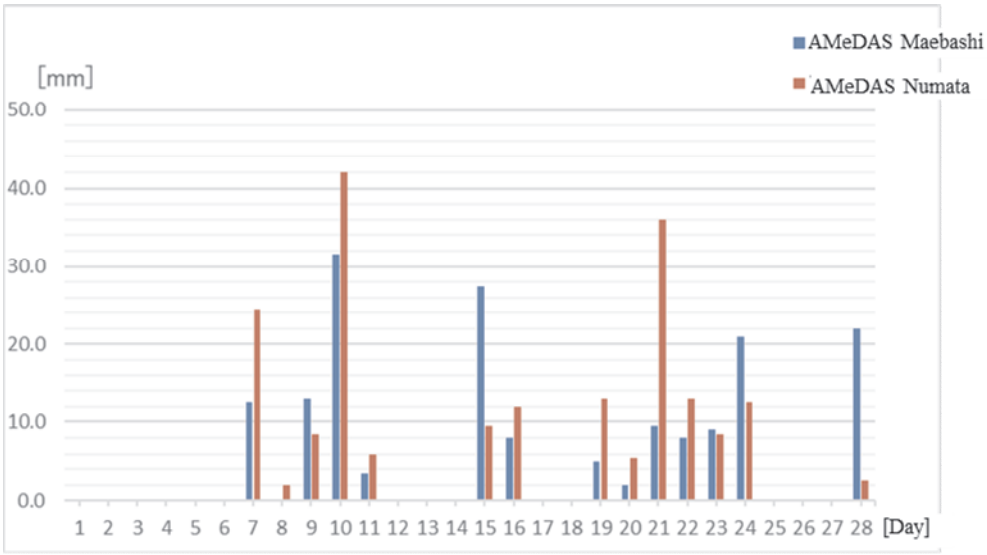


Figure 2 Daily precipitations in June 2019 (AMeDAS Maebashi, AMeDAS Numata)

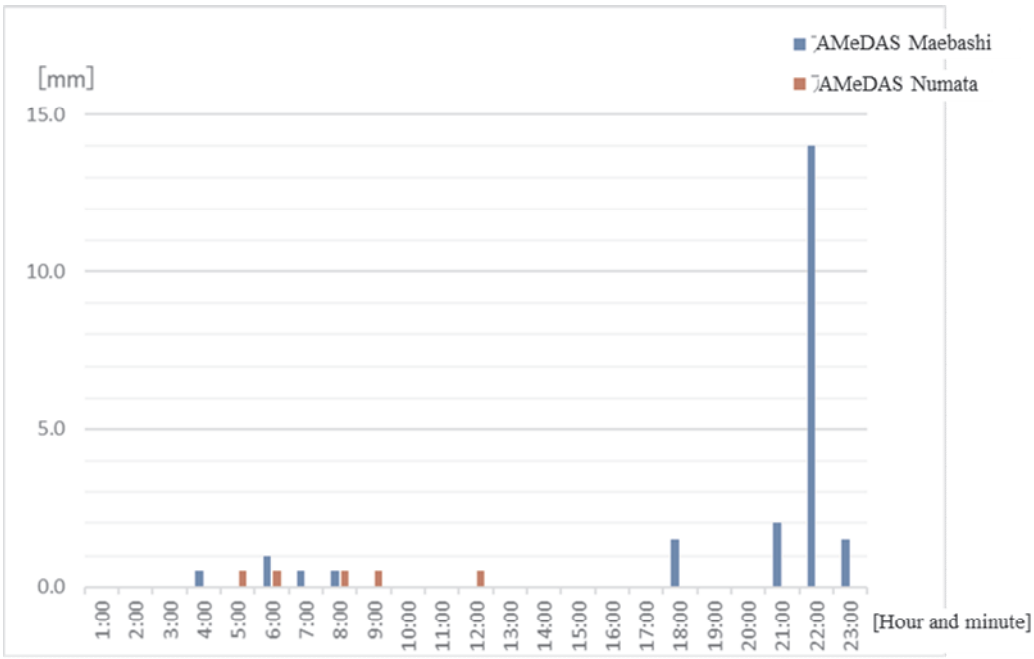


Figure 3 Hourly precipitations on June 28, 2019 (AMeDAS Maebashi, AMeDAS Numata)

2.7.3. Analytical Rainfall *[Refer to Attached Figure 11]*

According to the “Distribution map of hourly precipitation of the analytical rainfall[*20] by Japan Meteorological Agency", *hereinafter referred to as "the analyzed rainfall"*, the change of hourly precipitation on the day of the accident near the accident site is less than 10 mm from 00:00 to 20:30, however, it became 10 mm at 21:00 and gradually increased to reach the maximum value of the day of 34 mm at 21:30 and 22:00. After that, the precipitation decreased to 9 mm at 22:30 and became less than 1 mm at 23:00. In addition, in this series of changes of situation, the highly localized rainfall was grasped in around the accident site, and the precipitation in around the accident site was much compared to those measured at near Shikishima Station and near Yagihara Station, where the company's rain gauges are installed.

*20 *"Analyzed rainfall" is the hourly precipitation distribution with a fineness of 1 km square analyzed by the Japan Meteorological Agency, combining the observed results of radars installed nationwide by the Water Management and Land Conservation Bureau, the Road Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, and the Japan Meteorological Agency, and the observed results of rain gauges on the ground of the AMeDAS, etc.*

2.7.4. Wind Speed

According to the information of the Japan Meteorological Agency, the wind direction and wind speed at 22:00 on June 28, that is close to the time of the accident, are east wind of 3.3 m/s in Maebashi, and west north west wind of 2.9 m/s in Numata.

2.7.5. Earthquakes

According to the information from the Japan Meteorological Agency, the felt earthquakes, *i.e.*, seismic intensity 1 or higher, in June 2019 in Shibukawa City, where the accident site is located, were observed at seismic intensity 3 on June 18, and seismic intensity 2 on June 17 and June 24, and seismic intensity 1 on June 6, 8, and 11, once respectively.

2.8. Information on Evacuation and Rescue

According to the statements of the driver and the conductor, and the materials submitted from the company, the summary of the evacuation and guidance of passengers performed by the company staffs after the accident, were as shown in Table 4.

Table 4 Procedures for evacuation and relief, etc.

Time	Information on evacuation and relief, etc.
About 22:53 on June 28	Train derailment accident occurred.
About 23:25 on June 28	The company's rescue staffs arrived at the accident site
About 00:35 on June 29	Let passengers get off and start guiding to the bus
About 00:40 on June 29	Completed guidance of passengers to the bus

2.9. Information on the Waterway

2.9.1. Structures, etc., of the Waterway *[Refer to Attached Figure 12]*

The waterway, which was a state-owned property along with the village road, was transferred

to the former Akagi Village, now Shibukawa City, in 2003 and is owned by Shibukawa City at present.

The waterway draws water from the intake weir of the Mae Kurosawa River, which is located about 170 m upstream along the village road from the overflow place, and it is laid to continue to the nearby village in further downstream via the overflow place.

A part of the waterway is an underdrain[*21] such as a lidded status or a structure that allows water to pass through a synthetic resin pipe. However, the waterway near the upper part of the collapsed place was in the status of an open culvert without a lid. In addition, a screen[*22] was not installed in the waterway including the intake weir.

When the condition of the waterway was checked in the site investigation after the accident, a board, etc., for stopping water were installed at the intake weir, and twigs and leaves were accumulated there. According to the company, the board was installed by the local residents after the accident and before the site investigation was started.

*21 *"Underdrain" is a ditch provided underground for irrigation and drainage.*

*22 *"Screen" is a fence in which circular or square rods or plates are arranged in a grid pattern at regular parallel intervals to remove dust or foreign matter such as twigs or fallen leaves flowing through the waterway.*

2.9.2. Implementing Status of Daily Management to Maintain Water Flow Function

The waterway is a property owned by Shibukawa City, but daily management to maintain the water flow function is carried out by some local residents, *hereinafter referred to as "the waterway users"*, located downstream of the waterway. According to the waterway users, the implementing status of the management so far was roughly as follows.

The waterway is used by four local residents near the accident site as agricultural water for rice cultivation throughout the year. There was no request from Shibukawa City, who is the owner of the waterway, on the management to maintain the water flow function of the waterway, and the waterway users have voluntarily continued to do so as a custom for several generations.

For the drainage[*23] work of the waterway, the date for the work implemented by the waterway users is not systematically set, and when it was noticed that the water volume of the waterway passing the vicinity of the village has decreased, the work is carried out by removing the accumulated trees and leaves if a place, where the water flow is poor, was found in the waterway while walking to the weir through the village road.

The amount of water in the waterway generally decreases after heavy rain, and in most cases, twigs and leaves are accumulated on the board installed to adjust the amount of water flow in the intake weir, resulting in poor water flow. Until now, unlike the time of the accident, there was almost no accumulation in the middle of the waterway other than the location of the intake weir. The situation, that the amount of water in the waterway decrease due to the accumulation of such twigs and leaves, occurs about once every two months on average annually, and it occurs more often in the autumn when there are many fallen leaves, and rarely occurs in winter.

In the past, more households used the waterways, and plural waterway users used to work for drainage together, but now the works are implemented solely.

The waterway users went to the intake weir to check the status of the waterway in middle May, just before the occurrence of the accident, when is the preparation time for rice planting. At that time, the waterway users removed the twigs and leaves accumulated on the intake weir and changed the fixed position of the plate installed at the intake weir to adjust the amount of water intake since a large amount of water is required for planting rice.

The waterway user remembered that there was a flood in the middle of the waterway in the past as in the case of the accident, but at that time, a particular request or communication to awake attention from the waterway owner regarding drainage work and restrictions on the amount of water intake wasn't given, but the waterway user don't remember.

*23 *"drainage" means removing the accumulated fallen leaves, etc.*

2.9.3. Status of Flooding Occurred in the Past

According to the company, regarding the status of flooding in the waterway so far, in August 2009, at a position about 20m downstream from the location where the flood occurred at the time of the accident, it is said that the accumulation of leaves, etc., in the waterway caused poor water flow and overflowed water, which caused the slope outside the nearby railway site to loosen and collapse. At this time, the collapsed earth and sand, etc., did not flow into the track, so the train operation was not hindered. In light of the occurrence of this event, measures have been taken to raise the side wall of the waterway over about 10 m near the overflow point.

3. ANALYSIS

3.1. Analysis on the Status at the Time of the Derailment

As for the status of the derailment of the train, it is highly probable that the 1st axle of the front bogie of the 1st vehicle derailed because the train collided with earth and sand, etc., including fallen trees that flowed into the track due to the collapse of the slope, based on the followings.

(1) As described in 2.1.1 (1), the driver stated that he found the fallen trees on the track and immediately operated the emergency brake but the train collided with them. At the time of the collision, he felt the sound as "boom" and shaking, and stated that he could see the splashed mud adhered to the window in front of the driver's seat.

(2) As described in 2.3.1 (3), the train stopped at the front head of the 1st vehicle at around 98,440 m, and the 1st axle of the front bogie of the 1st vehicle derailed to left.

(3) As described in 2.3.1 (4), the earth and sand, etc., had been stacked in the down track in the inflowing place, centered at around 98,246 m, for about 6m in the direction of the track, and up to the height of the top surface of the rails.

(4) As described in 2.4.2, earth and sand adhered to the underfloor of the 1st and 2nd vehicles, and there were many damaged places on the equipment and wheel treads, and the front skirt of the 1st vehicle was damaged.

It is probable that the derailed place was the place where dirt and sand flowed into the track and

accumulated around 98,246m, based on the followings.

(5) As described in 2.4.1 (1) (i), there were two consecutive damages in the direction of travel to the head of the rail fastening device bolts on the outside of left rail on the down track near 98,251 m.

(6) As described in 2.4.1 (2), no trace of the running wheel flanges leading to derailment were found on the top surface of the rail before and after the inflowing place of dirt and sand.

Furthermore, it is probable that the status of the train after derailment was, as the 1st axle of the front bogie of the 1st vehicle derailed to left, the train ran as the wheel flange was rubbing leaf springs of the rail fastening device in the section of about 200 m till to the vicinity of the stopped position, with the wheels not falling off the track, based on the followings.

(7) As described in 2.1.1 (1), the driver stated that he felt shaking as if he was driving automobile on a gravel road till to the train stopped, but did not feel that the was derailed.

(8) As described in 2.4.1 (1) (ii), there were intermittent traces considered as being scratched by the wheel flanges, on the leaf springs of the rail fastening device on the outside of left rail from around 98,252 m to around 98,440 m.

(9) As described in 2.3.1 (3), the train has stopped with the bottom of the gear unit case contacted with left rail near the derailed 1st axle, and the snowplow contacted with right rail, and the left and right wheels of the 1st axle were not in contact with ballasts on the track, and the flanges of left wheels were in contact with the leaf spring of the rail fastening device.

It is likely that the PC sleepers, cable protection cover, vehicle underfloor equipment, etc., were damaged as described in 2.4.1 (1) (iii) and (iv) and 2.4.2, were caused as the stones, trees, etc., were caught under the vehicle floor by traveling after the derailment, and these were in contact with the PC sleepers, the cable protection cover, the vehicle underfloor equipment, etc., and damaged, based on the followings.

(10) As described in 2.1.1 (1), the driver stated that there were sound and impact as to drag a trees caught by the underfloor of the vehicle after the collision until the train stopped.

(11) As described in 2.3.1 (4), several timbers, including those with length of about 150 cm, a diameter of about 15 cm and the stones including largest one about 50 cm in length, about 30 cm in width, and about 15 cm in height were scattered on the track section about 100 m between the stopped position of the rear of the 4th vehicle of the train and the inflowing place of earth and sand.

3.2. Analysis of the Derailed Time

It is probable that the time when the train derailed was around 22:53, based on the followings.

(1) As described in 2.1.1 (1), the driver stated that he found that there was the fallen trees on the track about 50 m ahead from the train, and immediately operated the emergency brake, but the train collided with them.

(2) As described in 2.1.2, the emergency brake of the train was operated at 22:53:25.0 and the stop was detected 12.5 seconds after that, based on the records of the event recorder.

3.3. Analysis on the Handling Operation, etc.

3.3.1. Analysis on the Operation Control, etc.

It is probable that the operation control in the rainfall was not issued because the amount of rainfall exceeding the standard value to issue the operation controls before the occurrence of the accident was not grasped and there was no information to cause heavy rain, although the company has been prescribed the standard value to issue the operation control, etc., when it rains, as described in 2.6.1, based on the followings.

(1) As described in 2.6.1, the Shikishima and Yagihara effective rainfall at the time of the accident did not reach the standard value to issue operation control prescribed in the company.

(2) As described in 2.1.3, among total four train crews, *i.e.*, the train drivers and conductors of the trains that has passed the up and down tracks in around the accident site before the occurrence of the accident, the conductor of the inbound train stated that he felt uneasy due to heavy rain while driving in the vicinity of the accident site, but none of the four train crews felt any abnormality.

3.3.2. Analysis on the Operating Status When a Fallen Trees are Found in the Track

It is probable that the operating status when the driver noticed the fallen trees in the track was that, although the driver applied the emergency brake immediately after noticed the fallen trees in the track, the train could not stop before it, based on the followings.

(1) As described in 2.1.1 (1), the driver stated that he noticed that there was the fallen trees on the track about 50 m ahead from the train, and immediately operated the emergency brake, but the train collided with them.

(2) As described in 2.1.2, based on the records of the event recorder, the manual service brake was operated at 22:53:23.9 while traveling at the velocity of 76 km/h, the manual emergency brake was operated at 22:53:25.0, respectively, and the stop of the train was detected at 22:53: 37.5.

It is probable that the train could not stop before the fallen trees and dirt and sand including timber that flowed into the track, because it was difficult for the driver to find the fallen trees, dirt and sand, etc., including timbers that had flowed into the track, at a position further before the place where the driver had found fallen trees, etc., based on the followings.

(3) As described in 2.3.1 (2), the track shape in around the accident site was the straight track from 464 m before the inflowing place of dirt and sand, but it was nighttime when the accident occurred.

(4) As described in 2.3.2 (5) (iii), no lighting equipment managed by the company was installed in around the accident site.

3.3.3. Analysis on the Train Protection

As for the measures of the train protection after the train has stopped, it is certain that the train

protection procedure using the vehicle fusee and the train protection radio, which are the treatment prescribed in the company as a measure to stop the train in the adjacent track promptly, was not performed, although the driver supposed that the adjacent track, *i.e.*, up track, might be hindered, and reported it to the train dispatcher after the train stopped, based on the followings.

(1) As described in 2.1.1 (1), the driver stated that, after the train stopped, he communicated at first by the dedicated telephone to the conductor and then to the transport dispatcher by the train radio that the train had collided with the fallen trees in the track and stopped.

(2) As described in 2.6.2, the driver responded to the train radio from the transport dispatcher charged in radio, asking on the hindered track section, that it was "Joetsu line up and down tracks", *i.e.*, not only the down track on which the train was running, but also including the adjacent up track.

(3) As described in 2.6.2, the cracker plate of the protection radio operating device was found as not cracked in the vehicle investigation after the accident, and there was no evidence of ignition in the flame tube part of the vehicle fusee, in the inspection conducted by the company after the accident.

On the other hand, as described in 2.6.2, it is certain that measures have been taken to prevent other trains from entering the up and down tracks between Shibukawa Station and Numata Station, including the location where the accident occurred, by the train dispatcher charged in input who received a report from the driver that the train collided with the fallen trees and stopped, based on the contents of the operating status record of the centralized traffic control device.

The train protection is the measure to promptly stop related trains in order to prevent concurrent accidents, and it is necessary to give the top priority to the rapidity for its purpose. Therefore, when the driver noticed that there are fallen trees on the track, the driver should recognize the status that the fallen trees are obstructing the track, and has the possibility of an obstacle that requires to stop the train running on the adjacent track, and it is necessary to give priority to implement the train protection by using a protection radio, etc., at first. It is desirable for the company to implement continuous education and training to ensure that drivers can take such prompt train protection measures certainly. In addition, it is desirable for the company to study on the preparation of the device on the vehicle that automatically detects derailment and issues a protective alert according to the situation of the track section such as the single track or the double track, *i.e.*, existence or absence of adjacent tracks, and the number of trains in operation.

3.4. Analysis of the Weather Conditions

As for the weather conditions before the accident, it is likely that there was relatively large amount of rain falls in around the accident site before the accident occurred, based on the followings.

(1) As described in 2.7.2, AMeDAS Maebashi recorded the maximum hourly precipitation of 14 mm, between 21:00 and 22:00, June 28, the time when the accident occurred.

(2) As described in 2.7.3, the analyzed rainfall at 21:30 and 22:00 on June 28 in around the

accident site was 34 mm.

In addition, as described in 2.7.3, the analyzed rainfall of the Japan Meteorological Agency grasps highly localized rainfalls in around the accident site, and the precipitation in around the accident site was larger than the vicinity of Shikishima Station and the vicinity of Yagihara Station, where the company's rain gauges were installed. Therefore, it is likely that the precipitation near the accident site was not grasped by the rain gauges installed in both stations as installed in the span of about 10 km.

It is desirable for the company to study to enhance the understanding of the occurred status of the local rainfalls along the railway track, as to utilize effectively the meteorological information such as the analyzed rainfalls by the Japan Meteorological Agency, etc., in addition to the effective rainfalls based on the observation of the rain gauges installed by the company.

3.5. Analysis of the Status of the Collapsed Slope

3.5.1. Analysis of the Time When Earth and Sand Flowed into the Track

As described in 2.1.3, the inbound 758M train passed in around the accident site at about 21:49, about 64 minutes before the train ran in around the accident site, and the outbound 755M train passed in around the accident site at about 22:09, about 44 minutes before the train ran in around the accident site, however, since neither the drivers nor the conductors of each train felt any particular abnormality. Therefore, it is highly probable that the time when the dirt and sand flowed into the track was between around 22:09 when the outbound 755M train passed in around the accident site and around 22:53 when the train approached the accident site.

3.5.2. Analysis of Water Flow in Upper Part of the Collapsed Slope

As for the status of water flow in upper part of the collapse slope, it is probable that the water overflowed from the waterway was concentrated on the slope at the time of the occurrence of the accident, based on the followings.

(1) As described in 2.3.1 (5) (i), when the facility staff of the company checked the upper part of the collapsed slope, it was confirmed that overflow occurred near the place of the collapsed slope of the waterway, and from there, the overflowed water crossed the village road in a continuous flow path shape with a width of about 500 mm and a height of about 5 mm and flowed into the collapsed slope.

(2) As described in 2.3.1 (5), when the status of the upper part of the collapsed slope was checked in the site investigation after the accident, the trace of water flow was found on the village road in above the collapsed slope from the waterway to the collapsed slope.

Regarding the overflow from the waterway, as described in 2.3.1 (5) (ii), the sediment, etc., such as fallen leaves, twigs, etc., whose amount and density was completely block the ditch of the canal were existed along the waterway in the direction of the water flow for about 200 mm in the overflowed place of the waterway. Therefore, it is probable that these sediments interfered with the water flow function of the waterway and overflowed from the vicinity of the sediment.

Furthermore, as described in 3.4, it is likely that there was the relatively large amount of rainfall in the vicinity of the accident site before the occurrence of the accident. Therefore, it is likely that the amount of water flowing through the waterway increased and the overflow of water also increased due to the rainfall.

3.5.3. Analysis on the Collapse of the Slope

As described in 3.5.2, it is likely that slope collapses were caused because the water content of the topsoil of the slope increased and the slope became unstable, as it is probable that the water overflowed from the waterway flowed as concentrated into the slope.

Therefore, it is desirable for the company to take measures such as installing equipment for detecting disasters and slope protection work in the collapsed slope in preparation for damages caused by flooding, etc., from the waterway. If measures are required outside the company's site, it is desirable to request and provide information to the managers, etc., and discuss on the measures among the parties.

3.6. Analysis on the Waterway

3.6.1. Analysis on the Accumulation of Fallen Leaves, etc., in the Flooded Area

Regarding the accumulation of fallen leaves, etc., in the flooded area, as described in 2.9.1, a part of the waterway is in a state of being covered or in an underdrain like a structure through which synthetic resin pipes pass. However, the waterway near the upper part of the collapsed place was in an open status without the lids, and no screen was installed in the waterway including the intake weir. Therefore, it is probable that the structure of the waterway was such that fallen leaves were likely to accumulate in the waterway. In addition, as described in 2.9.1, a board was installed, after the accident, at the intake weir to stop the water, but twigs and leaves were piled up there after that. Therefore, it is probable that twigs and leaves were always carried along with the flow of the incoming water, and they were carried in the same way before the accident. Based on these facts, it is likely that the fallen leaves near the open channel of the waterway have accumulated in the waterway for some reasons even in just before the occurrence of the accident, or that the fallen leaves carried by the water that entered from the intake weir are accumulated for some reasons.

In order to prevent the similar accident in the accident site, it is necessary for the waterway owner to discuss with the parties including the waterway users and to develop the equipment with the structure that the water flow function of the waterway is not easily hindered, so that the waterway laid on the upper part of the collapsed slope should not flow into the slope due to poor water flow due to deposits such as fallen leaves.

3.6.2. Analysis on the Implementing Status of Daily Management to Keep Water Flow Function

As described in 2.9.2, regarding the implementing status of the daily management to keep the water flow function, the waterway users used to implement the dredging work to maintain the water flow function by voluntary management according to the conventional practice, and

these works were not set on a planned date in advance but was carried out when it was noticed that the amount of water in the waterway that was passed to the vicinity of the village had decreased. Therefore, it is probable that the management was not always properly performed according to the facilities of the waterway, which has a structure in which branches and leaves are likely to accumulate in the waterway, such as that the inspections, etc., have not been carried out in advance from the viewpoint of preventing flooding due to poor water flow caused by the sediments, and the waterway is in an open status without being covered, and the screen including the intake weir is not installed.

Therefore, it is necessary for the waterway owner to continue daily management to maintain the water flow function such as inspection and drainage according to the structure of the waterway facilities while coordinating with the related parties.

3.7. Analysis on the Management of the Earthwork Facilities

Regarding the status of periodic inspections of the earthwork facilities, it is considered as difficult to take necessary measures to prevent accidents such as performing detailed investigations, because it could not be predicted in advance that a large amount of water overflowing from the waterway and flow into the slope and the slope will collapse, based on the followings.

(1) As described in 2.3.2 (3), as a result of the latest periodic inspection, *i.e.*, usual general inspection, for the earthwork facilities including the part outside the company's site, it is judged as in a "healthy status", and as a result of rock fall inspection for the section including the collapsed slope, it is judged as “no change”.

(2) As described in 2.3.2 (4), the latest track patrol targeting the vicinity of the accident site was carried out on June 12, 2019 by boarding on the train, etc. According to its records, no abnormality was found in the collapsed slope.

However, in light of this accident, it is desirable for the company to identify the similar locations as the accident site, *i.e.*, where waterways are laid on the upper part of the slope, and to prevent accidents from happening by designate the places of railway facilities that require intensive patrols and monitoring, according to the status of the structure of the water flow facility and its surroundings for the identified places. In addition, it is desirable for the company to grasp the unstable places as much as possible by investigating and evaluating not only the risks related to the existence of the surrounding waterways, but also the risks that may cause disasters along the railway track, and to take further measures to prevent accidents from happening, such as making effective use of the grasped results and conducting inspections with particular care during periodic inspections of slopes, etc.

3.8. Analysis on Evacuation and Relief

Regarding the evacuation and rescue of passengers after the accident, based on the statements by the train crews described in 2.1.1 and the information on the evacuation and rescue shown in Table 4 in 2.8, it is highly probable that there was no particular problem in the responses of the

crews and the train dispatchers after the accident.

4. PROBABLE CAUSES

It is highly probable that the accident was that the train derailed caused as collided with dirt and sand including fallen trees that flowed into the track due to the collapse of the slope along the railway.

It is likely that the collapse of the slope was caused by that the slope became unstable due to the increased water content of the surface soil, as the fallen leaves, etc., had accumulated in the waterway laid in upper part of the collapsed slope, which hindered the water flow function of the waterway, and the water overflowing from this area was discharged as concentrated to the slope.

5. SAFETY ACTIONS

5.1. Measures to Prevention Recurrence Considered as Necessary

In order to prevent the similar accident in the accident site, it is necessary for the owner of the waterway, *i.e.*, Shibukawa City, to discuss with the parties , including the users of the waterway, to prepare the facilities with a structure that does not hinder the water flow function of the waterway, to prevent that the waterway laid in the upper part of the collapsed slope became to the poor water flow status due to deposits such as fallen leaves, etc., and water flowed into the slope due to overflowing from there, in addition, to cooperate with the parties to continue the daily management for the function maintenance such as inspection and drainage, etc., according to the structure of the facilities.

In addition, in preparation for damage caused by flooding from the waterway, it is desirable for the company to take measures such as installing equipment to detect disasters in the collapsed slope and take measures such as slope protection work, etc. If measures are required for outside the company's site, it is desirable to request and provide information to the manager, etc., of that site as necessary, and discuss the measures among the parties.

Furthermore, based on the accident, it is desirable for the company to identify the similar places as the accident site, where waterways is laid in the upper part of the slope, and designate as the railway facilities that require intensive patrol and monitoring according to the situation of the structure of the water flow facility and its surroundings, to prevent accidents from happening. In addition, it is desirable to understand the unstable place as much as possible by performing the investigation and evaluation for not only the risks related to the existence of the surrounding waterways, but also the risks that may cause disasters in the track side, and take further measures to prevent accidents from happening, such as to conduct inspections with particular care by utilizing these results obtained in the above, making effective use of them in the periodic inspections of slopes.

5.2. Measures Taken by the Company after the Accident

(1) Measures taken by the company

(i) Requested the owner of the waterway, *i.e.*, Shibukawa City, to take the following measures.

- Implementation of the measures to prevent recurrence of the flooding, such as thorough proper management of the waterway and improvement of facilities, etc.
- Regarding the waterways near the railway track same as the waterway, thorough proper management to prevent flooding based on installed environment and usage status.

(ii) The slope protection work was carried out by glue frame construction, spraying frame construction for the slopes that is feared to hinder railway operation due to the effects of flooding of surrounding waterways including collapsed slopes.

(iii) An urgent inspection was conducted in all lines of the company, targeting areas, where waterways are laid in the upper part of the cut slope along the track side similar to the accident site, etc., and urgent measures such as repairs were taken for areas where abnormalities such as waterway damage and poor water flow, etc., that might hinder the train operation were found in the result of the inspection. In addition, the company requested the owners of each waterway that took urgent measures, to ensure proper management of the waterway.

(2) Measures taken by Shibukawa City

(i) The following measures were taken for the waterway.

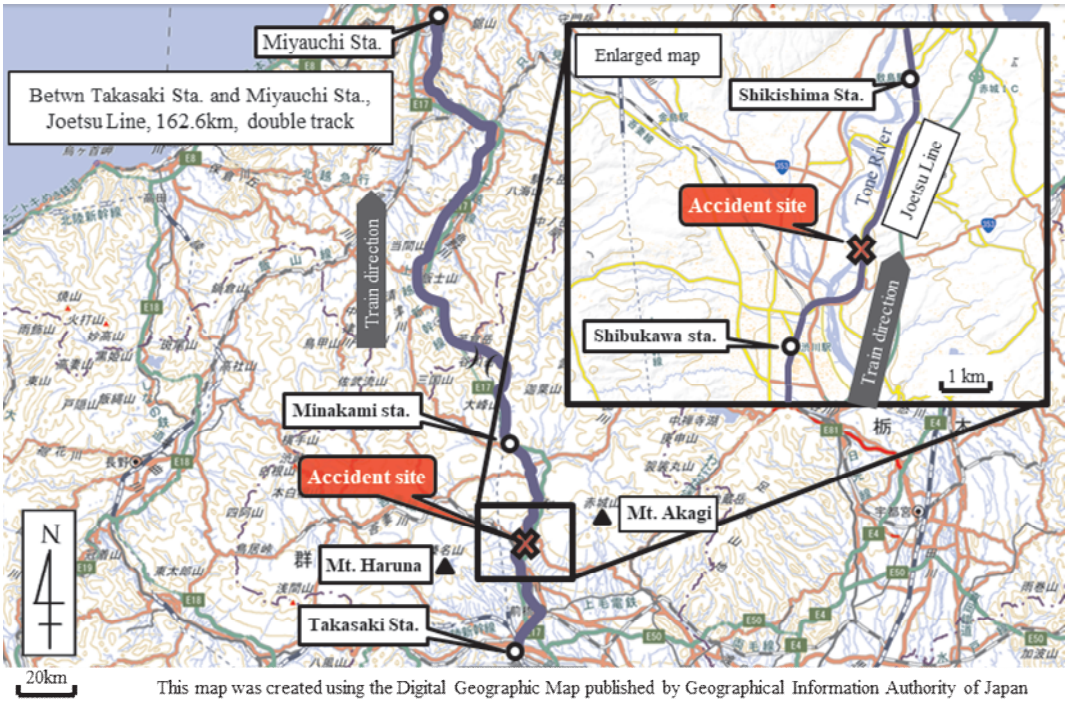
- The waterway in the section near the collapsed slope including the past overflow places were culverted, *i.e.*, synthetic resin pipes were installed in the section of about 100 m, and screens were installed at each of the intake weir and entrance of the culvert, pipe.
- As the cross-sectional area of the waterway is reduced due to culverting, *i.e.*, installing pipes, the amount of water intake may increase sharply due to the rise in the water level of the intake river during heavy rain, and the water may overflow from the pipe inlet. Therefore, a part of the opening was closed with mortar to suppress the amount of water flow.

(ii) The following warnings, etc., were given to the residents, self-government associations, including waterway users.

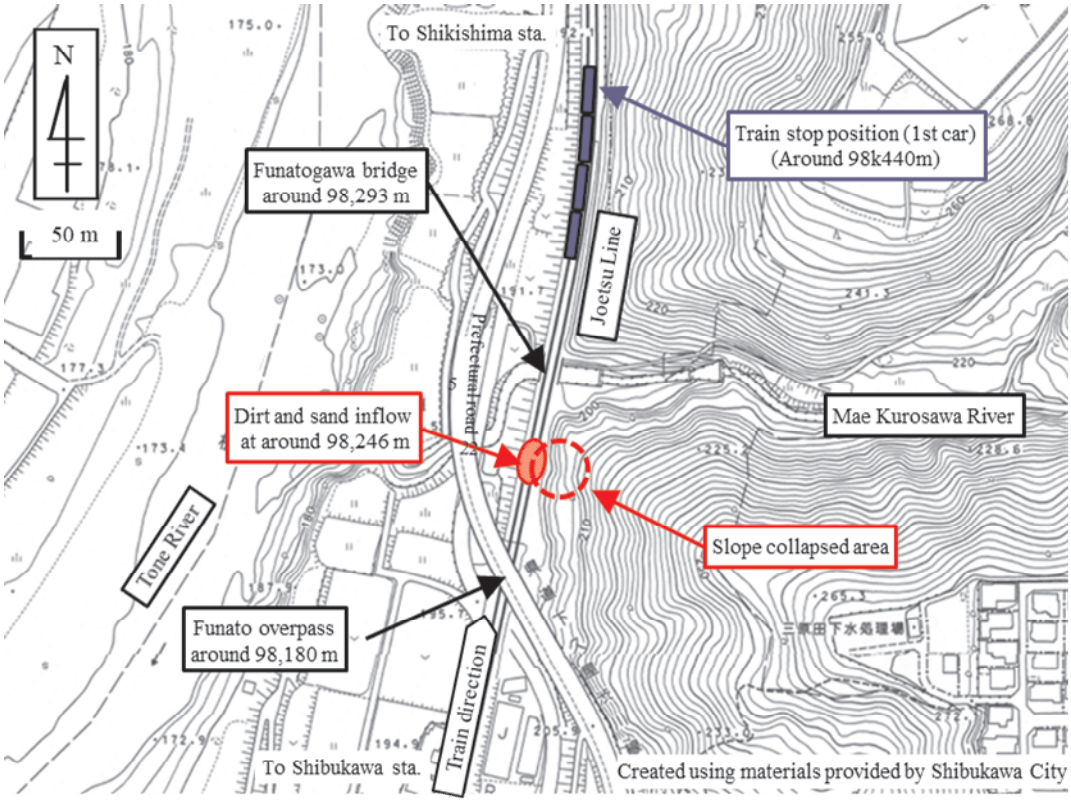
- Requested to inspect periodically on the waterways including the screen for poor water flow and requested thorough maintenance of appropriate functions such as draining as necessary.
- It was noted that there is a risk of overflow from the pipe inlet when the amount of water intake increases due to the reduction of the cross section of the waterway, and it is necessary to check at any time, especially in the event of heavy rain.

(iii) After extracting similar waterways near the railway track same as the waterway, the laying environment and usage conditions were investigated, and study on the measures to prevent flooding were started.

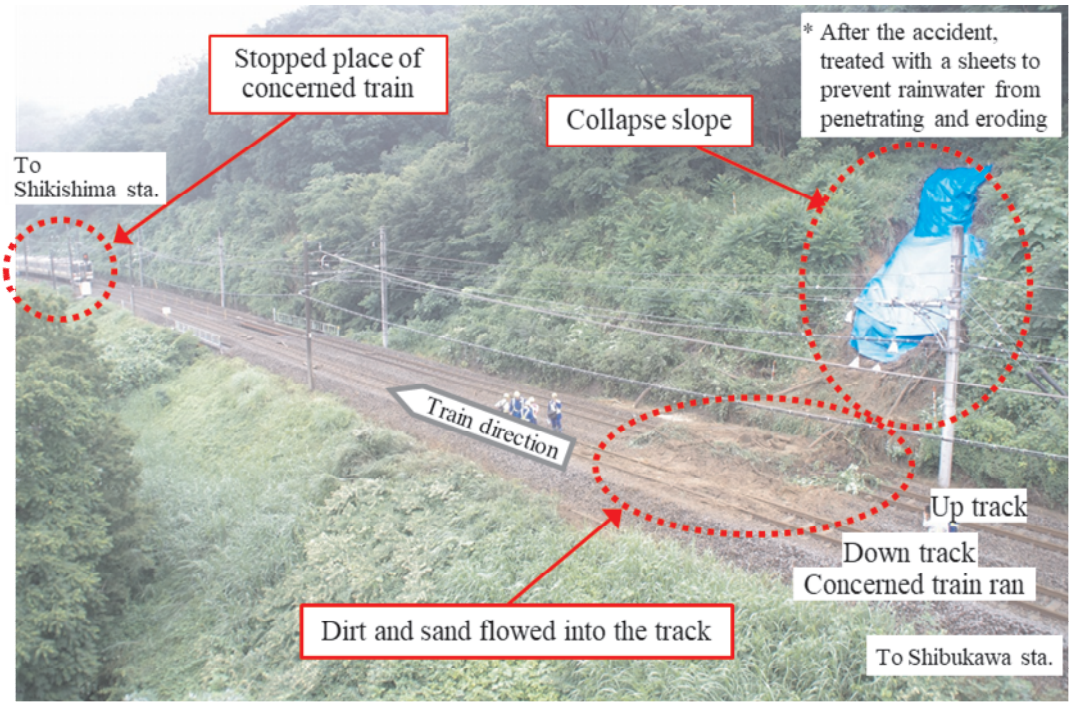
Attached Figure 1. Route of Joetsu Line and Topographical Map in around the Accident Site



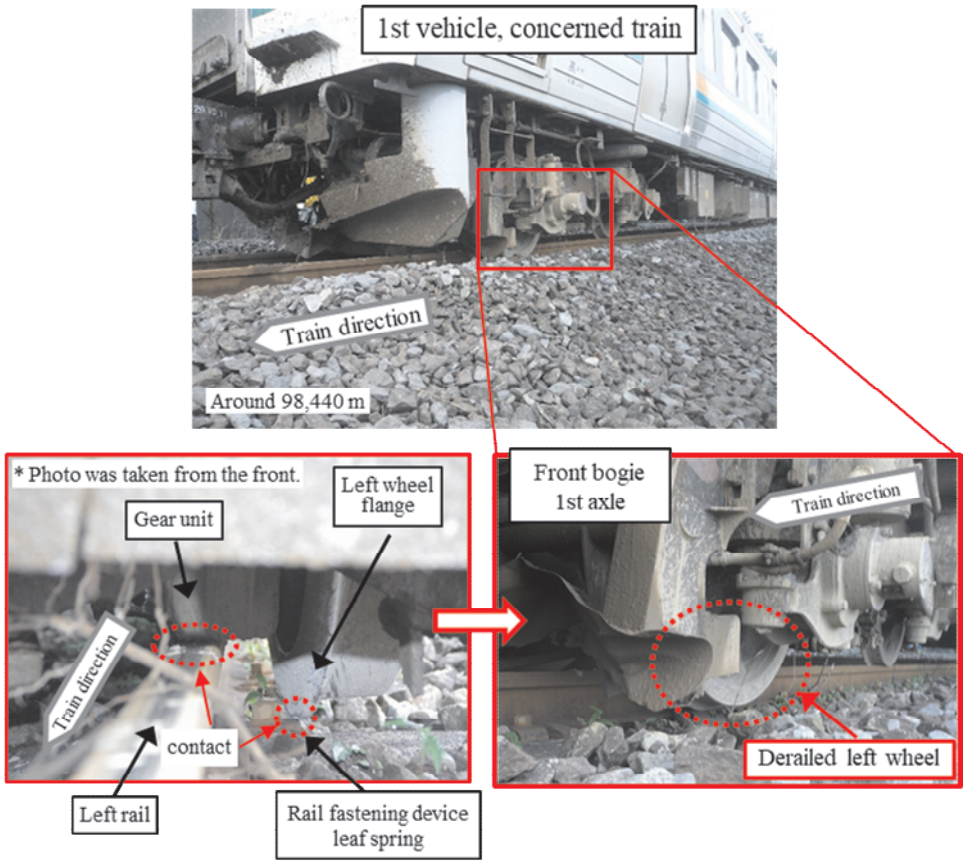
Attached Figure 2. Plane View of the Track in around the Accident Site



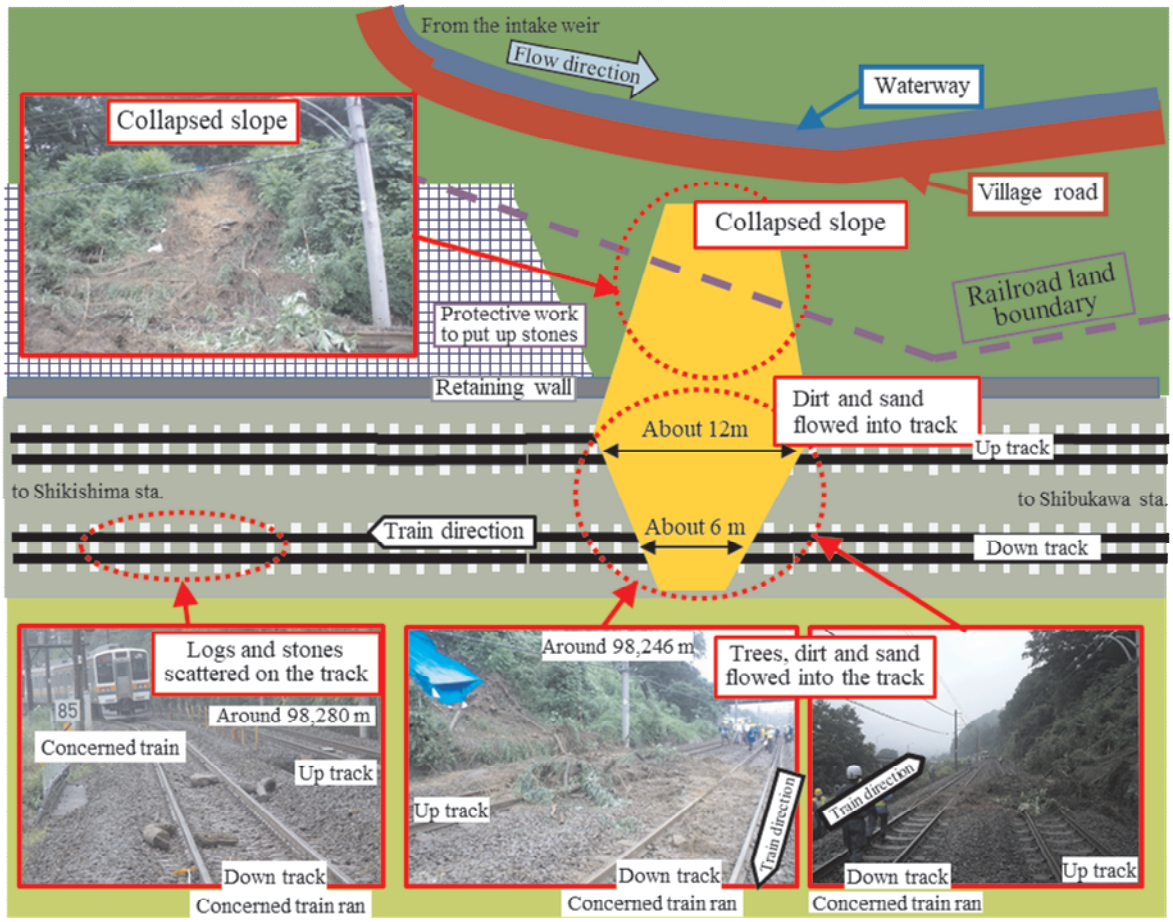
Attached Figure. 3 Status in around the Accident Site



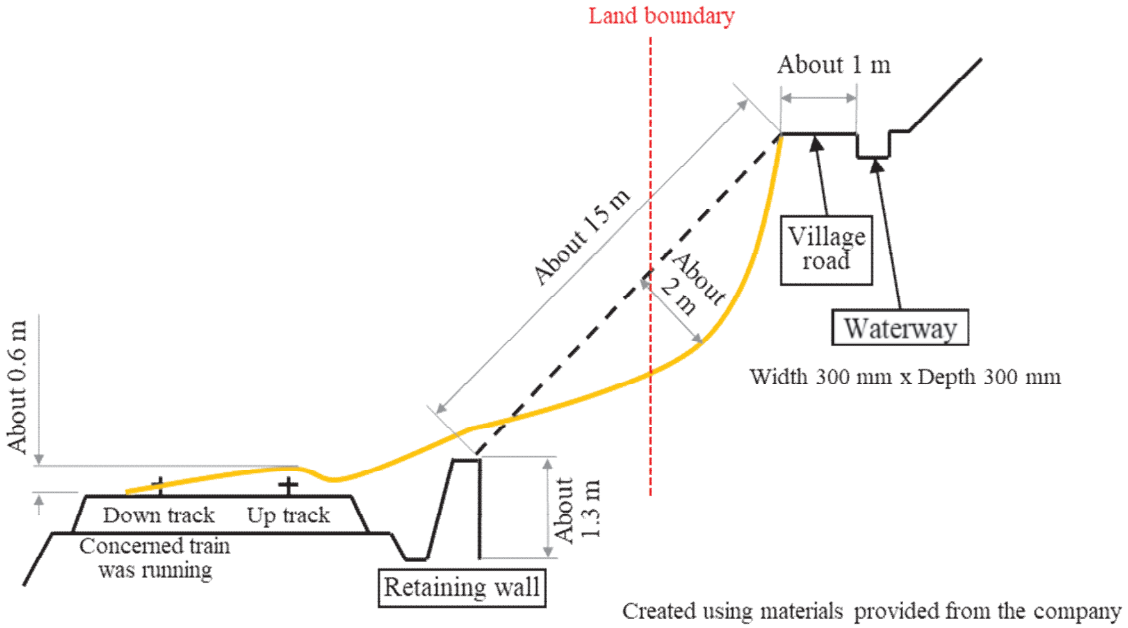
Attached Figure 4. Status of the Derailment



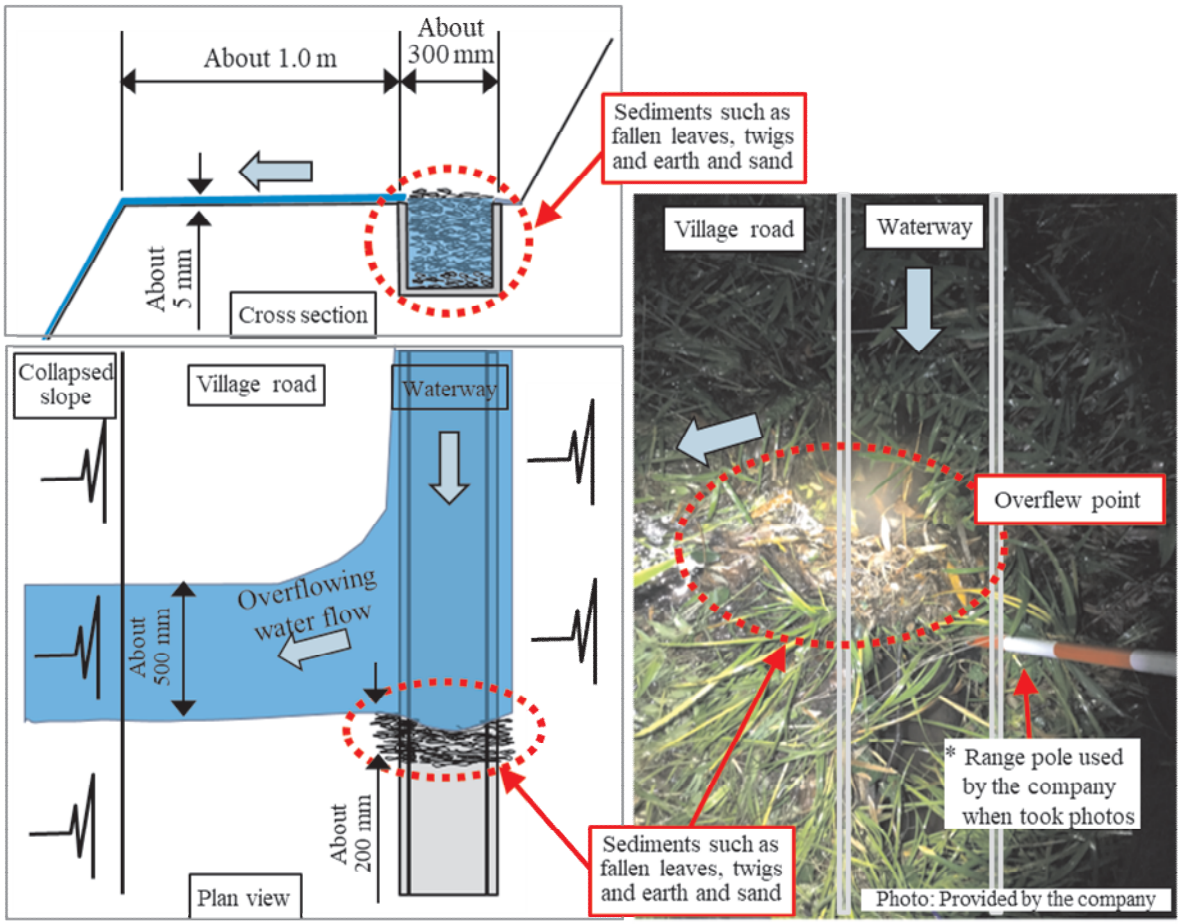
Attached Figure 5. Schematic Diagram in around the Accident Site



Attached Figure 6. Schematic Profile of the Collapsed Slope



Attached Figure 7. Status of the Upper Part of the Collapsed Slope



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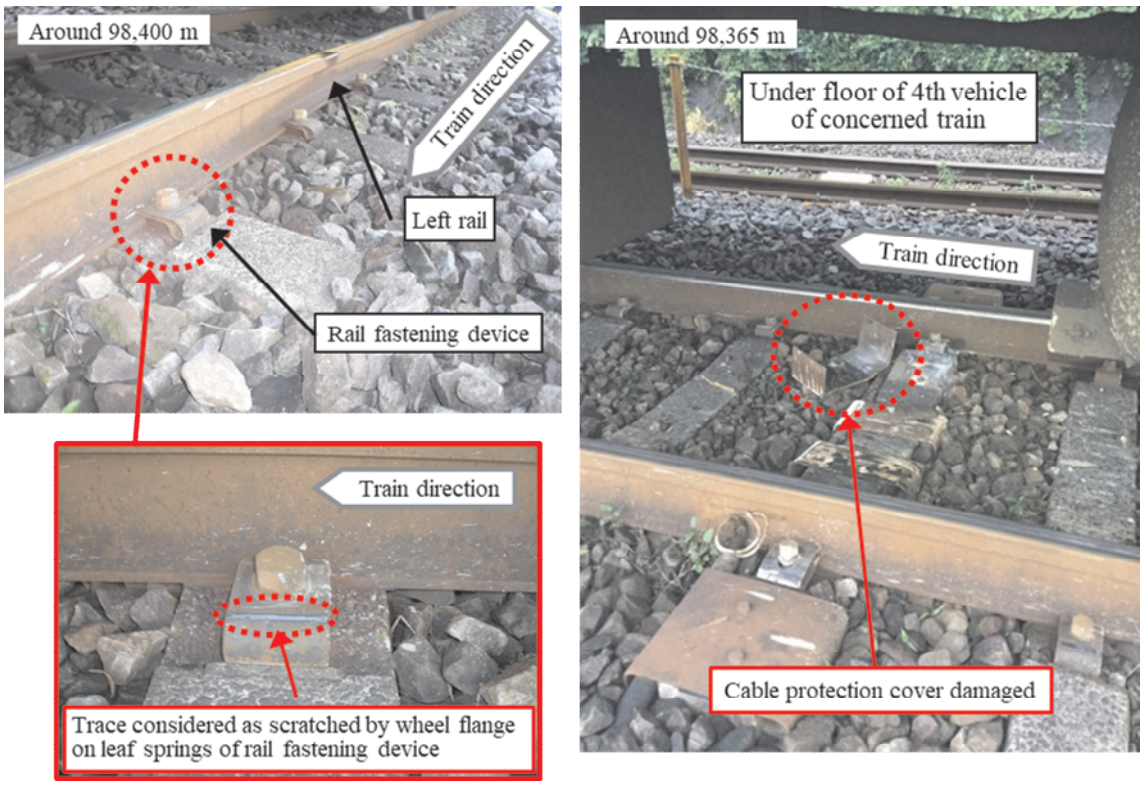
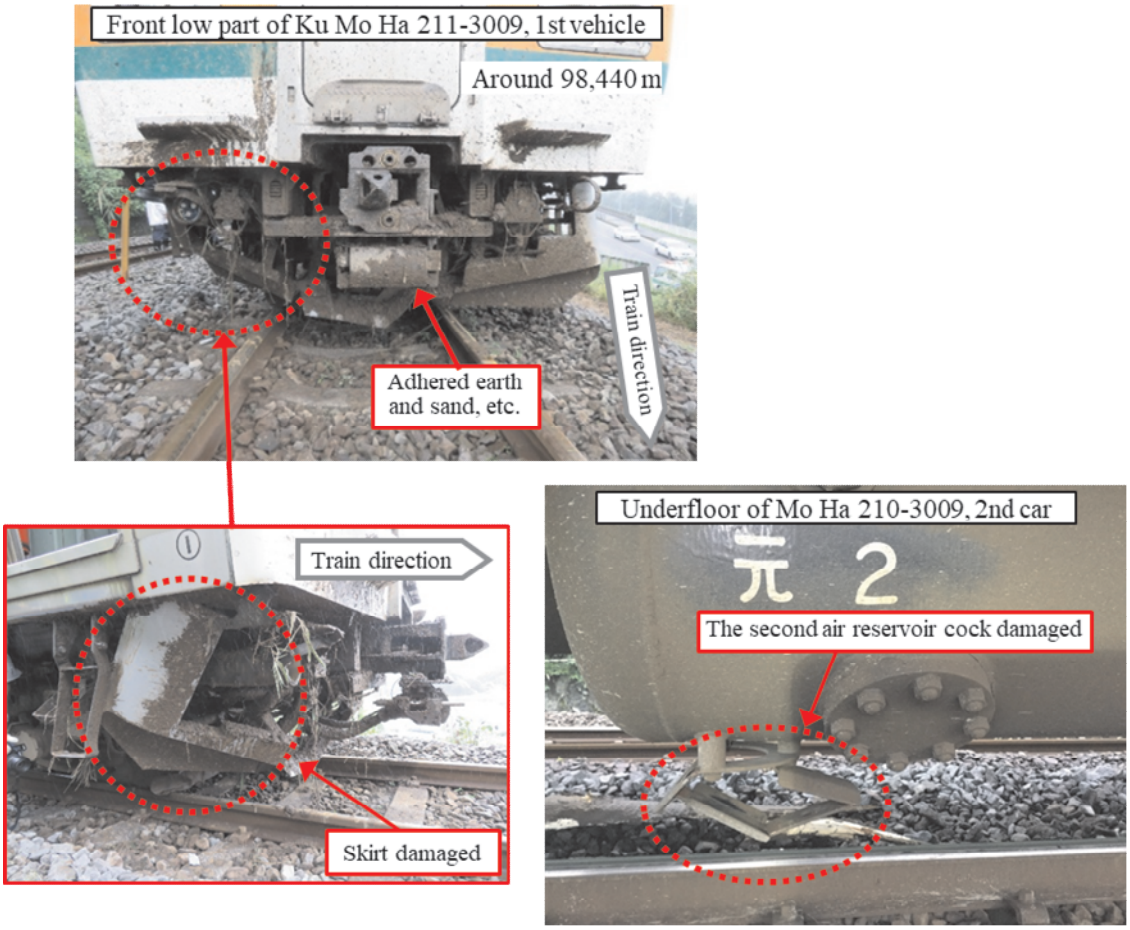
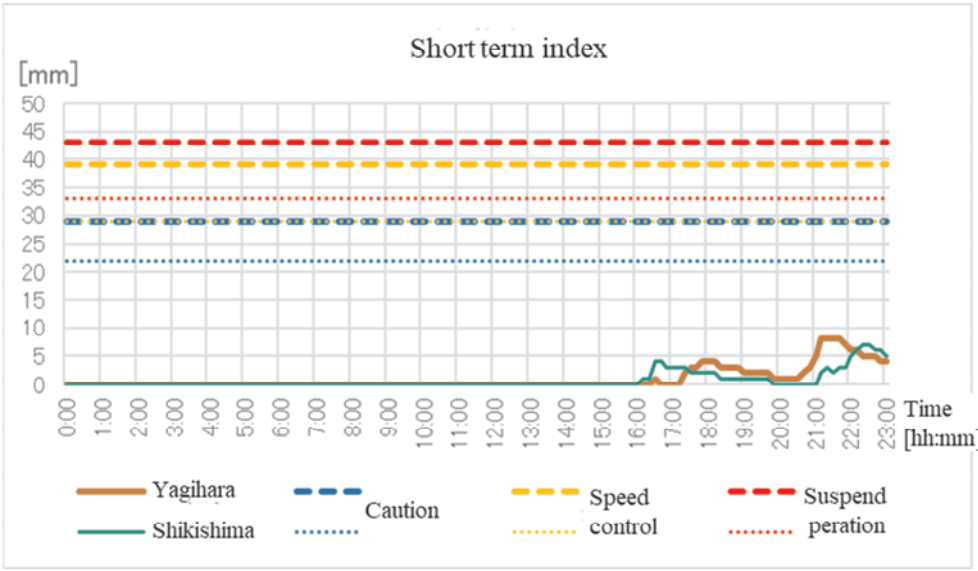
Attached Figure 8. Status of Major Damages of the Track

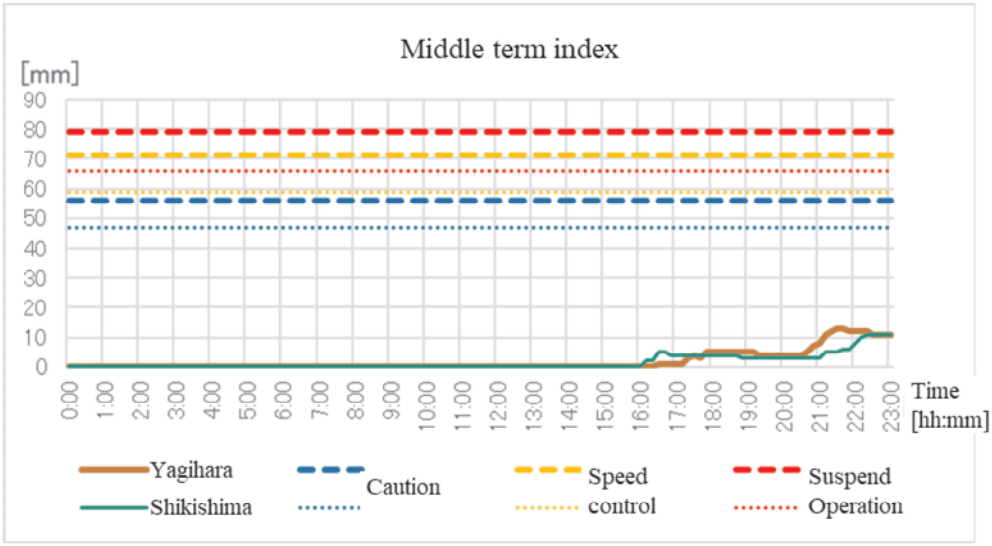


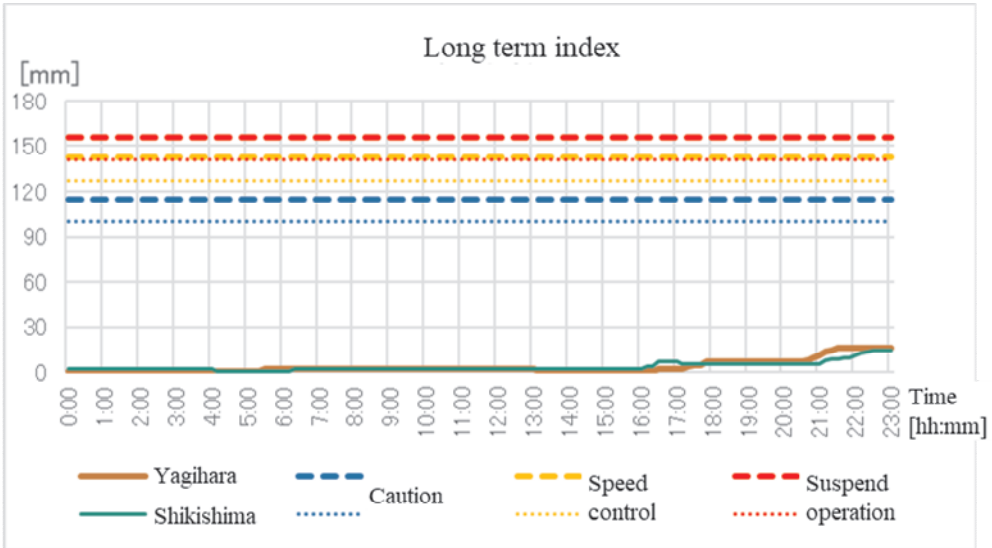
Attached Figure 9. Status of Major Damages of the Vehicle



Attached Figure 10. Shikishima and Yagihara Effective Rainfall

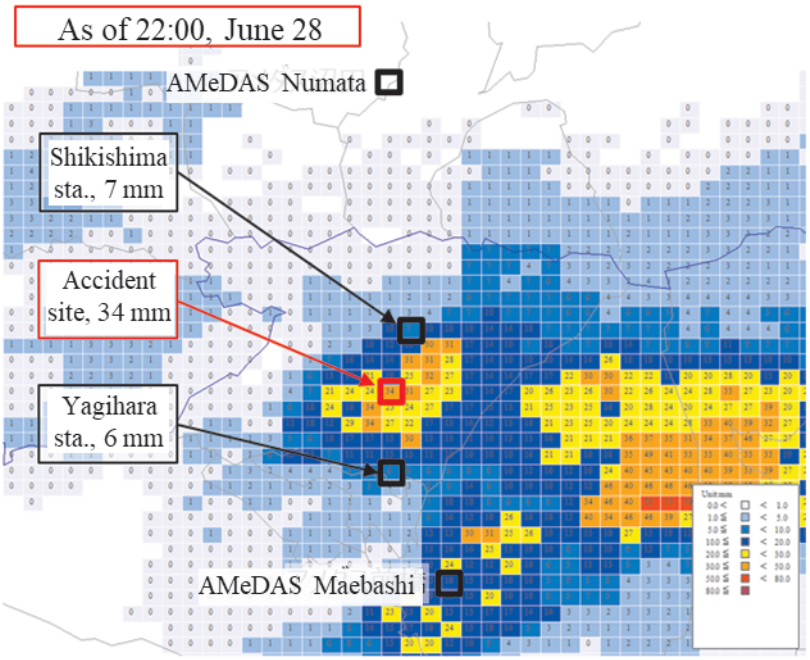




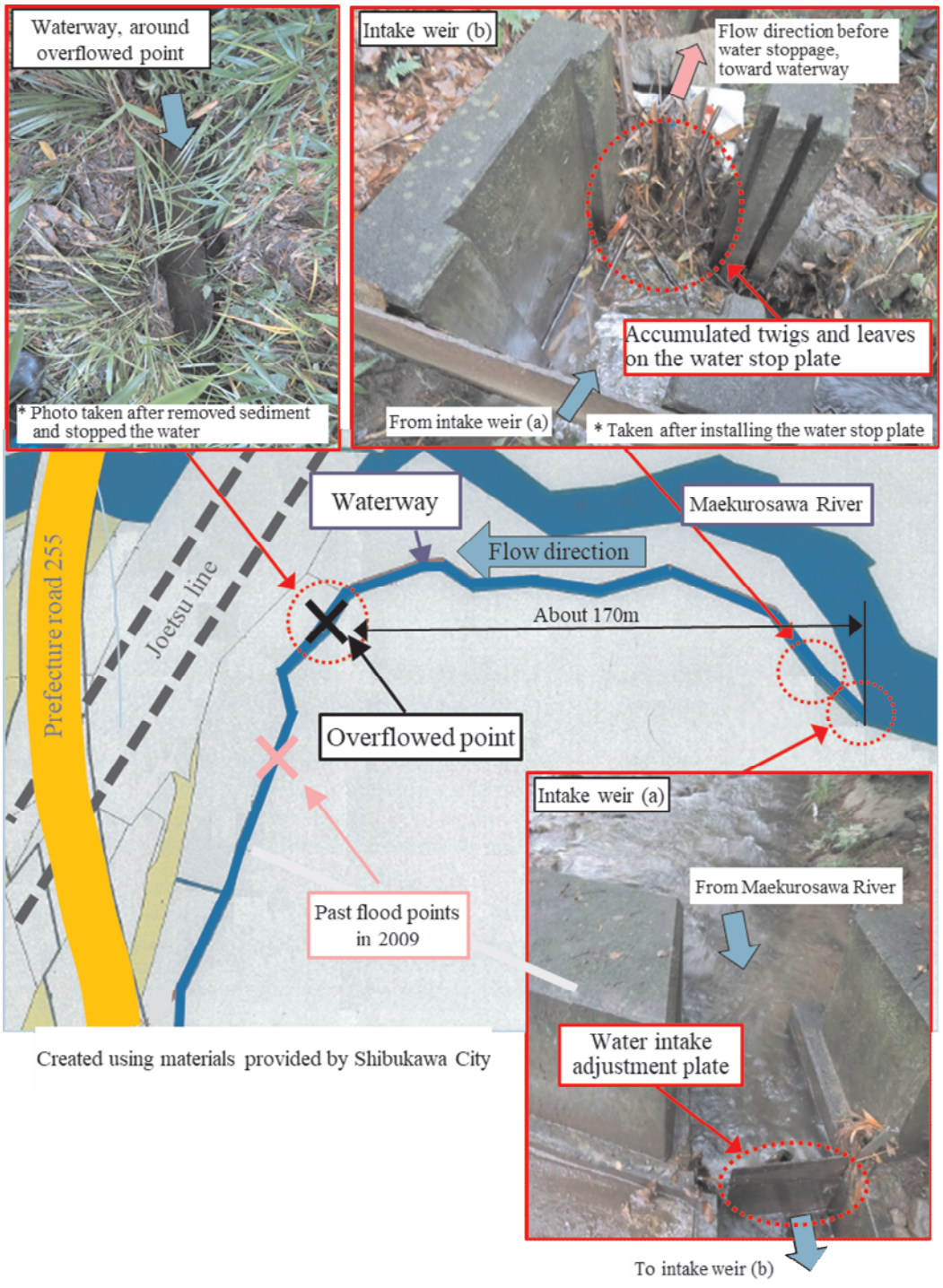


Attached Figure 11. Analyzed Rainfall in around the Accident Site

Time [hh:mm]	Precipitation [mm]
17:00	0
17:30	1
18:00	1
18:30	1
19:00	-
19:30	-
20:00	-
20:30	0
21:00	10
21:30	34
22:00	34
22:30	9
23:00	0



Attached Figure 12. Status of the Waterway



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