FY2018
Results of the Radioactive Material Monitoring in the Water Environment

March 2020
Ministry of the Environment

Contents

Note: In this report,

ND stands for “Not Detectable,”

FY stands for “Fiscal Year,” beginning in April and ending in March.

Outline

The following is an outline of the results of monitoring for radioactive material carried out in FY2018 based on the Water Pollution Control Act. Monitoring locations are as shown in Figure 1 and Figure 2.

1. National Radioactive Material Monitoring in the Water Environment throughout Japan (FY2018)

○ Monitoring commenced in FY2014 at 110 public water areas and groundwater locations in 47 prefectures in Japan for the purpose of clarifying the distribution of radioactive materials in those areas nationwide (hereinafter referred to as "Nationwide Monitoring"), in accordance with the Water Pollution Control Act.

○ A summary of the results for FY2018 is as follows.

<Overall outline>

• The total β radioactivity and the detected γ-ray emitting nuclides were within the past measurement trends[1]. Detection limits differ by nuclide and sampling location, but overall were around 0.001 to 0.1 Bq/L for water and around 1 to 100 Bq/kg for sediment[2], (“Bq/kg” of sediment indicates “dried sediment” in this report, and the same shall apply to Radioactive Material Monitoring performed in Fukushima Prefecture and the surrounding areas, and other national radioactive material monitoring.).

<Naturally occurring radionuclides>

• There were some locations where the value of K-40 and total β radioactivity were elevated in sediment samples from public water areas, but these levels were thought to have been influenced by natural rocks and soils.

• K-40 and total β radioactivity were detected at higher concentrations in groundwater samples at some locations, but they were thought to have been influenced by natural soils/rocks/ sea water.

<Artificial radionuclides>

• At some public water area monitoring locations, the artificial radionuclides Cs-134 and Cs-137 were detected exceeding their detection limits, but their values were within the past measurement trends.

○ It is appropriate to continue this monitoring from the following fiscal year onwards in order to clarify the distribution of radioactive materials in water environments.

2. Radioactive Material Monitoring in the Water Environment in and around Fukushima Prefecture (FY2018)

○ In response to the accident at the Tokyo Electric Power Company’s Fukushima Daiichi NPS (hereinafter referred to as the "Fukushima NPS Accident"), monitoring has been conducted continuously since August 2011 at around 600 public water area locations and around 400 groundwater locations in and around

[1] "Within the past measurement trends" means that the results of the latest monitoring survey are evaluated from a technical perspective as not displaying extreme deviation from the results of past similar monitoring surveys.

[2] See Table 3.1-1, Table 3.1-2, and Table 3.1-3 in Part 1 of this report for the details of the detection limits.

Fukushima prefecture for the purpose of clarifying the distribution of the accident-derived radioactive materials in water environments (hereinafter referred to as "Post-Earthquake Monitoring").

○ A summary of the results for FY2018 is as follows.

(1) Radioactive cesium

<Public water areas>

1) Water (detection limit: 1 Bq/L for both Cs-134 and Cs-137)

• While several locations showed a positive result for these radionuclides, they were not detectable in other locations.

2) Sediment (detection limit: 10 Bq/kg for both Cs-134 and Cs-137)

[Rivers]

• Out of all monitoring locations, the levels of both Cs-134 and Cs-137 were less than 200 Bq/kg at 3/4 of the locations, though they were detected at relatively higher levels at some limited locations, such as those within 20 km of Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant (hereinafter referred to as the "Within 20km"). The average values including past years were 100 Bq/kg or less at approximately half of the monitoring locations, while more than 90% of the other locations showed decreasing trends.

[Lakes]

• Out of all monitoring locations, the levels of both Cs-134 and Cs-137 were less than 3,000 Bq/kg at 3/4 of the locations, though they were detected at relatively high levels at some limited locations, such as those within 20 km of the power plant. The average values including past years were 100 Bq/kg or less at approximately 10% of the monitoring locations, while approximately 30% of the other locations showed fluctuations with approximately 70% of the monitoring locations showing either decreasing or unchanged trends.

[Coastal areas]

• Out of all monitoring locations, the levels of both Cs-134 and Cs-137 were less than 200 Bq/kg at 3/4 of the locations. The average values including past years were 100 Bq/kg or less at approximately 60% of the monitoring locations with over 80% of the other locations showing decreasing trends.

< Groundwater >

• Radioactive cesium was not detected in groundwater at any surveyed locations in FY2018 (detection limit: 1 Bq/L for both Cs-134 and Cs-137).

(2) Radionuclides other than radioactive cesium

• Sr-89: Was not detected at any surveyed groundwater locations.

• Sr-90: Was detected in collected sediment at several public water area locations, but remained at relatively low levels; was not detectable in water samples at any surveyed public water areas and at groundwater locations.

○ Measured activity concentrations have fluctuated at some locations. There is a possibility that this is due to the effects from the Fukushima nuclear accident, but the fluctuations could also be due to slight differences in sampling locations and the properties of individual samples. Therefore, it is appropriate to continue this monitoring on an ongoing basis over the following fiscal years.

3. Other Radioactive Material Monitoring Conducted Nationwide (FY2018)

○ The results of the Monitoring of Environmental Radioactivity Levels (hereinafter referred to as “Monitoring of Levels”), which has been conducted by the Nuclear Regulation Authority for the purpose of clarifying the existence or nonexistence of the effects from nuclear facilities, etc., nationwide, were all within the past measurement trends.

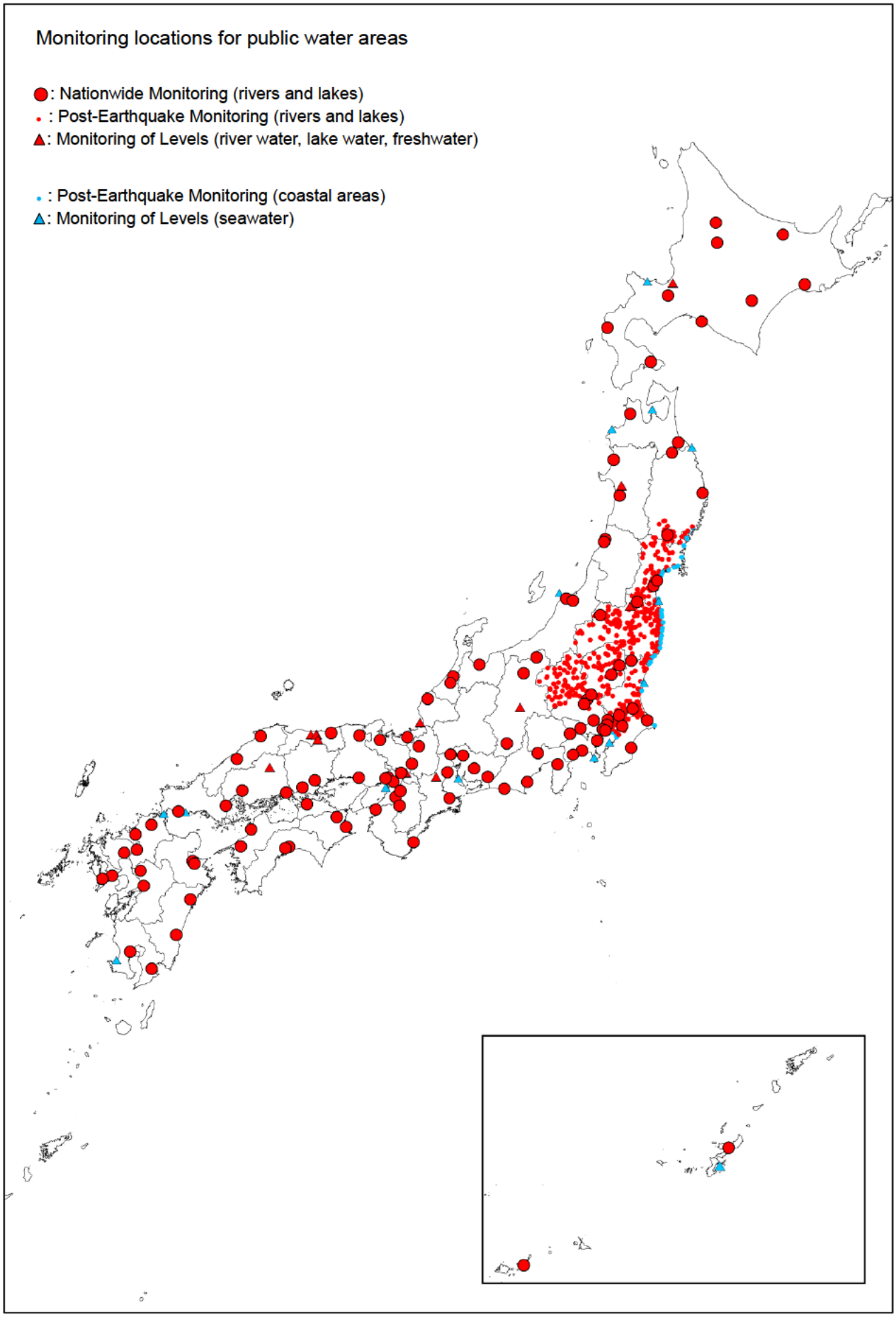


Figure 1 Locations for monitoring radioactive materials (public water areas)

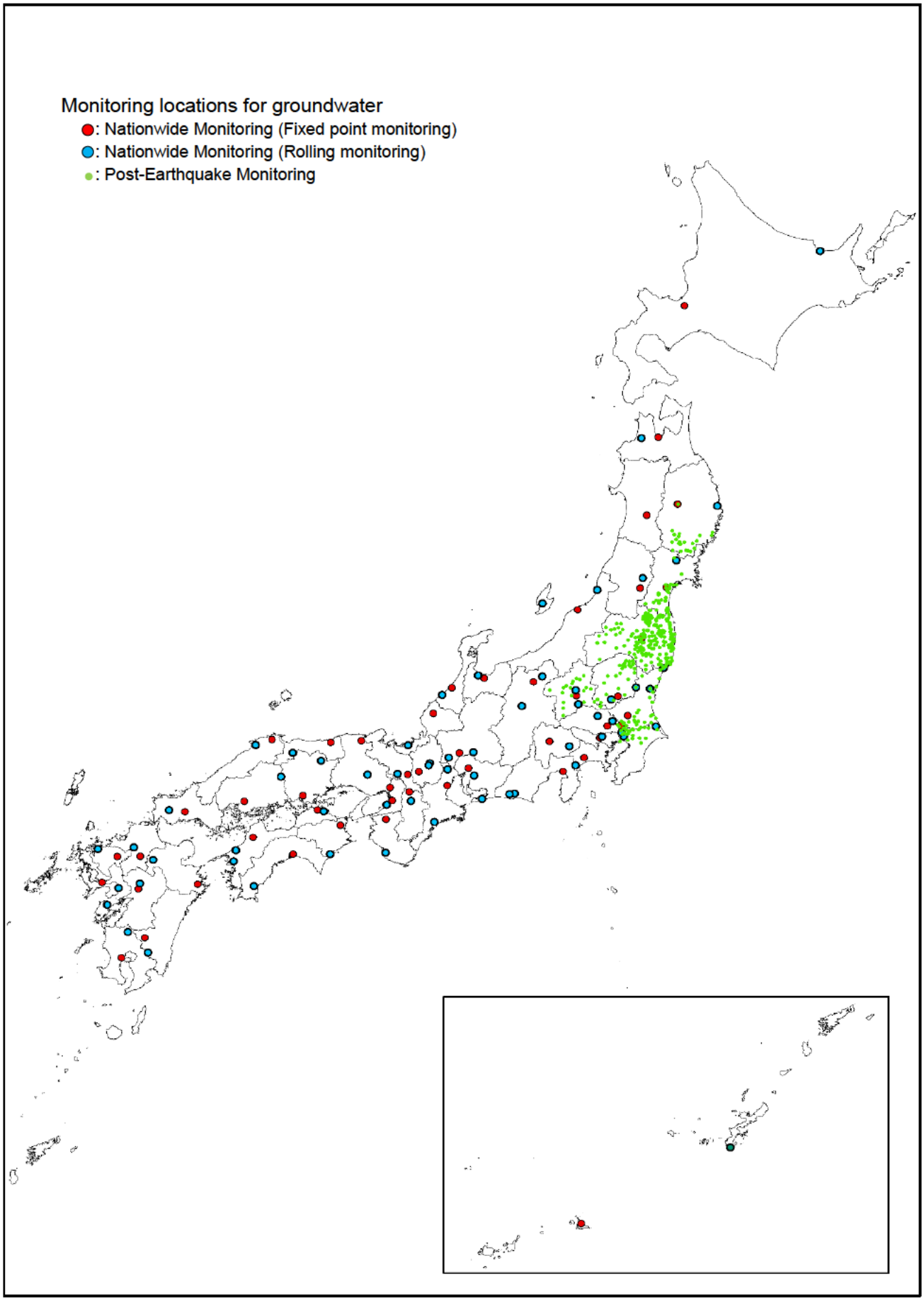


Figure 2 Locations for monitoring radioactive materials (groundwater)

Part 1: National Radioactive Material Monitoring in the Water Environment throughout Japan (FY2018)

1 Objective and Details

1.1 Objective

In response to the Fukushima NPS Accident, during which radioactive materials were discharged causing environmental pollution, the Water Pollution Control Act was amended. It was decided that the Minister of the Environment should monitor pollution caused by radioactive materials in public water areas and groundwater and release the results from the perspective of preserving the health and living environment of the people.

Based on the above, this monitoring aims to clarify the distribution of radioactive materials in public water areas and groundwater nationwide.

1.2 Details

(1) Monitoring locations

- Public water areas: 110 locations (rivers: 107 locations; lakes: three locations)
- Groundwater: 110 locations

Monitoring locations were selected based on the following policy with a view to ensuring balanced nationwide monitoring (specific locations are as shown in Tables 1.2-2 and 1.2-3 and Figures 1.2-1 and 1.2-2).

1) Public water areas

- At least one sampling location was selected in each prefecture, and additional locations were added according to the area and population of each prefecture.
- Locations within each prefecture were selected based on the following policy:
  a) Select representative rivers (including lakes) within each prefecture using the same numbers listed above, taking into account the area and population in their basins.
  b) Regarding rivers selected as explained in a), select locations from among those monitored for hazardous materials, etc., conducted under the Water Pollution Control Act, selected in consideration of water utilization points. Within a single river, give priority to a location in the lower reaches (including lakes located downstream).
  c) As this monitoring does not aim to clarify the effects from specific sources, exclude locations close to those subject to Environmental Monitoring around Nuclear Facilities, etc. (Radiation Monitoring Grants) in principle.

2) Groundwater

- Two sampling locations were chosen in each prefecture, and one more location was added for each prefecture in which the amount of groundwater utilized had been large over the past several years.
- Locations within each prefecture were selected from the locations for continuous monitoring of environmental standard items in groundwater based on the following policy, principally.
  a) Select regional representative wells (such as wells built for monitoring or major wells with an

especially large amount of water utilization) taking into consideration the amount of utilization of groundwater from each groundwater basin and water vein (hereinafter referred to as "groundwater basins, etc.").

b) Prioritize wells owned or managed by local governments, etc., in consideration of the convenience of coordination in case any additional survey is required.

c) Select one location for continuous fixed-point monitoring from among the locations selected in the manner above, taking into account that location's level of utilization and the representativeness of that groundwater basin in the wider area. Perform rolling monitoring at the remaining locations (for five years in principle).

d) As this monitoring does not aim to clarify the effects from specific sources, exclude locations close to those subject to Environmental Monitoring around Nuclear Facilities, etc. (Radiation Monitoring Grants), in principle.

(2) Targets

- Public water areas : Water and sediment (For lakes, water surveys are conducted both at surface layer and bottom layer.)
  (Additionally, as a reference, radioactive concentrations in soil and ambient dose rates around riverbeds, etc., in the environment surrounding the sampling locations are to be measured.)
- Groundwater : Water
  (Additionally, as a reference, ambient dose rates near the sampling locations are to be measured.)

(3) Frequencies and periods

- Public water areas : Once a year
  However, monitoring was conducted four times a year at two locations (one location in eastern and western Japan, respectively) in order to check for any seasonal variations.
- Groundwater : Fixed point monitoring was conducted once a year, and rolling monitoring was conducted once every five years for each location in principle.

FY2018 monitoring periods are as shown in Table 1.2-4.

(4) Conducted analyses

The following analyses were conducted for collected samples:

- Measurement of total β radioactivity concentrations.
- γ-ray spectrometry measurement using a germanium semiconductor detector (In principle, all detectable radionuclides, including artificial radionuclides and major naturally occurring radionuclides, were analyzed).

(5) Evaluation of measurement results

The measurement results were evaluated upon the guidance/advice of “Evaluation Committee on the National Radioactive Material Monitoring in the Water Environment for the whole of Japan” (Table 1.2-1) comprised of professionals.

1) Comparison with the past measurement trends

Obtained values were compared with the past measurement trends, and if any deviation was suspected, the validity of the measured values was rechecked (potential number transcription errors, incorrect calibration of equipment, etc.).

Because this monitoring has just commenced, there are no accumulated data for some locations. Therefore, results from similar environmental monitoring surveys conducted so far will be used for comparison for the time being. Specifically, results from the Monitoring of Environmental Radioactivity Levels and Monitoring of the Surrounding Environment conducted by the Nuclear Regulation Authority, as well as the results from the Radioactive Material Monitoring in Water Environments in and around Fukushima Prefecture conducted by the Ministry of the Environment were utilized. When making comparisons, due consideration was given to the possibility that the values of Cs-137 and other accident-derived radionuclides would have increased after the Fukushima NPS Accident.

Essentially, nationwide data for the past two decades were used for comparison. Considering the effects from the Fukushima NPS Accident and informed by actual measurements, “three years after the accident” was assumed to be a steady state, and therefore, data of artificial radionuclides from between Mar 11, 2011 to Mar 10, 2014 were excluded.

2) Measures to be taken when a value deviating from the past measurement trends was detected

The following measures were taken when a value deviating from the past measurement trends was detected (see Figure 1.2-3).

2)-1 Release of preliminary values

Any value that is suspected of deviating from the past measurement trends should be immediately evaluated professionally by the chair and the deputy chair, and if it is judged highly urgent (when it has been confirmed that the value is highly likely to deviate from the past measurement trends, and additional detailed analyses are considered to be necessary), a preliminary report should be released as promptly as possible.

In such a case, the following related data should be compiled as basic data for professional evaluation. Members of the Evaluation Committee other than the chair and the deputy chair should be informed of the relevant information together with the professional evaluation by the chair and the deputy chair (see Table 1.2-1 for the chair and other committee members).

i) Results of the measurement concerning water and sediment (γ-ray spectrometry and total β radioactivity concentrations), and ambient dose rates

ii) Sampling dates, sampling locations (maps, water depth, river width, etc.), sampling methods, and sampling circumstances (photos)

iii) Weather data for about one week close to the measurement date (the amount of precipitation, in particular)

iv) Ambient dose rates measured for the past month or so at neighboring points

v) Changes in detected values of a relevant radionuclide compared to the past

2)-2 Detailed analyses and release of the results

For data for which the preliminary report was released as explained in 2)-1 above, the following detailed analyses are to be conducted and the results are to be released.

- Specific analyses to identify radionuclides (including measurement of individual radionuclides through radiochemical analyses)
- Additional measurements in the surrounding areas of the relevant surveyed location

(6) Disclosure of measurement results

The measurement results data are made publicly available on the following Ministry of the Environment website:

http://www.env.go.jp/en/water/rmms/surveys.html

Table 1.2-1 List of members of the Evaluation Committee on the National Radioactive Material Monitoring in the Water Environment for the whole of Japan

IIMOTO Takeshi (Deputy chair)	Professor, Division for Environment, Health and Safety, the University of Tokyo
ISHII Nobuyoshi	Principal Researcher, Environmental Transfer Parameter Research Group, Department of Radioecology and Fukushima Project, Center for Advanced Radiation Emergency Medicine, Quantum Medical Science Directorate, National Institutes for Quantum and Radiological Science and Technology
TOKUNAGA Tomochika	Professor, Department of Environment Systems, Graduate School of Frontier Sciences, the University of Tokyo
HAYASHI Seiji	Research Group Manager & Head of Environmental Assessment Section, Fukushima Branch, National Institute for Environmental Studies
FUKUSHIMA Takehiko (Chair)	Director of the Center, Ibaraki Kasumigaura Environmental Science Center

Table 1.2-2 List of locations for FY2018 Nationwide Monitoring (public water areas) (No. 1)

No.	Prefecture	Property	Sampling location		
			Water area	Location	Municipality
1	Hokkaido Prefecture	River	Ishikari River	Domestic water intake at Ish kari River in Asahikawa City	Asahikawa City
2		River	Ishikari River	Intake at the Shirakawa water purification plant in Sapporo City	Sapporo City
3		River	Teshio River	Nakashibetsu Bridge (Intake at the Higashiyama water purification plant in Shibetsu City)	Shibetsu City
4		River	Tokoro River	Tadashi Bridge	Kitami City
5		River	Kushiro River	Intake at the Aikoku water purification plant in Kushiro City	Kushiro City
6		River	Tokachi River	Nantai Bridge	Obihiro City
7		River	Sarugawa River	Sarugawa Bridge (Tomigawa)	Hidaka Town
8		River	Matsukura River	Mitsumori Bridge (Before the confluence with Torasawa River)	Hakodate City
9		River	Shir beshi-toshibetsu River	Intake at the Kitahiyama simple water plant in Kitahiyama Town	Setana Town
10	Aomori Prefecture	River	Iwaki River	Tsugaru-ohashi Bridge	Nakadomari Town
11		River	Mabechi River	Shiriuchi Bridge	Hachinohe City
12	Iwate Prefecture	River	Mabechi River	Fugane Bridge	Ninohe City
13		River	Heigawa River	Miyako Bridge	Miyako City
14		River	Kitakami River	Chitose Bridge	Ichinoseki City
15	Miyagi Prefecture	River	Abukuma River	Iwanuma (Abukuma Bridge)	Iwanuma City
16		River	Natori River	Yuriage-ohashi Bridge	Natori City
17	Akita Prefecture	River	Yoneshiro River	Noshiro Bridge	Noshiro City
18		River	Omono River	Kurose Bridge	Akita City
19	Yamagata Prefecture	River	Mogami River	Ryou Bridge	Sakata City
20		River	Akagawa River	Shinkawa Bridge	Sakata City
21	Fukushima Prefecture	River	Agano River	Shingo Dam	Kitakata City
22		River	Abukuma River	Taisho Bridge (Fushiguro)	Date City
23		River	Kujigawa River	Takachihara Bridge	Yamatsuri Town
24	Ibaraki Prefecture	Lake	Lake Kasumigaura	Center of the lake	Miho Village
25		River	Kokai River	Fumimaki Bridge	Toride City
26	Tochigi Prefecture	River	Nakagawa River	Shinnaka Bridge	Nakagawa Town
27		River	Kinugawa River	Kinugawa Bridge (Hoshakuji Temple)	Utsunomiya City
28	Gunma Prefecture	River	Tonegawa River	Toneozeki Weir	Chiyoda Town / Gyoda City (Saitama Prefecture)
29		River	Watarase River	Watarase-ohashi Bridge	Tatebayashi City
30	Saitama Prefecture	River	Arakawa River	Kuge Bridge	Kumagaya City
31		River	Arakawa River	Akigase Intake Weir	Saitama City / Shiki City
32		River	Edogawa River	Nagareyama Bridge	Nagareyama City (Chiba Prefecture) / Misato City
33	Chiba Prefecture	River	Tonegawa River	Kakozeki Weir	Tonosho Town
34		River	Ichinomiya River	Nakano Bridge	Ichinomiya Town
35		Lake	Lake Inbanuma	Lower area of water supply intake	Sakura City
36	Tokyo Metoropolis	River	Edogawa River	Shinkatsushika Bridge	Katsushika City
37		River	Tamagawa River	Haijima raw water supply point	Akishima City
38		River	Sumida River	Ryogoku Bridge	Chuo City / Sumida City
39		River	Arakawa River	Kasai Bridge	Koto City / Edogawa City
40	Kanagawa Prefecture	River	Tsurumi River	Rinko Tsurumigawa Bridge	Yokohama City
41		River	Sagami River	Banyu Bridge	Hiratsuka City
42		River	Sakawa River	Sakawa Bridge	Odawara City
43	Niigata Prefecture	River	Shinano River	Heisei-ohashi Bridge	Niigata City
44		River	Agano River	Oun Bridge	Niigata City
45	Toyama Prefecture	River	Jinzu River	Hagiura Bridge	Toyama City
46	Ishikawa Prefecture	River	Saigawa River	Okuwa Bridge	Kanazawa City
47		River	Tedori River	Hakusangoguchi Dike	Hakusan City
48	Fukui Prefecture	River	Kuzuryu River	Fuseda Bridge	Fukui City
49		River	Kitagawa River	Takatsuka Bridge	Obama City
50	Yamanashi Prefecture	River	Sagami River	Katsuragawa Bridge	Uenohara City
51		River	Fujikawa River	Nanbu Bridge	Nanbu Town
52	Nagano Prefecture	River	Shinano River	Ozeki Bridge	Iiyama City
53		River	Saigawa River	Koichi Bridge	Nagano City
54		River	Tenryu River	Tsutsuji Bridge	Iida City

Table 1.2-2 List of locations for FY2018 Nationwide Monitoring (public water areas) (No. 2)

No.	Prefecture	Property	Sampling location		
			Water area	Location	Municipality
55	Gifu Prefecture	River	Kisogawa River	Tokai-ohashi Bridge（Naruto）	Kaizu City
56		River	Nagara River	Tokai-ohashi Bridge	Kaizu City
57	Shizuoka Prefecture	River	Kanogawa River	Kurose Bridge	Numazu City
58		River	Ooi River	Fujimi Bridge	Yaizu City / Yoshida Town
59		River	Tenryu River	Kaketsuka Bridge	Iwata City / Hamamatsu City
60	Aichi Prefecture	River	Shonai River	Mizuwake Bridge	Nagoya City
61		River	Yahagi River	Iwazutenjin Bridge	Okazaki City / Toyota City
62		River	Toyogawa River	Eshima Bridge	Toyokawa City
63	Mie Prefecture	River	Suzuka River	Ogura Bridge	Yokkaichi City
64		River	Miyakawa River	Watarai Bridge	Ise City
65	Shiga Prefecture	River	Adogawa River	Joan Bridge	Takashima City
66		Lake	Lake Biwako	Karasakioki-Chuo	—
67	Kyoto Prefecture	River	Yuragawa River	Yuragawa Bridge	Maizuru City
68		River	Katsura River	Before the confluence of three tributaries of Katsura River	Oyamazaki Town
69	Osaka Prefecture	River	Inagawa River	Gunko Bridge	Itami City (Hyogo Prefecture)
70		River	Yodogawa River	Sugaharashirokita-ohashi Bridge	Osaka City
71		River	Ish kawa River	Takahashi	Tondabayashi City
72	Hyogo Prefecture	River	Kakogawa River	Kakogawa Bridge	Kakogawa City
73		River	Mukogawa River	Hyakkenbi	Takarazuka City
74		River	Maruyama River	Kaminogo Bridge	Toyooka City
75	Nara Prefecture	River	Yamato River	Fujii	Oji Town
76		River	Kinokawa River	Okura Bridge	Gojo City
77	Wakayama Prefecture	River	Kinokawa River	Shinrokkaizeki Weir	Wakayama City
78		River	Kumano River	Kumano-ohashi Bridge	Shingu City
79	Tottori Prefecture	River	Sendai River	Gyotoku	Tottori City
80	Shimane Prefecture	River	Hiikawa River	Kandatsu Bridge	Izumo City
81		River	Gonokawa River	Sakurae-ohashi Bridge	Gotsu City
82	Okayama Prefecture	River	Asahikawa River	Otoite Weir	Okayama City
83		River	Takahashi River	Kasumi Bridge	Kurashiki City
84	Hiroshima Prefecture	River	Ota River	Water supply intake in Hesaka	Hiroshima City
85		River	Ashida River	Kominomi Bridge	Fukuyama City
86	Yamaguchi Prefecture	River	Nishiki River	Domestic water intake for the city	Iwakuni City
87		River	Koto River	Suenobu Bridge	Ube City
88	Tokushima Prefecture	River	Yoshino River	Takase Bridge	Ishii Town
89		River	Nakagawa River	Nakagawa Bridge	Anan City
90	Kagawa Prefecture	River	Dokigawa River	Marugame Bridge	Marugame City
91	Ehime Prefecture	River	Shigenobu River	Deai Bridge	Matsuyama City
92		River	Hijikawa River	Hijikawa Bridge	Ozu City
93	Kochi Prefecture	River	Kagami River	Kachuzeki Weir	Kochi City
94		River	Niyodo River	Hatazeki Weir (1) Center of flow	Ino Town
95	Fukuoka Prefecture	River	Onga River	Hinode Bridge	Nogata City
96		River	Nakagawa River	Shiobara Bridge	Fukuoka City
97		River	Ch kugo River	Senoshita	Kurume City
98	Saga Prefecture	River	Kasegawa River	Kase Bridge	Saga City
99	Nagasaki Prefecture	River	Honmyo River	In front of Tenma Park	Isahaya City
100		River	Uragami River	Ohashizeki Weir	Nagasaki City
101	Kumamoto Prefecture	River	K kuchi River	Shiroishi	Nagomi Town
102		River	Midori River	Uesugizeki Weir	Kumamoto City
103	Oita Prefecture	River	Oita River	Funaichi-ohashi Bridge	Oita City
104		River	Oono River	Shirataki Bridge	Oita City
105	Miyazaki Prefecture	River	Gokase River	Miwa	Nobeoka City
106		River	Oyodo River	Shinaioi Bridge	Miyazaki City
107	Kagoshima Prefecture	River	Kotsuki River	Iwasaki Bridge	Kagoshima City
108		River	Kimotsuki River	Matase Bridge	Kanoya City
109	Okinawa Prefecture	River	Genka River	Water intake	Nago City
110		River	Miyara River	Omoto water intake	Ishigaki City

Table 1.2-3 List of locations for FY2018 Nationwide Monitoring (groundwater) (No. 1)

No.	Prefecture	Property	Municipality	District	Monitoring method
1	Hokkaido Prefecture	Groundwater	Sapporo City	Kitasanjonishi, Chuo Ward	Fixed point monitoring
2		Groundwater	Abashiri City	Onnenai	Rolling monitoring
3	Aomori Prefecture	Groundwater	Aomori City	Shinmachi	Fixed point monitoring
4		Groundwater	Tsugaru City	Kizukurisuehiro	Rolling monitoring
5	Iwate Prefecture	Groundwater	Morioka City	Motomiya	Fixed point monitoring
6		Groundwater	Miyako City	Shinkawacho	Rolling monitoring
7	Miyagi Prefecture	Groundwater	Sendai City	Honcho, Aoba Ward	Fixed point monitoring
8		Groundwater	Kurihara City	Wakayanagi Kamihataoka	Rolling monitoring
9	Akita Prefecture	Groundwater	Daisen City	Niiyaji	Fixed point monitoring
10		Groundwater	Akita City	Kawabematsubuchi	Rolling monitoring
11	Yamagata Prefecture	Groundwater	Yamagata City	Hatagomachi	Fixed point monitoring
12		Groundwater	Higashine City	Chuo	Rolling monitoring
13	Fukushima Prefecture	Groundwater	Koriyama City	Asahi	Fixed point monitoring
14		Groundwater	Iwaki City	Nishikimachi	Rolling monitoring
15	Ibaraki Prefecture	Groundwater	Tsukuba City	Kenkyugakuen	Fixed point monitoring
16		Groundwater	Kamisu City	Onohara	Rolling monitoring
17		Groundwater	Hitachiota City	Kanaicho	Rolling monitoring
18	Tochigi Prefecture	Groundwater	Shimotsuke City	Machida	Fixed point monitoring
19		Groundwater	Tochigi City	Jonaicho	Rolling monitoring
20		Groundwater	Motegi Town	Iino	Rolling monitoring
21	Gunma Prefecture	Groundwater	Maebashi City	Shikishimacho	Fixed point monitoring
22		Groundwater	Shibukawa City	Akagimachi Takizawa	Rolling monitoring
23		Groundwater	Fujioka City	Tatsuishi	Rolling monitoring
24	Saitama Prefecture	Groundwater	Saitama City	Mikura, Minuma Ward	Fixed point monitoring
25		Groundwater	Kasukabe City	Hiro	Rolling monitoring
26		Groundwater	Konosu City	Mida	Rolling monitoring
27	Chiba Prefecture	Groundwater	Kashiwa City	Funato	Fixed point monitoring
28		Groundwater	Funabashi City	Natsumidai	Rolling monitoring
29		Groundwater	Matsudo City	Tokiwadaira	Rolling monitoring
30	Tokyo Metoropolis	Groundwater	Koganei City	Kajinocho	Fixed point monitoring
31		Groundwater	Nerima City	Sekimachikita	Rolling monitoring
32	Kanagawa Prefecture	Groundwater	Hadano City	Imaizumi	Fixed point monitoring
33		Groundwater	Hakone Town	Kowakudani	Rolling monitoring
34	Niigata Prefecture	Groundwater	Niigata City	Nagata, Chuo Ward	Fixed point monitoring
35		Groundwater	Sado City	Yahata	Rolling monitoring
36		Groundwater	Murakami City	Matsubaracho	Rolling monitoring
37	Toyama Prefecture	Groundwater	Toyama City	Funahashikitamachi	Fixed point monitoring
38		Groundwater	Imizu City	Imai	Rolling monitoring
39	Ishikawa Prefecture	Groundwater	Hakusan City	Kuramitsu	Fixed point monitoring
40		Groundwater	Komatsu City	Hamasamimachi	Rolling monitoring
41	Fukui Prefecture	Groundwater	Fukui City	Ote	Fixed point monitoring
42		Groundwater	Obama City	Horiyashiki	Rolling monitoring
43	Yamanashi Prefecture	Groundwater	Showa Town	Saijyoshinden	Fixed point monitoring
44		Groundwater	Tsuru City	Shimoya	Rolling monitoring
45	Nagano Prefecture	Groundwater	Nagano City	Tsurugamidoricho	Fixed point monitoring
46		Groundwater	Nakano City	Chuo	Rolling monitoring
47		Groundwater	Matsumoto City	Chuo	Rolling monitoring
48	Gifu Prefecture	Groundwater	Gifu City	Kanoshimizucho	Fixed point monitoring
49		Groundwater	Yoro Town	Naka	Rolling monitoring
50		Groundwater	Kani City	Imawatari	Rolling monitoring
51	Shizuoka Prefecture	Groundwater	Numazu City	Hara	Fixed point monitoring
52		Groundwater	Iwata City	Mitsuke	Rolling monitoring
53		Groundwater	Hamamatsu City	Kaminishicho, Higashi Ward	Rolling monitoring
54	Aichi Prefecture	Groundwater	Nagoya City	Kawaharatori, Showa Ward	Fixed point monitoring
55		Groundwater	Toyota City	Maebayashicho	Rolling monitoring
56		Groundwater	Tahara City	Okubocho	Rolling monitoring

Table 1.2-3 List of locations for FY2018 Nationwide Monitoring (groundwater) (No. 2)

No.	Prefecture	Property	Municipality	District	Monitoring method
57	Mie Prefecture	Groundwater	Suzuka City	Inoucho	Fixed point monitoring
58		Groundwater	Inabe City	Inabecho Kam kasada	Rolling monitoring
59		Groundwater	Kihoku Town	Nagashima	Rolling monitoring
60	Shiga Prefecture	Groundwater	Moriyama City	Miyakecho	Fixed point monitoring
61		Groundwater	Hikone City	Kamiokabecho	Rolling monitoring
62		Groundwater	Higashiomi City	Inokocho	Rolling monitoring
63	Kyoto Prefecture	Groundwater	Kyoto City	Toraishicho, Nakagyo Ward	Fixed point monitoring
64		Groundwater	Kameoka City	Amarubecho Wakunari	Rolling monitoring
65	Osaka Prefecture	Groundwater	Sakai City	Daisennakamachi, Sakai Ward	Fixed point monitoring
66		Groundwater	Kishiwada City	Harukidaikokucho	Rolling monitoring
67	Hyogo Prefecture	Groundwater	Itami City	Kuchisakai	Fixed point monitoring
68		Groundwater	Toyooka City	Saiwaicho	Fixed point monitoring
69		Groundwater	Nishiwaki City	Shimotoda	Rolling monitoring
70	Nara Prefecture	Groundwater	Nara City	Sakyo	Fixed point monitoring
71		Groundwater	Tenri City	Nakayamacho	Rolling monitoring
72	Wakayama Prefecture	Groundwater	Kinokawa City	Takano	Fixed point monitoring
73		Groundwater	Shirahama Town	Taira	Rolling monitoring
74	Tottori Prefecture	Groundwater	Tottori City	Saiwaicho	Fixed point monitoring
75		Groundwater	Kofu Town	Ebi	Rolling monitoring
76	Shimane Prefecture	Groundwater	Matsue City	Nishikawatsucho	Fixed point monitoring
77		Groundwater	Izumo City	Himebara(1)	Rolling monitoring
78	Okayama Prefecture	Groundwater	Kurashiki City	Fukui	Fixed point monitoring
79		Groundwater	Tsuyama City	Kamocho Tatsuchu	Rolling monitoring
80	Hiroshima Prefecture	Groundwater	Hiroshima City	Kamisenocho, Aki Ward	Fixed point monitoring
81		Groundwater	Shobara City	Tojocho Kushiro	Rolling monitoring
82	Yamaguchi Prefecture	Groundwater	Yamaguchi City	Ouchimihori	Fixed point monitoring
83		Groundwater	Mine City	Ominecho Nishibun	Rolling monitoring
84	Tokushima Prefecture	Groundwater	Tokushima City	Fudohoncho	Fixed point monitoring
85		Groundwater	Kaiyo Town	Takazono	Rolling monitoring
86	Kagawa Prefecture	Groundwater	Takamatsu City	Bancho	Fixed point monitoring
87		Groundwater	Sanuki City	Shido	Rolling monitoring
88	Ehime Prefecture	Groundwater	Matsuyama City	Hiraimachi	Fixed point monitoring
89		Groundwater	Seiyo City	Uwacho Kamimatsuba	Rolling monitoring
90		Groundwater	Ozu City	Shiba	Rolling monitoring
91	Kochi Prefecture	Groundwater	Kochi City	Kerako	Fixed point monitoring
92		Groundwater	Shimanto City	Fuba	Rolling monitoring
93	Fukuoka Prefecture	Groundwater	Kurume City	Tanushimarumachi Akinari	Fixed point monitoring
94		Groundwater	Chikushino City	Yamae	Rolling monitoring
95	Saga Prefecture	Groundwater	Saga City	Yamatochoni ji	Fixed point monitoring
96		Groundwater	Imari City	Hatatsucho Koba	Rolling monitoring
97	Nagasaki Prefecure	Groundwater	Isahaya City	Eidamachi	Fixed point monitoring
98		Groundwater	Shimabara City	Uenohara	Rolling monitoring
99	Kumamoto Prefecture	Groundwater	Kumamoto City	Suizenji, Chuo Ward	Fixed point monitoring
100		Groundwater	Amakusa City	Saitsumachi	Rolling monitoring
101		Groundwater	Koshi City	Sakae	Rolling monitoring
102	Oita Prefecure	Groundwater	Saiki City	Kamioka	Fixed point monitoring
103		Groundwater	Hita City	Hidaka	Rolling monitoring
104	Miyazaki Prefecture	Groundwater	Miyakonojo City	Minamiyokoichicho	Fixed point monitoring
105		Groundwater	Kobayashi City	Minaminish kata	Fixed point monitoring
106		Groundwater	Miyakonojo City	Minamiyokoichicho	Rolling monitoring
107	Kagoshima Prefecture	Groundwater	Kagoshima City	Tamazatocho	Fixed point monitoring
108		Groundwater	Isa City	Okuchimemaru	Rolling monitoring
109	Okinawa Prefecture	Groundwater	Miyakojima City	Hirarahigashinakasonezoe	Fixed point monitoring
110		Groundwater	Itoman City	Mabuni	Rolling monitoring

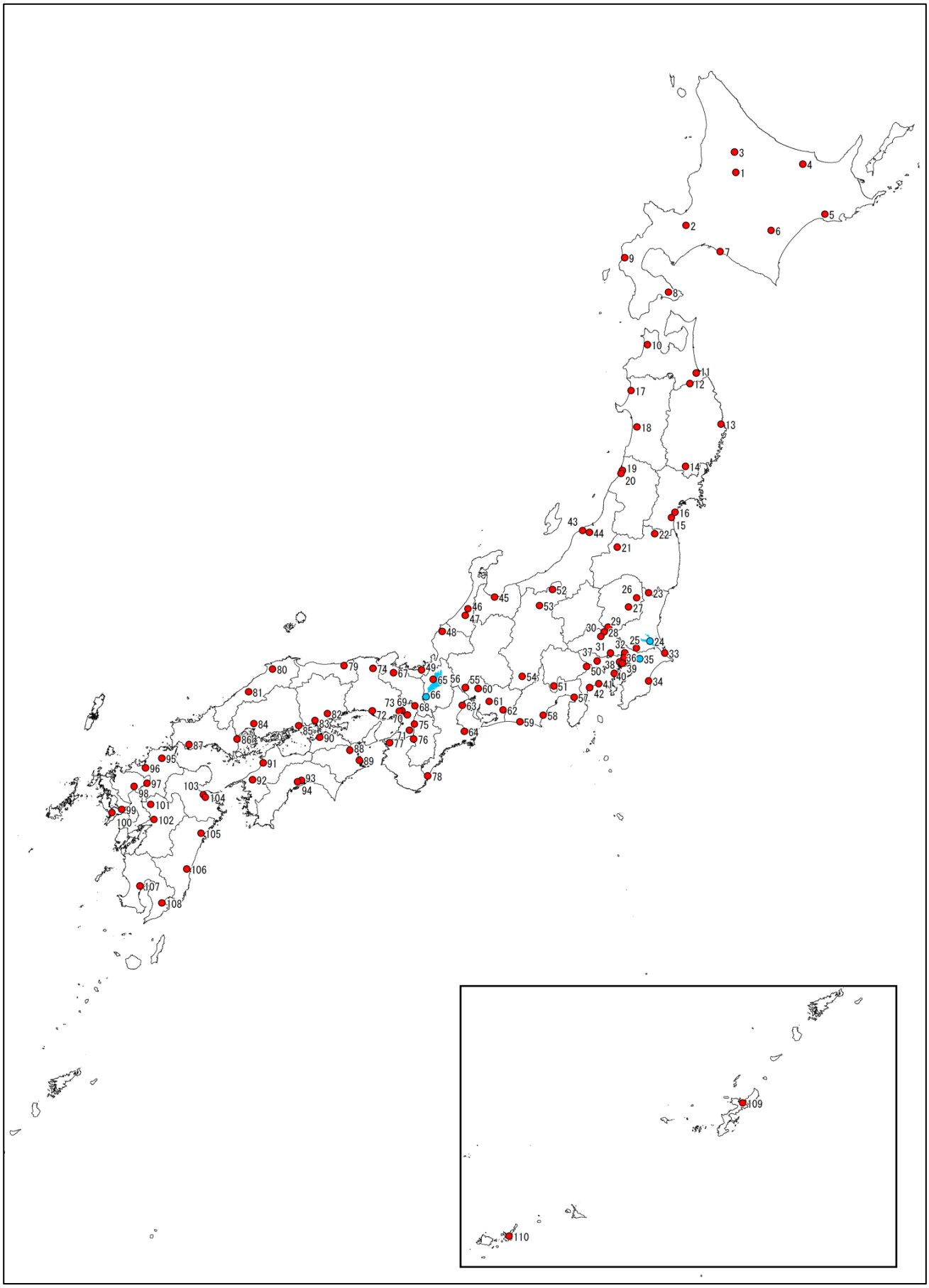


Figure 1.2-1 Map showing locations for FY2018 Nationwide Monitoring (public water areas)

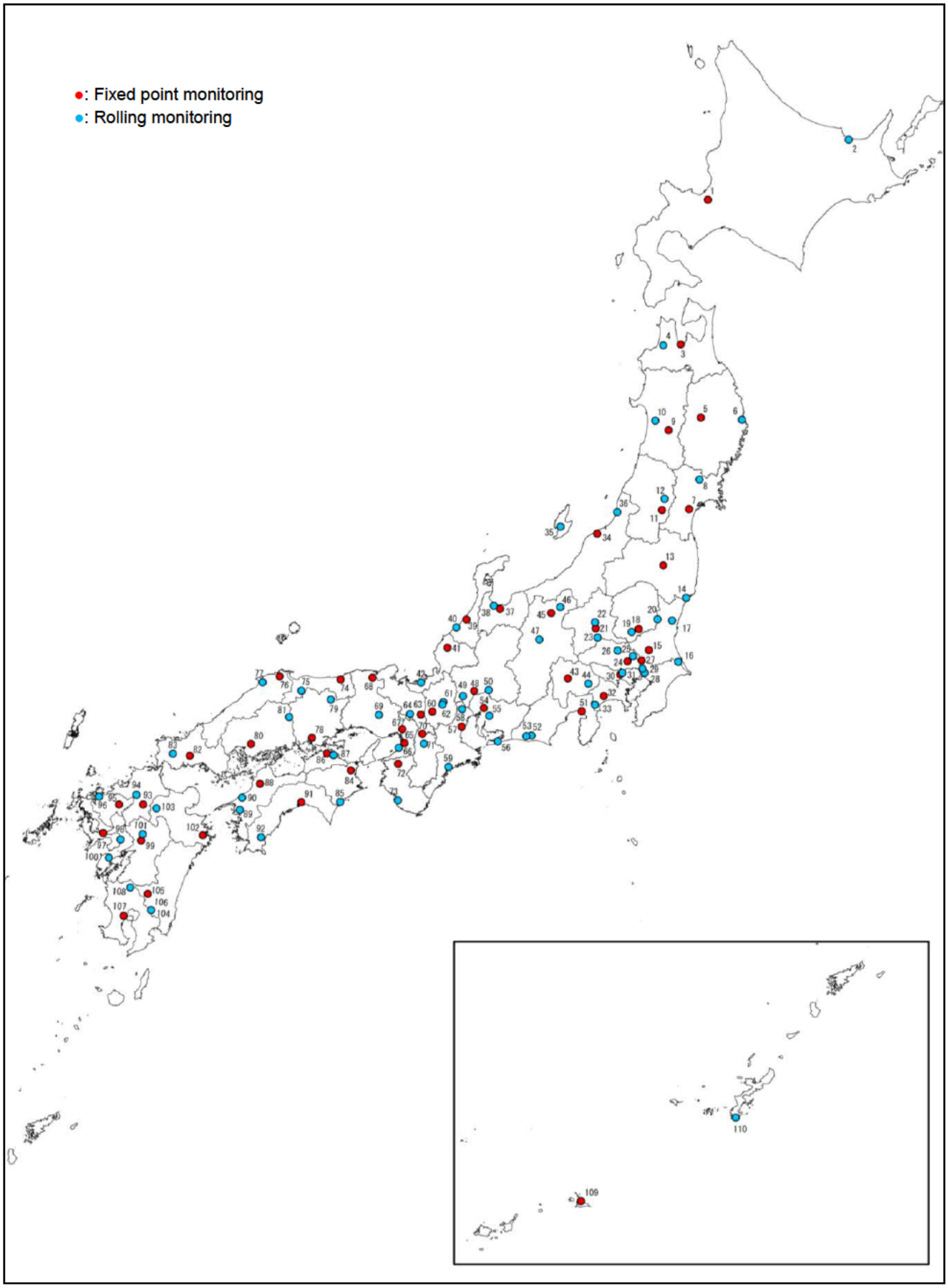


Figure 1.2-2 Map showing locations for FY2018 Nationwide Monitoring (groundwater)

Table 1.2-4 Monitoring points and period by block (FY2018)

Blocks	Prefectures	Public water areas		Groundwater	
		Number of Locations (*1)	Period	Number of locations	Period
Hokkaido block	Hokkaido	9	Aug 21 to Sep 21	2	Aug 20 to Aug 29
Tohoku block	Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima	14	Aug 20 to Oct 26	12	Aug 20 to Oct 5
Kanto block	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Niigata, Yamanashi and Shizuoka	26 (2)	Aug 20 to Oct 29	27	Aug 20 to Sep 19, Dec 10 (*2)
Chubu block	Toyama, Ishikawa, Fukui, Nagano, Gifu, Aichi and Mie	15	Aug 20 to Nov 8	18	Aug 20 to Sep 27
Kinki block	Shiga, Kyoto, Osaka, Hyogo, Nara, and Wakayama	14 (1)	Aug 22 to Oct 24	14	Aug 22 to Sep 19
Chugoku-Shikoku Block	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, and Kochi	16	Aug 20 to Oct 19	19	Aug 20 to Oct 19
Kyushu and Okinawa block	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, and Okinawa	16	Aug 20 to Sep 20	18	Aug 21 to Oct 9
Survey to check for seasonal variations	Gunma and Okayama	2	May 22 to Jan 18	-	-

(*1) Numbers in parentheses designate monitoring locations for lakes; plain numbers are for rivers.

(*2) The groundwater at No.53 was collected on December 10, and collection from other locations was completed by September 19.

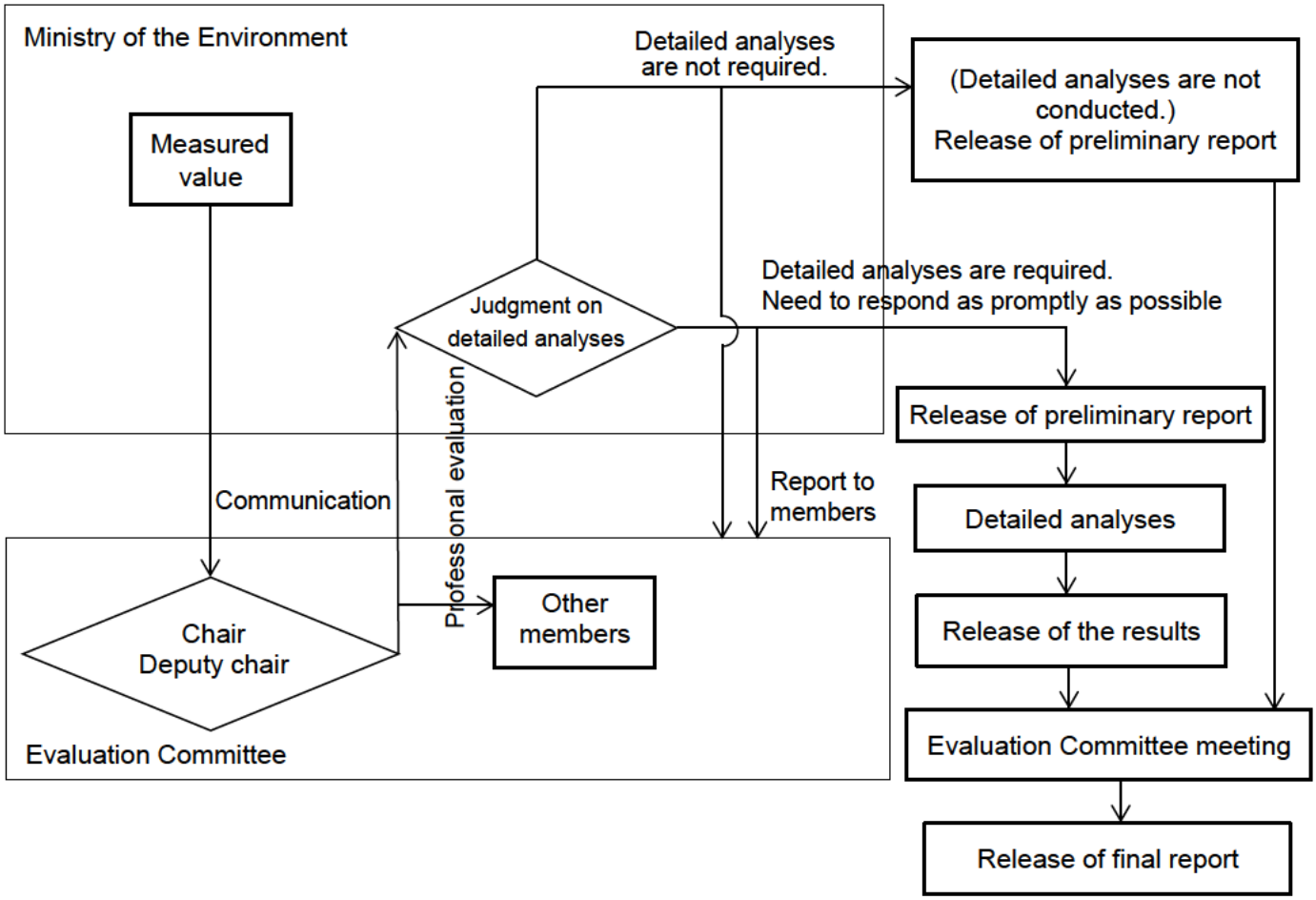


Figure 1.2-3 Procedures for professional evaluation of the results of the Nationwide Monitoring

2 Survey Methods and Analysis Methods

2.1 Survey methods

Samples were collected based on the following guidelines in principle, as outlined below.

- Water Quality Survey Method (Sep 30, 1971; Notice Kansuikan No. 30 issued by the Director General of the Water Quality Preservation Bureau, Ministry of the Environment)
- Sediment Survey Method (Aug 8, 2012; Notice Kansuitaisuihatsu No. 120725002 issued by the Director General of the Environmental Management Bureau, Ministry of the Environment)
- Groundwater Quality Survey Method (Sep 14, 1989; Notice Kansuikan No. 189 issued by the Director General of the Water Quality Preservation Bureau, Ministry of the Environment)
- Environmental Sample Collection Method (1983, Ministry of Education, Culture, Sports Science and Technology (hereinafter referred to as "MEXT")'s Radioactivity Measurement Method Series)
- Sample Pretreatment for Instrumental Analysis Using Germanium Semiconductor Detectors (1982, MEXT's Radioactivity Measurement Method Series)

(1) Public water areas

- Water:

  Water samples of around 160 L (hydrochloric acid added) and around 2 L (nitric acid added) were collected at the predetermined points. From the 160 L sample (hydrochloric acid added), 80 L was used for γ-ray spectrometry analyses and the remaining 80 L was preserved for possible detailed analyses. From the 2 L sample (nitric acid added), 1 L was used to measure total β radioactivity concentrations.

  Additionally, the transparency (or Secchi disk depth) was measured when collecting water samples, and in the case that transparency was thought to have been affected by rainwater based on comparison to prior measurements, or if there was no past data to compare, the measured transparency was 50 cm or less and it was suspected that rainwater may have influenced transparency, the water was not used as samples.

- Sediment:

  Bottom sediment samples of around 6 L were collected at the predetermined points at a depth of around 10 cm from the surface layer by using an Ekman-Birge grab sampler etc., and 3 L out of the 6 L was used for γ-ray spectrometry analyses.

- Soil:

  Soil samples (around 5 cm in diameter) were collected at a depth of around 5 cm at five points within a 3 to 5 meter square (four vertexes and the diagonal intersection point), or, when it was difficult to find an appropriate square to determine five such sampling locations, soil from five points at 3 to 5 meter intervals along a river was collected and was brought back separately. Samples thus collected at the five points were mixed in equal amounts respectively and were used for analyses.

- Ambient dose rates (soil sampling locations):

  Ambient dose rates were measured by installing NaI (Tl) scintillation survey meters at a height of 1 m

from the ground surface on both banks of a river (or in the case of a lake, installing a NaI (Tl) scintillation survey meter at one point on lake side) so that the meters would face the sampling location of river water (or lake water).

(2) Groundwater

• Water:

Groundwater samples of around 160 L (hydrochloric acid added) and 2 L (nitric acid added) were collected at the predetermined wells, etc., 80 L of the 160 L sample (hydrochloric acid added) was used for γ-ray spectrometry analyses and the remaining 80 L was preserved for possible detailed analyses. 1 L of the 2 L sample (nitric acid added) was used to measure total β radioactivity concentrations.

When collecting water samples, it was confirmed that water temperature, transparency, pH, and electrical conductivity remained constant by allowing the water to pass for several minutes, and changes in the transparency, etc., thereafter were recorded as notes.

• Ambient dose rates:

Ambient dose rates were measured by installing NaI (Tl) scintillation survey meters at a height of 1 m from the ground surface outdoors near the relevant wells, etc., so that they would face the sampling location of groundwater (or the groundwater layer).

2.2 Analysis methods

For public water areas (water and sediment) and groundwater (water), total β radioactivity concentrations and γ-ray spectrometry with a germanium semiconductor detector were conducted using the methods below. As a general rule, the γ-ray spectrometry measurement covered all detectable radionuclides (including artificial radionuclides and naturally occurring radionuclides). Measurements were described to two significant digits, and the unit of measurements were "Bq/L" for water samples from public water areas and groundwater samples, and "Bq/kg (dry weight)" for sediment samples from public water areas, respectively.

The adopted analysis methods were essentially in line with the MEXT's Radioactivity Measurement Method Series, and detection limits were set around 0.001 to 0.01 Bq/L for water samples and around 1 to 30 Bq/kg for sediment samples. (However, these detection limits did not apply to radionuclides with short half-lives or those with extremely low γ-ray emission rates.)

• Measurement of total β radioactivity concentrations: The samples were concentrated and dried, and then measurements were taken using a low-background gas-flow proportional counter.

• γ-ray spectrometry measurement: After proper pretreatment, the samples were placed in a U-8 container or a 2L Marinelli beaker and measured using a germanium semiconductor detector. The following 62 types of γ-ray emitting radionuclides (18 naturally occurring radionuclides and 44 artificial radionuclides) were surveyed. The measured results of γ-ray emitting radionuclides were corrected for attenuation, and figures were reported as activity concentration after sampling.

Table 2.2-1 Surveyed γ-ray emitting radionuclides

Naturally occurring radionuclides (18 radionuclides)		Artificial radionuclides (44 radionuclides)				
Ac-228	Ra-224	Ag-108m	Co-58	I-131	Np-239	Te-129m
Be-7	Ra-226	Ag-110m	Co-60	I-132	Ru-103	Te-132
Bi-212	Th-227	Am-241	Cr-51	La-140	Ru-106	Y-91
Bi-214	Th-228	As-74	Cs-134	Mn-54	Sb-124	Y-93
K-40	Th-231	Ba-140	Cs-136	Mn-56	Sb-125	Zn-63
Pa-234m	Th-234	Bi-207	Cs-137	Mo-99	Sb-127	Zn-65
Pb-210	Tl-206	Ce-141	Fe-59	Nb-95	Sr-91	Zr-95
Pb-212	Tl-208	Ce-143	Ga-74	Nb-97	Tc-99m	Zr-97
Pb-214	U-235	Ce-144	Ge-75	Nd-147	Te-129	

3 Results

An outline of detectable radioactive materials at each monitoring location is as follows.

3.1 Detection of total β radioactivity and γ-ray emitting radionuclides

(1) Public water areas

1) Water

The results of the measurements of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas are as shown in Table 3.1-1 and Figure 3.1-1.

i) Total β radioactivity

The detection rate for total radioactivity was 92.0% with detected values ranging from not detectable to 2.8 Bq/L; they were all within the past measurement trends.

ii) γ-ray emitting radionuclides

As shown in Table 3.1-1 and Figure 3.1-1, six types of γ-ray emitting radionuclides (four naturally occurring radionuclides and two artificial radionuclides) were detected, while other types of γ-ray emitting radionuclides were not detectable at any of the locations surveyed.

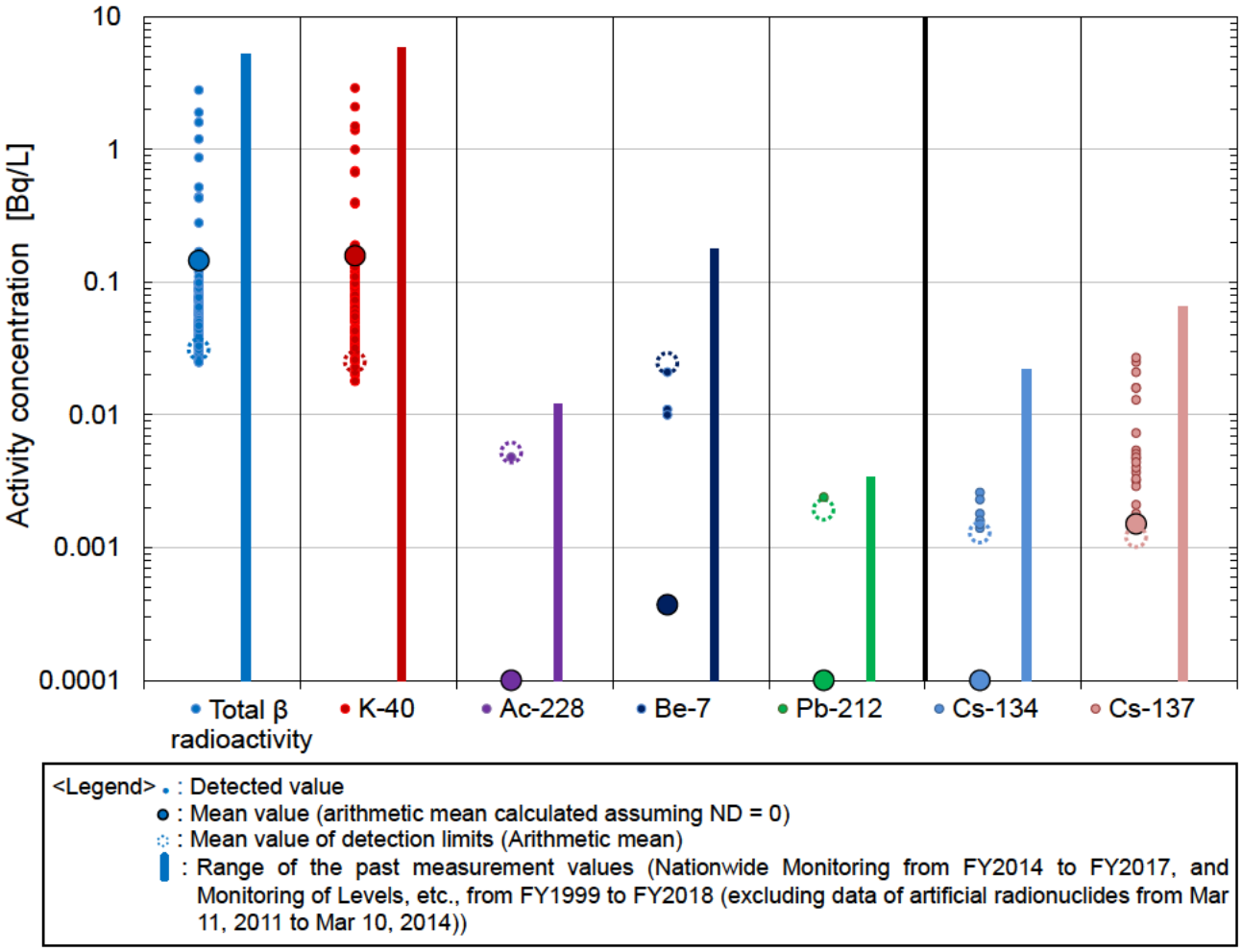
The detection rates of naturally occurring radionuclides were 3% or less, except for K-40, for which the detection rate was 95.6%. All of the measured values of naturally occurring radionuclides were within the past measurement trends.

Regarding artificial radionuclides, the detection rate was 5.3% for Cs-134 and 16.8% for Cs-137, while the nuclide concentration of Cs-134 was 0.0026 Bq/L or less, Cs-137 was 0.027 Bq/L or less: all of which were within the past measurement trends.

Table 3.1-1 Detection of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas

Radionuclides			Number of samples	Number of detec ions	Detection rate [%]	Measured values [Bq/L]		Maximum records [Bq/L]	
						Range	Detection limits	Nationwide monitoring (FY2014-FY2017)	Monitoring of Levels (*1)
Total β radioactivity			113	104	92.0	ND - 2.8	0.022 - 0.22	5.2	0.24
γ-ray emitting radionuclides	Naturally occurring	K-40	113	108	95.6	ND - 2.9	0.012 - 0.087	5.8	2.3
		Ac-228	113	1	0.9	ND - 0.0048	0.0028 - 0.020	0.012	0.0037
		Be-7	113	3	2.7	ND - 0.021	0.0074 - 0.082	0.057	0.18
		Pb-212	113	1	0.9	ND - 0.0024	0.0009 - 0.0081	0.0034	No data
	Artificial	Cs-134	113	6	5.3	ND - 0.0026	0.0008 - 0.0046	0.022	0.015
		Cs-137	113	19	16.8	ND - 0.027	0.0007 - 0.0043	0.065	0.041

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1999 to FY2018 (excluding data of artificial radionuclides from Mar 11, 2011 to Mar 10, 2014)



(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely depending on the type of radionuclide.

Figure 3.1-1 Detection of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas

2) Sediment

The results for total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas are as shown in Table 3.1-2 and Figure 3.1-2.

i) Total β radioactivity

Total β radioactivity was detected at all locations surveyed, with detected values ranging from 160 to 1,400 Bq/kg: some of which exceeded the range of the past measurement records, however, they were all attributable to naturally occurring radionuclides and considered to be within the past measurement trends.

ii) γ-ray emitting radionuclides

As shown in Table 3.1-2 and Figure 3.1-2, 10 types of γ-ray emitting radionuclides (eight naturally occurring radionuclides and two artificial radionuclides) were detected, while no other types of γ-ray emitting radionuclides were detectable.

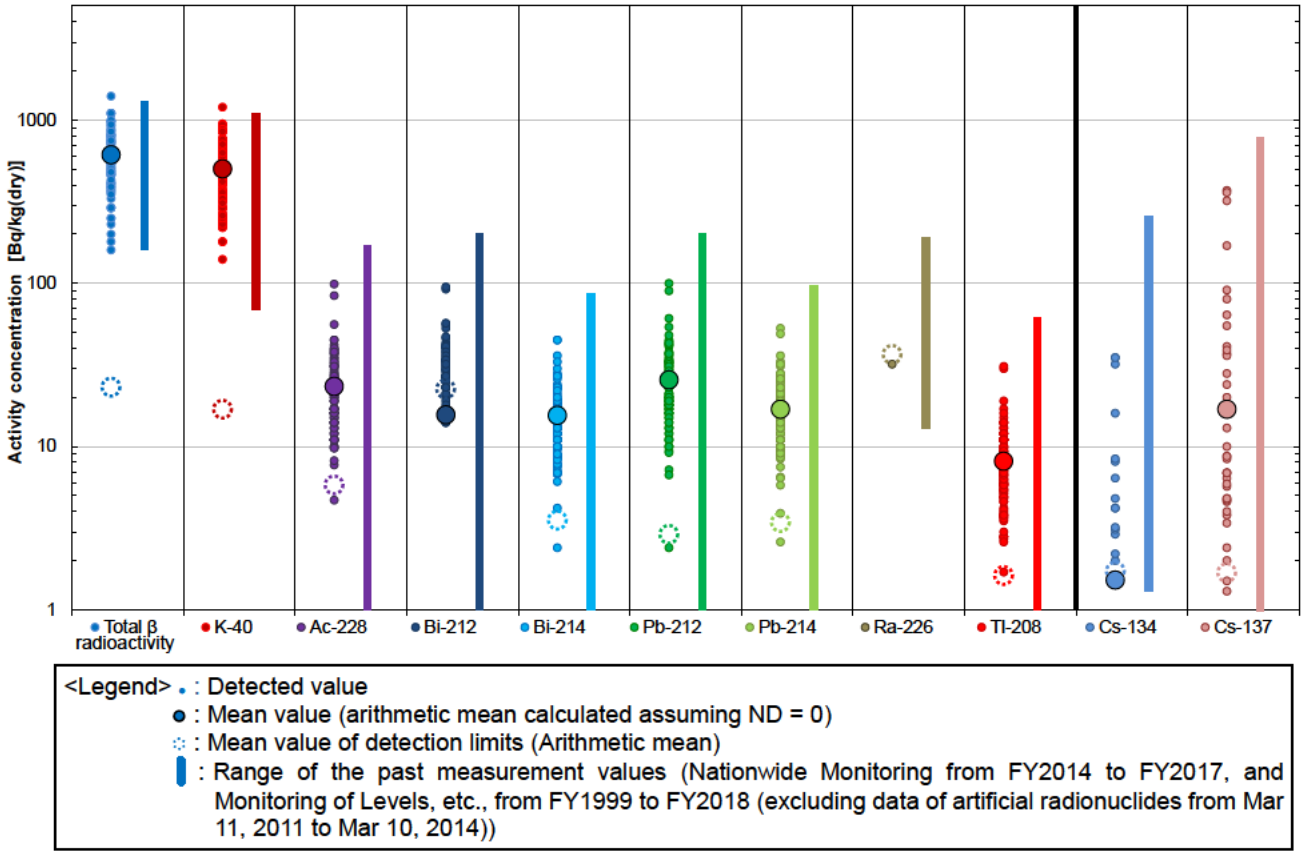
The detection rates of the six naturally occurring radionuclides other than Bi-212, and Ra-226 exceeded 95%. K-40 exceeded the range of the past measurement records at some locations; however, K-40 is generally contained in natural soils and rocks: the values were all considered to be within the past measurement trends (described later).

As for artificial radionuclides, the detection rates of Cs-134 and Cs-137 were 13.6% and 33.6% respectively, while detected values were 35 Bq/kg or less for Cs-134 and 370 Bq/kg or less for Cs-137: all of which were within the past measurement trends.

Table 3.1-2 Detection of total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas

Radionuclides			Number of samples	Number of detections	Detection rate [%]	Measured values [Bq/kg (dry)]		Maximum records [Bq/kg(dry)]	
						Range	Detection limits	Nationwide monitoring (FY2014-FY2017)	Monitoring of Levels (*1)
Total β radioactivity			110	110	100	160 - 1,400	14 - 36	1,300	1,300
γ-ray emitting radionuclides	Naturally occurring	K-40	110	110	100	140 - 1,200	9.5 - 31	1,100	800
		Ac-228	110	109	99.1	ND - 99	3.2 - 9.8	170	ND
		Bi-212	110	51	46.4	ND - 95	11 - 40	200	No data
		Bi-214	110	110	100	2.4 - 45	1.9 - 7.8	87	ND
		Pb-212	110	110	100	2.4 - 100	1.6 - 6.3	200	No data
		Pb-214	110	110	100	2.6 - 53	1.7 - 8.4	96	No data
		Ra-226	110	1	0.9	ND - 32	18 - 170	190	122
		Tl-208	110	109	99.1	ND - 31	0.83 - 3.1	61	No data
	Artificial	Cs-134	110	15	13.6	ND - 35	0.89 - 3.5	260	30
		Cs-137	110	37	33.6	ND - 370	0.78 - 3.3	780	110

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment studies conducted in Japan nationwide from FY1999 to FY2018 (excluding data of artificial radionuclides from Mar 11, 2011 to Mar 10, 2014)



(*) Details of the detection of Cs-134 and Cs-137 are explained later.
(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely with the type of radionuclide.

Figure 3.1-2 Detection of total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas

(2) Groundwater

The measurement results for total β radioactivity and γ-ray emitting radionuclides in groundwater samples are as shown in Table 3.1-3 and Figure 3.1-3.

i) Total β radioactivity

The detection rate of total β radioactivity was 90.0% with detected values ranging from not detectable to 1.3 Bq/L: some of which exceeded the range of the past measurement records, however, they were all attributable to K-40 (naturally occurring radionuclide) and considered to be within the past measurement trends.

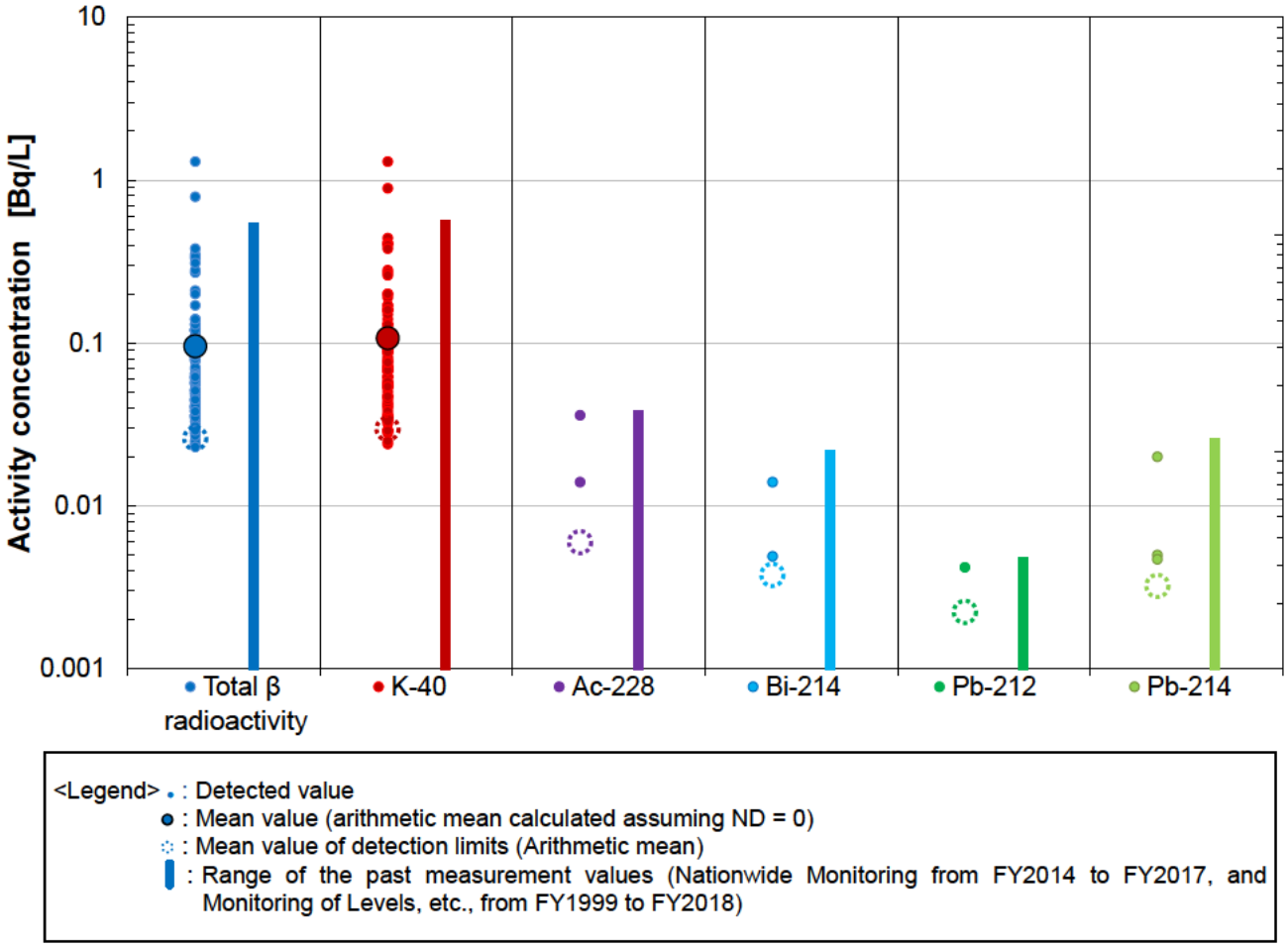
ii) γ-ray emitting radionuclides

Five types of γ-ray emitting radionuclides (all naturally occurring radionuclides), as shown in Table 3.1-3 and Figure 3.1-3, were detected, while no other types of γ-ray emitting radionuclides were detected. The detection rate was less than 3% except for the detection rate of K-40 which was 85.5%. K-40 exceeded the range of the past measurement records at some locations, however, K-40 is generally contained in natural soils, rocks, and seawater, etc., and considered to be within the past measurement trends (described later).

Table 3.1-3 Detection of total β radioactivity and γ-ray emitting radionuclides in groundwater samples

Radionuclides			Number of samples	Number of detections	Detection rate [%]	Measured values [Bq/L]		Maximum records [Bq/L]	
						Range	Detection limits	Nationwide Monitoring (FY2014 - FY2017)	Monitoring of Levels (*1)
Total β radioactivity			110	99	90.0	ND - 1.3	0.022 - 0.071	0.54	No data
γ-ray emitting radionuclides	Naturally occurring	K-40	110	94	85.5	ND - 1.3	0.013 - 0.075	0.56	0.28
		Ac-228	110	2	1.8	ND - 0.036	0.0030 - 0.015	0.038	No data
		Bi-214	110	2	1.8	ND - 0.014	0.0020 - 0.0088	0.022	No data
		Pb-212	110	1	0.9	ND - 0.004	0.0012 - 0.0064	0.0048	No data
		Pb-214	110	3	2.7	ND - 0.020	0.0018 - 0.0079	0.026	No data

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1999 to FY2018



(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely with the type of radionuclide.

Figure 3.1-3 Detection of total β radioactivity and γ-ray emitting radionuclides in groundwater samples

3.2 Discussion regarding detected radionuclides

(1) Detection of naturally occurring radionuclides

1) Correlation between activity concentrations of K-40 in water samples and seawater

As explained in 3.1 above, activity concentrations of K-40 detected in water samples collected in public water areas were all within the past measurement trends. All the locations where relatively high concentrations of K-40 were detected were located in the tide zone and the electrical conductivity (EC) was high (1,600 mS/m at the maximum). Therefore, seawater inflow is a concern as a cause for these high concentrations and a comparison was made using all available data to clarify the correlation between activity concentrations of K-40 and EC (see Figure 3.2-1).

As shown in Figure 3.2-1, a positive correlation was found between them.

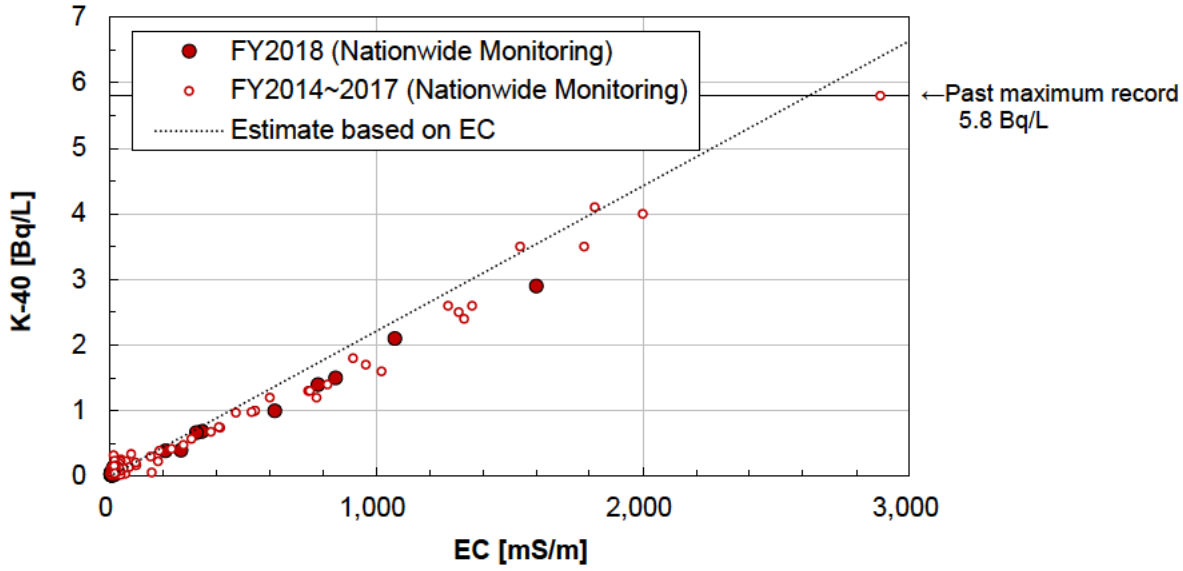


Figure 3.2-1 Correlation between K-40 concentrations and electrical conductivity (EC) in water samples from public water areas

On the other hand, according to the results of the Monitoring of Levels, conducted for 20 years from FY1999 to FY2018 (monitoring of 959 samples collected from 19 prefectures), the average concentration (arithmetic mean) of K-40 was approximately 9.9 Bq/L and the maximum concentration was 15 Bq/L (see Table 3.2-1).

Table 3.2-1 Results of the Monitoring of Levels, etc., concerning K-40 in seawater (*1)

Number of surveys	Number of detections	Detection rate [%]	Average [Bq/L]	Maximum [Bq/L]
959	924	96.4	9.9	15

(*1) Results of the Monitoring of Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1999 to FY2018

EC of seawater is generally around 4,500 mS/m, and the estimated activity concentrations of K-40 with the possible effects from seawater were obtained by using the following formula based on the measurement results of EC for the relevant river water.

$$\text{(Activity concentration of K-40 in river water)} = \text{(Average activity concentration of K-40 in seawater)} \times \frac{\text{(Measured EC in the river water)}}{\text{(Ordinary values of EC in seawater)}}$$

The estimated activity concentrations of K-40 in the river water are indicated with a dotted line (·····) in Figure 3.2-1, and the estimated values fall in line extremely well with the measured activity concentrations of K-40. Therefore, the high activity levels of K-40 obtained in the latest measurements are considered to have been caused by the intrusion of seawater.

Since the concentrations of K-40 in groundwater samples exceeded the range of the past measurement records at two locations (No. 17 and No. 66), the correlation between K-40 concentration and EC was assessed using all available data in the same manner as the case of the public water areas (see Figure 3.2-2, scales of the vertical and horizontal axes differ from those for Figure 3.2-1). Overall, no clear correlation between K-40 concentration and EC was found. However, for No. 66, it was considered to be affected by seawater judging from the environment of the collection point and the exceedingly high EC compared to other sampling locations.

For No. 17, although K-40 showed a relatively high value regardless of its low EC, it was well in line with the estimated value of K-40[3] calculated from the K (stable) concentration measured for verification, and it was confirmed that there was no problem in the measurement. The K (stable) concentration was also within the range of nationwide surveys of groundwater[4].

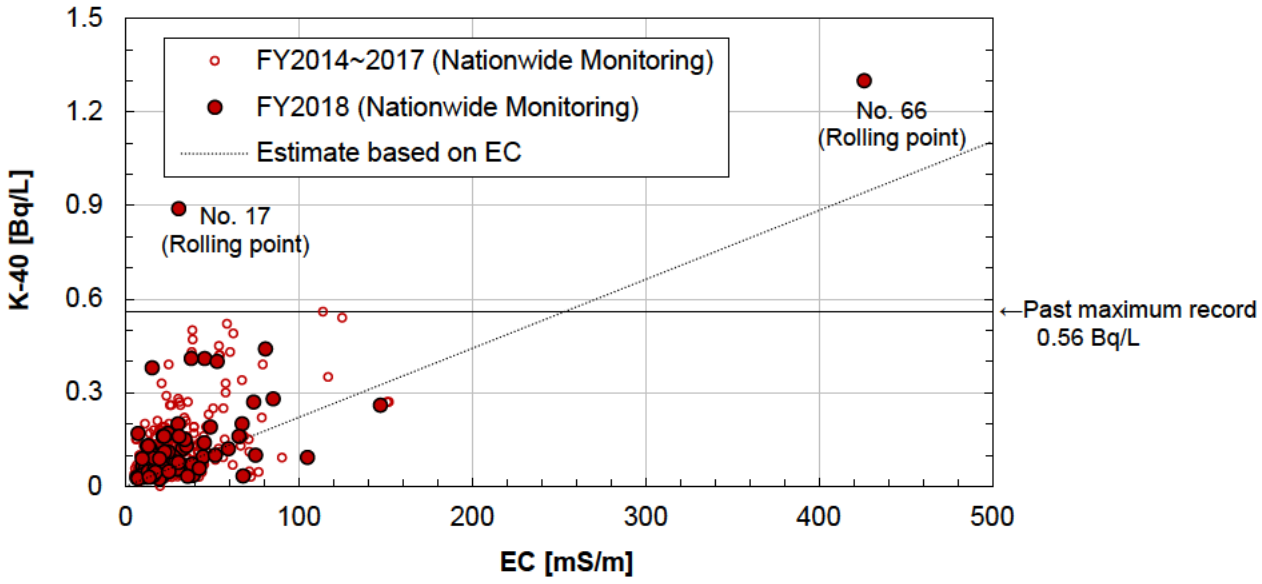


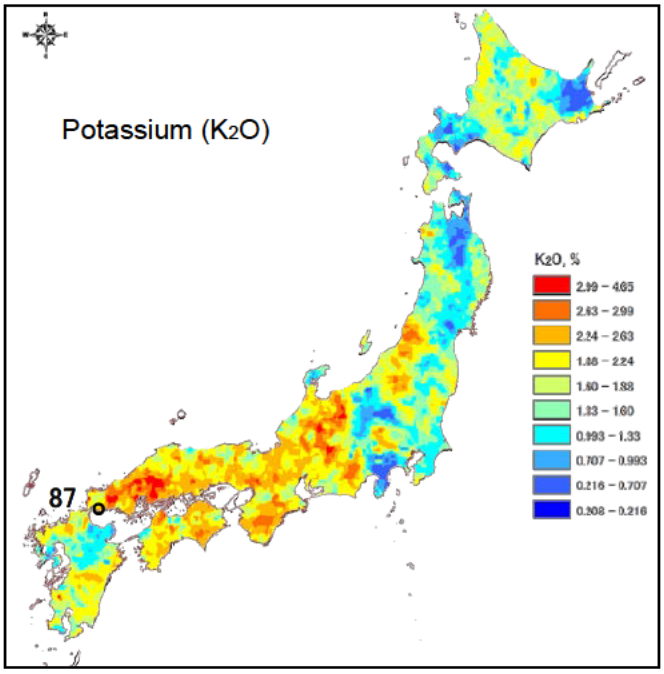
Figure 3.2-2 Correlation between the K-40 concentration and electrical conductivity (EC) in groundwater Sample

[3] K-40 has a very long half-life of 1.28×10^9 years and is known to be present in 0.0117% of natural potassium. The K-40 concentration can be estimated by calculation based on its K (stable) concentration.

[4] The K (stable) concentrations ranged from 0.17 to 33.95 mg/L in nationwide surveys of groundwater (Source: National Institute of Agro-Environmental Sciences, Material No. 20 "Survey Data on Groundwater Quality in Rural Areas (1986-1993)" by National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry and Fisheries (March 1997).

2) K-40 in sediments

In public water sediment, activity concentrations of K-40 exceeded the range of the past measurement records at one site (No. 87). Potassium (K_2O) is an element contained in the earth's crust. As shown in Figure 3.2-3, No. 87 is located in an area with relatively high potassium concentrations.



Reference: Website of the Geological Survey of Japan, AIST
https://gbank.gsj.jp/geochemmap/setumei/radiation/setumei-radiation.htm

Figure 3.2-3 Distribution of potassium (K_2O) in soil in Japan

3) Uranium and thorium series radionuclides in sediment samples

As explained in 3.1(1)2) above, uranium and thorium series radionuclides were detected at relatively high concentration levels in sediment samples from public water areas. The detection status is shown in Table 3.2-2.

Table 3.2-2 Detection of uranium and thorium series naturally occurring radionuclides

Radionuclides			Number of samples	Number of detections	Detection rate [%]	Measured values [Bq/kg(dry)]	
						Range	Detection limit
γ-ray emitting radionuclides	Uranium series	Ra-226	110	1	0.9	ND - 32	18 - 170
		Pb-214	110	110	100	2.6 - 53	1.7 - 8.4
		Bi-214	110	110	100	2.4 - 45	1.9 - 7.8
	Thorium Series	Ac-228	110	109	99.1	ND - 99	3.2 - 9.8
		Pb-212	110	110	100	2.4 - 100	1.6 - 6.3
		Bi-212	110	51	46.4	ND - 95	11 - 40
		Tl-208	110	109	99.1	ND - 31	0.83 - 3.1

These naturally occurring radionuclides exist widely within the earth's crust and the past monitoring has confirmed high correlations among the series.

Figure 3.2-4 and Figure 3.2-5 show the correlation among uranium series radionuclides and among thorium series radionuclides detected at the monitoring for FY2018 (These are plotted out based on radionuclides with high detection rate (uranium series: Pb-214 and thorium series: Pb-212) with instances of non-detection excluded).

Figure 3.2-4 and Figure 3.2-5 reveal high correlations among uranium series or among thorium series radionuclides.

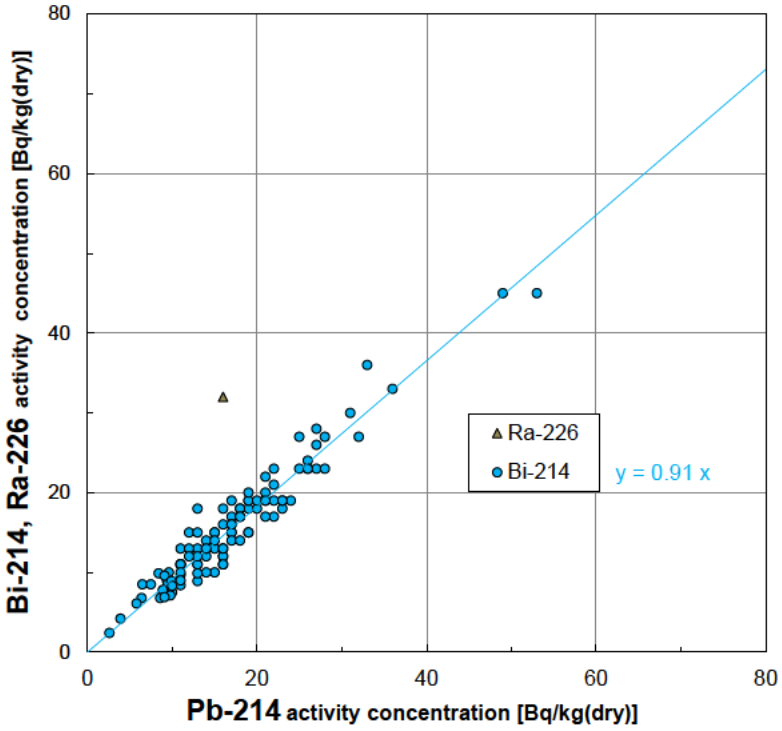
<Note>

The tendency shown in the radionuclides of the two series are considered to be reflected in the geology of the locations at which they had been detected.

It is generally accepted that granite contains larger amounts of naturally occurring radionuclides than other kinds of rocks and that natural radiation doses correlate to some extent with uranium and thorium series radionuclides (both according to the Geological Society of Japan[5]).

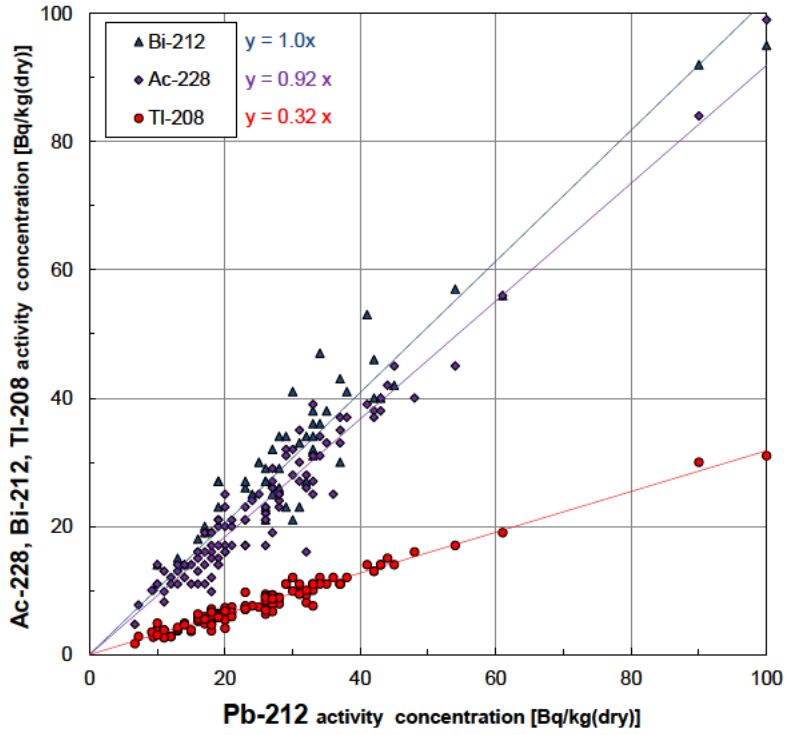
For reference, Figure 3.2-6 shows the distribution map of granite in Japan, while Figure 3.2-7 shows the distribution map of natural radiation doses in Japan.

[5] http://www.geosociety.jp/hazard/content0058 html



Correlation coefficient	Bi-214	Ra-226
Pb-214	0.96	-

Figure 3.2-4 Correlations among uranium series radionuclides



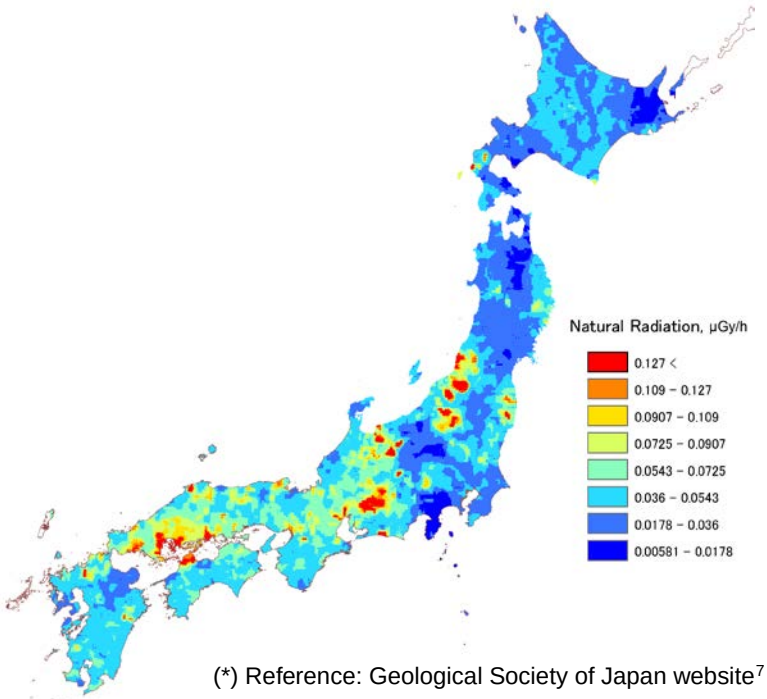
Correlation coefficient	Ac-228	Bi-212	Tl-208
Pb-212	0.97	0.95	0.98

Figure 3.2-5 Correlations among thorium series radionuclides

(*) Reference: Seamless Digital Geological Map of Japan (1:200,000) ®; AIST website[6]

Figure 3.2-6 Distribution of granite in Japan

(Parts highlighted in pink in the Figure are locations where granite exists.)



(*) Reference: Geological Society of Japan website[7]

Figure 3.2-7 Natural radiation doses in Japan (Gy = Sv for γ-rays and β-rays)

[6] https://gbank.gsj.jp/seamless/
[7] http://www.geosociety.jp/hazard/content0058 html

(2) Detection of artificial radionuclides

1) Cs-134 and Cs-137 in water samples from public water areas

Radioactive cesium was detected in water samples from public water areas in Tohoku and Kanto blocks (19 locations in total; both Cs-134 and Cs-137 were detected at six locations; only Cs-137 was detected at 13 locations).

As for the six locations where both Cs-134 and Cs137 were detected (all in Tohoku and Kanto blocks), concentration ratio was tested as a reference. The results showed a good correlation between them and the calculated activity concentration ratio was approximately 10.5. Assuming that detected Cs-134 and Cs-137 are those discharged due to the Fukushima NPS Accident in March 2011, this ratio fell in line extremely well with the theoretical ratio (approx. 10.5) as of September 2018 (see Figure 3.2-8). This suggests that Cs-134 and Cs-137 detected in the Tohoku and Kanto blocks were indeed derived from the Fukushima NPS Accident.

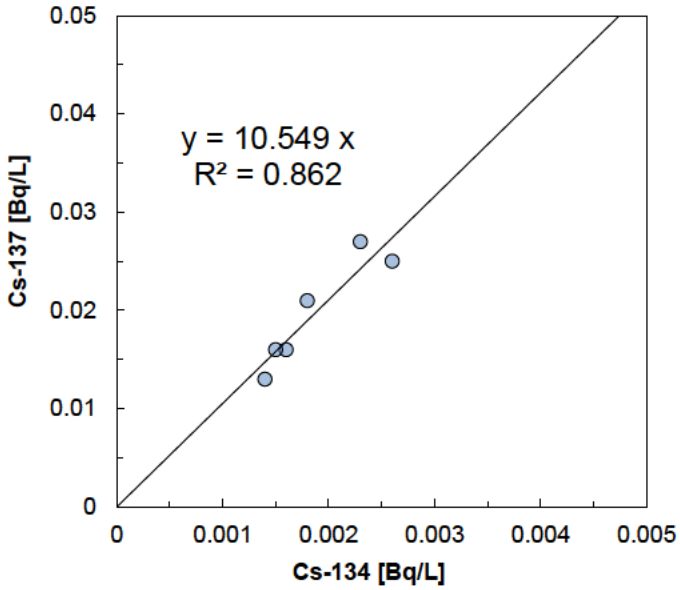


Figure 3.2-8 Concentration ratios (Cs-137/Cs-134) [Water (public water areas)]

(Reference: Changes in concentration ratios (Cs-137/Cs-134) over time, accounting for half-life periods)

Radionuclide	Half-life (year)	2011/3	2013/3	2015/3	2017/3	2018/9
Cs-134	2.0648	1	0.51	0.26	0.13	0.08
Cs-137	30.1671	1	0.96	0.91	0.87	0.84
Cs137／Cs134		1	1.87	3.50	6.54	10.5

(*) The concentration ratio at the time of the latest monitoring (around September 2018) is estimated to be approximately 10.5 (highlighted in yellow in the table above).

2) Cs-134 and Cs-137 in sediment samples from public water areas

Radioactive cesium was detected in sediment samples from public water areas in Hokkaido, Tohoku, Kanto, Chubu, and Kinki blocks (37 locations in total; both Cs-134 and Cs-137 were detected at 15 locations (all in Tohoku and Kanto Blocks); only Cs-137 was detected at 22 locations).

For locations that have not been surveyed by Post-Earthquake Monitoring, radioactive cesium species were also detected. Therefore, to better clarify the concentration levels of the detected radioactive cesium species in such locations, the following comparisons were made:

(i) Among the above-mentioned, for the same locations within the same prefectures where Post-Earthquake Monitoring is carried out, a comparison between data was carried out.

(ii) For locations where Post-Earthquake Monitoring is not conducted for the same locations within the same prefectures, collected data was compared to data from nearby locations obtained via Post-Earthquake Monitoring.

(iii) For locations where Post-Earthquake Monitoring is not conducted nearby, collected data was compared with data obtained through the Monitoring of Levels and other reports.

i) Comparison with past Post-Earthquake Monitoring results within the same prefectures

Regarding locations where Post-Earthquake Monitoring is conducted within the same prefectures (excluding locations where the Monitoring has been conducted at the same points), the measured values in the latest monitoring were compared with the past measurement records for the same locations (see Figure 3.2-9).

Measured values from the latest monitoring were found to be within the past measurement trends.

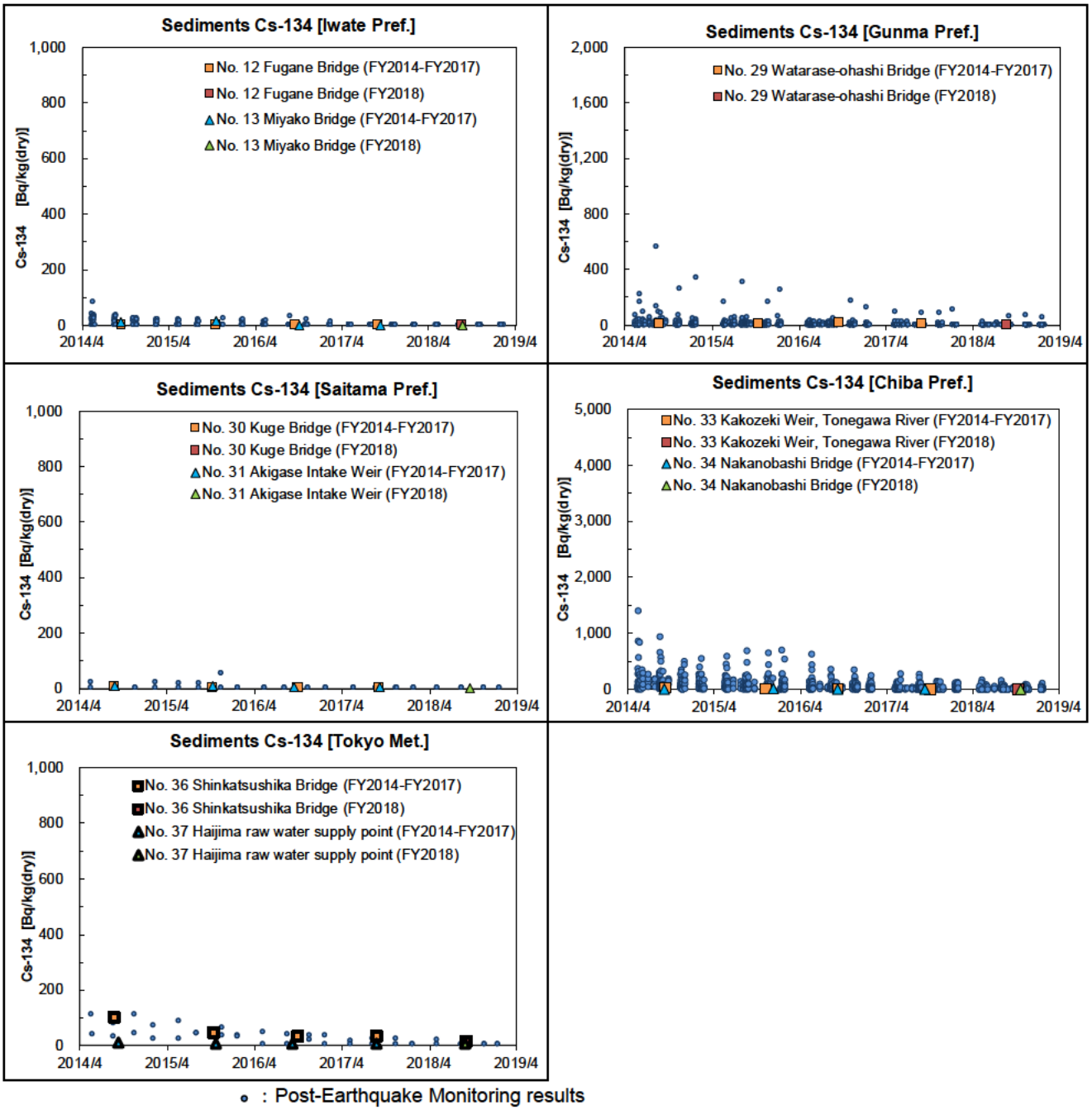
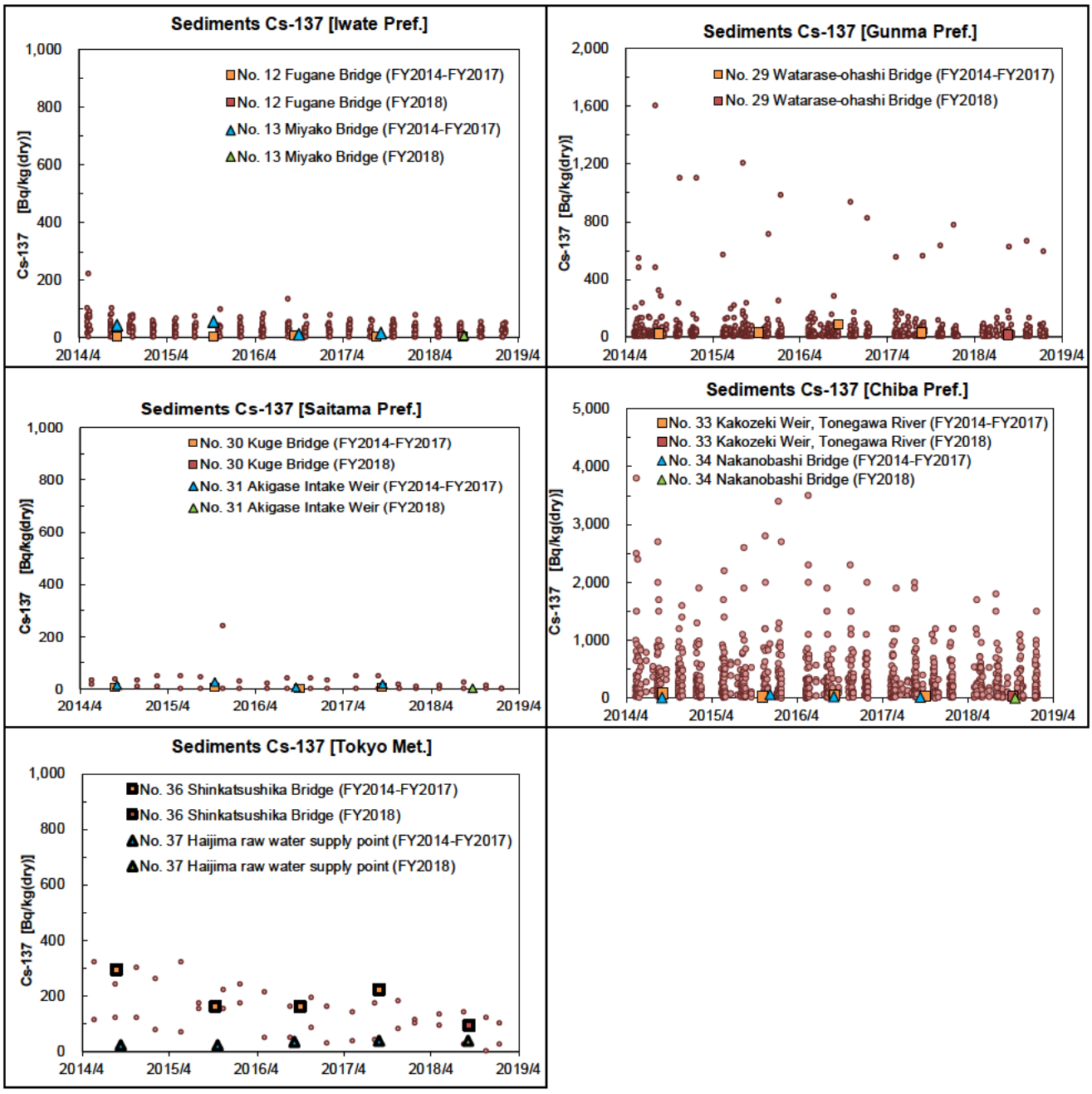


Figure 3.2-9 (1) (i) Comparison with past Post-Earthquake Monitoring results within the same prefectures [Cs-134]



∘ : Post-Earthquake Monitoring results

Figure 3.2-9 (2) (i) Comparison with past Post-Earthquake Monitoring results within the same prefectures [Cs-137]

ii) Comparison with past Post-Earthquake Monitoring results for nearby locations

Regarding Location No. 40 (Rinko Tsurumigawa Bridge, Tsurumi River, Yokohama City, Kanagawa Prefecture), it was considered reasonable to make a comparison with the past data for nearby locations although Post-Earthquake Monitoring had not been conducted in Kanagawa Prefecture. Therefore, a comparison was made with the past data for Location No. 38 (Ryogoku Bridge, Sumida River, Chuo City/Sumida City, Tokyo Metropolis) and Location No. 39 (Kasai Bridge, Arakawa River, Koto City/Edogawa City, Tokyo Metropolis), both of which are located at the mouths of the Sumida River and the Arakawa River to Tokyo Bay (see Figure 3.2-10). As a result, it was found that the measured values for Location No. 40 were within the past measurement trends.

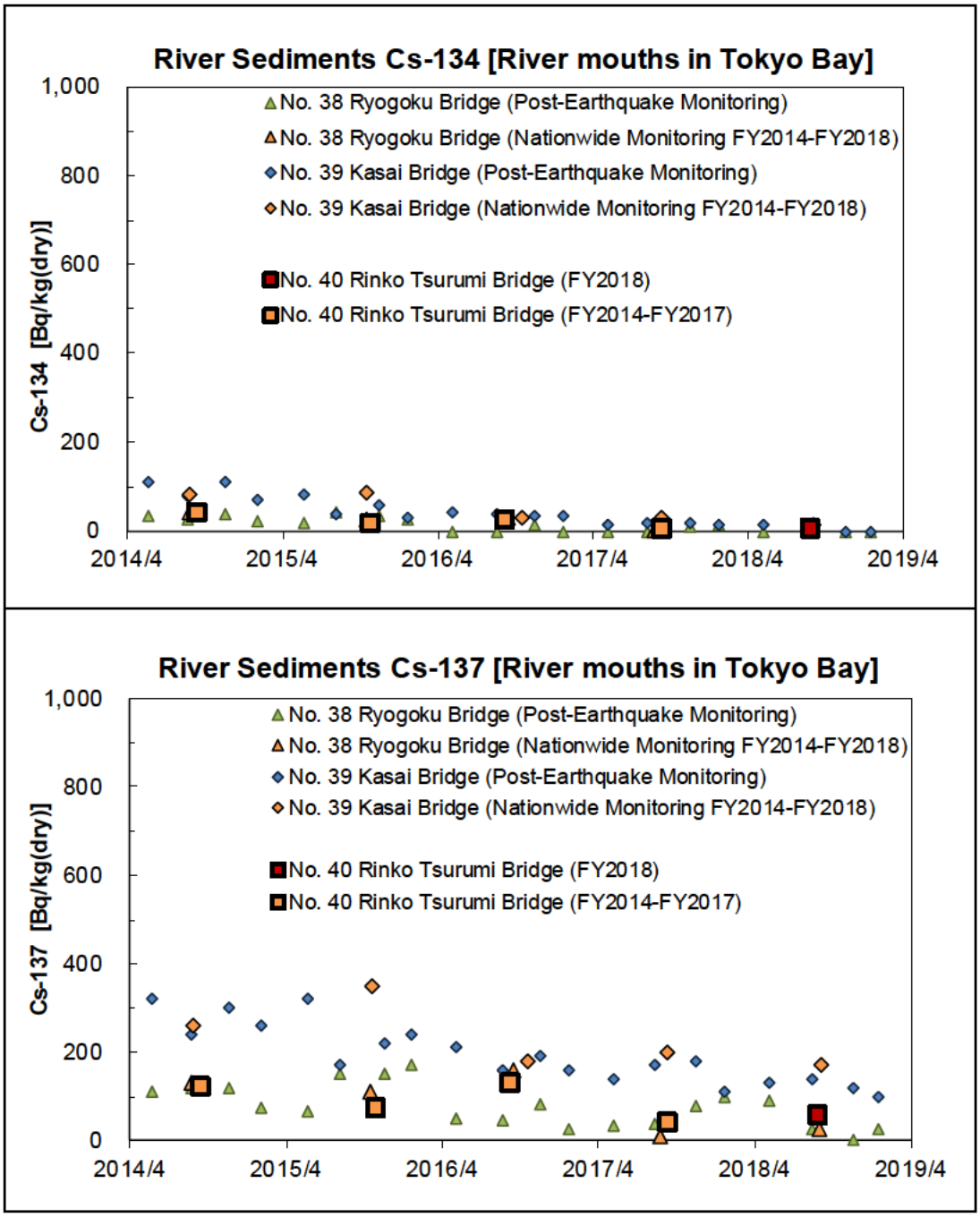
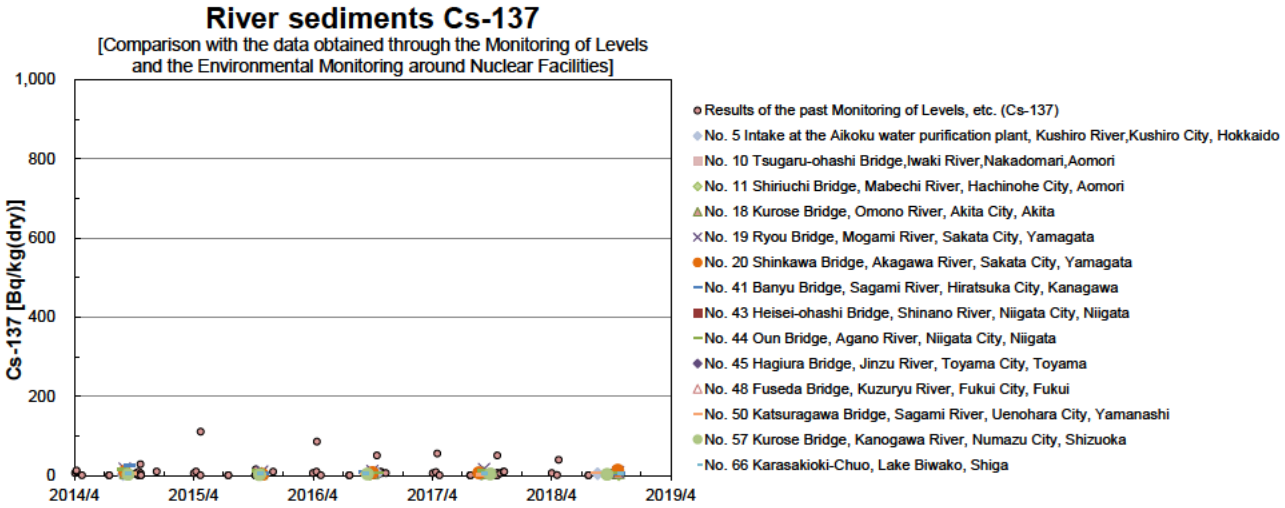


Figure 3.2-10 (ii) Comparison with past Post-Earthquake Monitoring results for nearby locations

iii) Comparison with the data obtained from the Monitoring of Levels, etc.

For locations where Post-Earthquake Monitoring has not been conducted nearby, a comparison with the results of the Monitoring of Levels was performed in order to evaluate their concentration levels (see Figure 3.2-11).

At 14 locations, only Cs-137 was detected and the measured values all fell within the past measurement trends.



(*) Locations where the detected values were found in this year are plotted in the Figure.

Figure 3.2-11 (iii) Comparison with the data obtained through the Monitoring of Levels

As a reference, concentration ratios were evaluated in the same manner as the case of the water samples for 15 locations where (all in the Tohoku and Kanto blocks) both Cs-137 and Cs-134 were detected. As a result, a good correlation was confirmed. The calculated activity concentration ratio was approximately 10.3 (Cs-137/Cs-134). Assuming that detected Cs-134 and Cs-137 are those discharged due to the Fukushima NPS Accident in March 2011, this ratio should be approximately equal to the theoretical ratio (approx. 10.5) as of September 2018 (see Figure 3.2-12). This suggests that Cs-134 and Cs-137 detected in sediment samples collected in the Tohoku and Kanto blocks were indeed derived from the Fukushima NPS Accident.

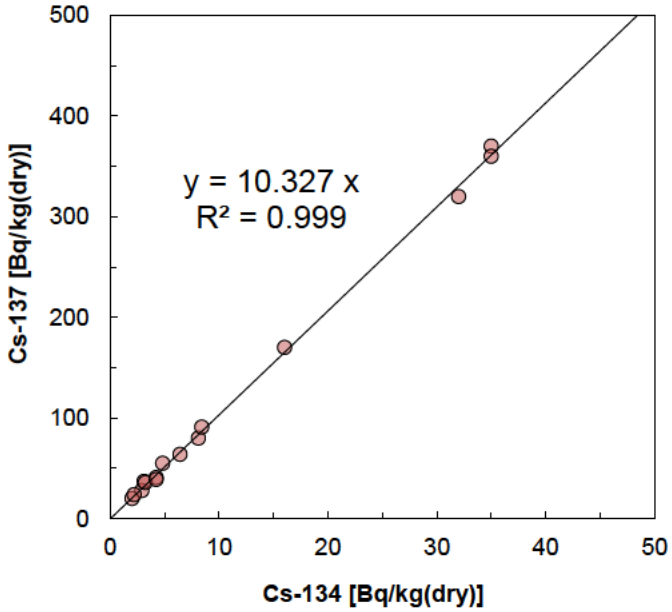


Figure 3.2-12 Concentration ratio (Cs-137/Cs-134) [Sediment (public water areas)]

(Reference: Changes in concentration ratios (Cs-137/Cs-134) over time, accounting for half-life periods)

Radionuclide	Half-life (year)	2011/3	2013/3	2015/3	2017/3	2018/9
Cs-134	2.0648	1	0.51	0.26	0.13	0.08
Cs-137	30.1671	1	0.96	0.91	0.87	0.84
Cs137／Cs134		1	1.87	3.50	6.54	10.5

(*) The concentration ratio at the time of the latest monitoring (around September 2018) is estimated to be approximately 10.5 (highlighted in yellow in the table above).

Given these facts, Cs-134 and Cs-137 detected in sediment samples from public water areas (excluding the case in which only Cs-137 was detected) were mostly considered to be derived from the Fukushima NPS Accident, but the detected values were all within the past measurement trends.

3) Cs-134 and Cs-137 in groundwater

Cs-134 and Cs-137 were not detected in groundwater samples collected at any of the 110 locations (detection limit: approx. 0.001 to 0.002 Bq/L).

3.3 Survey results on seasonal variations

For survey results on seasonal variations of radionuclides values, at two locations[8] (both in rivers), namely, Location No. 28 (Toneozeki Weir, Tonegawa River, Chiyoda Town, Gunma Prefecture) and Location No. 83 (Kasumi Bridge, Takahashi River, Kurashiki City, Okayama Prefecture), surveys were conducted four times during the period from May 22, 2018 to Jan 18, 2019. These two locations had been previously surveyed four times each from FY2014 to FY2017, and the current analysis includes the results from those prior years.

Radionuclides were detected as shown in Table 3.3-1 and Table 3.3-2. Figure 3.3-1 and 3.3-2 show the changes in radionuclides detected since FY2014. Table 3.3-1 and Table 3.3-2 also show the coefficients of variation[9] (= sample standard deviation /average) indicating for the fluctuations in detected values.

The coefficients of variation in water samples ranged from 17% to 25% for total β radioactivity and K-40, and stood at 40% for Cs-137, respectively.

The coefficients of variation in sediment samples ranged from 6.4% to 27% for total β radioactivity and naturally occurring radionuclides (Ac-228, Bi-212, Bi-214, Pb-212, Pb-214, Tl-208, and K-40), and for artificial nuclides, 74% for Cs-134, 58% for Cs-137[10].

The reason why the coefficients of variation of radioactive cesium in sediment samples are relatively higher than those in naturally occurring radionuclides is considered to have been associated with the fact that naturally occurring radionuclides are generally contained in minerals, while radioactive cesium is adsorbed in them. Further, Cs-134 has a half-life of approximately two years and physically attenuates faster than Cs-137 (half-life: approximately 30 years). Therefore, the coefficients of variation of Cs-134 are larger than those of Cs-137.

For reference, sediment grain size distribution and Cs-137 concentration change for Location No. 28 are shown in Figure 3.3-3.

Continuous monitoring conducted four times each year at two locations is necessary to clarify variations in the environment.

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[8] It was decided that one location each would be selected in eastern and western Japan. To make the selection, all 110 locations were first divided into two areas for convenience (Locations No. 1 to No. 55 were classified as eastern Japan and Locations No. 56 to No. 110 were classified as western Japan) and the middle number in each area was selected.

[9] In this report: coefficient of variation = sample standard deviation divided by the average; hereinafter the same shall apply.

[10] Regarding variations due to, among other things, the number of times of the survey conducted for radioactive materials in the environment FY2012 survey instances show 12 to 16% variations in the amount of radioactive cesium contained in riverbed sediment (nine samples collected during the same period). At River Site No. 28 where radioactive cesium was detected, a drop in water transparency probably due to sludge disturbance caused by pleasure boats or winds in the vicinity was observed. Then, the water and bottom sampling points were slightly relocated due to that those points were made off-limits, with recognizable variations in sediment grain-size distribution. Because the changes in sediment grain-size distribution might have affected the concentration of radioactive cesium, the changes in sediment grain-size distribution and Cs-137 concentration at River Site No. 28 are graphically summarized in Figure 3.3-3. This has revealed that sediment samples with high clay and silt contents tend to have higher Cs-137 concentrations. Accordingly, it was inferred that the variation in the amount of radioactive cesium in samples from River Site No. 28 had occurred due to the changes in the grain-size distribution in the sediment samples. In addition, the monitoring during the flood season recognized an increase in clay and silt ratio as well as periodic changes which would have been declining over time towards the next year’s flood season. The same shall apply to Cs-137 concentration.

Table 3.3-1 Detection trends for radioactive materials at the same location [River No. 28]

No.28	Water [Bq/L]				Sediment [Bq/kg(dry)]										
Radionuclides	Total β radioactivity	K-40	Cs-134	Cs-137	Total β radioactivity	K-40	Ac-228	Be-7	Bi-212	Bi-214	Pb-212	Pb-214	Tl-208	Cs-134	Cs-137
Aug 25, 2014	0.068	0.097	0.0015	0.0074	410	290	15	<24	<32	<12	18	11	5.8	19	60
Oct 27, 2014	0.12	0.11	0.0020	0.0072	350	330	9.8	<36	<17	11	16	11	4.3	13	44
Dec 15, 2014	0.12	0.078	<0.0010	0.0048	350	280	12	<38	<28	13	21	16	4.7	21	76
Jan 26, 2015	0.11	0 094	0.0018	0.0049	380	280	15	<25	<23	13	16	11	5.0	17	61
Oct 13, 2015	0.090	0.12	<0.0022	0.0029	720	290	23	<76	<46	14	28	14	6.5	51	230
Nov 24, 2015	0.099	0.11	<0.0014	0.0035	460	370	18	<68	<30	15	18	15	4.0	25	110
Dec 25, 2015	0.071	0 096	<0.0014	0.0043	490	320	22	<44	<21	16	16	17	5.4	26	110
Jan 22, 2016	0.10	0.11	<0.0014	0.0052	430	320	20	<28	<23	12	18	13	6.1	21	96
May 24, 2016	0.062	0 059	<0.0014	0.0030	410	280	15	<54	37	12	17	19	5.0	15	74
Sep 15, 2016	0.061	0 078	<0.0014	0.0061	460	300	21	59	29	13	21	17	7.6	26	140
Nov 14, 2016	0.13	0 095	<0.0017	0.0035	400	250	18	<66	<30	16	19	18	5.0	19	96
Jan 20, 2017	0.084	0.083	<0.0013	0.0025	450	260	12	<29	<30	18	19	13	4.7	11	72
May 29, 2017	0.064	0.039	<0.0011	0.0023	320	280	12	<22	<19	9.4	16	13	5.4	5.5	41
Aug 29, 2017	0.074	0.093	<0.0014	0.0026	420	280	19	80	<27	15	19	12	5.4	15	130
Nov 16, 2017	0.11	0.093	<0.0014	0.0036	470	330	18	<49	<22	16	18	14	6.1	9.4	85
Jan 16, 2018	0.066	0.12	<0.0015	0.0052	370	320	14	<25	<29	12	16	13	4.3	4.4	38
May 22, 2018	0.065	0.056	<0.0014	0.0031	360	300	12	<100	<25	11	16	9.5	3.6	2.6	31
Aug 31, 2018	0.10	0.13	<0.0015	0.0033	370	270	17	<96	<29	11	18	13	5.9	3.1	37
Nov 21, 2018	0 072	0.10	<0.0013	0.0027	450	270	13	<56	<24	12	20	14	5.1	5.3	62
Jan 18, 2019	0 081	0.095	<0.0012	0.0016	420	270	16	<26	<23	11	15	11	5.6	2.9	38
Coefficient of variation	25 %	24 %	-	40 %	20 %	9.9 %	23 %	-	-	17 %	16 %	19 %	17 %	74 %	58 %

(*) The coefficients of variation are shown only for radionuclides detected five times or more.

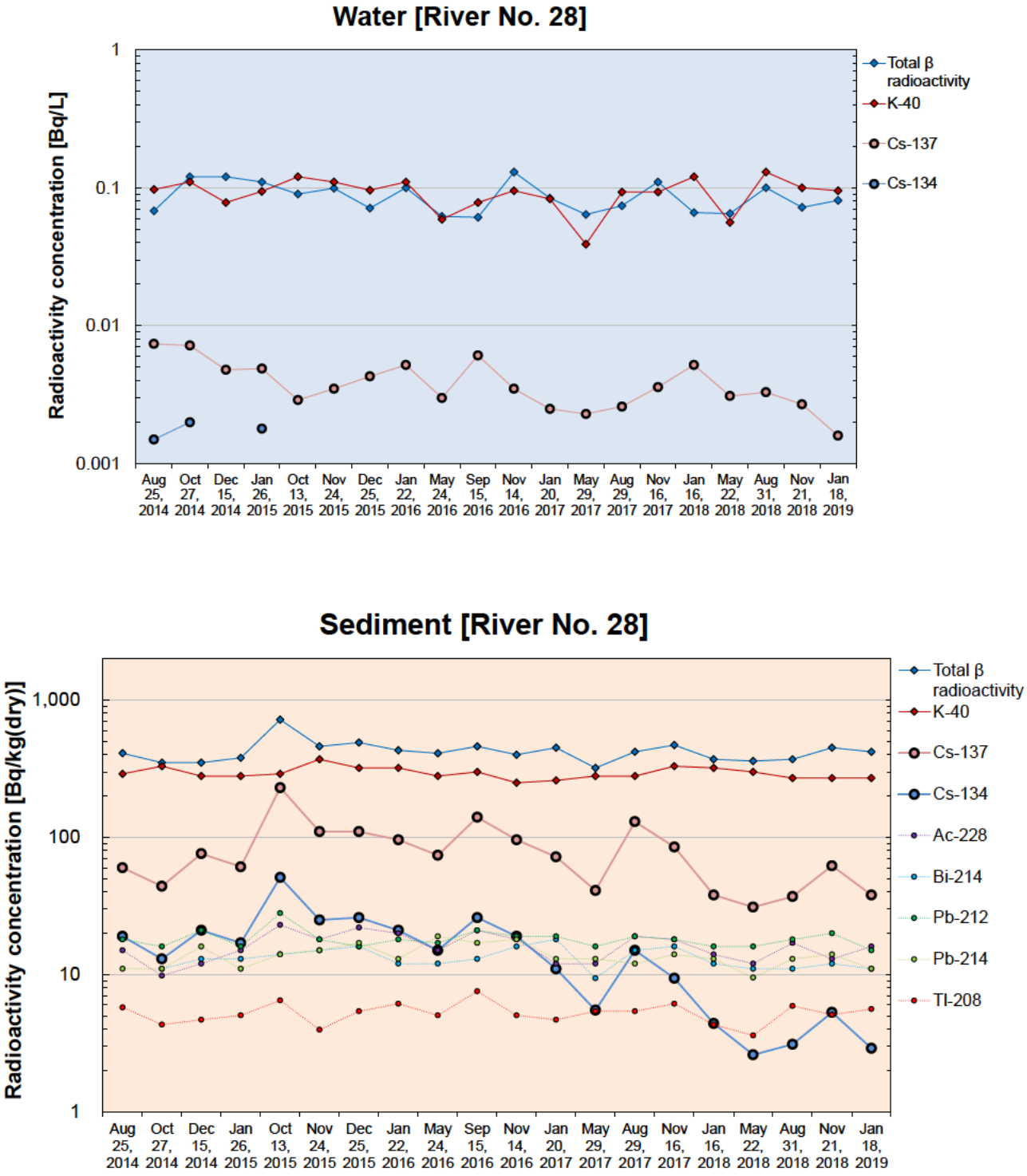

Figure 3.3-1 Changes in detection trends for radioactive materials at the same location [River No. 28]

Table 3.3-2 Detection trends for radioactive materials at the same location [River No. 83]

No.83	Water [Bq/L]				Sediment [Bq/kg(dry)]									
Radiocuclides	Total β radioactivity	K-40	Be-7	Pb-212	Total β radioactivity	K-40	Ac-228	Bi-212	Bi-214	Pb-212	Pb-214	Ra-226	Th-234	Tl-208
Aug 30, 2014	0.046	0.034	<0.024	<0.0019	1,000	870	13	42	15	28	21	50	<30	9.0
Oct 28, 2014	0.064	0.045	0.012	<0.0021	980	830	25	34	21	28	23	<42	<41	7.2
Dec 15, 2014	0.037	<0.028	<0.0073	<0.0019	890	910	12	23	17	24	19	36	30	7.6
Jan 26, 2015	0.038	0.034	<0.0073	0.0013	920	770	19	28	17	27	15	<39	42	9.0
Oct 16, 2015	0.048	0.045	<0.024	<0.0019	1,000	920	25	28	16	28	21	<37	<31	8.3
Nov 30, 2015	0.047	0.042	<0.018	<0.0015	1,000	920	21	<33	19	26	20	<46	<47	8.6
Dec 22, 2015	0.041	0.038	<0.013	<0.0015	950	840	29	37	16	26	22	<44	<45	5.4
Jan 25, 2016	0.035	0.031	<0.0085	<0.0014	940	840	25	<34	19	27	18	<41	<47	6.8
May 30, 2016	0.039	0.050	<0.011	<0.0017	930	840	17	<35	19	24	24	<42	<160	8.3
Aug 23, 2016	0.045	0.043	<0.040	<0.0015	1,100	900	18	34	14	21	16	<38	<140	7.6
Nov 15, 2016	0.030	0.046	<0.022	<0.0015	940	840	24	<28	18	22	17	<42	<150	7.6
Jan 27, 2017	0.041	0.036	<0.0078	<0.0014	990	840	15	<29	14	23	17	<39	<140	6.1
May 29, 2017	0.047	0.049	<0.0089	<0.0013	990	850	19	27	16	20	16	<38	<140	7.9
Aug 25, 2017	<0.024	0.042	<0.029	<0.0014	960	850	19	28	15	23	19	<31	<72	6.5
Nov 27, 2017	0.037	0.029	<0.016	<0.0013	950	790	28	30	19	28	24	<36	<80	9.7
Jan 16, 2018	0.044	0.041	<0.0093	<0.0016	960	860	27	<33	22	31	18	<44	<160	7.6
May 26, 2018	0.032	0.038	<0.029	<0.0014	930	800	32	<29	17	29	20	<48	<150	8.5
Oct 16, 2018	0.041	0.051	<0.018	<0.0013	860	710	31	36	23	34	28	<170	<78	11
Nov 27, 2018	0.043	0.054	<0.012	<0.0012	850	640	30	34	17	29	21	<45	<150	9.2
Jan 17, 2019	<0.024	0.042	<0.0076	<0.0012	840	670	30	40	21	32	24	<48	<160	8.2
Coefficient of variation	18 %	17 %	-	-	6.4 %	9.3 %	27 %	17 %	15 %	14 %	17 %	-	-	16 %

(*) The coefficients of variation are shown only for radionuclides detected five times or more.

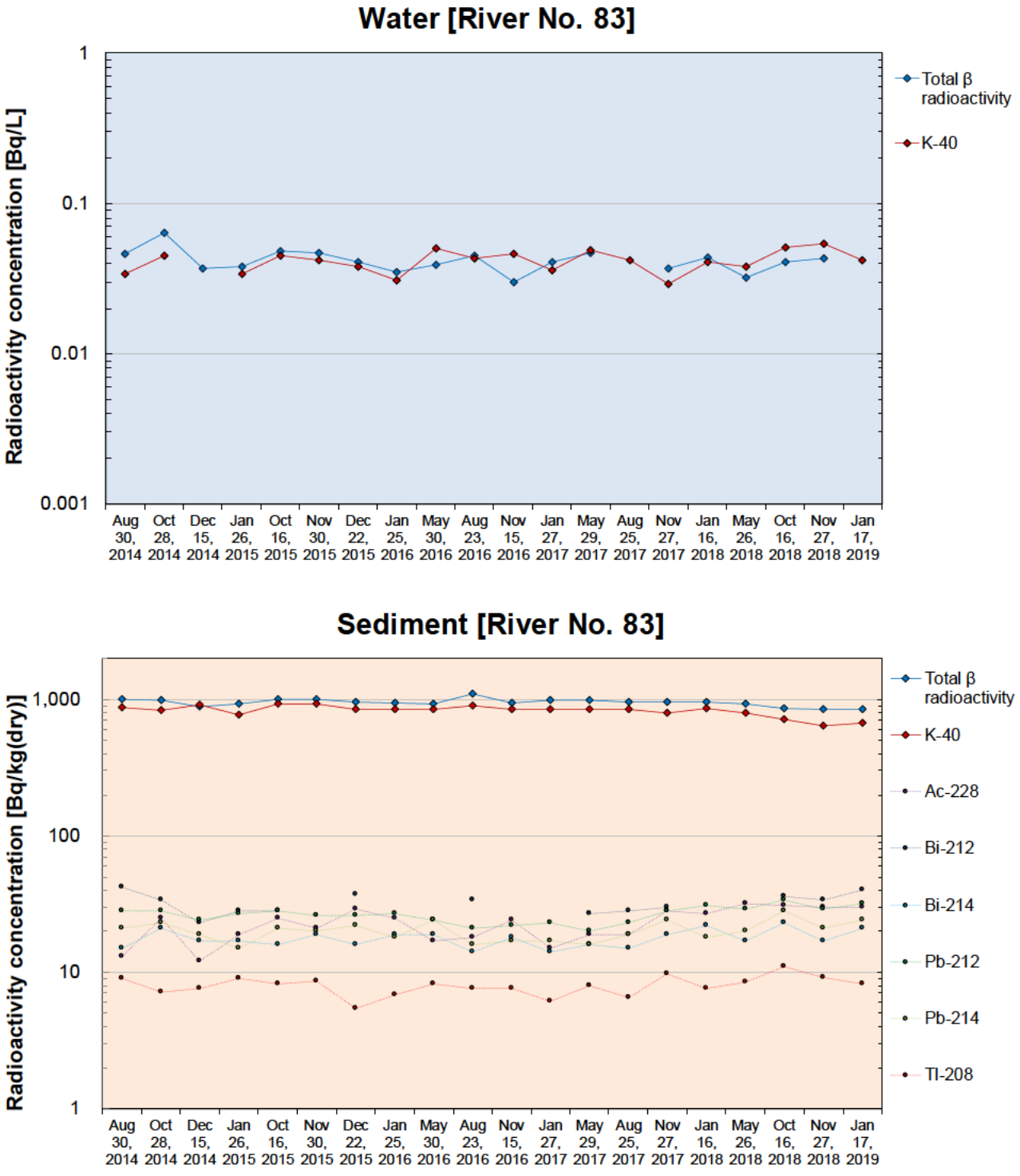

Figure 3.3-2 Changes in detection trends for radioactive materials at the same location [River No. 83]

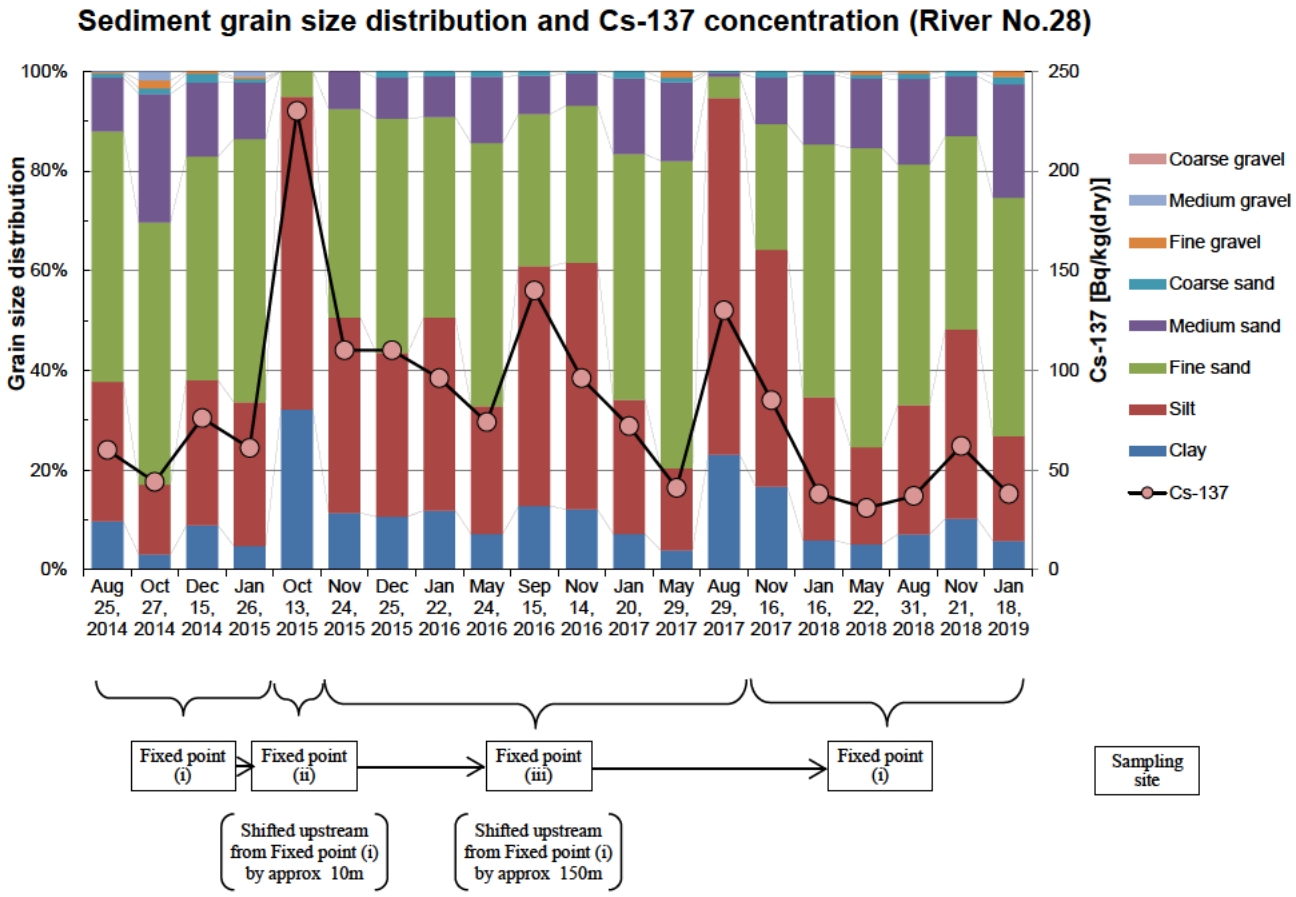

Figure 3.3-3 Changes in sediment grain size distribution and Cs-137 concentration [River No. 28]