Provisional Translation

Application No. FDEC-R3-175
December 21, 2021

Nuclear Regulatory Authority

1-1-3 Uchisaiwai-cho, Chiyoda-ku, Tokyo
Tokyo Electric Power Company Holdings Inc.
President Tomoaki Kobayakawa

Application for approval to amend the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility

Pursuant to the provisions of Article 64-3, Paragraph (2) of "Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors", TEPCO submit "the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility" as per the attached document.

Regard to the "the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility" and the "Annexes of the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility," the following sections shall be attached.

The amended part, the reason for the amendment, and the contents of the amendment shall be as follows;

○the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility

The following amendments are made to the installation of the dilution/discharge system and related facilities for the ALPS treated water and the ocean discharge of the ALPS treated water.

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- New description of ALPS treated water dilution/discharge facilities and related facilities
- Optimization of the description

II Design and equipment of specified nuclear facilities

2.5 Contaminated Water Treatment Facilities, etc.

Text

- Addition due to change of use for med - low concentration tank in K4 area for installation of ALPS treated water dilution/discharge system and related facilities

Appendix 12

- Addition due to change of use for med - low concentration tank in K4 area for installation of ALPS treated water dilution/discharge system and related facilities

2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities

Text

- New description of basic design/basic specifications of ALPS treated water dilution/discharge facilities and related facilities.

Attachment 1

- New description of overview and system configuration diagram

Attachment 2

- New description of specific safety measures for diluted ALPS treated water discharge facilities

Attachment 3

- New description of instructions on structural strength and seismic resistance of dilution/discharge facilities for ALPS treated water.

Attachment 4

- New description of items to be confirmed for ALPS treated water dilution/discharge facilities and related facilities.

Attachment 5

・New description of instructions for designing water discharge facilities

Attachment 6

・New description of construction schedule

III Safety of Specified Nuclear Facilities

Part 3 (Supplementary Explanation Regarding Safety)

2 Supplementary explanation on the management of radioactive waste, etc.

2.1 Management of radioactive waste, etc.

2.1.2 Management of Radioactive Liquid Waste, etc.

・Added descriptions on the discharge of ALPS treated water into the sea.

2.2 Dose assessment

2.2.3 Dose assessment by radioactive liquid waste, etc.

・Added descriptions on the discharge of ALPS treated water into the sea.

2.2.6 TEPCO Holdings' Action in Response to Basic Policy on the Handling of the ALPS treated water from the Fukushima Daiichi Nuclear Power Station

・New description of measures based on the government policy

3 Supplementary explanation on radiation management

3.1 Radiation protection and management

3.1.4 Reduction of radioactive materials in seawater, seabed soil, groundwater and drainage channels in ports and harbors

・Reflection of the installation position of the partition and change of the sampling point

・Reflection of drawings in line with the actual conditions of the site

〇Annexes of the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility

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・New description of supplementary explanation of ALPS treated water dilution/discharge facilities as Annex 27

Annex 27 Supplementary explanation of diluted ALPS treated water discharge facility

I. Structural Strength of ALPS Treated Water Dilution/Discharge Facilities

・New description of structural strength of ALPS treated water discharge facilities

II. Permissible level of nominal values for ALPS Treated Water Dilution/Discharge Facilities

・New description of permissible level of nominal values for ALPS treated water dilution/discharge facilities

Supplementary Attachment

Comparison Table of amendments in the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility (Table of Contents)

Current	Revised	Revised Reason
Introduction I Overall Process and Risk Assessment of Specified Nuclear Facilities (Omission) II Design and equipment of specified nuclear facilities (Omission) 2.49 Intake Facility in Unit 3 reactor containment・・・・・・・・・・・・・・ II-2-49-1 III Safety of Specified Nuclear Facilities (Omission) Part 3 (Supplementary Explanation Regarding Safety) (Omission) 2 Supplementary explanation of the management of radioactive waste, etc. (Omitted below)	Introduction I Overall Process and Risk Assessment of Specified Nuclear Facilities (Omission) II Design and equipment of specified nuclear facilities (Omission) 2.49 Intake Facility in Unit 3 reactor containment・・・・・・・・・・・・・ II-2-49-1 2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities・II-2-50-1 III Safety of Specified Nuclear Facilities (Omission) Part 3 (Supplementary Explanation Regarding Safety) (Omission) 2 Supplementary explanation on the management of radioactive waste, etc. (Omitted below)	Addition to the installation of ALPS treated water dilution/discharge facilities and related facilities Optimization of the description

The Japanese version shall prevail.

Comparison Table of amendments in the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility (Chapter II, 2.5 Contaminated Water Treatment Facilities, etc.)

Current	Revised	Rivised Reason
2.5 Contaminated water treatment facilities, etc. (Omission) 2.5.2 Basic Specifications 2.5.2.1 Main Specifications 2.5.2.1.1 Contaminated water treatment facilities, storage facilities (tanks, etc.) and related facilities (transfer pipes, transfer pumps, etc.) (Omission) (46) Storage Tanks for ALPS Treated Water, etc. ※1, 3 Total capacity (nominal) 1,153,489 m3 (expansion if necessary) Cardinal number 820 units (additional if necessary) Volume (single unit) 700m3, 1,000m3, 1,060m3, 1,140m3, 1,160m3, 1,200m3, 1,220 m3, 1,235m3, 1,330m3, 1,356m3, 2,400m3, 2,900m3 /unit*2 Materials SS400, SM400A,SM400B, SM400C,SM490A, SM490C Thickness (side plate) 12mm (700m3, 1,000m3, 1,160m3, 1,200m3, 1,220m3, 1,235m3, 1,330m3, 1,356m3), 18.8mm (2,400m3), 15mm (1,000m3, 1,060m3, 1,140m3, 1,330m3, 2,900m3), 16mm (700m3) ※1 Nominal capacity and operational capacity is different from nominal capacity. ※2 Operating capacity shall be up to 100% water level gauge. ※3 The nominal capacity of tanks to be added in the future (J6, K1 North, K2, K1 South, H1, J7, J4 (1160m^3), H1 East, J8, K3, J9, K4, H2, H4 North, H4 South, G1 South, H5, H6 (I), B, B South, H3, H6 (II), G6, G1, G4 South, G4 North, and G5 Area) shall be the upper limit of the operating water level. (Omission)	2.5 Contaminated water treatment facilities, etc. (Omission) 2.5.2 Basic Specifications 2.5.2.1 Main Specifications 2.5.2.1.1 Contaminated water treatment facilities, storage facilities (tanks, etc.) and related facilities (transfer pipes, transfer pumps, etc.) (Omission) (46) Storage Tanks for ALPS Treated Water, etc. ※1, 3, 4 Total capacity (nominal) 1,153,489 m3 (expansion if necessary) Cardinal number 820 units (additional if necessary) Volume (single unit) 700m3, 1,000m3, 1,060m3, 1,140m3, 1,160m3, 1,200m3, 1,220 m3, 1,235m3, 1,330m3, 1,356m3, 2,400m3, 2,900m3 /unit*2 Materials SS400, SM400A,SM400B, SM400C,SM490A, SM490C Thickness (side plate) 12mm (700m3, 1,000m3, 1,160m3, 1,200m3, 1,220m3, 1,235m3, 1,330m3, 1,356m3), 18.8mm (2,400m3), 15mm (1,000m3, 1,060m3, 1,140m3, 1,330m3, 2,900m3), 16mm (700m3) ※1 Nominal capacity and operational capacity is different from nominal capacity. ※2 Operating capacity shall be up to 100% water level gauge. ※3 The nominal capacity of tanks to be added in the future (J6, K1 North, K2, K1 South, H1, J7, J4 (1160m^3), H1 East, J8, K3, J9, K4, H2, H4 North, H4 South, G1 South, H5, H6 (I), B, B South, H3, H6 (II), G6, G1, G4 South, G4 North, and G5 Area) shall be the upper limit of the operating water level. ※4 A portion of the K4 area tanks is used as measurement/confirmation tank in "II 2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities". (Omission)	Addition of ALPS treated water dilution/discharge facilities and related facilities

Current

Attachment 12

Policy on Design and Confirmation of Medium-and Low-Concentration Tanks

(Omission)

Appendix 6

Table 2 Weir Contents of Foundation Outer Weir in Each Tank Installation Area (1/2)

Installation Location	Tank Installation on Cardinal number	Assumed leakage		Foundation perimeter weir Weir volume (m^3)	(planned value)			
		Cardinal number	Capacity (m^3)		Foundation circumference Area inside the weir (m^2)	Tank Proprietary area (m^2)	Pooled Area (m^2)	Foundation perimeter weir Height (m)
			①	②※1	③	④	⑤※2	⑥※3
J1(I)	28	1.4	1,400	1,823 or more	5,158	3,051	2,107	0.865 or more
J1(II)	35	1.75	1,750	2,281 or more	6,494	3,842	2,652	0.860 or more
J1(III)	37	1.85	1,850	2,,411 or more	6,875	4,068	2,807	0.859 or more
J2※4	42	2.1	5,040	6,208 or more	6,883 6,139 1,073	4,556 3,728 -	2,327 2,411 1,073	1.121 or more ※4 0.771 or more ※4 1.621 or more ※4
J4	35	1.75	5,075	6,208 or more	12,660	6,991	5,669	1.095 or more
J7	42	2.1	2,520	3,146 or more	7,671	4,547	3,124	1.007 or more
H1 East	24	1.2	1,464	1,857 or more	4,562	2,606	1,956	0.949 or more
J8	9	1	700	818 or more	1,100	512	588	1.391 or more
K3	12	1	700	836 or more	1,248	572	676	1.236 or more
J9	12	1	700	826 or more	1,332	704	628	1.315 or more
K4	35	1.75	1,750	2,190 or more	5,145	2,944	2,201	0.995 or more
H2	44	2.2	5,280	6,548 or more	15,035	8,697	6,338	1.033 or more
H4 North	35	1.75	2,100	2,656 or more	6,630	3,861	2,769	0.959 or more
H4 South	51	2.55	2,910	3,567 or more	7,413	4,128	3,285	1.086 or more
G1 South	23	1.15	1,530	1,868 or more	3,815	2,129	1,686	1.108 or more
H5	32	1.6	1,920	2,510 or more	6,471	3,521	2,950	0.851 or more
H6(I)	12※6	1	1,200	1,473 or more	2,564	1,200	1,364	1.080 or more
B	37	1.85	2,470	2,875 or more	4,287	2,262	2,025	1.420 or more
B South	7	1	1,330	1,485 or more	1,349	574	775	1.917 or more
H3※4	10	1	1,356	1,633 or more	2,126 365	1,109 -	1,017 365	1.050 or more ※4 1.550 or more ※4
H6(II)	24	1.2	1,630	2,034 or more	4,855	2,834	2,021	1.007 or more
G3 North	6	1	1,100	1,322 or more	1,677	569	1,108	1.193 or more ※4 1.393 or more ※4
G3 West	40※5	2.5	2,600	3,453 or more	8,072	4,320	3,752	0.878 or more
G7	10				1,019	520	499	0.315 or more
G6	38	1.90	2,530	3,024 or more	6,002	3,536	2,466	1.226 or more
K2	28	1.40	1,480	1,948 or more	4,462	2,133	2,329	0.836 or more
D	41※7	2.05	2,140	2,679 or more	5,781	3,097	2,684	0.998 or more
G1	66	3.30	4,480	5,408 or more	12,407	7,769	4,638	1.166 or more
G4 South	26	1.3	1,770	2,168 or more	5,064	3,083	1,981	1.094 or more

Revised

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(Omission)

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J1(I)	28	1.4	1,400	1,823 or more	5,158	3,051	2,107	0.865 or more
J1(II)	35	1.75	1,750	2,281 or more	6,494	3,842	2,652	0.860 or more
J1(III)	37	1.85	1,850	2,,411 or more	6,875	4,068	2,807	0.859 or more
J2※4	42	2.1	5,040	6,208 or more	6,883 6,139 1,073	4,556 3,728 -	2,327 2,411 1,073	1.121 or more ※4 0.771 or more ※4 1.621 or more ※4
J4	35	1.75	5,075	6,208 or more	12,660	6,991	5,669	1.095 or more
J7	42	2.1	2,520	3,146 or more	7,671	4,547	3,124	1.007 or more
H1 East	24	1.2	1,464	1,857 or more	4,562	2,606	1,956	0.949 or more
J8	9	1	700	818 or more	1,100	512	588	1.391 or more
K3	12	1	700	836 or more	1,248	572	676	1.236 or more
J9	12	1	700	826 or more	1,332	704	628	1.315 or more
K4	35※8	1.75	1,750	2,190 or more	5,145	2,944	2,201	0.995 or more
H2	44	2.2	5,280	6,548 or more	15,035	8,697	6,338	1.033 or more
H4 North	35	1.75	2,100	2,656 or more	6,630	3,861	2,769	0.959 or more
H4 South	51	2.55	2,910	3,567 or more	7,413	4,128	3,285	1.086 or more
G1 South	23	1.15	1,530	1,868 or more	3,815	2,129	1,686	1.108 or more
H5	32	1.6	1,920	2,510 or more	6,471	3,521	2,950	0.851 or more
H6(I)	12※6	1	1,200	1,473 or more	2,564	1,200	1,364	1.080 or more
B	37	1.85	2,470	2,875 or more	4,287	2,262	2,025	1.420 or more
B South	7	1	1,330	1,485 or more	1,349	574	775	1.917 or more
H3※4	10	1	1,356	1,633 or more	2,126 365	1,109 -	1,017 365	1.050 or more ※4 1.550 or more ※4
H6(II)	24	1.2	1,630	2,034 or more	4,855	2,834	2,021	1.007 or more
G3 North	6	1	1,100	1,322 or more	1,677	569	1,108	1.193 or more ※4 1.393 or more ※4
G3 West	40※5	2.5	2,600	3,453 or more	8,072	4,320	3,752	0.878 or more
G7	10				1,019	520	499	0.315 or more
G6	38	1.90	2,530	3,024 or more	6,002	3,536	2,466	1.226 or more
K2	28	1.40	1,480	1,948 or more	4,462	2,133	2,329	0.836 or more
D	41※7	2.05	2,140	2,679 or more	5,781	3,097	2,684	0.998 or more
G1	66	3.30	4,480	5,408 or more	12,407	7,769	4,638	1.166 or more
G4 South	26	1.3	1,770	2,168 or more	5,064	3,083	1,981	1.094 or more

Rivised Reason

Addition of ALPS treated water dilution/discharge facilities and related facilities

Current

Table 2 Weir Contents of Foundation Outer Weir in Each Tank Installation Area (2/2)

Installation Location	Tank Installation Cardinal number	Assumed leakage: Cardinal number	Assumed leakage: Capacity (m^3)	Foundation perimeter weir Weir volume (m^3)	(planned value) Foundation circumference Area inside the weir (m^2)	(planned value) Tank Proprietary area (m^2)	(planned value) Pooled Area (m^2)	(planned value) Foundation perimeter weir Height (m)
			①	②※1	③	④	⑤※2	⑥※3
G4 North ※4	6	1	1,356	1566 or more	1,203 457	617 -	586 457	1.376 More ※4 1.661 More ※4
G5	17	1	1,356	1610 or more	3,236	1,973	1,263	1.274 Not less than

※1 ②=⑤×⑥

Since the height of the weir around the foundation differs depending on the location in J2, H3, G4 North, the weir content is shown in the sum.

Since the G3 West and G7 share the outer peripheral weir of the foundation, the estimated leakage capacity and the weir capacity of the outer peripheral weir of the foundation are shown in total.

※2 ⑤=③-④

※3 ⑥=① ⑤ +0.2 (20cm margin)

The height of the weir around the foundation of J2, H3 is calculated by calculating the height of the weir capable of storing the assumed leakage volume, and adding 20 centimeters to each of the heights.

※4 J2, H3, G3 north and G4 north have different basal altitudes depending on the location, so the planned values are shown.

※5 Rainwater recovery tank for 1 of 40 units

※6 Rainwater recovery tank for 1 of 12 tanks

※7 12 of 41 units are post-RO fresh water receiving tanks (RO treated water storage tanks and evaporation concentrated water storage tanks)

(Omission)

Revised

Table 2 Weir Contents of Foundation Outer Weir in Each Tank Installation Area (2/2)

Installation Location	Tank Installation Cardinal number	Assumed leakage: Cardinal number	Assumed leakage: Capacity (m^3)	Foundation perimeter weir Weir volume (m^3)	(planned value) Foundation circumference Area inside the weir (m^2)	(planned value) Tank Proprietary area (m^2)	(planned value) Pooled Area (m^2)	(planned value) Foundation perimeter weir Height (m)
			①	②※1	③	④	⑤※2	⑥※3
G4 North ※4	6	1	1,356	1566 or more	1,203 457	617 -	586 457	1.376 More ※4 1.661 More ※4
G5	17	1	1,356	1610 or more	3,236	1,973	1,263	1.274 Not less than

※1 ②=⑤×⑥

Since the height of the weir around the foundation differs depending on the location in J2, H3, G4 North, the weir content is shown in the sum.

Since the G3 West and G7 share the outer peripheral weir of the foundation, the estimated leakage capacity and the weir capacity of the outer peripheral weir of the foundation are shown in total.

※2 ⑤=③-④

※3 ⑥=① ⑤ +0.2 (20cm margin)

The height of the weir around the foundation of J2, H3 is calculated by calculating the height of the weir capable of storing the assumed leakage volume, and adding 20 centimeters to each of the heights.

※4 J2, H3, G3 north and G4 north have different basal altitudes depending on the location, so the planned values are shown.

※5 Rainwater recovery tank for 1 of 40 units

※6 Rainwater recovery tank for 1 of 12 tanks

※7 12 of 41 units are post-RO fresh water receiving tanks (RO treated water storage tanks and evaporation concentrated water storage tanks)

※8 30 out of 35 tanks are measurement/confirmation tanks in "II 2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities."

(Omission)

Rivised Reason

Addition of ALPS treated water dilution/discharge facilities and related facilities

Current

Appendix 8

(Supplementary Appendix) RO Concentrated Water Storage Tank, Multinuclear Seed Treatment Water Storage Tank, Sr Treatment Water Storage Tank, and Concentrated Waste Liquid Storage Tank by Area

Area	Tank Nominal Capacity [m³]	(39) Storage Tanks for RO concentrated water	(46) Storage Tanks for ALPS Treated Water,	(60) Storage Tanks for Sr treated water	(61) Storage Tanks for Concentrated liquid waste
G3 East	1,000	0	24		
G3 North	1,000	6	0		
G3 West	1,000	39	0		
J1	1,000	100	0		
Other	1,000	16	0		
G7	700	10	0		
J5	1,235		35		
D	1,000	19	0		10
J2	2,400		42		
J3	2,400		22		
J4	2,900		30		
	1,160		5		
J6	1,200		38		
K1 North	1,200			12	
K2	1,057			28	
K1 South	1,160			10	
H1	1,220		63		
J7	1,200		42		
H1 East	1,220		24		
J8	700		9		
K3	700		12		
J9	700		12		
K4	1,000		35		
H2	2,400		44		
H4 North	1,200		35		
H4 South	1,060		13		
	1,140		38		
G1 South	1,160		8		
	1,330		15		
H5	1,200		32		
H6(I)	1,200		11		
B	1,330		10		
	700		27		
B South	1,330		7		
H3	1,356		10		
H6(II)	1,356		24		
G6	1,330		38		
G1	1,356		66		
G4 South	1,356		26		
G4 North	1,356		6		
G5	1,356		17		
Total		190	820	50	10

Revised

Appendix 8

(Supplementary Appendix) RO Concentrated Water Storage Tank, Multinuclear Seed Treatment Water Storage Tank, Sr Treatment Water Storage Tank, and Concentrated Waste Liquid Storage Tank by Area

Area	Tank Nominal Capacity [m³]	(39) Storage Tanks for RO concentrated water	(46) Storage Tanks for ALPS Treated Water,	(60) Storage Tanks for Sr treated water	(61) Storage Tanks for Concentrated liquid waste
G3 East	1,000	0	24		
G3 North	1,000	6	0		
G3 West	1,000	39	0		
J1	1,000	100	0		
Other	1,000	16	0		
G7	700	10	0		
J5	1,235		35		
D	1,000	19	0		10
J2	2,400		42		
J3	2,400		22		
J4	2,900		30		
	1,160		5		
J6	1,200		38		
K1 North	1,200			12	
K2	1,057			28	
K1 South	1,160			10	
H1	1,220		63		
J7	1,200		42		
H1 East	1,220		24		
J8	700		9		
K3	700		12		
J9	700		12		
K4	1,000		35※		
H2	2,400		44		
H4 North	1,200		35		
H4 South	1,060		13		
	1,140		38		
G1 South	1,160		8		
	1,330		15		
H5	1,200		32		
H6(I)	1,200		11		
B	1,330		10		
	700		27		
B South	1,330		7		
H3	1,356		10		
H6(II)	1,356		24		
G6	1,330		38		
G1	1,356		66		
G4 South	1,356		26		
G4 North	1,356		6		
G5	1,356		17		
Total		190	820	50	10

※ 30 tanks of K4 area will be used as measurement/confirmation tank in "II 2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities".

Rivised Reason

Addition of ALPS treated water dilution/discharge facilities and related facilities

The Japanese version shall prevail.

Current	Revised	Rivised Reason
(Not currently listed)	2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities (New described) (Omitted below)	Addition to the installation of ALPS treated water dilution/discharge facilities and related facilities

Current	Revised	Revised reason
2.1.2 Management of Radioactive Liquid Waste, etc. 2.1.2.1 Overview (Omission) (2)Radioactive liquid waste, etc. (liquid generated after the accident) Radioactive liquid wastes generated after the accident include the following. Water has been injected into the reactors of Units 1 to 3 to cool down the reactors, but the injected water has leaked into the reactor buildings, etc., and has remained as stagnant water. The contaminated water is stored inside the buildings and tanks, etc. to prevent from leaking outside. A portion of the contaminated water is purified by the contaminated water treatment facility to reduce radioactive materials. The treated water generated by the purification process is stored in tanks, and the desalinated treated water is reused by injecting into the reactors. The treated water from the contaminated water treatment facility and the water from the outlet of the treatment facility is treated to reduce radioactive materials (except tritium) using a radionuclide removal system, and then the treated water is stored in tanks. The seawater and ground water that flowed into the turbine buildings of Units 5 and 6, and the rainwater in the barrier where the concentration of radioactive materials exceeds the criteria for sprinkling water will be transferred to the storage facility (tanks) as stagnant water and stored. (Omission) 2.1.2.3 Radioactive Liquid Waste to be Managed and Management Methods (Omission) (5) Liquid waste management methods The water shall be drained after analyzing the major nuclides and confirming that the criteria are satisfied. (In the pre-drainage analysis, Sr-90 shall be assessed in the same method as in (4) Recycling.) If the criteria are not satisfied, the water shall not be drained. Investigate the cause and implement countermeasures before discharging Regarding the treated water from the sub-drainage and other purification facilities that pump up groundwater from the vicinity of the Unit 1 to 4 buildings and the Unit 5 and 6 buildings where the accident occurred, it is necessary to confirm that there are no significant changes in the quality of the water through periodic analysis, and that the sum of ratios of legally required concentration indicated in the public notice for three months is in compliance with the dose assessment for the discharge of the treated water from the sub-drainage and other purification facilities (for details, see "III.2.2.3 Dose assessment due to radioactive liquid waste, etc."). (Attachment 1, Attachment 2) ① Pre-drainage analysis When discharging radioactive liquid waste, etc., sampling should be carried out in advance in tanks, etc., and the concentration of radioactive materials should be measured, and the waste should be discharged if it meets the following criteria, and if it does not meet the criteria, necessary treatment (purification treatment, etc.) should be carried out.	2.1.2 Management of Radioactive Liquid Waste, etc. 2.1.2.2 Overview (Omission) (2)Radioactive liquid waste, etc. (liquid generated after the accident) Radioactive liquid wastes generated after the accident include the following. Water has been injected into the reactors of Units 1 to 3 to cool down the reactors, but the injected water has leaked into the reactor buildings, etc., and has remained as stagnant water. The contaminated water is stored inside the buildings and tanks, etc. to prevent from leaking outside. A portion of the contaminated water is purified by the contaminated water treatment facility to reduce radioactive materials. The treated water generated by the purification process is stored in tanks, and the desalinated treated water is reused by injecting into the reactors. The treated water from the contaminated water treatment facility and the water from the outlet of the treatment facility is treated to reduce radioactive materials (except tritium) using a radionuclide removal system, and then the treated water is stored in tanks. <u>The treated water that satisfies the sum of ratios of legally required concentrations, with the exception of tritium less than 1 (hereinafter referred to as "ALPS treated water") will be diluted with seawater and then discharged into the sea.</u> The seawater and ground water that flowed into the turbine buildings of Units 5 and 6, and the rainwater in the barrier where the concentration of radioactive materials exceeds the criteria for sprinkling water will be transferred to the storage facility (tanks) as stagnant water and stored. (Omission) 2.1.2.3 Radioactive Liquid Waste to be Managed and Management Methods (Omission) (5)Liquid waste management methods <u>ALPS treated water is analyzed for its radionuclides other than H-3 and H-3 in the measurement/confirmation equipment prior to drainage, and Tepco confirmed that radionuclides other than H-3 satisfy the criteria. The treated water is drained after diluting with seawater using dilution facility in order to reduce H-3 concentration.</u> The water <u>of groundwater by-pass and the treated water within and the sub-drain purification equipment</u> shall be drained after analyzing the major nuclides and confirming that the criteria are satisfied. (In the pre-drainage analysis, Sr-90 shall be assessed in the same method as in (4) Recycling.) If the criteria are not satisfied, the water shall not be drained. Investigate the cause and implement countermeasures before discharging Regarding the treated water from the sub-drainage and other purification facilities that pump up groundwater from the vicinity of the Unit 1 to 4 buildings and the Unit 5 and 6 buildings where the accident occurred, it is necessary to confirm that there are no significant changes in the quality of the water through periodic analysis, and that the sum of ratios of legally required concentration indicated in the public notice for three months is in compliance with the dose assessment for the discharge of the treated water from the sub-drainage and other purification facilities (for details, see "III.2.2.3 Dose assessment due to radioactive liquid waste, etc."). (Attachment 1, Attachment 2) ① Pre-drainage analysis When discharging radioactive liquid waste, etc., sampling should be carried out in advance in tanks, etc., and the concentration of radioactive materials should be measured, and the waste should be discharged if it meets the following criteria, and if it does not meet the criteria, necessary treatment (purification treatment, etc.) should be carried out.	Added due to discharge of ALPS treated water into the sea

The Japanese version shall prevail.

Current	Revised	Revised reason
The nuclides to be assessed in the analysis before discharge shall be major nuclides. Discharge to the ocean will not be carried out without the approval of the relevant ministries.	Discharge to the ocean will not be carried out without the approval of the relevant ministries.	Deleted due to discharge of ALPS treated water into the sea
	For ALPS treated water, it shall be confirmed that the sum of ratios of legally required concentration of H-3 is less than 1 by measurement, etc. In addition, the drainage flow rate and diluted seawater flow rate are set so that the H-3 concentration in the drainage vertical shaft (upstream tank) is less than 1,500Bq/L and more than 100 times diluted with seawater. The amount of drained H-3 shall be within the range of 22 TBq/year. The radionuclides to be measured other than H-3 and concentration confirmation methods shall be stipulated in the in-house manual.	Added due to discharge of ALPS treated water into the sea
For the water of groundwater by-pass, it shall be confirmed that Cs-134 is less than 1Bq/L, Cs-137 is less than 1Bq/L, Sr-90 is less than 5Bq/L, and the H-3 is less than 1,500Bq/L by measurement.	For the water of groundwater by-pass, it shall be confirmed that Cs-134 is less than 1Bq/L, Cs-137 is less than 1Bq/L, Sr-90 is less than 5Bq/L, and the H-3 is less than 1,500Bq/L by measurement.	
For the treated water within the sub-drain and other remediation equipment, it shall be confirmed that Cs-134 is less than 1Bq/L, Cs-137 is less than 1Bq/L, Sr-90 is less than 3(1) Bq/L*, H-3 is less than 1,500Bq/L by measurement, as well as that no other artificial gamma-ray emitting have not been detected during the above measurement. (* Sr-90 shall be confirmed to be less than 1Bq/L at approx. once every 10 days) In addition to the treated water, the water pumped up to collection tanks shall be confirmed to be less than 1,500Bq/L by H-3 measurement.	For the treated water within the sub-drain and other remediation equipment, it shall be confirmed that Cs-134 is less than 1Bq/L, Cs-137 is less than 1Bq/L, Sr-90 is less than 3(1) Bq/L*, H-3 is less than 1,500Bq/L by measurement, as well as that no other artificial gamma-ray emitting have not been detected during the above measurement. (* Sr-90 shall be confirmed to be less than 1Bq/L at approx. once every 10 days) In addition to the treated water, the water pumped up to collection tanks shall be confirmed to be less than 1,500Bq/L by H-3 measurement.	
For other radioactive liquid wastes, etc. to be drained, the radioactive materials concentration of the major nuclides shall be confirmed and it is confirmed that the sum of ratios of legally required concentration is less than 0.22.	For other radioactive liquid wastes, etc. to be drained, the radioactive materials concentration of the major nuclides shall be confirmed and it is confirmed that the sum of ratios of legally required concentration is less than 0.22.	
(Omitted below)	(Omitted below)	

The Japanese version shall prevail.

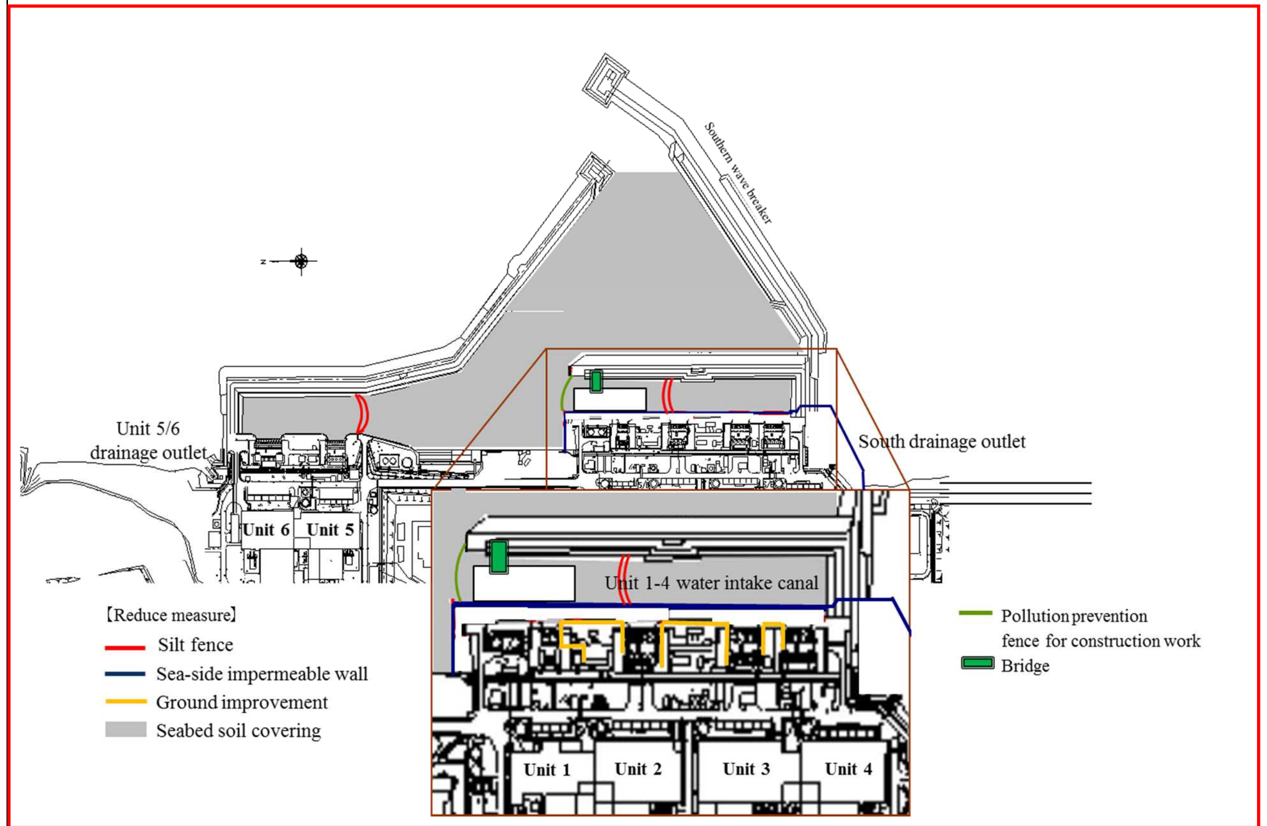
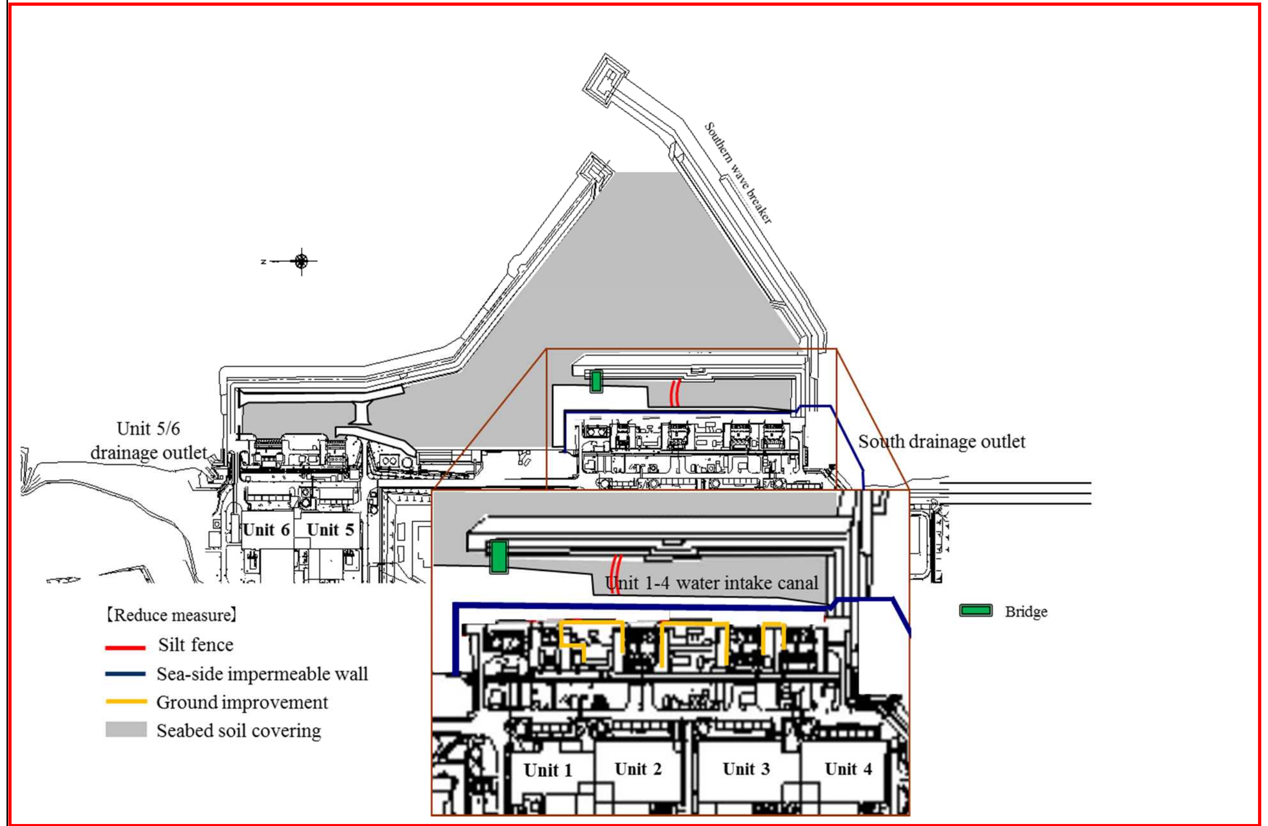
Current	Revised	Revised reason
2.2.3 Dose Assessment by Radioactive Liquid Waste, etc. 2.2.3.1 Dose assessment method (1) Nuclides to be assessed	2.2.3 Dose Assessment by Radioactive Liquid Waste, etc. 2.2.3.1 Dose assessment method (1) Nuclides to be assessed For ALPS treated water, radionuclides other than H-3 and H-3 shall be assessed. The relevant radionuclides other than H-3 shall be stipulated in the in-house manual.	Added due to discharge of ALPS treated water into the sea
For the treated water within sub-drain and other treatment equipment. Cs-134, Cs-137, Sr-90, H-3 (hereinafter referred to as "major nuclides") and 37 other nuclides (total 41 nuclides*) shall be regarded as nuclides to be assessed. (* For the detail of 41 nuclides, refer to "III Part 3 2.1.2 Control of radioactive liquid waste, etc.") For the treated water of the stagnant water in units 5 and 6, the nuclides to be assessed in the water treated by the treatment equipment, the treatment unit, and the desalination equipment shall be the major nuclide significant in dose assessment among the 41 nuclides. For the water treated by the treatment equipment, those shall be the major nuclide and Co-60 significant in dose assessment among the 41 nuclides. The nuclides to be assessed in other radioactive liquid waste, etc. shall be the major nuclides significant for dose assessment among 41 nuclides.	For the treated water within sub-drain and other treatment equipment. Cs-134, Cs-137, Sr-90, H-3 (hereinafter referred to as "major nuclides") and 37 other nuclides (total 41 nuclides*) shall be regarded as nuclides to be assessed. (* For the detail of 41 nuclides, refer to "III Part 3 2.1.2 Control of radioactive liquid waste, etc.") For the treated water of the stagnant water in units 5 and 6, the nuclides to be assessed in the water treated by the treatment equipment, the treatment unit, and the desalination equipment shall be the major nuclide significant in dose assessment among the 41 nuclides. For the water treated by the treatment equipment, those shall be the major nuclide and Co-60 significant in dose assessment among the 41 nuclides. The nuclides to be assessed in other radioactive liquid waste, etc. shall be the major nuclides significant for dose assessment among 41 nuclides.	
(Omission)	(Omission)	
2.2.3.2 Dose assessment in each system (1)System to be assessed Dose assessment shall be performed on the following systems. ○Drainage system ・Water in groundwater bypass ・Rainwater inside the barrier ・Treated water from sub-drains and other water treatment facilities ○Water sprinkling system ・Rainwater inside the barrier ・Treated water of the stagnant water at Units 5 and 6	2.2.3.2 Dose assessment in each system (1)System to be assessed Dose assessment shall be performed on the following systems. ○Drainage system ・ALPS treated water ・Water in groundwater bypass ・Rainwater inside the barrier ・Treated water from sub-drains and other water treatment facilities ○Water sprinkling system ・Rainwater inside the barrier ・Treated water of the stagnant water at Units 5 and 6	
(2) Dose assessment for drain	(2) Dose assessment for drain For ALPS treated water, the sum of ratios of legally required concentrations of radionuclides other than H-3 shall be determined to be less than 1 prior to drain by measurement, etc. The water to be drained is diluted (100 times or more) with seawater and it will be drained while the concentration of H-3 is controlled to be less than 1,500Bq/L, so that the effective dose is 0.035 mSv/year.	
For the water in groundwater bypass, its effective dose is 0.22 mSv/year because the water is treated after confirming that the following operational subjects are satisfied.	For the water in groundwater bypass, its effective dose is 0.22 mSv/year because the water is treated after confirming that the following operational subjects are satisfied.	
(Omission)	(Omission)	
For treated water from the sub-drain and other treatment facilities, its effective dose of the main nuclides in drained water is lower than 0.15 mSv/year because the water is drained after confirming that the following operational subjects are satisfied.	For treated water from the sub-drain and other treatment facilities, its effective dose of the main nuclides in drained water is lower than 0.15 mSv/year because the water is drained after confirming that the following operational subjects are satisfied.	
(Omission)	(Omission)	
For other drainage systems, drainage is conducted after confirming that the effective dose is 0.22	For other drainage systems, drainage is conducted after confirming that the effective dose is 0.22	

The Japanese version shall prevail.

Current	Revised	Revised reason
mSv/year or less. Therefore, the effective dose of radioactive liquid waste, etc. shall be 0.22 mSv/year, which is the maximum of the above. (Omitted below)	mSv/year or less. Therefore, the effective dose of radioactive liquid waste, etc. shall be 0.22 mSv/year, which is the maximum of the above. (Omitted below)	

The Japanese version shall prevail.

Current	Revised	Revised reason
(Not currently listed)	2.2.6 Action in response to the "Basic Policy on handling of the ALPS treated water" (New described) (Omitted below)	Added due to discharge of ALPS treated water into the sea.

Current	Revised	Revised reason
3.1.4 Reduction of radioactive materials in seawater, seabed soil, groundwater and drainage channels in ports and harbors 3.1.4.3 Basic Approach to Reduction Measures (Omission) (2)Monitoring (Omission)  Fig. 1 Measures to Reduce Radioactive Materials in Seawater and Seabed Soil in the Port, and Groundwater	3.1.4 Reduction of radioactive materials in seawater, seabed soil, groundwater and drainage channels in ports and harbors 3.1.4.3 Basic Approach to Reduction Measures (Omission) (2)Monitoring (Omission)  Fig. 1 Measures to Reduce Radioactive Materials in Seawater and Seabed Soil in the Port, and Groundwater	Installation of partitions for diluted discharge of ALPS treated water Reflection of drawings in line with the actual conditions of the site

Current	Revised	Revised reason
(see below)	(see below)	Installation of partitions for diluted discharge of ALPS treated water and change of sampling points Reflection of drawings in line with the actual conditions of the site

Current

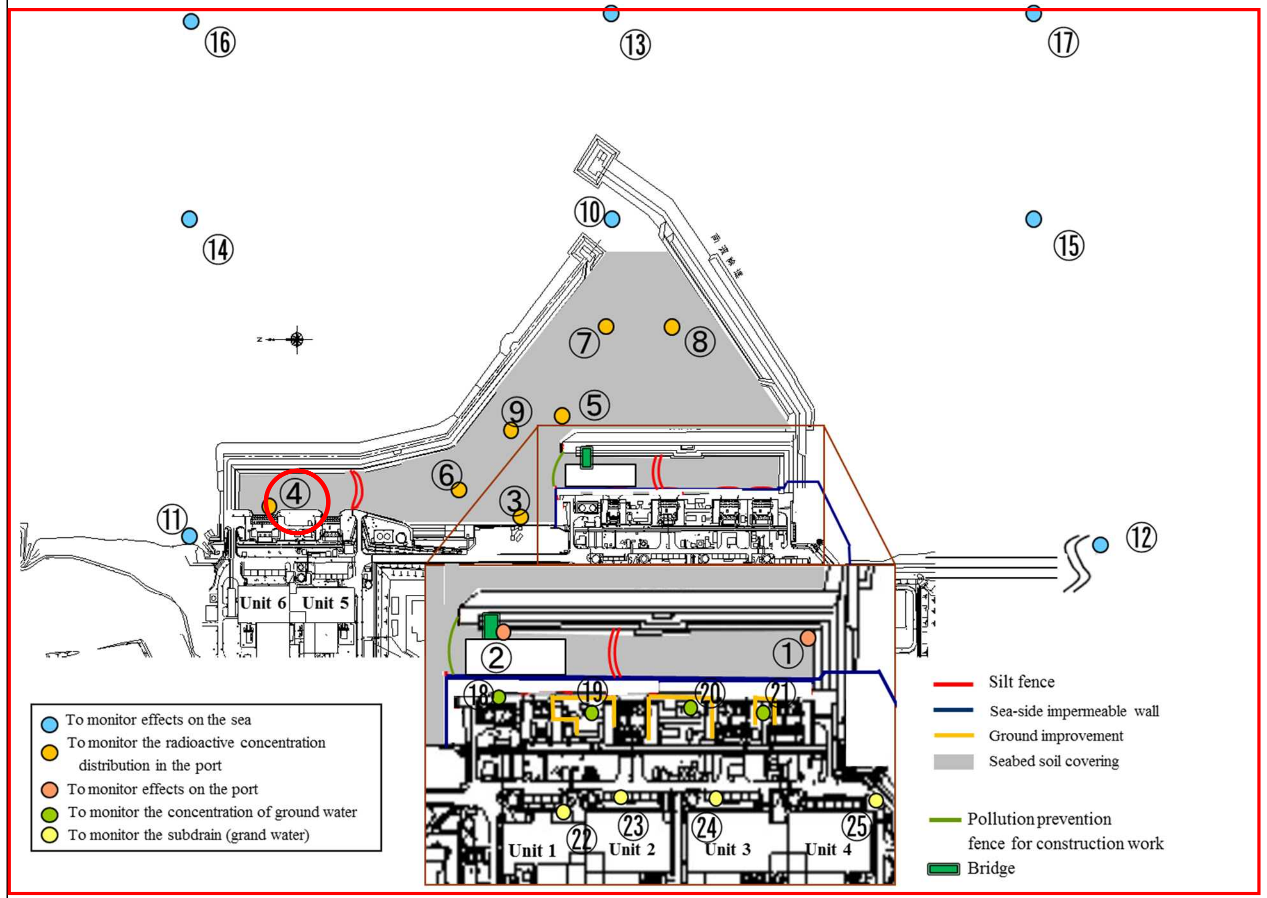


Fig. 2 Plans for monitoring seawater inside and outside port and groundwater (sampling points)

(Omission)

Table 1. Monitoring plans for seawater, groundwater, and drainage channels inside and outside ports (analysis items, frequency)

Area		Sampling point	Gamma ray	H-3	Total β	Sr-90
			Analysis items and frequencies			
In the Unit 1-4 water intake canal	①	Southern part of Unit 1-4 water intake canal (in front of the impermeable wall) ※1	Once a day	Once a week	Once a day	Once a week
	②	Northern part of Unit 1-4 water intake canal (north of eastern wave breaker) ※1	Once a day	Once a week	Once a day	Once a week
In the port	③	In front of shallow draft quay ※1	Once a day	Once a week	Once a day	Once a week
	④	In front of Unit 6 water intake ※1	Once a day	Once a week	Once a day	-
	⑤	Central area in the port ※1	Once a day	Once a week	Once a day	Once a week
	⑥	Northern area in the port ※1	Once a day	Once a week	Once a day	Once a week
	⑦	Eastern area in the port ※1	Once a day	Once a week	Once a day	-

Revised

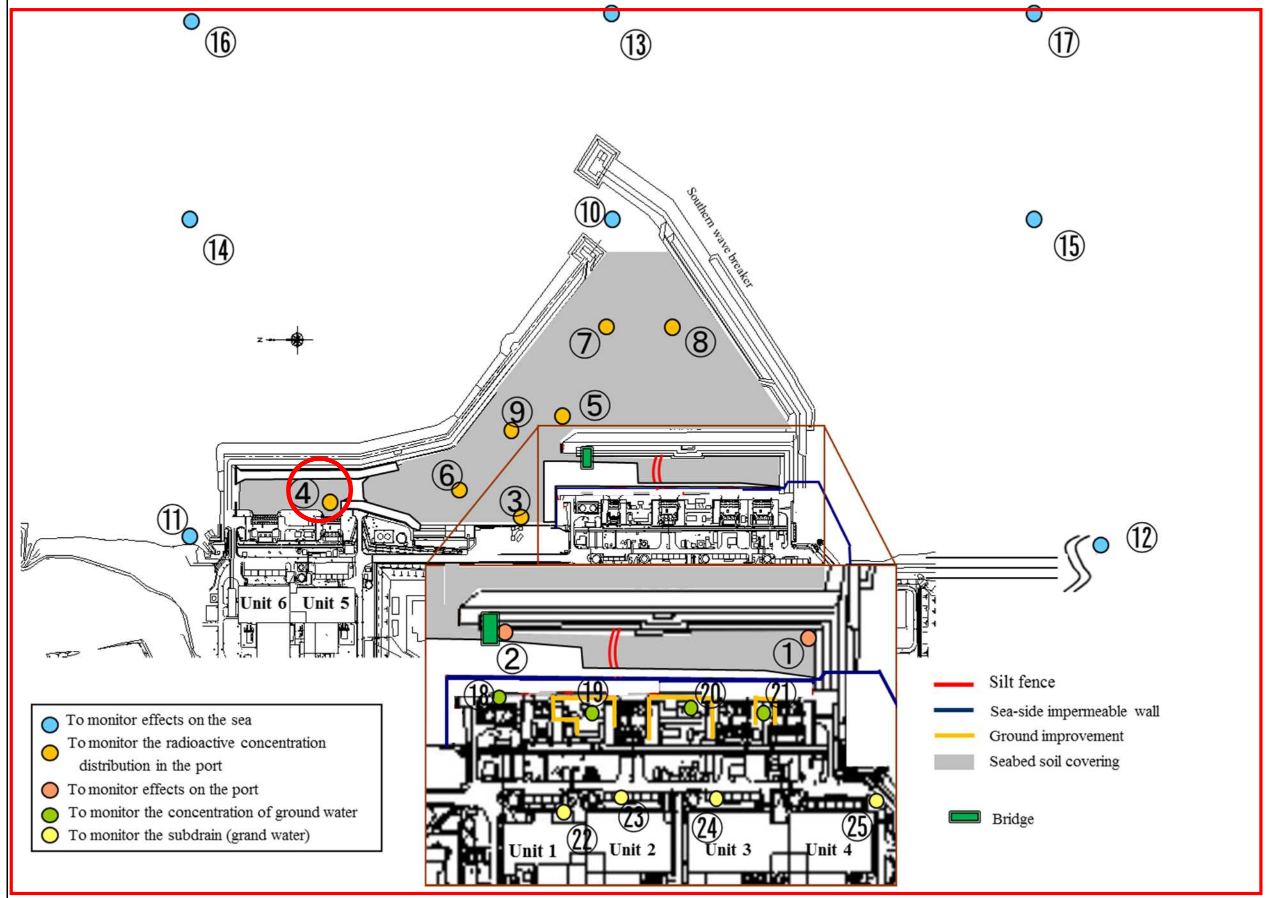


Fig. 2 Plans for monitoring seawater inside and outside port and groundwater (sampling points)

(Omission)

Table 1. Monitoring plans for seawater, groundwater, and drainage channels inside and outside ports (analysis items, frequency)

Area		Sampling point	Gamma ray	H-3	Total β	Sr-90
			Analysis items and frequencies			
In the Unit 1-4 water intake canal	①	Southern part of Unit 1-4 water intake canal (in front of the impermeable wall) ※1	Once a day	Once a week	Once a day	Once a week
	②	Northern part of Unit 1-4 water intake canal (north of eastern wave breaker) ※1	Once a day	Once a week	Once a day	Once a week
In the port	③	In front of shallow draft quay ※1	Once a day	Once a week	Once a day	Once a week
	④	In front of Unit 5 water intake ※1	Once a day	Once a week	Once a day	-
	⑤	Central area in the port ※1	Once a day	Once a week	Once a day	Once a week
	⑥	Northern area in the port ※1	Once a day	Once a week	Once a day	Once a week
	⑦	Eastern area in the port ※1	Once a day	Once a week	Once a day	-

The Japanese version shall prevail.

Current	Revised	Revised reason

Current

	⑧	Southern area in the port ※1	Once a day	Once a week	Once a day	-
	⑨	Western area in the port ※1	Once a day	Once a week	Once a day	-
	⑩	Port entrance ※1	Once a day	Once a week	Once a day	Once a week

(Omitted below)

Revised

	⑧	Southern area in the port ※1	Once a day	Once a week	Once a day	-
	⑨	Western area in the port ※1	Once a day	Once a week	Once a day	-
	⑩	Port entrance ※1	Once a day	Once a week	Once a day	Once a week

(Omitted below)

Current	Revised	Revised Reason
Annexes of the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility (Omission) Annex 26 Supplementary information on Intake Facilities in Unit 3 reactor containment I. Structural Strength and Seismic resistance of Intake Facilities in Unit 3 reactor containment	Annexes of the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility (Omission) Annex 26 Supplementary information on Intake Facilities in Unit 3 reactor containment I. Structural Strength and Seismic resistance of Intake Facilities in Unit 3 reactor containment Annex 27 Supplementary information on the ALPS Treated Water Dilution/Discharge Facilities I. Structural Strength of ALPS Treated Water Dilution/Discharge Facilities II. Permissible level of nominal values for ALPS Treated Water Dilution/Discharge Facilities	Addition to the installation of ALPS treated water dilution/discharge facilities and related facilities

The Japanese version shall prevail.

Current	Revised	Rivised Reason
(Not currently listed)	Annex 27 Supplementary information on the ALPS Treated Water Dilution/Discharge Facilities (New described) (Omitted below)	Addition to the installation of ALPS treated water dilution/discharge facilities and related facilities

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(Refer to comparison table for any amendments)

The Japanese version shall prevail.

2.5 Contaminated Water Treatment Facilities, etc.

(Refer to comparison table for any amendments)

2.50 ALPS Treated Water Dilution/Discharge Facilities and Related Facilities

2.50.1 Basic Design

2.50.1.1 ALPS Treated Water Dilution/Discharge Facilities

2.50.1.1.1 Purpose of Installation

The tanks* on the premises of the Fukushima Daiichi NPS store the water, which radionuclides other than tritium has been removed to a sufficiently low concentration by ALPS (hereinafter referred to as "ALPS treated water, etc.").

The purpose of this facility is to dilute ALPS treated water, etc. with seawater and discharge into the sea after confirming that the water satisfies the concentration where sum of the ratios of legally required concentration of radionuclides, excluding tritium is less than 1 (hereinafter referred to as "ALPS treated water.").

Since the sum of ratios of legally required concentration of ALPS treated water, etc. varies depending on the storage period, the water with that of 1 or more (hereinafter referred to as " Treated water to be re-purified") shall be secondarily treated with ALPS or the Secondary Treated Facility installed separately, and the radionuclides (excluding tritium) shall be reduced until the sum of ratios of legally required concentration is less than 1.

※: The Reverse Osmosis membrane (hereinafter referred to as "RO") concentrated salt water storage tanks, the multi-nuclide treated water storage tanks, and Sr treated storage tanks.

RO concentrated salt water storage tanks initially stored the concentrated salt water discharged from the RO device, but after the completion of the treatment of the concentrated water, RO concentrated water storage tanks store ALPS treated water, etc. Sr treated storage tanks initially stored treated water discharged from RO concentrated salt water treatment facility (already closed down), but after the completion of the treatment of treated water, Sr treated storage tanks store ALPS treated water, etc.

2.50.1.1.2 Required function

(1) The amount of discharge into the sea shall be capable of exceeding the amount of contaminated water generated (the increased amount due to the inflow of groundwater and rainwater).

(2) In order to confirm that the water before dilution/discharge is ALPS treated water, it shall be capable of uniformizing the radionuclides concentration in the tanks/tank group and sampling.

(3) ALPS treated water can be diluted with seawater and drained away to discharge facility.

(4) There is a function to immediately stop discharging ALPS treated water into the sea in case an abnormal matter happens.

(5) There is a function to dilute the ALPS treated water 100 times or more so that the level of tritium concentration in diluted ALPS treated water after diluting with seawater is sufficiently below the legally required concentration (60,000Bq/L)

2.50.1.1.3 Design Policy

(1) Processing capacity

a. ALPS Treated Water Dilution/Discharge Facility shall be designed to have a processing capacity to exceed the amount of contaminated water generated (the increased amount due to the inflow of groundwater and rainwater).

b. ALPS Treated Water Dilution/Discharge Facility shall be designed to have a capacity that can dilute ALPS treated water 100 times or more so that the level of tritium concentration after seawater dilution is sufficiently below the legally required concentration (60,000Bq/L).

(2) Prevention of leakage of radionuclides and uncontrolled discharge

ALPS Treated Water Dilution/Discharge Facility, which handles the ALPS treated water, shall be designed in such a way that the following sections are considered in order to prevent the leakage of liquid radionuclides and the uncontrolled discharge out of the premises.

a. Appropriate materials according to installation environment and internal fluid properties should be used for equipment to prevent leakage.

b. In the event of liquid radioactive material leakage, early detection of the leak shall be enabled, and the leak liquid shall be easily removed.

c. Alarms such as leak detection, etc. shall be indicated in the centralized monitoring room of the seismic isolation building, etc., to ensure that information on abnormality is exactly conveyed to operators and appropriate measures are taken.

d. Equipment containing ALPS treated water shall be set in areas where barriers are equipped in the vicinity to prevent the spread of leakage. In addition, the pipes containing ALPS treated water shall isolate from drains as much as possible, and lay in steel boxes, etc. in areas where the pipes cross drains.

e. Discharge of ALPS treated water shall be performed after measuring and confirming the radionuclides concentration prior to dilution/discharge, confirming that the sum of ratios of legally required concentration of radionuclides in ALPS treated water is less than 1, confirming the tritium concentration, and confirming the fact that ALPS treated water can be diluted 100 times or more with regard to the flow rate of dilution equipment. Also, the design shall be such that water cannot be discharged prior to measurement/confirmation due to operational error, etc.

(3) Soundness Considerations

ALPS Treated Water Dilution/Discharge Facility shall be designed to allow effective maintenance in accordance with the importance of the equipment.

(4) Design Considerations for Inspect ability

ALPS Treated Water Dilution/Discharge Facility shall be designed to allow inspections to confirm that ALPS treated water is drained away to discharge facility.

(5) Consideration for Preventing Improper Operation

ALPS Treated Water Dilution/Discharge Facility shall be designed to require double-action for critical operations such as discharge and transfer in order to prevent operational error and misjudgment. The operation related to the discharge permission shall be designed to require the key switch operation, in addition to the double-action.

(6) Consideration for Monitoring and Operation

ALPS Treated Water Dilution/Discharge Facility shall be designed so that remote control and operation condition monitoring can be conducted by monitoring and control equipment in the centralized monitoring room of the seismic isolation building.

(7) Corrosion Consideration

Within the ALPS Treated Water Dilution/Discharge Facility, pumps containing ALPS treated water shall be manufactured by two-phases stainless steel, etc., which has excellent corrosion resistance. As for piping containing ALPS treated water, stainless steel pipe having corrosion resistance, polyethylene pipe, synthetic rubber, and steel pipe of carbon steel, whose inner is coated to provide corrosion resistance, shall be used.

(8) Consideration for Long-Term Stops

For the dynamic equipment and equipment to stop discharging ALPS treated water into the sea due to an abnormality within the ALPS Treated Water Dilution/Discharge Facility, dual lines should be installed to prevent long-term stop due to a failure. In addition, the power supply shall be designed so that the power supply can receive two different high-voltage buses in the plant.

(9) Codes, Standards, etc.

For design, selection of materials, and manufacturing and inspection, reliability shall be ensured by applying Codes for nuclear power generation facilities: rules on design and construction for nuclear power plants (JSME) and Japanese Industrial Standards (JIS) etc.*

※ "JIS G 3454 Carbon steel pipes for pressure service ", " JIS G 3457 Arc welded carbon steel pipes ", " JIS G 3459 Stainless steel pipes ", "JIS G 3468 Large diameter welded stainless steel pipes", and "JWWA K 144 Higher performance polyethylene pipes for water supply"

2.50.1.1.4 Major Equipment

ALPS Treated Water Dilution/Discharge Facility consists of measurement/confirmation equipment, transfer equipment, and dilution equipment.

In the measurement/confirmation equipment, after the radioactive material concentration in the tanks / tank group is uniformized, sampling and analysis are performed to confirm the tritium concentration and the fact that the sum of ratios of legally required concentration of radionuclides in ALPS treated water is less than 1.

Thereafter, ALPS treated water is transferred to the dilution equipment by the transfer equipment, diluted with seawater and transferred to discharge vertical shaft (upper-stream storage), and drained away to discharge facility.

(1) Measurement/confirmation equipment

Measurement/confirmation equipment consists of measurement/confirmation tanks, stirring equipment, circulation pumps, transfer pipes, etc., for the purpose of uniformizing the radioactive material concentration of ALPS treated water and sampling prior to discharge.

For the measurement/confirmation tanks, 10 tanks as a group, 3tank groups (total of 30 tanks) in K4 area are reused.

Stirring equipment are installed in each of measurement/confirmation tank and stir the contents of the tanks.

Two circulation pumps are installed to circulate and stir the water in tanks of one group (10 tanks). In addition, both the stirring equipment and the circulation pumps ensure a sufficient processing capacity to uniformize the concentrations of radionuclides in the K4 area tanks.

(2) Transfer equipment

The transfer equipment consists of ALPS treated water transfer pump and pipes to transfer the water, which has been confirmed as ALPS treated water in the measurement/confirmation equipment, to the dilution equipment.

ALPS treated water transfer pump shall consist of two units, the operational unit and the stand-by unit, and transfer ALPS treated water to the dilution equipment.

Also, emergency isolation valves shall be installed in front of seawater pipe header and one place inside each seawall as tsunami protection measure so that the transfer can be stopped quickly in case that an abnormal event occurs

(3) Dilution equipment

The dilution equipment consists of seawater transfer pumps, seawater pipes, discharge guide, and discharge vertical shaft (upper-stream storage) for the purpose of diluting the ALPS treated water with seawater, transporting it to the discharge vertical shaft (upper-stream storage), and drained away to discharge facility.

The seawater transfer pumps transfer the seawater from the intake channel of Unit 5 to the discharge vertical shaft. Furthermore, Dilution equipment shall ensure a capacity to dilute the ALPS treated water 100 times or more so that tritium concentration of the ALPS treated water transferred by this equipment shall be sufficiently below the legally required concentration (60,000Bq/L)

2.50.1.1.5 Items to be checked during service period

ALPS treated water shall be transferred from the measurement/confirmation equipment to discharge vertical shaft and drained away to discharge facility.

2.50.1.1.6 Countermeasure to Natural disasters

(1) Fire

ALPS Treated Water Dilution/Discharge Facility shall be applied for incombustible or flame retardant as practically as feasible to prevent fire.

In this facility, patrol inspections are conducted to detect fire as soon as possible and design should be considered to detect fire with fire detection at circulation pumps, ALPS treated water transfer pumps, and areas around electrical panels and cubicles. Furthermore, fire extinguishers shall be installed near each facility to enable initial firefighting and to facilitate firefighting activities.

In addition, guidance signs shall be installed in the building for guidance during evacuation.

(2) Tsunami

A part of measurement/confirmation equipment and transfer equipment within ALPS Treated Water Dilution/Discharge Facility, excluding the dilution equipment, shall be installed at about 33.5m or more T.P. where the tsunami is not expected to reach. In addition, when a large tsunami warning is issued, transfer and dilution systems will be stopped with consideration of the damage risk due to tsunami.

(3) Typhoon (strong wind)

Within ALPS Treated Water Dilution/Discharge Facility, the circulation pump and ALPS treated water transfer pump shall be installed in the steel structured building which is unlikely to be damaged by the typhoon (strong wind). Other mechanical items such as transfer piping installed outdoors shall be designed to prevent them from falling over by fixing them with foundation bolts.

Within ALPS Treated Water Dilution/Discharge Facility, electric components such as control panels etc. shall be installed in the lightweight steel frame building for ALPS electrical panel and cubicles room, which is unlikely to be damaged by a typhoon (strong wind).

(4) Snow cover

To prevent damage to facilities due to snow cover, buildings shall be designed with snow cover loads based on the Enforcement Order of the Building Standards Law and Detailed Enforcement Regulations of Fukushima Prefectural Building Standards Law.

(5) Lightning strike

Dynamic equipment and electrical components shall be prevented from damage due to lightning strikes by equipment grounding.

(6) Tornado

If the possibility of tornadoes is anticipated, the equipment will be stopped with consideration of the damage risk due to tornadoes.

2.50.1.1.7 Structural strength and earthquake resistance

(1) Structural strength

Within each equipment consisting ALPS Treated Water Dilution/Discharge Facility, major equipment containing ALPS treated water is classified as Class 3, equivalent to waste treatment facilities in the Ministerial Ordinance Establishing Technical Standards for Nuclear Power Generation Facilities. As for steel pipes, the provisions of Class 3 equipment in JSME S NC1-2012 Nuclear Power Plant Standards Design and Construction Standard (hereafter, "Design and Construction Standards") shall be applied, and Japanese Industrial Standards (JIS) and other Japanese and foreign commercial standards shall also be applied as necessary. For year designation of Japanese Industrial Standards (JIS) for material specified by JSME standard may not be considered from the viewpoint of material procurement within the scope of technical validity.

Polyethylene pipes are evaluated to have the structural strength by using the ISO standards or JWWA standards within the applicable range. Pressure resistant hose and expansion joints are evaluated to have the structural strength by using the rage of pressure and temperature specified by manufacturer.

(2) Earthquake resistance

The equipment consist of ALPS Treated Water Dilution/Discharge Facility shall be designed to withstand design seismic force considered appropriately, as well as having seismic design classifications with reference to seismic classification at nuclear fuel processing facilities and facilities handling nuclear fuel materials without sealing, etc. after considering the importance of safety function and safety impact(public exposure impact) and impact to decommissioning activities in case that the function is lost due to an earthquake. For the seismic resistance of major equipment and pipes, structural strength assessment shall be basically conducted in compliance with “Technical Guidelines for Aseismic Design of Nuclear Power Plants (JEAC 4601)” and assessment method and standard shall be adopted in line with actual situation.

When installing equipment that cannot be assessed for earthquake resistance due to lack of support materials, etc., earthquake resistance shall be ensured by using a flexible material.

2.50.1.2 Discharge Facility

2.50.1.2.1 Purpose of Installation

The purpose of this facility shall be to discharge the drained water from ALPS Treated Water Dilution/Discharge Facility (water satisfies the concentration where sum of the ratios of legally required concentration of all radionuclides including tritium diluted with seawater) into the sea which is about 1km away from the shore by the water head difference between discharge vertical shaft and sea level.

2.50.1.2.2 Required Function

(1) The drained water from ALPS Treated Water Dilution/Discharge Facility (the water satisfies the concentration where sum of the ratios of legally required concentration of all radionuclides including tritium diluted with seawater) can be discharged into the sea which is about 1km away from the shore by the water head difference between discharge vertical shaft and sea level.

2.50.1.2.3 Design Policy

(1) Hydraulic Design

The design is to transport the water in the discharge shaft to the outlet, which is about 1 km away, due to the difference in hydraulic head between the discharge shaft (downstream water tank) and the sea surface. And the wall height of the water discharge shaft (downstream water tank) shall be designed in consideration of hydraulic loss and water level rising due to surging in the water discharge facility.

(2) Structure

This facility shall have the structure which is less susceptible to earthquake by fixing bottom of this facility to bedrock. And discharge tunnel shall be installed inside bedrock and the shield method shall be adopted to consider the risk during construction of excavation of sea bed and the durability during service period. Then this facility shall have water tightness to place the seal material on covering plate made of reinforced concrete composing the discharge tunnel.

(3) Soundness Consideration

The structure is set up to confirm that this facility is within allowance stress level to the normal load, wave load and seismic load. It is also confirmed that no lifting occurs in the structure. And it is confirmed that the durability during service period is ensured to perform irradiation to inspect width of crack and salt damage on the body made of reinforced concrete, and to set appropriate covering depth for reinforcement.

Note that maintenance is not required due to design considerations for body made of reinforced concrete during the service period.

(4) Design Considerations for Inspect ability

Discharge equipment shall be designed to allow to confirm the required function.

(5) Codes, Standards, etc.

For design, selection of materials, and manufacturing and inspection, this facility shall be evaluated in accordance with the following.

- “Design of Civil Engineering Structure of Thermal and Nuclear Power Plant (enlarged and revised edition)”, (general incorporated association) Electric Power Civil Engineering Association
- “Standard Specifications of Concrete (design edition)”, (Public Interest Incorporated Association) Japan Society of Civil Engineers,(established in 2017)
- “Standard Specifications of Tunnels〔common edition〕/ 〔shield method edition〕”, (Public Interest Incorporated Association) Japan Society of Civil Engineers, (established in 2016)
- “Standard Specifications of Tunnels〔open cut method edition〕”, (Public Interest Incorporated Association) Japan Society of Civil Engineers, (established in 2016)
- “Technical Standards of the Port Facilities”, (Public Interest Incorporated Association) the Ports & Harbors Association of Japan, (2018)
- “Specifications for Highway Bridges I common edition”, (Public Interest Incorporated Association) Japan Road Association,(2017)
- “Specifications for Highway Bridges IV substructure edition”, (Public Interest Incorporated Association) Japan Road Association,(2017)
- “Design Guidance of Utility Tunnel”, Japan Road Association,(1986)

2.50.1.2.4 Major Facilities

Discharge facility shall be composed of discharge vertical shaft (down-stream storage), discharge tunnel discharge and outlet for the purpose of discharge of the water that overfloated a partition wall of discharge vertical shaft (upper-stream storage) to discharge vertical shaft (down-stream storage) into the sea which is about 1km away from the shore.

2.50.1.2.5 Countermeasure to Natural Disasters

(1) Fire

This facility shall be applied for incombustible or flame retardant as practically as feasible. In addition, risk of fire is extremely low because seawater is filled in this facility.

(2) Tsunami

Because the flooding by tsunami is not avoidable, this facility shall have the wave pressure residence according to recoverability of this facility.

(3) Typhoon (storm surge)

This facility shall be designed to consider the effect of rising sea level by Typhoon (storm surge).

2.50.1.2.6 Structural strength and earthquake resistance

(1) Structural strength

Within each equipment consisting discharge equipment, Japanese Industrial Standards (JIS) and other Japanese and foreign commercial standards shall be applied.

(2) Earthquake resistance

The equipment consist of discharge equipment shall be designed to withstand design seismic force considered appropriately, as well as having seismic design classifications with reference to seismic classification at nuclear fuel processing facilities and facilities handling nuclear fuel materials without sealing, etc. after considering the importance of safety function and safety impact(public exposure impact) and impact to decommissioning activities in case that the function is lost due to an earthquake.

2.50.2 Basic Specifications

2.50.2.1 Main Specifications of ALPS Treated Water Dilution/Discharge Facility

2.50.2.1.1 Measurement/confirmation equipment

(1) Circulation pump (finished product)

Number of units	2
Capacity	160 m^3/h (per unit)

(2) Stirring equipment (finished product)

Number of units	30

(3) Measurement/confirmation tank※

Total Volume (Nominal)	30, 000 m^3
Number of units	30
Volume (single unit)	1, 000m^3 per unit
Material	SS400
Thickness (side plate)	15mm

※: A portion of the K4 area tanks, which are out of storage tanks for ALPS treated water, etc. in "II 2.5 Contaminated water treatment facilities, etc.", shall be reuse. Note that the nominal capacity is the upper limit of the operating water level.

(4) Piping

Main piping specifications (1/2)

Name	Specification	
From the measurement/confirmation tank outlet to the circulation pump inlet (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	200A／Sch.20S SUS316LTP 0.49MPa 40°C
(Polyethylene pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 200A Polyethylene 0.49MPa 40°C

Main piping specifications (2/2)

Name	Specifications	
(Pressure resistant hose)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	Equivalent to 200A Synthetic rubber 0.49MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 200A Synthetic rubber 0.49MPa 40°C
From the circulation pump outlet to the measurement/confirmation tank inlet (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	125A／Sch.20S 150A／Sch.20S 200A／Sch.20S SUS316LTP 0.98MPa 40°C
(Polyethylene pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 150A Polyethylene 0.98MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 125A Synthetic rubber 0.98MPa 40°C

2.50.2.1.2 Transfer equipment

(1) ALPS treated water transfer pump (finished product)

Number of units 2

Capacity 30 m^3/h (per unit)

(2) Piping

Main piping specifications (1/2)

Name	Specification	
Between measurement/confirmation tank (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	200A／Sch.20S SUS316LTP 0.49MPa 40°C
(Polyethylene pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 200A Polyethylene 0.49MPa 40°C
(Pressure resistant hose)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	Equivalent to 200A Synthetic rubber 0.49MPa 40°C
From the measurement/confirmation tank outlet to the ALPS treated water transfer pump inlet (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	100A／Sch.20S 150A／Sch.20S SUS316LTP 0.49MPa 40°C
(Polyethylene pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 100A Equivalent to 150A Polyethylene 0.49MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 100A Synthetic rubber 0.49MPa 40°C

Main piping specifications (2/2)

Name	Specifications	
From the ALPS treated water transfer pump outlet to seawater pipe header inlet (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	100A／Sch.40 STPG370 0.98MPa 40°C
(Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	65A／Sch.20S 100A／Sch.20S 150A／Sch.20S SUS316LTP 0.98MPa 40°C
(Polyethylene pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 100A Polyethylene 0.98MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 65A Equivalent to 100A Synthetic rubber 0.98MPa 40°C

2.50.2.1.3 Dilution equipment

(1) Seawater transfer pump (finished product)

Number of units	3
Capacity	7,086 m^3/h (per unit)

(2) Discharge guide

Number of units	1
Main dimensions	2,100mm × 2,100mm × 7,096mm（Upper-stream side） 2,140mm × 2,140mm × 11,144mm（Bottom-stream side）
Material	SUS316L

(3) Discharge vertical shaft (Upper-stream storage)

Number of units	1
Structure	Reinforced concrete construction

(4) Piping

Main piping specifications (1/2)

Name	Specification	
From the seawater transfer pump outlet to the seawater pipe header inlet connection (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	800A／12.7mm 900A／12.7mm STPY400 0.60MPa 40°C
(Steel pipe)	Nominal diameter Material Max. design pressure Max. operating temperature	900A/Sch.20S SUS329J4LTP 0.60MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 800A Equivalent to 900A Synthetic rubber 0.60MPa 40°C

Main piping specifications (2/2)

Name	Specifications	
Seawater pipe header (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	1800A／13mm 2200A／16mm SM400B 0.60MPa 40°C
From the seawater pipe header outlet to the discharge guide (Steel pipe)	Nominal diameter/thickness Material Max. design pressure Max. operating temperature	1800A／13mm SM400B 0.60MPa 40°C
(Expansion joint)	Nominal diameter Material Max. design pressure Max. operating temperature	Equivalent to 1800A Synthetic rubber 0.60MPa 40°C

2.50.2.2 Major Specifications of Discharge Facilities

(1) Discharge vertical shaft (Down-stream storage)

Number of units	1
Structure	Reinforced concrete construction

(2) Discharge tunnel

Number of units	1
Structure	Reinforced concrete construction

(3) Outlet

Number of units	1
Structure	Reinforced concrete construction

2.50.3 Attached Materials

Attachment 1: System overview and schematic diagram

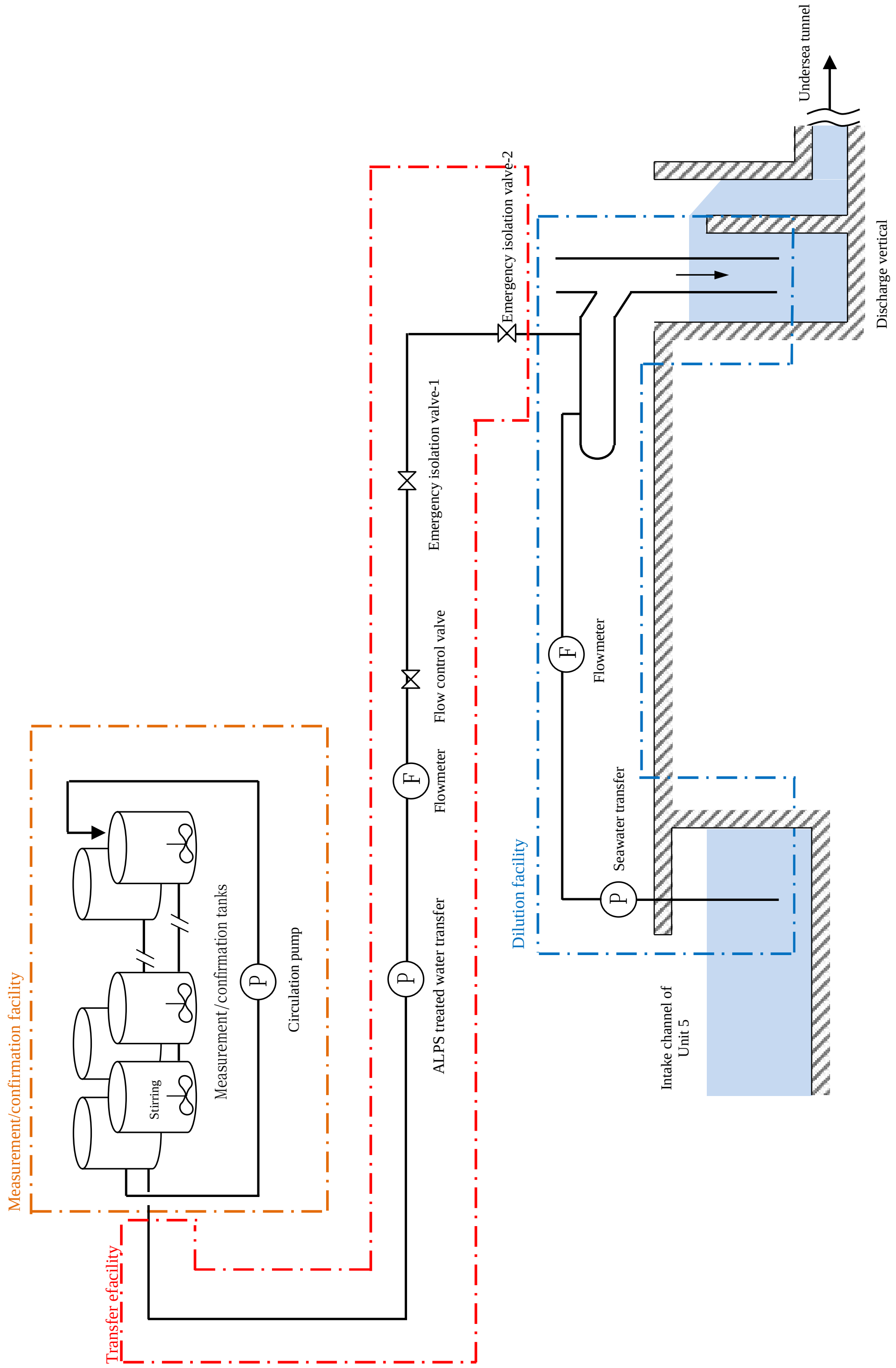
Attachment 2: Specific measures to ensure safety of ALPS Treated Water Dilution/Discharge Facility, etc.

Attachment 3: Instructions on structural strength of ALPS Treated Water Dilution/Discharge Facility, etc.

Attachment 4: Items to be checked for ALPS Treated Water Dilution/Discharge Facility and related facilities.

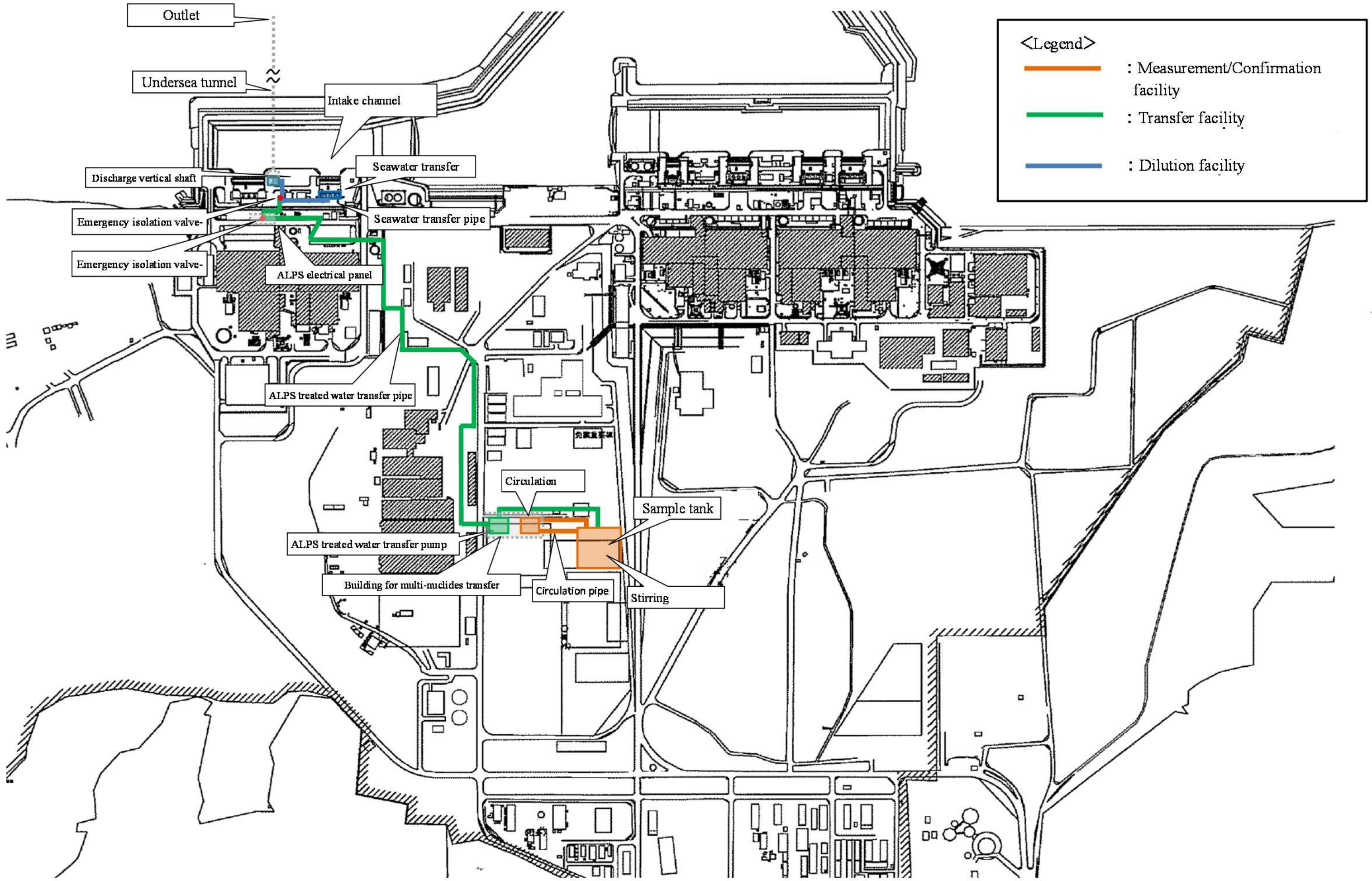
Attachment 5: Instructions on design of discharge facility

Attachment 6: Construction schedule



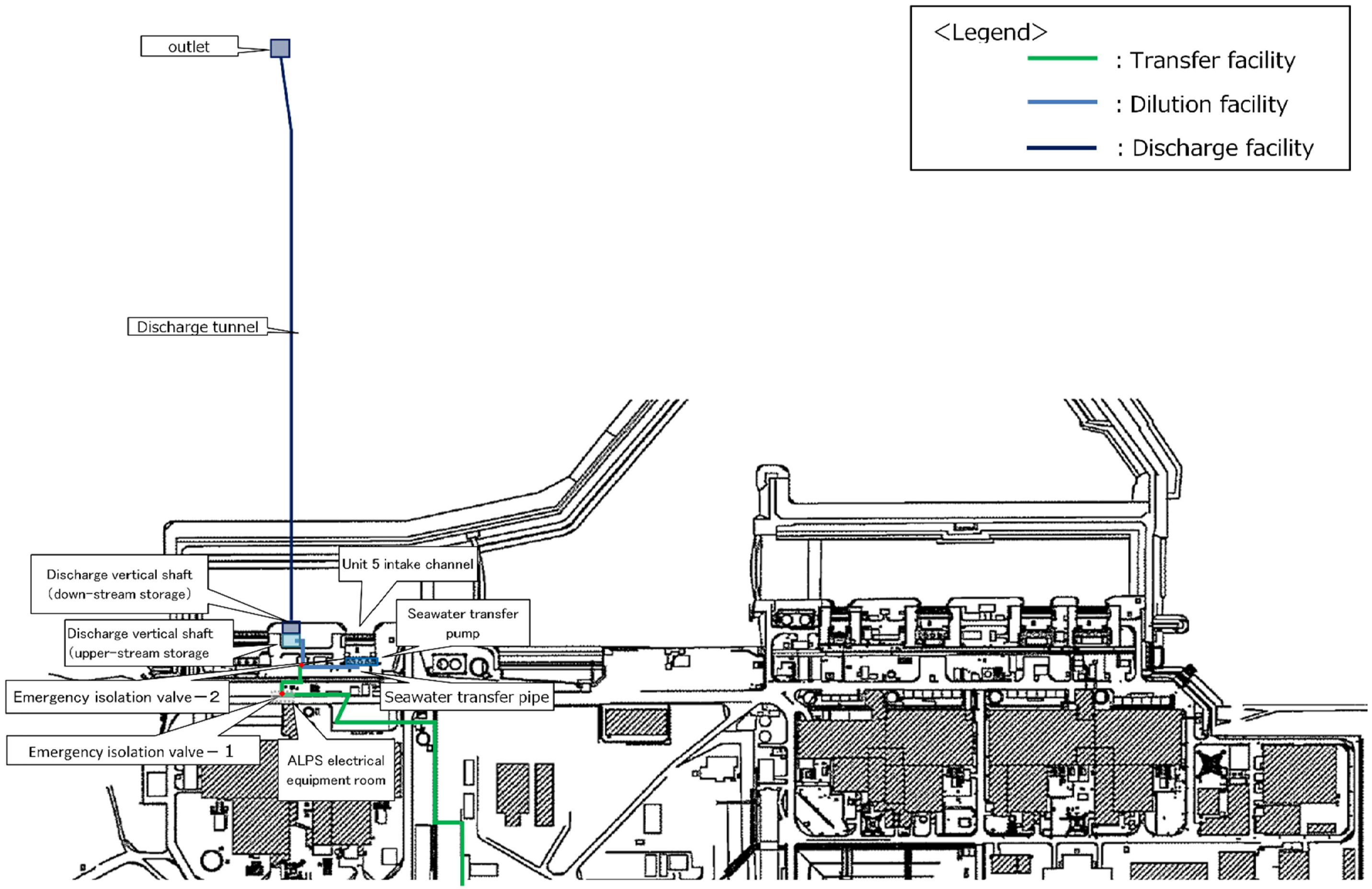
(a) System Overview

Fig. 1 Overview of ALPS Treated Water Dilution/Discharge Facilities and Related Facilities (1/3)



(b) Layout overview (overall)

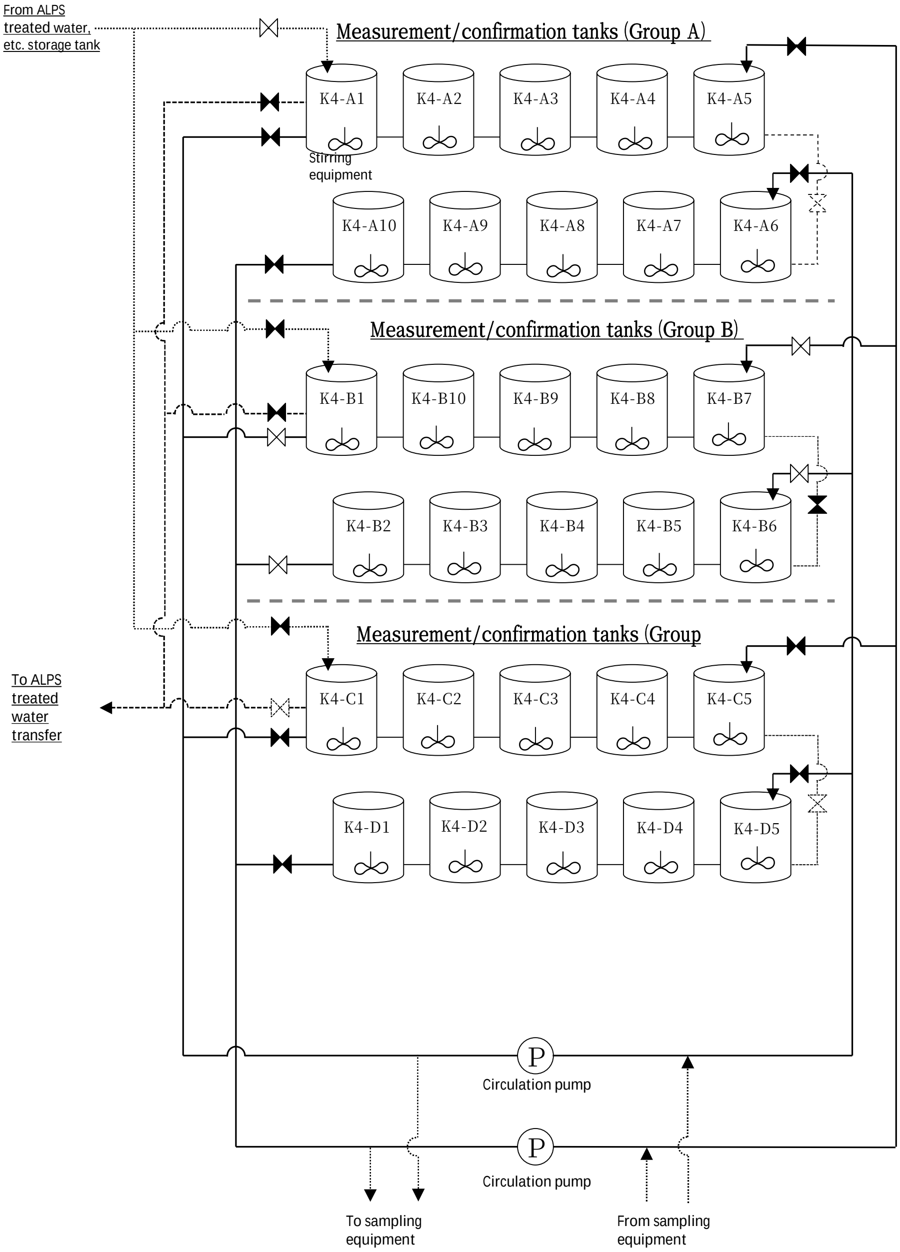
Fig.1 Overview of ALPS Treated Water Dilution/Discharge Facilities and Related Facilities (2/3)



(c) Layout overview (sea side)

Fig.1 Overview of ALPS Treated Water Dilution/Discharge Facilities and Related Facilities (3/3)

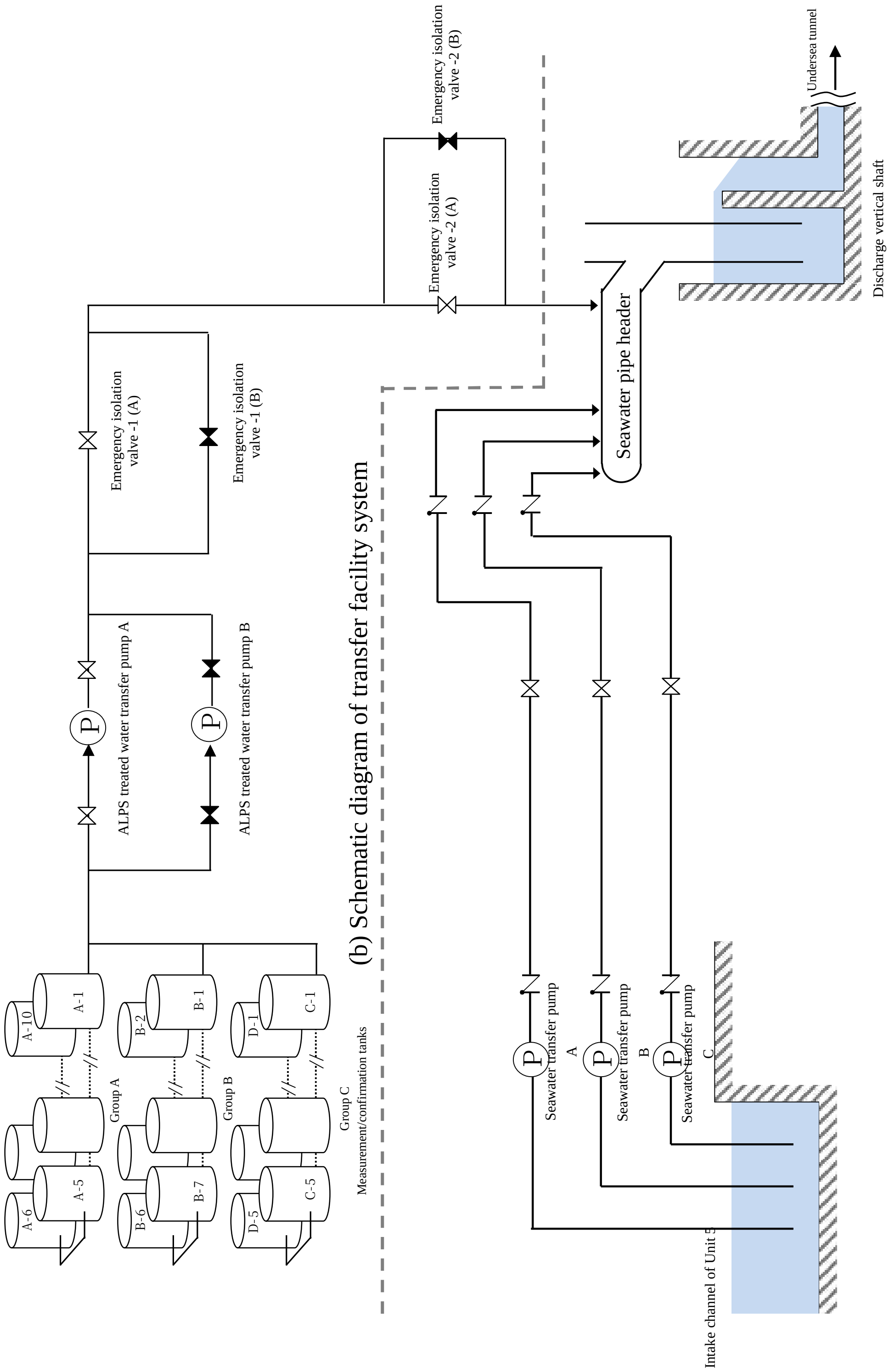
The measurement/confirmation tank groups are divided into A, B and C groups and the process of ①:Receiving, ②: Measurement/Confirmation Process, and ③: Discharge Process shall be conducted repeatedly in each group. The situation in the figure shows group A (Receiving Process), group B (Measurement/Confirmation Process), and group C (Discharge Process).
For the receiving and discharge process. recieving and transfer are conducted on the condition that valves for measurement/confirmation tank group (between 5 tanks) are open.



(a) Schematic diagram of measurement/confirmation facility system

Fig. 2 Schematic diagram ALPS Treated Water Dilution/Discharge Facilities (1/2)

The Japanese version shall prevail.



(c) Schematic diagram of dilution facility system

Fig.2 Schematic diagram of ALPS Treated Water Dilution/Discharge Facilities

(2/2)

The Japanese version shall prevail.

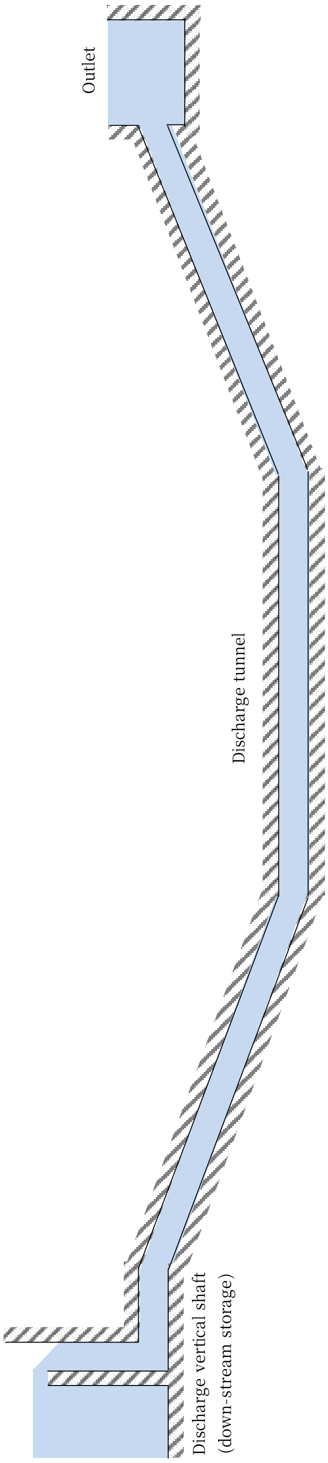


Fig.3 Schematic diagram of discharge facility system

Attachment 2

Specific measures to ensure safety of ALPS Treated Water Dilution/Discharge Facility, etc.

Since the liquid to be handled by ALPS Treated Water Dilution/Discharge facility is ALPS treated water and it contains radionuclide, specific safety measures shall be established and implemented as follows for leakage prevention, detection/expansion, uncontrolled discharge, environmental condition measurement, uniformize the concentration of radionuclide by using measurement equipment, and dilution of ALPS treated water with seawater.

1. Considerations for Prevention for Leakage of Radioactive Materials, etc.

(1) Leakage prevention

a. Circulation pump and transfer pump for ALPS treated water shall be manufactured by two-phase stainless steel, etc. which has the strength in corrosion resistance.

b. Transfer pipes for ALPS treated water are manufactured by corrosion resistant polyethylene pipes, and pressure resistant hoses and carbon and stainless-steel pipes are used with enough thickness. The inner surfaces of the main carbon steel pipes are coated with the corrosion resistance. In addition, the parts requiring flexibility shall be rubber expansion joints having corrosion resistance.

c. The shaft seal part of circulation pump and ALPS treated water transfer pump shall have a mechanical seal structure that prevents leakage.

(2) Leakage detection and prevention of expansion

a. For circulation pumps, ALPS treated water transfer pumps, and emergency isolation valves, a barrier shall be provided around these equipment and a leak detector is provided inside the barrier in order to detect leakage at an early stage and prevent the leakage expansion

b. The alarm for leakage detection shall be displayed at centralized monitoring room of the seismic isolation building, etc., and the operational monitoring parameters such as the flow rate shall be checked by the operator and appropriate measures will be taken.

c. The following measures will be taken for the ALPS treated water transfer pipe.

・ Regarding transfer pipes laid outdoors, polyethylene pipes and these joints are fusion welded to prevent leakage, and the protective cover will be set on the part of flange joints such as joints between polyethylene pipes and steel pipes to prevent leakage expansion.

・ Transfer pipes should be isolated as quickly as possible from discharges and the pipes should be laid in steel boxes, etc. where straddle discharges so that the leaked water shall not be discharged into the environment through drains in the unlikely event of a leakage. In addition, sand bags shall be provided so that leaked water does not flow directly into the drainage channel from the steel box end.

・Leakage from transfer pipes shall be detected at an early stage be means of patrol inspection.

2. Prevention for uncontrolled discharge of ALPS treated water

In order to prevent ALPS treated water from uncontrolled discharge into the sea, emergency isolation valves shall be installed in transfer equipment and the valves will be closed if the normal operating condition is deviated.

The interlocks, configuration and arrangement of the emergency isolation valves will be listed below.

(1)Interlock

Regarding following condition, the emergency isolation valve is activated to stop the discharge of ALPS treated water into the sea.

a. The flow rates of the dilution and the transfer volumes are set in the ALPS treated water which is discharged. The closing interlock for the emergency isolation valve is installed when flow rate's set point cannot be secured or over the transfer volume.

b. The closing interlock for the emergency isolation valve is installed when the abnormal matter is detected from the radiation monitor* installed in the transfer line.

*: Measurement/confirmation equipment confirms that sum of the ratios of legally required concentration of radionuclides (excluding tritium) is less than 1. But just in case, the radiation monitor is also installed in the transfer facilities.

In case an abnormal value is detected from sea monitoring, emergency isolation valve shall be close optional and discharge of ALPS treated water into the sea is stopped emergently.

(2) Configuration

Two emergency isolation valves shall be installed in series with ALPS treated water transfer line in order to secure the closing. Emergency isolation valves installed with spare systems in parallel to prevent a long time stops due to failure.

(3)Arrangement

The emergency isolation valves are installed to stop discharge as quickly as possible when above interlocks are activated. Therefore, among the two emergency isolation valves arranged in series, the emergency isolation valves of downstream is installed in front of seawater pipe header to minimize the amount of discharge when valve is activated. The upstream valve shall be installed inside the seawall to consider the damage risk caused by tsunami.

3. Environmental Conditions measures

(1) Freezing

There is no concern of freezing in the process of transferring water.

When the water transfer is stopped, the outdoor laying polyethylene pipes may break due to freezing. Therefore, insulation materials are installed to the pipes to prevent freezing. The rigid polyurethanes and etc., are installed for insulation materials which have high airtightness and thermal insulation properties and sufficient thickness will be required to ensure from freezing. The thickness of insulation materials are considered following conditions; sufficient time (about 50 hours) to freeze 25%※ of water inside , outside temperature -8°C, initial temperature inside water 5°C and the thickness of insulating material 21.4 mm, in which recorded after the Great East Japan Earthquake, in accordance with "prevention of freezing of the construction facility (The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan)". The outdoor temperature of -8°C does not continue more than half days, which is based on the measured data since the earthquake.

※: Recommended freezing rate of water in pipes of 25% or less in "JIS A 9501 Standard practice for thermal insulation works"

(2) Ultraviolet rays

In order to prevent deterioration due to ultraviolet rays, insulation materials which have carbon black with anti-ultraviolet rays are installed to outdoor polyethylene pipes. Or, to install insulation materials which does not have carbon black with anti-ultraviolet rays, coating materials with carbon black or steel plates with hardly deteriorated from ultraviolet rays are installed.

(3) Thermal deterioration

Thermal deterioration is concerned for polyethylene pipes. However, the possibility of thermal deterioration of the polyethylene pipes is sufficiently low. It is because the temperature of ALPS treated water is close to the normal temperature.

4. Uniformization of radioactive materials concentrations by measurement/confirmation equipment

In the measurement/confirmation equipment, the concentration of radioactive materials in the tank groups shall be almost uniformized by circulating the water in the tank groups with a circulation pump before sampling so that representative samples can be obtained. The capacity for circulation volume will be secured greater than the capacity of the tank group based on the " Guidelines concerning measurement of radioactive materials discharged from light-water type nuclear reactor for power generation". In addition, stirring equipment will be installed in each tank to promote uniformization.

5. Dilution and mixture of ALPS Treated Water with Seawater

The ALPS treated water is diluted by injecting the ALPS treated water into the seawater pipe header where the dilution seawater flows. The injected ALPS treated water flows down in the seawater pipe and mixes with the surrounding seawater and the concentration of radioactive materials will decrease.

6. References

Reference 1: Instruction for dilution and mixture of ALPS treated water

Reference 1

Instruction for dilution and mixture of ALPS treated water

1.Outline

ALPS treated water is diluted with seawater at a ratio corresponding to tritium concentration and discharged into the sea. Since the dilution is carried out by injecting ALPS treated water into the seawater pipe header and mixing it, the mixing behavior of ALPS treated water inside the seawater pipe was determined by analysis, and the assumed dilution effect was evaluated.

2.Analysis condition

(1) Analysis object

In the analysis, ALPS treated water is regarded as pure water, and the advection and diffusion conditions of pure water in seawater are evaluated.

Physical properties in the analysis are as follows.

Table-1 Physical Properties of Tritium Water

Physical properties	Value	Remarks
Temperature	20 °C	Room temperature
Density ※1	Pure water :998.2 kg/m^3 Seawater:1025 kg/m^3	Density of pure water and sea water at 20 °C
Viscosity ※2	Pure water:1.002×10^{-3} Pa・s Seawater:1.080×10^{-3} Pa・s	Viscosity of pure water and sea water at 20 °C

Diffusion of tritium water in a main flow pipe is considered to be due to turbulence. Diffusion degree is calculated by giving the turbulent Schmidt number, which is a dimensionless number related to turbulent diffusion. (For details, later mentioned in (3))

※1: Pure water: JSME steam tables (1999) CD-ROM version

Seawater: International Equation of State of Seawater UNESCO (1981)

※2: Pure water: JSME steam tables (1999) CD-ROM version

Seawater: Nakamura, Standard symbols for marine hydrodynamic relationships and the water density, kinematic viscosity coefficient of water, Shipbuilding Association Journal 429 (1965)

(2) Evaluation model

When pure water is injected into the seawater pipe header where three main flow pipes from the discharge of the seawater transfer pump merge, the mixing status of the injected water in the seawater pipe header and the seawater pipe is analyzed, and the concentration in each part in the seawater pipe header and the seawater pipe is determined.

The models of main flow pipe (seawater transfer pipe), pure water injection pipe, seawater pipe header, and seawater pipe toward the discharge shaft were shown in Fig. 1.

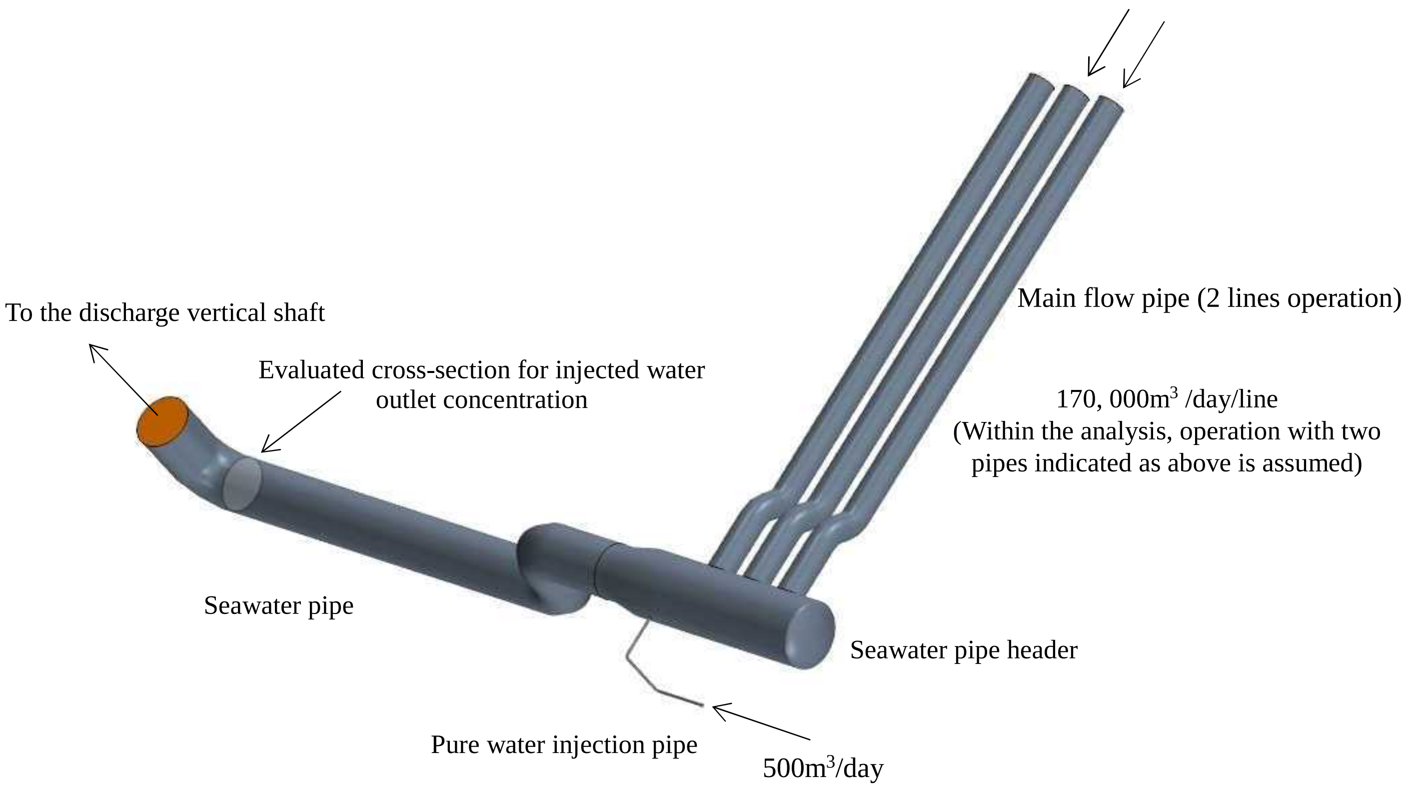


Fig. 1 Analytical Model

The analysis was performed by three-dimensional detailed analysis (CFD)-code STAR-CCM + (ver. 11). The main models are shown below.

Basic formula	: Incompressible mass conservation formula, momentum conservation formula (Reynolds Average Navier Stokes (RANS))
Turbulence model	: RNG k-ε model (standard k-ε model is also used for sensitivity analysis)
Near Wall Surfaces	: Wall Function Model
Discretization Method	: Finite Volume Method
Material advection and diffusion model	: Chemical species advection diffusion model

(3) Analysis case

Flow rates in the main flow pipe (seawater transfer pipe) and pure water injection pipe were applied for the standard flow rates, respectively.

In the analysis, the turbulent diffusion behavior controlled by the turbulent diffusion coefficient (turbulent Schmitt number) determined experimentally has a large impact on the injected pure water concentration.

Therefore, the turbulent Schmitt number was set to the upper limit value presented by various literatures so that the turbulent diffusion becomes small (local concentration of the injected pure water becomes high) through the literature [*1*2*3] survey, and the analysis was carried out.

*1: Gualtieri, G., et al., Fluids, 2, 17(2017)

*2: Tominaga, Y., et al, Atmospheric Environment, 42, 37(2007)

*3: Flesch, T, K., et al., Agricultural and Forest Meteorology ,111 (2002)

3.Analysis result

Contour diagrams of the concentrated distribution for the flow rate and the injected pure water-diagram are shown below.

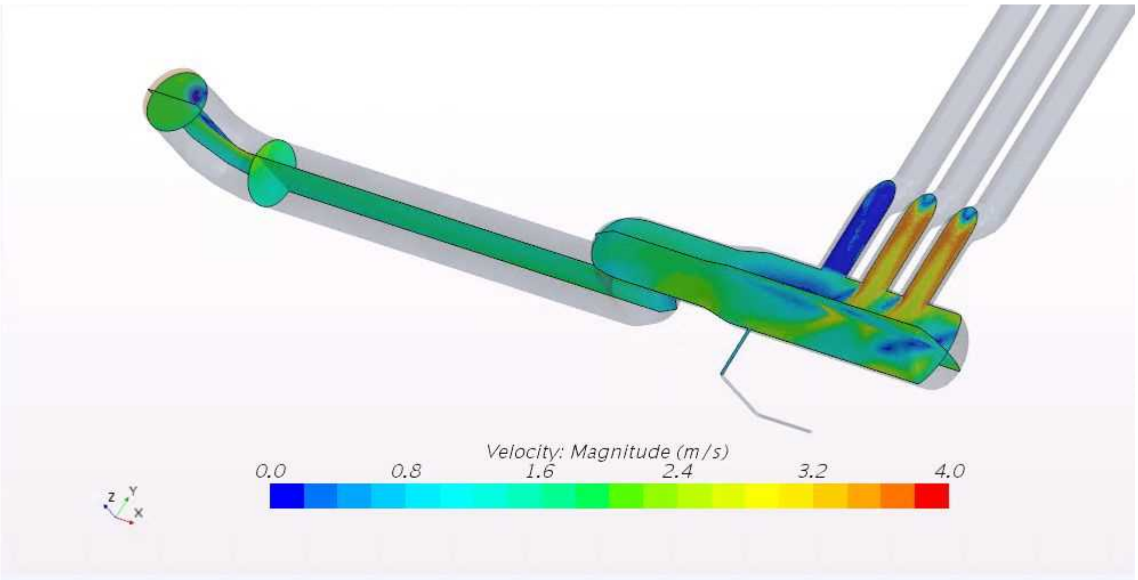


Fig. 2 Flow rate

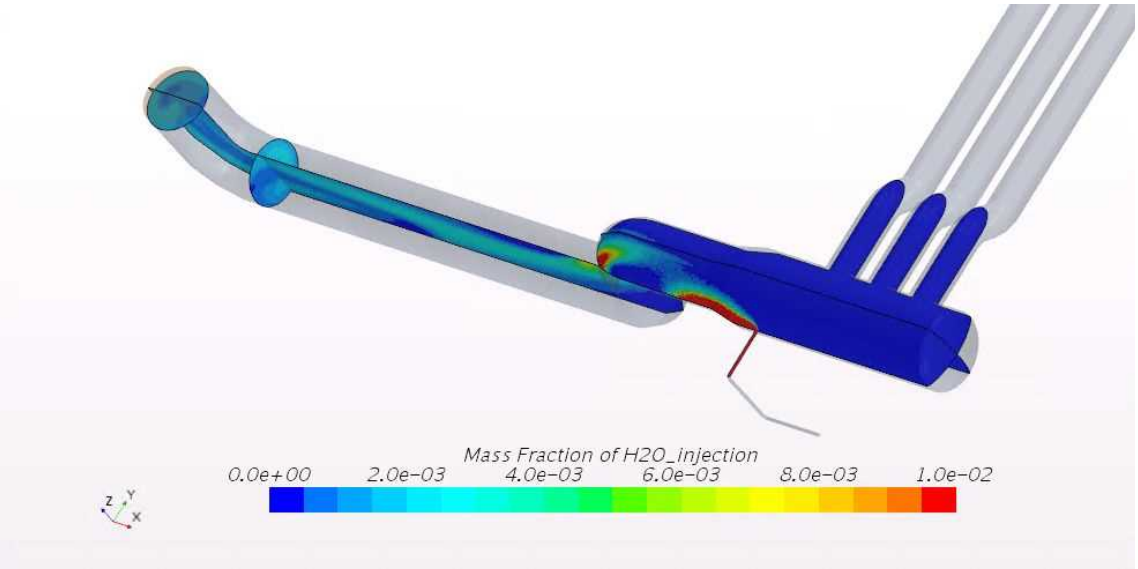


Fig. 3 Mass concentrated distribution

The mass concentrated distribution shows the situation in which injected pure water is distributed from the seawater pipe header to the seawater pipe, and is calculated by the following equation.

Injected pure water mass concentration = mass of injected pure water ／ (mass of injected pure water + mass of injected seawater into main flow pipe)

The Japanese version shall prevail.

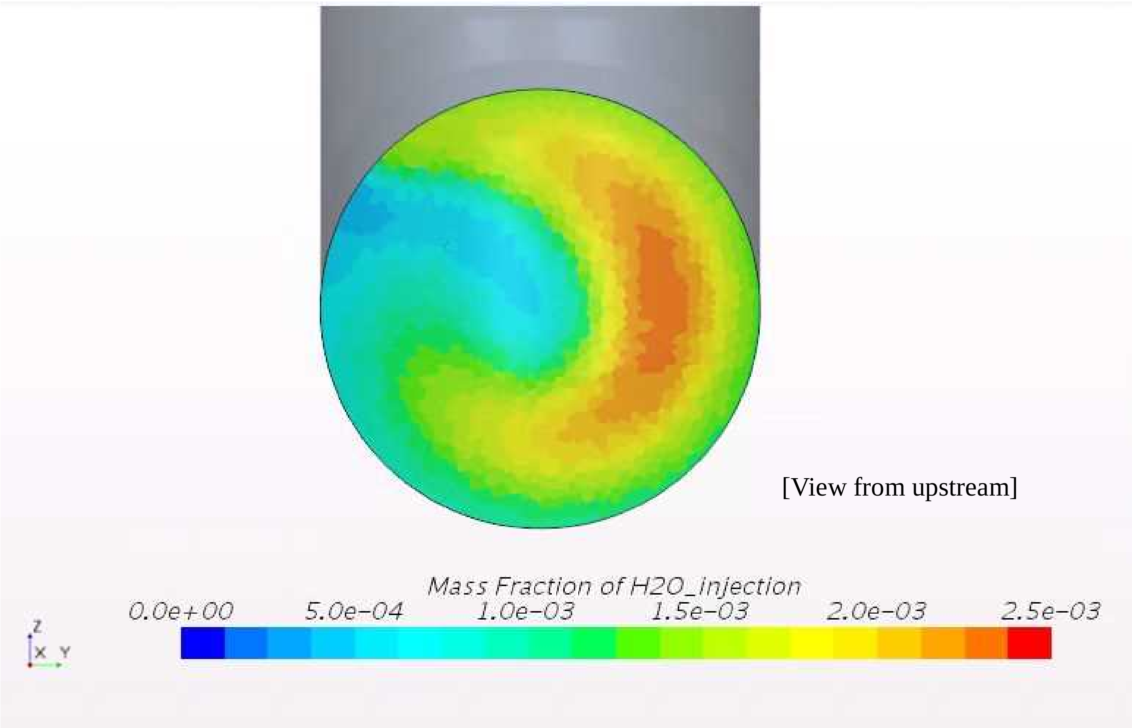


Fig. 4 Mass concentrated distribution

Evaluated cross-section for injected water outlet concentration

The maximum concentration at the end of the seawater pipe toward the discharge vertical shaft was approx. 0.00231 (0.231%).

4.Summary

The average and maximum concentrations of the injected water in the evaluated cross-section for injected water outlet are as follows:

Table-2 Analysis Results

	Average mass concentration (%)	Maximum mass concentration (%)
Turbulent Schmitt number: 1.3 RNG k-ε model Representative mesh size 0.05m	0.141	0.231

As a result of analysis under the condition of setting Schmitt number in which the degree of mixing is considered to be small, the maximum mass concentration in evaluated cross-section for injected water outlet was calculated to be 0.231%.

From this result, it was concluded that the injected water was thinned by 100/0.231　430 times even in the maximum concentration part in the seawater pipe toward the discharge vertical shaft.

Attachment 3

Instructions on structural strength and seismic resistance of
ALPS Treated Water Dilution/Discharge Facility, etc.

Structural strength shall be assessed for several pieces of equipment constituting ALPS Treated Water Dilution/Discharge Facility in accordance with the basic policy for assessment on structural strength and seismic resistance.

1. Basic Policy

1.1 Basic policy for structural strength assessment

For the steel pipes of ALPS Treated Water Dilution/Discharge Facility, the pipes containing ALPS treated water shall be assessed in compliance with Class-3 equipment of the " JSME S NC1-2012 Codes for nuclear power generation facilities: rules on design and construction for nuclear power plants ".

1.2 Basic policy for seismic resistance

Based on the precondition that ALPS Treated Water Dilution/Discharge Facility is used for handling the ALPS treated water, which is treated until the sum of the ratios of legally required concentration of radionuclides rather than tritium is less than 1, and considering the level of radiation impact on the public due to the loss of facility function and the measures to mitigate the impact such as agile response etc., seismic resistance of the facility is classified as seismic class C.

2. Method and result of structural strength assessment

2.1 Main piping (steel pipe)

The structural assessment points are shown in Fig. 1 to 4.

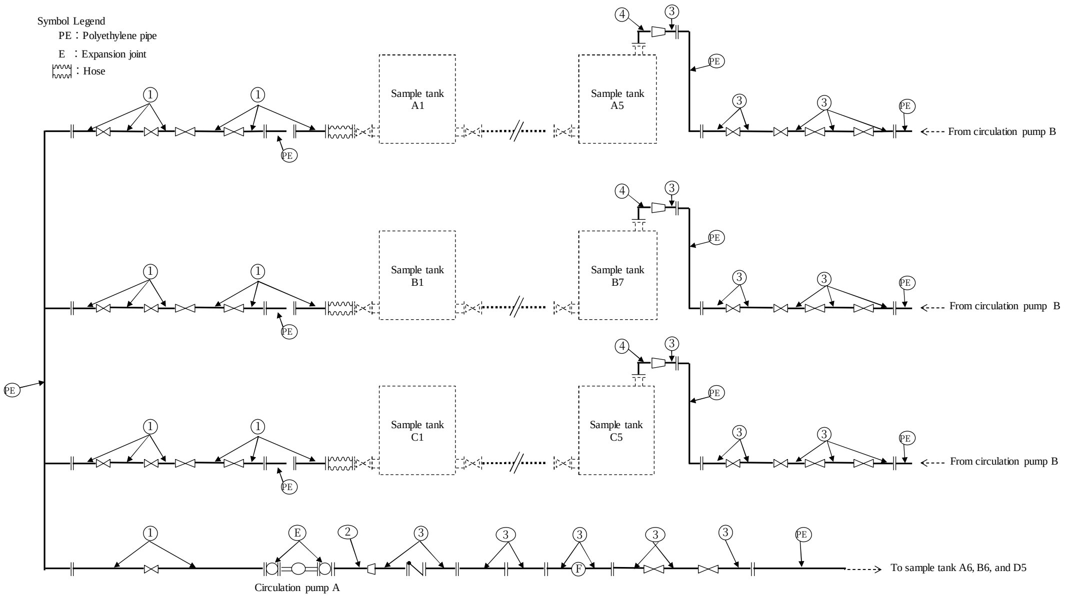


Fig. 1 Schematic diagram of piping (1/4)

(Measurement/confirmation facility)

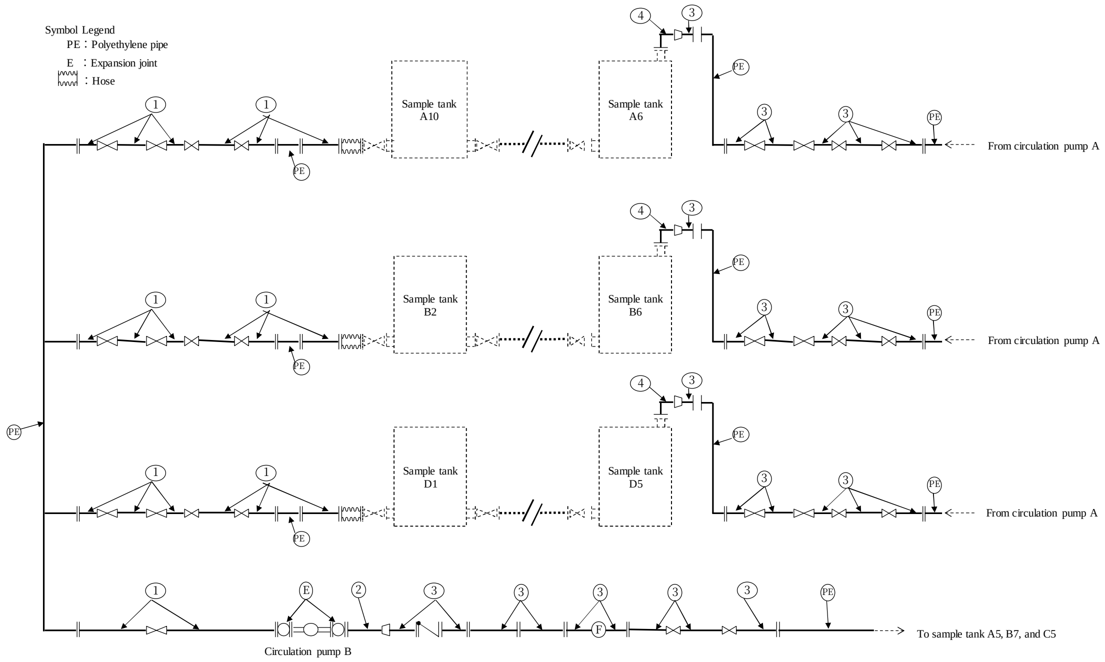


Fig. 2 Schematic diagram of piping (2/4)

(Measurement/confirmation facility)

The Japanese version shall prevail.

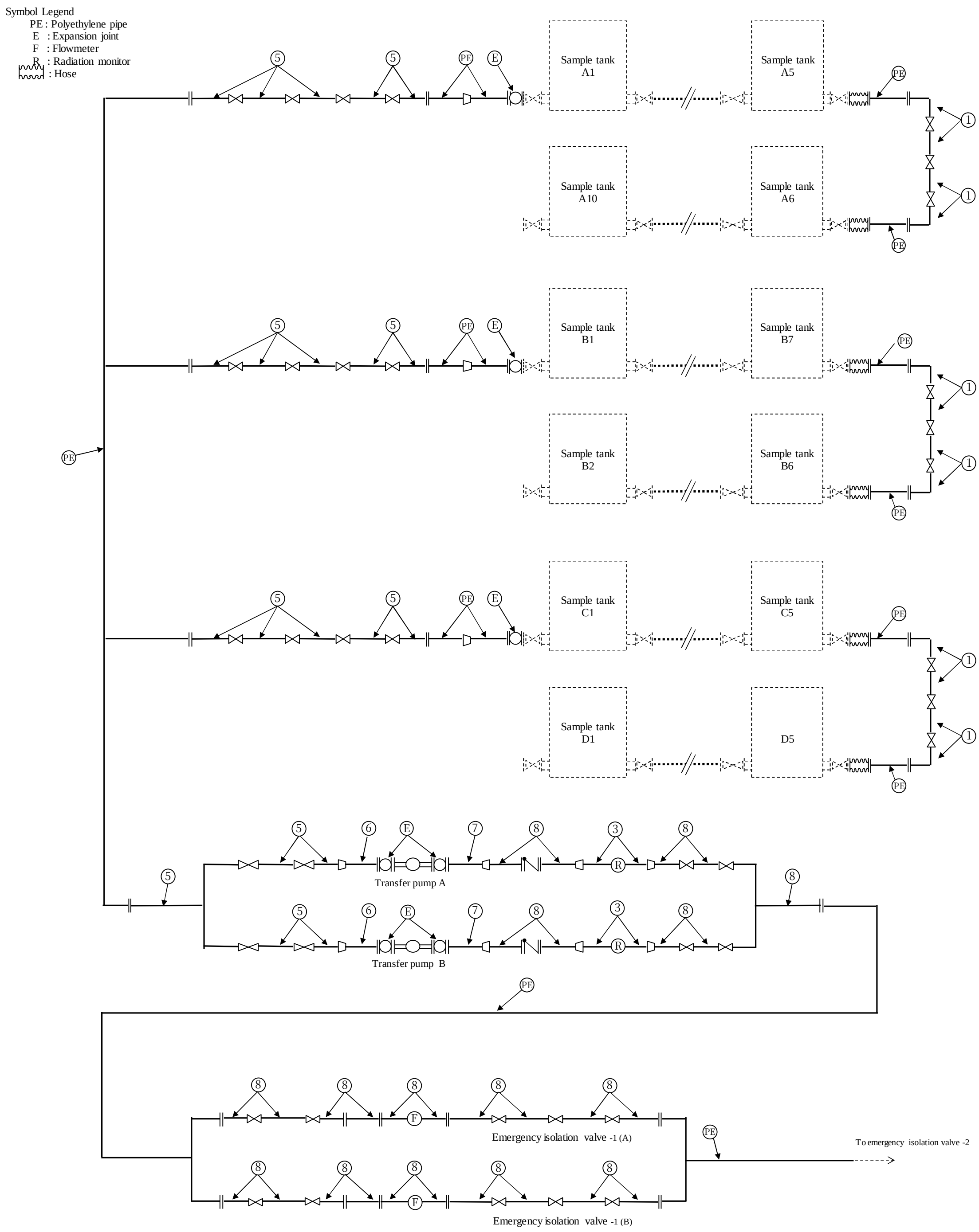


Fig. 3 Schematic diagram of piping (3/4)

(Transfer facility)

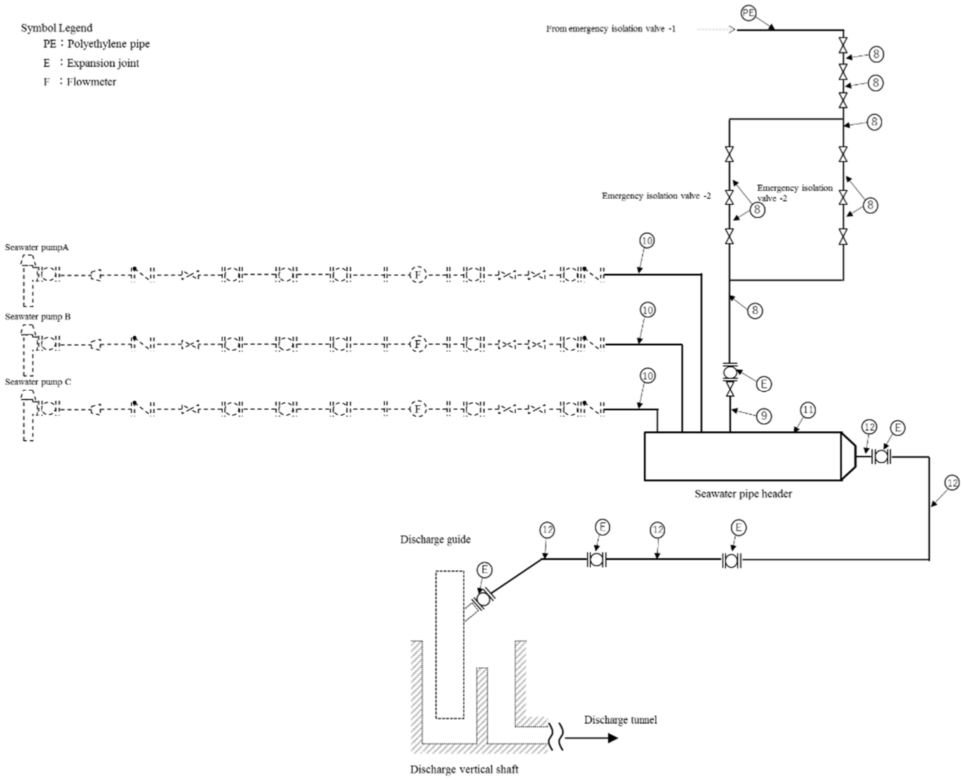


Fig. 4 Schematic diagram of piping (4/4)

(Transfer facility, Dilution facility)

2.2 Assessment method

The required thickness of the pipe shall be one of the following values, whichever is larger:

a. Pipe receiving pressure on the inner surface

Pipe thickness required for calculation: $t = \frac{PD_0}{2S\eta + 0.8P}$

P : Maximum design pressure (MPa)

D_0 : Outer diameter of pipe (mm)

S : Allowable tensile stress of material at maximum operating temperature (MPa)

η : Efficiency of the expansion joint

b. Minimum thickness required for design and construction standards for carbon steel pipes: t_r

Values obtained from “Table PPD-3411-1” of Design/Construction Standards PPD-3411 (3)

2.3 Assessment results

Assessment results are given in Table -1. It is assessed that these satisfy the required thickness and have sufficient structural strength.

Table-1 Assessment results of structural strength of main pipe (steel pipes)

Equipment to be assessed	Outer diameter (mm)	Material	Maximum design pressure (MPa)	Maximum operating temp (°C)	Required thickness (mm)	Minimum thickness (mm)
Pipe ①	216.3	SUS316LTP	0.49	40	0.46	5.68
Pipe ②	139.8	SUS316LTP	0.98	40	0.59	4.37
Pipe ③	165.2	SUS316LTP	0.98	40	0.69	4.37
Pipe ④	216.3	SUS316LTP	0.98	40	0.91	5.68
Pipe ⑤	165.2	SUS316LTP	0.49	40	0.35	4.37
Pipe ⑥	114.3	SUS316LTP	0.49	40	0.24	3.50
Pipe ⑦	76.3	SUS316LTP	0.98	40	0.32	3.00
Pipe ⑧	114.3	SUS316LTP	0.98	40	0.48	3.50
Pipe ⑨	114.3	STPG370	0.98	40	3.40	5.25
Pipe ⑩	914.4	STPY400	0.60	40	4.56	11.43
Pipe ⑪	2235.2	SM400B	0.60	40	11.14	15.00
Pipe ⑫	1828.8	SM400B	0.60	40	9.11	12.00

3. Concept to classify the seismic resistance classes

The ALPS Treated Water Dilution/Discharge Facility is classified as seismic class C by the measures, assessment and mitigation method as follows.

3.1 Possibility of mixed water in measurement/confirmation tank

In order to prevent the event that the water with the sum of the ratios of legally required concentrations of radionuclides rather than tritium is 1 or more mixes in the measurement/confirmation tank, following design and operational countermeasure shall be taken.

- As the pipes used for transfer to the measurement/confirmation tank is only the transfer pipe for ALPS, etc. there is no possibility that Sr treated water, etc., mixes from a viewpoint of piping configuration.
- For the water inside the G1 area tank that was recently transferred using the transfer pipe of the ALPS, it has been confirmed that the sum of the ratios of legally required concentrations of radionuclides excluding tritium, ※ is less than 1
- Water transfer into measurement/confirmation tanks of the ALPS Treated Water Dilution/Discharge Facility shall be conducted after confirming sum of the ratios of legally required concentrations of radionuclides, excluding tritium,※ is less than 1 at the storage tanks for ALPS, etc. or storage tanks for ALPS treated water, etc.

※: 7 radionuclides, Cs-134, Cs-137, Sr-90, Co-60, Sb-125, Ru-106, I-129

3.2 The level of radiation impact on the public due to loss of function

A dose assessment was performed on the measurement/confirmation tanks for the ALPS Treated Water Dilution/Discharge Facilities to confirm the radiation impact on the public due to the loss of function. According to the assessment condition of “II 2.5 Contaminated water treatment facilities, etc. Attachment 12 Appendix 7,” the parameters of analysis result of multi-nuclide treated water conducted in July 2013 are used as radioactive concentration in the tank water in terms of assessment condition.

3.2.1 Exposure assessment due to direct ray/skyshine ray in the leaked water

Assuming that the sliding of the tank due to the earthquake damaged the connecting pipes, etc. and all the storage water in the measurement/confirmation tanks leaked out, in addition to that, the water continues to exist on one large cylinder that has the same volume and height as the tank group, the exposure dose from the direct ray and skyshine ray at the nearest dose assessment point (No. 70) is less than 1 μSv / year. Therefore, there is almost no radiation impact on the public.

3.2.2 Exposure assessment due to vapor transfer of leaked water

It is assumed that the sliding of the tank due to the earthquake damaged the connecting pipes, etc. and the leaked water spread over the entire storable area of the foundation outer barrier of the measurement/confirmation tank, and the vaporized water diffused from the leaked water containing tritium. On the above condition, assuming that it takes two weeks to recover the leaked water, the internal exposure dose of tritium ingested by breathing by the residents living at the nearest dose evaluation point (No. 70) is sufficiently lower than the class C standard of 50 μSv. Therefore, there is almost no radiation impact on the public.

3.3 Mitigation measure such as immediate response etc.

The measurement/confirmation tanks of the ALPS-Treated Water Dilution /Discharge Facility are operated by connecting each tank with a flexible connecting pipe and opening the connecting valve when transferring the water to the tank. Considering the loss of function due to the earthquake, the following measures such as immediate response shall be taken to mitigate the impacts.

- When earthquake with a seismic intensity of 5 lower or higher occurs, on-site confirmation shall be conducted with priority, and if leakage is confirmed, the connecting valve shall be closed immediately.
- A foundation outer barrier shall be installed to prevent seismic class C tanks, etc., from being damaged by the earthquake and causing the storage water to leak significantly outside the site. The barrier shall be seismic class B, and the required strength shall be secured against the horizontal design seismic intensity required for class B structures.
- If the storage water leaks and retains inside the foundation outer barrier, the leaked water shall be recovered by temporary pump, high-pressure suction vehicles, etc. The recovered leaked water is transferred to a sound tank and building.

3.4 Structural soundness assessment for measurement/confirmation tanks

The seismic resistance evaluation as a seismic class C is covered by “II 2.5 Contaminated water treatment facility, etc. Attachment 12 Appendix 2” the seismic class B evaluation

End

Attachment 4

Items to be checked for ALPS Treated Water Dilution/Discharge Facility and Related Facilities

Major confirmatory matters related to ALPS Treated Water Dilution/Discharge Facility and related facilities are shown in Tables 1 to 7.

Table-1 Check items
(circulation pumps, ALPS treated water transfer pumps, stirring equipment, seawater transfer pumps)

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・ Earthquake resistance	Visual check	Check the visual of each part.	No significant defects.
	Installation check	Check the installation conditions of the equipment.	Carried out construction and installation based on the Implementation Plan.
	Leakage check ※1	Check no leakage from the pressure resistant parts under the operating pressure.	No significant leakage from the pressure resistant parts.
Performance	Operation performance check ※1	Check the pump operation.	Satisfying the criteria described in the Implementation Plan. In addition, No abnormal noise, smoke, vibration, etc.

※1: Not applicable to the stirring equipment because it is the rotation machinery with propeller wings installed in the water of the measurement/confirmation tanks and there is no leakage point to be confirmed. In addition, it is difficult to confirm abnormal noise, smoke vibration, etc. to be confirmed during the operation performance check. Therefore, it is confirmed whether it is activated or not by electric current measurement, etc.

Table-2-1 Check items (main pipes (steel pipes))

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength・Earthquake resistance	Materials check	Confirm the main materials described in the Implementation Plan.	Following the Implementation Plan.
	Dimensions check	Confirm the dimensions and thickness described in the Implementation Plan with the records.	Following the Implementation Plan.
	Visual check ※1	Check the visual of each part.	No significant defects.
	Installation check ※1	Check the installation conditions of the pipes.	Carrying out construction and installation based on the Implementation Plan.
	Pressure resistance/ Leakage check ※1	Hold a fixed time at 1.25 times the maximum working pressure, confirm that the product withstands the pressure and that there is no leakage from the pressure resistant parts.	Withstanding 1.25 times the maximum working pressure with no abnormalities. In addition, no leakage from the pressure resistant parts.
Functions and performance	Confirmation of water flow	Check the water flow	Confirm water flow.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table-2-2 Check items (main pipes (polyethylene pipes))

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength・Earthquake resistance	Materials check	The main materials described in the Implementation Plan shall be confirmed with records.	Following the Implementation Plan.
	Dimensions check	The main dimensions described in the Implementation Plan shall be confirmed with records.	Following the Implementation Plan.
	Visual check ※1	Check the visual of each part.	No significant defects.
	Installation check ※1	Check the installation conditions of the pipes.	Carrying out construction and installation based on Implementation Plan.
	Pressure resistance/ Leakage check ※1	After holding for a fixed period at the maximum operating pressure of the pipes or higher, confirm that the product withstands the same pressure and that there is no leakage from the pressure resistant parts.	Withstanding the maximum allowable working pressure and no abnormalities. In addition, no leakage from the pressure resistant parts.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	Possible to flow water.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table-2-3 Check items (Main piping (pressure resident hose))

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Materials check	Confirm the main materials described in the Implementation Plan with records.	Following the Implementation Plan.
	Dimensions check	Confirm the dimensions described in the Implementation Plan with records	Following the Implementation Plan.
	Visual check ※1	Check the visual of each part.	No significant defects.
	Installation check ※1	Check the installation conditions of the pipes.	Carrying out construction and installation based on Implementation Plan.
	Pressure resistance/ Leakage check ※1	After holding for a fixed time at 1.25 times the maximum pressure during operation, confirm that the product withstands the same pressure. Additionally, confirm that there is no leakage from the pressure resistant parts.	Withstanding 1.25 times the maximum pressure during operation and no abnormalities. In addition, no leakage from the pressure resistant parts.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	Possible to flow water.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table-2-4 Check items (Main piping (expansion joint))

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Materials check	Confirm the main materials described in the Implementation Plan with records.	Following the Implementation Plan.
	Dimensions check	Confirm the dimensions described in the Implementation Plan with records.	Following the Implementation Plan.
	Visual check ※1	Check the visual of each part.	No significant defects.
	Installation check ※1	Check the installation conditions of the pipes.	Carrying out construction and installation based on Implementation Plan.
	Pressure resistance/ Leakage check ※1	After holding for a fixed time at 1.25 times the maximum pressure during operation, confirm that the product withstands the same pressure. Additionally, confirm that there is no leakage from the pressure resistant parts.	Withstanding 1.25 times the maximum pressure during operation and no abnormalities. In addition, no leakage from the pressure resistant parts.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	Possible to flow water.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table 3 Check Items (Leakage Detectors and Alarms)

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength	Visual check	Check the visual of each part.	No significant defects.
	Installation check	Check the installation position and conditions of the equipment.	Carrying out construction and installation based on Implementation Plan.
Function	Leakage alarm confirmation	Check that the alarm activation as set.	Alarm activation within the allowable range.

Table-4-1 Check Items (Measurement/Confirmation Tanks) ※1

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Materials check	Confirm the materials to be used with a certificate of material. Check the delivery records and product specifications for the connecting pipe and connecting valve.	Using the materials described in the Implementation Plan. The product specifications (maximum working pressure) of the connecting pipes and connecting valves shall be equal to or higher than the water head pressure of the tanks.
	Dimensions check	Check the main dimensions (plate thickness, inner diameter, and height).	Following the Implementation Plan.
	Visual check	Check the visual of the tank body (including paint conditions), connecting pipes and connecting valves.	No significant defects.
	Installation check	Check the assembly and installation.	No abnormality in the assembly condition and installation condition.
		Check the unevenness of the tank foundation.	No abnormal unevenness.
	Pressure resistance/ Leakage check	Perform pressure resistance and leakage tests based on design and construction standards.	No significant leakage from any part and no drop in water level.
	Ground bearing capacity confirmation	Check the bearing capacity of the foundation of the tanks in the bearing capacity tests.	Satisfying the necessary bearing capacity.
Functions and performance	Alarm confirmation	Confirm that alarm is activated by a signal associated with tank's water level "high-high".	Alarm activation by a signal associated with tank's water level "high-high"※2.
	Dimensions check ※3	Check the inner capacity of the barrier around the foundation.	Satisfying the capacity inside barrier equivalent to the required capacity.

The Japanese version shall prevail.

	Visual check	Check the visual of the barrier around the foundation.	No significant defects.
	Storage function	Confirm tanks can store water without leakage.	No leakage from the tanks and attached facilities (connecting pipes, connecting valves, manholes, drain valves).

※1: These items are basically confirmed with the pre-service inspection records, but witness or quality records confirmation is conducted as necessary.
※2: The signal name varies depending on tank.
※3: This item is confirmed with the inner capacity of the barrier at K4 tank area in "II 2.5 Attachment 12 Appendix 6 Table-2".

Table-4-2 Check items (Measurement/Confirmation Tank inlet pipes (steel pipes)) ※1

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Materials check	Confirm the main materials described in the Implementation Plan with a certificate of material or delivery note.	Following Implementation Plan.
	Dimensions check	Confirm the main dimensions described in the Implementation Plan with a certificate of material or delivery note.	Following the Implementation Plan.
	Visual check	Check the visual of each part by witness or with records.	No abnormalities in appearance.
	Installation check	Check the installation conditions in accordance with drawing by witness or with records.	Carrying out the construction and installation based on drawing.
	Pressure resistance/ Leakage check (Remark 1)	① After holding for a fixed time at 1.5 times the maximum pressure during operation, confirm that the product withstands the same pressure. Additionally, confirm that there is no leakage from the pressure resistant parts by witness or with records.	Withstand 1.5 times the maximum pressure during operation and no abnormalities. In addition, no leakage from the pressure resistant parts
		② Confirm no leakage from the pressure resistant parts under operational pressure by witness or with records.	No leakage from pressure resistant parts.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	Possible to flow water.

※1: These items are basically confirmed with the pre-service inspection records, but witness or quality records confirmation is conducted as necessary.

※2: Alternative inspection such as torque check is carried out for flange part of pipes where leakage inspection at pressure resistant parts cannot be conducted under the operational pressure.

Remark 1: Pressure resistance/Leakage check shall be confirmed by either ① or ②.

Table-5 Check Items (Water discharge guide)

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Materials check	Confirm the records regarding to main materials described in the Implementation Plan.	Following the Implementation Plan.
	Dimensions check	Check the main dimensions (width, length, height).	Following the Implementation Plan.
	Visual check※1	Check the visual of each part.	No significant defects.
	Installation check※1	Check the installation conditions in accordance with drawing by witness or with records.	Carrying out the construction and installation based on drawing.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	Possible to flow water.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table- 6 Check Items (Discharge vertical shaft (Tanks for upper-stream)

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Visual check※1	Check the visual of each part.	No abnormalities in appearance.
	Leakage check※1	Conduct the leak test in compliance with design/construction standard.	No significant leakage from any part and no drop in water level.

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked as necessary.

Table- 7 Check Items (Discharge vertical shaft (Tanks for downer-stream), Discharge tunnel, Outlet)

Matters to be Confirmed	Check items	Details	Acceptance Criteria
Structural strength ・Earthquake resistance	Visual check※1	Check the visual of each part.	No abnormalities in appearance.
Functions and performance	Confirmation of water flow	Check that water flow is possible.	No fluctuation of water level. (Discharge vertical shaft (Tanks for downer-stream))

※1: On site, it shall be within the scope that can be implemented, and the quality records shall be checked if necessary. In addition, on site, it shall be within the scope that can be implemented since seawater will be filled in this facility in the middle of construction.

Appendix 1 Basic Specifications of Measurement/Confirmation Tank
Appendix 2 Schematic of water discharge guide

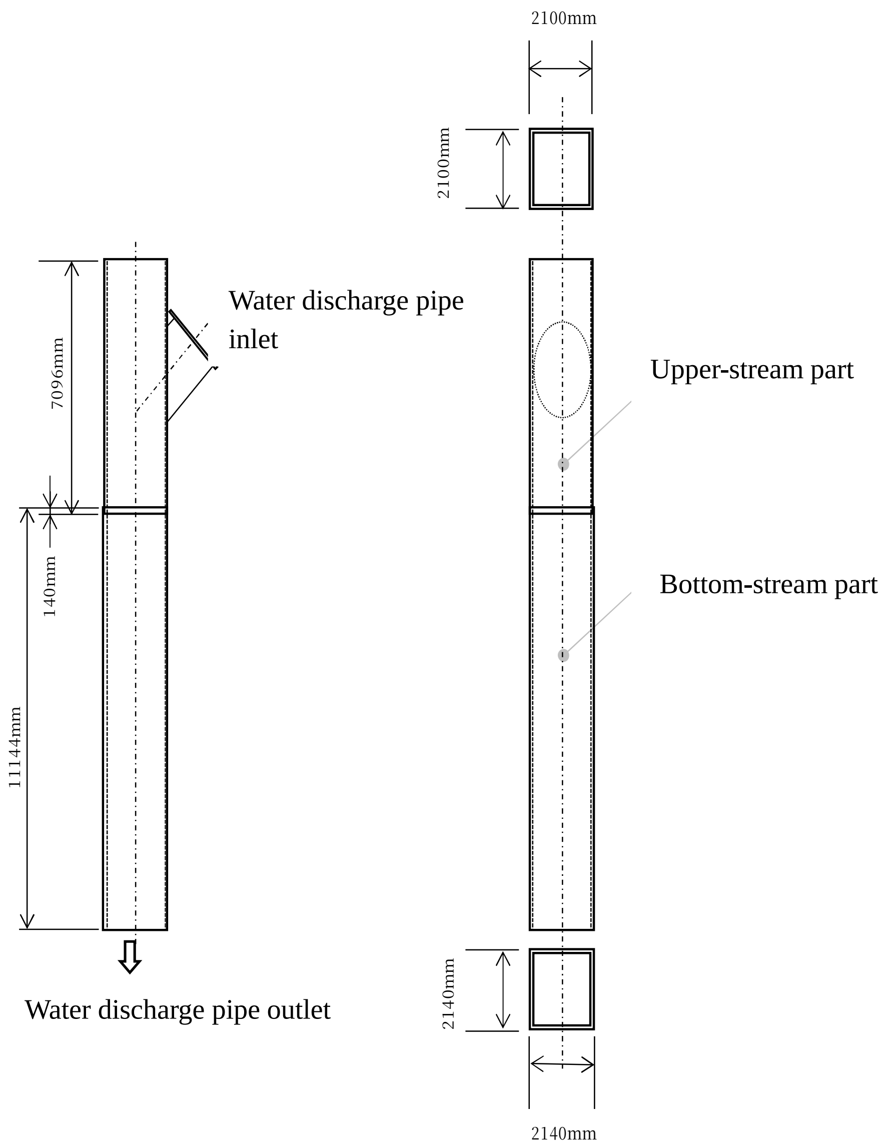
Basic Specifications of Measurement/Confirmation Tank

Measurement/Confirmation tank

Tank capacity		m^3	1,000
Main dimensions	Inner diameter	mm	10,000
	Shell plate thickness	mm	15
	Bottom plate thickness	mm	25
	Height	mm	14,565
Nozzle stub thickness	100A	mm	8.6
	200A	mm	12.7
	600A	mm	16.0
Material	Shell plate and bottom plate	—	SS400
	Tube stand	—	STPT410, SS400

	Connecting pipe (pressure resistant hose (finished product))	Connecting valve (finished product)
Nominal diameter	Equivalent to 200 A	Equivalent to 200 A
Material	EPDM synthetic rubber	FCD450-10
Max. operating pressure	1.0 MPa	1.0 MPa
Max. operating temp.	50°C	50°C

	Inlet piping (steel pipe)
Thickness	8.6 mm (100 A)
Material	STPT410
Max. operating pressure	1.0 MPa
Max. operating temp.	50°C



Schematic of water discharge guide

Instructions on design of discharge facility

Evaluation shall be conducted on the discharge equipment (discharge vertical shaft (upper-stream storage), discharge tunnel, and outlet).

1. Design Details

1.1 Basic Policy on Design

The discharge equipment shall be evaluated in accordance with the following.

・ “Design of Civil Engineering Structure of Thermal and Nuclear Power Plant (enlarged and revised edition)”, (general incorporated association) Electric Power Civil Engineering Association

・ “Standard Specifications of Concrete (design edition)”, (Public Interest Incorporated Association) Japan Society of Civil Engineers,(established in 2017)

・ “Standard Specifications of Tunnels〔common edition〕/ 〔shield method edition〕”, (Public Interest Incorporated Association) Japan Society of Civil Engineers, (established in 2016)

・ “Standard Specifications of Tunnels〔open cut method edition〕”, (Public Interest Incorporated Association) Japan Society of Civil Engineers, (established in 2016)

・ “Technical Standards of the Port Facilities”, (Public Interest Incorporated Association) the Ports & Harbors Association of Japan, (2018)

・“Specifications for Highway Bridges I common edition”, (Public Interest Incorporated Association) Japan Road Association,(2017)

・“Specifications for Highway Bridges IV substructure edition”, (Public Interest Incorporated Association) Japan Road Association,(2017)

1.2 Basic Policy on Earthquake Resistance

In view of handling the drainage water from ALPS Treated Water Dilution/Discharge Facility (water satisfies the concentration where sum of the ratios of legally required concentration of all radionuclides including tritium diluted with seawater), discharge facility is classified as seismic class C according to the degree of radiological impact on the public due to the loss of function of the facility, etc.

2. Design Method

2.1 Evaluation Conditions

2.1.1 Allowance Stress Level of the Materials Used

Among the materials used in the discharge facility, concrete shall be ordinary concrete, and the design standard strength is 24N/mm^2, 30N/mm^2, 42N/mm^2. Reinforcement shall be SD345.

The allowance stress level for each material used are shown in Table-1 to 2.

Table-1 Allowance Stress Level of Concrete

Design concrete strength	Long term		Short term	
	Compression (N/mm^2)	Shear (N/mm^2)	Compression (N/mm^2)	Shear (N/mm^2)
24	9.0	0.45	13.5	0.675
30	11.0	0.50	16.5	0.75
42	16.0	0.73	24.0	1.095

Table-2 Allowance stress level of reinforcement

Materials used	Long term	Short term
	Compression and tension (N/mm^2)	Compression and tension (N/mm^2)
SD345	200	300

2.1.2 Soil Constants

The soil constants used in the design are shown in Table-3.

Table-3 Soil Constants

Number of layers	Soil	Unit volume weight γ (kN/m^2)	Unit volume weight in water γ'(kN/m^2)	Adhesive force C(kN/m^2)	Inside friction angle φ (°)	Deformation factor E0 (kN/m^2)
1	Embankment	18.0	8.0	0	30.0	17.70
2	Sandstone	18.4	8.4	0	38.6	94.40
3	Mudstone	17.1	7.1	1500	0	506.00

The Japanese version shall prevail.

2.1.3 Groundwater Level

T.P. +1.0m (G.L. -1.5m).

2.1.4 Unit Volume Weight

The unit volume weight of the materials used in the design is shown in Table-4.

Table-4 Unit volume weight

Material	Unit Volume Weight (kN/m^3)
Reinforced concrete	24.5
Steel	77.0
Ground	See Table-3
Water (seawater)	10.1

2.1.5 Environmental conditions of the structures

The environmental conditions of the structures shall be corrosive environmental conditions, and the limit value of the crack width shall be 0.004c (mm). However, c is the distance from concrete surface to the reinforcement surface.

2.1.6 Load

Normal and seismic loads shall be considered in the design.

The seismic force acting on the body is calculated by the seismic intensity method in principle.

$$P=K \cdot W$$

P: Seismic force

K: Designed Horizontal seismic intensity

W: Body weight

2.2 Evaluation method

The check items are shown in Table 5.

Table 5 Items to be checked for discharge facility

Items to be checked		Discharge vertical shaft (down-stream storage)	Discharge Tunnel	Outlet	Content of check
At all times	Structure	○	○		Within allowance stress level
	Structure (Waves)			○	Within allowance stress level
	Crack	○	○	○	The crack width shall not exceed the allowance crack width.
	Salt damage	○	○	○	The chloride ion concentration at the steel position does not reach the generation limit of steel corrosion.
	Floating	○		○	No floating shall occur.
During an earthquake		○	○	○	Should be within allowance stress level from earthquake

2.3 Evaluation results

2.3.1 Discharge vertical shaft (downer-stream storage)

The working stress of discharge vertical shaft (downer-stream storage) is compared with the allowance stress of it, and the results of checking parts where the ratio of the working stress to the allowance stress is the maximum are shown in Table-6.

The structure is established after confirming that the load is within the allowance stress for normal load and seismic load. And, it is confirmed that the floating of the structure does not occur. In addition, the crack width and salt damage on the body made of reinforced concrete are checked to confirm that the durability during the service period is ensured.

During the service period, maintenance is not required due to design considerations for the body made of reinforced concrete.

Table-6 Checking results of discharge vertical shaft (downer-stream storage)

Target part	Load case	Stress	Working stress (N/mm^2)	Allowance stress (N/mm^2)	Working stress/allowance stress
Bottom plate	At all times	Bending moment	179	200	0.90
Side wall Second lift	At all times	Bending moment	184	200	0.92

2.3.2 Discharge tunnel

The working stress of the discharge tunnel is compared with the allowance stress, and the checking results of the parts where the ratio of the working stress to the allowance stress is the maximum are shown in Table-7.

The structure is established after confirming that the load is within the allowance stress for normal load and seismic load. Crack width and salt damage on covering plate made of reinforced concrete are checked to ensure durability during the service period.

Note that maintenance is not required due to design considerations for body made of reinforced concrete during the service period.

Table-7 Checking results of discharge tunnel

Target part	Load case	Stress	Working stress (N/mm^2)	Allowance stress (N/mm^2)	Working stress/allowance stress
Covering plate (starting part)	At all times	Bending moment	79	200	0.40
Covering plate (deepest part)	At all times	Bending moment	93	200	0.47

2.3.3 Outlet

Comparing the working stress at the outlet with the allowance stress, the results of checking the parts where the ratio of the working stress to the allowance stress becomes the maximum are shown in Table-8.

Normal waves and seismic loads are checked to be within the allowance stresses, and the structure is established. And, it is confirmed that the floating of the structure does not occur. In addition, the crack width and salt damage on the body made of reinforced concrete are checked to confirm that the durability during the service period is ensured.

Note that maintenance is not required due to design considerations for body made of reinforced concrete during the service period.

Table 8. Results of checking outlet

Target part	Load case	Stress	Working stress (N/mm^2)	Allowance stress (N/mm^2)	Working stress/allowance stress
Bottom plate	At all times (Waves)	Shearing force	0.23	0.50	0.46
Side wall	At all times (Waves)	Shearing force	0.24	0.50	0.48

Appendix 1 Checking Durability

Appendix 2 Checking Floating

Appendix 1

Instruction for checking durability

Methods and results of checking for durability of discharge equipment (discharge vertical shaft (downer-stream storage), discharge tunnel, and outlet) are shown for.

1. Checking Method

1.1 Crack width

Checking for cracks shall confirm that the generated bending crack width w is not more than the allowance bending crack width wa. The checking formula is shown below.

$$w / wa \leqq 1.0$$

The calculation formula is shown below.

$$w = 1.1 k_1 k_2 k_3 \{4c + 0.7(c_s - \phi)\} \left[\frac{\sigma_{se}}{E_s} \left(\text{or} \quad \frac{\sigma_{pe}}{E_p} \right) + \varepsilon'_{csd} \right]$$

w: Bending crack width (mm)

k1: Coefficient representing the effect of surface shape of reinforcement on crack width (= 1.0)

k2: Coefficient representing the effect of quality of concrete on crack width

k2 = 15 / (f'c + 20) + 0.7

f'c: Concrete compressive strength (N/mm^2)

k3: Coefficient representing the effect of the number of stages of tension reinforcement

k3 = 5(n+2)/ (7n+8)

n: Number of stages of tension reinforcement

c: Covering depth for reinforcement (mm). Here, depth to main reinforcement

Cs: Distance between the centers of reinforcement (mm)

φ: Diameter of tension reinforcement and nominal diameter of minimum reinforcement (mm)

ε'csd: Value to consider the increase of crack width due to shrinkage and creep, etc. of concrete.

σse: Amount of increase in reinforcement stress level near the surface (N/mm^2)

Es: Young's modulus of reinforcement (N/mm^2)

1.2 Salt damage

Calculate the design value of chloride ion concentration at the reinforcement position, Cd, and confirm that it does not reach the limit concentration of generation of steel corrosion, Clim. The checking formula is shown below.

$$\gamma i \cdot Cd / Clim \leqq 1.0$$

γi : Structure coefficient (= 1.0)

The values in Table-1 shall be used for the design conditions to be used for the durability check.

Table-1 Design conditions used for checking durability

		Discharge vertical shaft (downstream tank)	Discharge tunnel	Outlet
Useful life	(years)	30		
Chloride ions on surface	C_0(kg/m^3)	13.0	9.0	15.1
Limit concentration of generation of corrosion	C_{lim}(kg/m^3)	1.80	2.19	2.00
Diffusion coefficient	D_k (cm/year)	0.16	0.05	0.28

The durability shall be checked according to the simplified design method of the "Standard Specification of Concrete". The basic concept of checking is shown below.

・Under given environmental conditions, the combination of the design diffusion coefficient Dd for chloride ions and the design value of covering depth for reinforcement cd shall be appropriately set to satisfy the checking of salt damage.

・In order to satisfy the set design diffusion coefficient Dd, the combination of bending crack width w and water-cement ratio W/C of concrete shall be appropriately set.

The design value cd of the covering depth for reinforcement is obtained by previously considering the construction error Δce (=5mm) by following formula.

$$c_d = c - \Delta c_e$$

C : Covering depth for reinforcement on the design drawing

Design diffusion coefficient Dd is calculated by the following formula.

$$D_d = \gamma_c \cdot D_k + \left(\frac{w}{l}\right) \cdot \left(\frac{w}{w_a}\right)^2 \cdot D_0$$

γc: Material coefficient of concrete (= 1.0)

Dk: Characteristic value of diffusion coefficients for chloride ions in concrete

D0: Constant representing the effect of cracking on the movement of chloride ions in concrete (=400)

2. Checking Results

2.1 Crack width

2.1.1 Discharge vertical shaft (downer-stream storage)

Comparing the generated bending crack width of Discharge vertical shaft (downer-stream storage) with the allowance bending crack width, Table-2 shows the results of checking parts where the ratio of the generated bending crack width to the allowance bending crack width is the maximum.

Table-2. Checking Results of Discharge vertical shaft (downer-stream storage)

Target part	Generated bending crack width (mm)	Allowance bending crack width (mm)	Generated bending crack width/allowance bending crack width
Bottom plate	0.284	0.590	0.48
Side wall	0.293	0.602	0.49

2.1.2 Discharge tunnel

Comparing the generated bending crack width of the Discharge tunnel with the allowance bending crack width, Table-3 shows the results of checking parts where the ratio of the generated bending crack width to allowance bending crack width is the maximum.

Table-3 Checking results of water discharge tunnel

Target part	Generated bending crack width (mm)	Allowance bending crack width (mm)	Generated bending crack width/allowance bending crack width
Covering plate (Discharge vertical shaft part)	0.133	0.177	0.75
Covering plate (deepest part)	0.148	0.177	0.84

2.1.3 Outlet

Comparing the generated bending crack width at the outlet with the allowance bending crack width, Table-4 shows the results of checking parts where the ratio of the generated bending crack width to allowance bending crack width is the maximum.

Table-4. Checking result of outlet

Target part	Generated bending crack width (mm)	Allowance bending crack width (mm)	Generated bending crack width/allowance bending crack width
Bottom plate	0.262	0.400	0.66
Side wall	0.302	0.400	0.76

2.2 Salt damage

2.2.1 Discharge vertical shaft (downer-stream storage)

The chloride ion concentration at the reinforcement position of the discharge vertical shaft (downer-stream storage) shall be compared with limit concentration of generation of the reinforcement corrosion. And the results of checking parts where the ratio of the chloride ion concentration to limit concentration of generation of the reinforcement corrosion at the reinforcement position is the maximum are shown in Table-5.

Table-5 Checking results of discharge vertical shaft (downer-stream storage)

Target part	Chloride ion concentration at the reinforcement position (kg/m^3)	Limit concentration of generation of the reinforcement corrosion (kg/m^3)	Chloride ion concentration at reinforcement position/ limit concentration of generation of the reinforcement corrosion
Bottom plate	1.77	1.80	0.98
Side wall	1.79	1.80	0.99

2.2.2 Discharge tunnel

The chloride ion concentration in the discharge tunnel obtained by the consideration shall be compared with the limit concentration of generation of the reinforcement corrosion. And the results of checking parts where the ratio of the chloride ion concentration to the limit concentration of generation of the reinforcement corrosion at the position of reinforcement is the maximum are shown in Table-6.

Table-6 Checking results of discharge tunnel

Target part	Chloride ion concentration at the reinforcement position (kg/m^3)	Limit concentration of generation of the reinforcement corrosion (kg/m^3)	Chloride ion concentration at reinforcement position/ limit concentration of generation of the reinforcement corrosion
Lining board (Water discharge shaft part)	1.97	2.19	0.90
Lining board (deepest part)	2.16	2.19	0.98

2.2.3 Outlet

Comparing the chloride ion concentration at the outlet determined by the consideration with the limit concentration of generation of the reinforcement corrosion, the results of checking parts where the ratio of the chloride ion concentration at the reinforcement position to the limit concentration of generation of the reinforcement corrosion is the maximum are shown in Table-7.

Table-7. Checking result of the outlet

Target part	Chloride ion concentration at the reinforcement position (kg/m^3)	Limit concentration of generation of the reinforcement corrosion (kg/m^3)	Chloride ion concentration at reinforcement position/ limit concentration of generation of the reinforcement corrosion
Bottom plate	1.93	2.00	0.97
Side wall	1.95	2.00	0.98

Instruction for Checking of Floating

Methods and results of checking for floating of discharge equipment (discharge vertical shaft (downer-stream storage) and outlet) are shown for.

1. Checking method

1.1 Calculation formula

Consideration of floating shall be carried out by the following equation.

$Fs = W/U$

$U = Vw \cdot \gamma w$

U: Buoyancy (kN)

W: Vertical load (kN)

Vw: Volume below ground water level (m^3)

γw: Unit volume weight of water (seawater) (kN/m^3)

1.2 Consideration Conditions

Table-1 shows the safety factor for the floating of the discharge vertical shaft (downer-stream storage).

Table-1 Safety factor against floating

Load condition in storage (seawater load)	In service	
Applied condition	At all times and at the time of waves	During an earthquake
Safety factor for the floating	1.20	

2. Checking Results

2.1 Discharge vertical shaft (downer-stream storage)

Table-2 shows the results of checking the floating of discharge vertical shaft (downer-stream storage) under conditions where the calculated values are stricter.

Table-2. Checking results for floating of discharge vertical shaft (downer-stream storage)

	At all times
Calculated value	1.59
Safety factor for the floating	1.20

2.2 Outlet

Table-3 shows the results of checking the floating of the outlet under conditions where the calculated values are stricter.

Table-3. Checking results for the floating of the outlet

	At the time of waves
Calculated value	1.22
Safety factor for the floating	1.20

Construction schedule

	2022												2023											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Installation of ALPS Treated Water Dilution/ Discharge Facilities and Related Facilities													①,	②,	③	△								

▭ : On-site installation and assembly

①: When tests related to structure, strength, or leakage are ready to be conducted

②: When the equipment assembly is completed.

③: When the construction work related to the construction plan is completed

2.1.2 Management of Radioactive Liquid Waste, etc.

(Refer to comparison table for any amendments)

2.2.3 Dose Assessment by Radioactive Liquid Waste, etc.

(Refer to comparison table for any amendments)

2.2.6 Action in response to the "Basic Policy on handling of the ALPS treated water"

At the 5th Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning (held on April 13, 2021), the "Basic Policy on handling of the ALPS treated water" (hereinafter referred to as the "Government Policy") was issued.

Tepco issued "TEPCO Holdings' Action in Response to Government's Policy on the Handling of the ALPS treated water from the Fukushima Daiichi Nuclear Power Station", on April 16 in same year and will take measure in accordance with Government Policy.

① The tritium concentration of discharged water diluted with seawater is less than 1,500Bq/L (Refer to 2.1.2.3 (5) Discharge Management Methods)

② The amount of discharged tritium is within the range of 22 TBq per year (Refer to 2.1.2.3 (5) Discharge Management Methods)

③ Emergency isolation valves are installed to stop the transfer of ALPS treated water when abnormal event happens (refer to II 2. 50.1.5.1 (2) Transfer equipment)

④ The safety for radiation impact on humans and the environment in case of discharge into the sea of ALPS treated water shall be assessed.

For the radiation impact on humans and the environment described in ④ above, the evaluation results at the design stage as of November 2021 are attached as a reference.

Reference 1 Radiological Impact Assessment Report Regarding the Discharge of ALPS Treated Water into the Sea (design stage)

Reference 1

Radiological Impact Assessment Report Regarding the Discharge of ALPS Treated Water into the Sea (design stage)

November 2021
Tokyo Electric Power Company Holdings, Incorporated

The assessment in this report will be revised as appropriate based on progress in discussions around design and operation of plans regarding discharged into the sea, opinions from relevant parties, reviews by IAEA experts, and cross check assessments by third parties.

Introduction

This is a report of the radiological impact assessment (hereinafter "RIA") to assess the impact of the discharge into the sea of ALPS treated water originating from the Fukushima Daiichi Nuclear Power Stations (hereinafter "FDNPS"). The RIA begins with background information about the accident at FDNPS during the 2011 off the Pacific coast of Tohoku Earthquake, how contaminated water was generated, and how it has been controlled, treated and stored. The RIA then describes processes by which alternatives to disposal at sea were reviewed, the preferred method to discharge the ALPS treated water, and an evaluation of the quality of the water to be discharged. The RIA then models the discharge of the ALPS treated water and the concentrations of discharged water at many locations. Finally, the RIA assesses the impacts of the discharged water on humans, marine biota, and the marine environment.

Following the unprecedented accident at the FDNPS during the 2011 off the Pacific coast of Tohoku Earthquake, cooling water has been being continuously injected into the plants to cool the damaged reactors and nuclear fuels. The injected water accumulates at the bottom of the buildings after it touches the damaged fuel.

Seawater from the tsunami, rainwater penetrating the building from the damaged building's ceiling and walls, and ground water continue to accumulate at the bottom of the building. All water coming from these sources which mixes with the aforementioned cooling water is treated as contaminated water.

TEPCO has taken multi-layered measures[1] not only to prevent the contaminated water from leaking outside the buildings, but it also has reduced the volume of contaminated water generated from approx. 540m^3/day (as of May 2014) to approx. 140m^3/day (as of 2020). It is the company's goal to further reduce this volume to 100m^3/day or below by 2025.

Contaminated water is treated by cesium absorption units and "the Advanced Liquid Processing System" (hereinafter "ALPS"), and then the water is stored in the tanks on the site's premises. As of June 2021, there were 1,047 tanks for storage of ALPS treated water, etc. [2] and strontium removed water (before ALPS treatment)[3], and the current volume is approx. 1.265 million m^3, whereas the total installed capacity of the tanks is approx. 1.37 million m^3. Although it is necessary to carefully review the effectiveness of the measures to suppress the generation of contaminated water and the predictions for the volume of the contaminated water to be generated in the future, given the records of contaminated

[1] Example of multi-layered measures:

a To suppress the volume of contaminated water generated, pumped up contaminated water is purified by the cesium absorption unit and desalinated by a reverse osmosis membrane device to be used as cooling water which cools nuclear fuel damaged from the accident.

b Also, groundwater flowing into the building is suppressed. Specifically, groundwater is pumped up from high ground and from near the building, and a land-side impermeable wall (frozen soil wall) is installed around buildings to keep groundwater around the buildings at a low level.

c Contaminated water generated inside the building is pumped up to prevent external leaking by maintaining the water level in buildings to constantly be lower than the groundwater level outside.

d Pumped up contaminated water is stored in tanks installed on high ground after being treated by facilities such as cesium absorption units and ALPS, etc. to prevent the spread of contamination and for dose reduction.

[2] "ALPS treated water" refers to contaminated water treated with ALPS where the sum of ratios of legally required concentrations of radionuclides other than tritium is less than one. "Treated water to be re-purified" refers to contaminated water treated with ALPS where the sum of ratios of legally required concentrations of radionuclides other than tritium is not less than one. "ALPS treated water, etc." refers to both "ALPS treated water" and "treated water to be re-purified".

Here, the legally required concentration is a standard for releasing radioactive waste into the environment stipulated in the "Announcement Stipulating the Dose Limit Based on Regulations Regarding the Refining Business of Nuclear Raw Material and Nuclear Fuel Material". If the radioactive waste contains more than one radioactive material, the sum of the ratios of concentration of radionuclides inside radioactive waste to legally required concentration should be less than 1.

[3] "Strontium removed water" is water from which cesium (Cs) and strontium (Sr) have been removed.

water generated thus far, its volume is expected to reach the planned volume is expected to be reached in around the spring 2023, when considering the records of contaminated water generated up to the present.

As presented in the “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station” [1] revised by the Government of Japan through its “Inter-Ministerial Council for Contaminated Water and Decommissioning Issues” in December 2019, the decommissioning of FDNPS involves continuous risk reduction activities to protect humans and the environment from the known risks of radioactive materials. The long-term process for the decommissioning of FDNPS spanning the next few decades requires responses to challenges involving greater radiation risks such as retrieval of fuel debris and securing a temporary storage area for spent fuels. In order to adequately address these challenges, it is imperative to steadily reduce the overall risks with a mid-long term perspective issues.

The same applies to the handling of contaminated water. The risks have been steadily mitigated by reducing the dose (a measure of the energy deposited by radiation in a target) at the boundary of the FDNPS site to below 1mSv/year, which is the dose limit set based on the recommendations of the International Commission on Radiological Protection (hereinafter “ICRP”) for the general public, through multi-layered measures to reduce the generated volume of contaminated water which contains significant quantities of radioactive materials, and by removing radioactive materials from the contaminated water using ALPS and other devices such as cesium adsorption units. In order to proceed safely and steadily with the decommissioning of FDNPS, which is expected to continue over the next few decades, it is necessary to conduct safe discharges into the sea, after removing radioactive materials from the contaminated water to the maximum extent possible through the facilities including ALPS, and diluting it before discharge, so as to ensure that discharges would not cause a substantial impact on humans and the maritime environment.

Over the past several years since the accident, feasible methods of disposing of contaminated water, ALPS treated water, and etc. have been considered, in the light of opinions from local government and residents and in cooperation with the Government of Japan, International Atomic Energy Agency (hereinafter “IAEA”), and experts, notably under the auspices of the Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues. In 2013, The Government of Japan established the Tritiated Water Task Force under the Contaminated Water Treatment Countermeasures Committee. In this Task Force, technical studies have been conducted, such as reviewing of the scientific knowledge on tritium and comparison of the five theoretically possible disposal methods (i.e., mining injection, offshore release, vapor release, hydrogen release, underground burial) , which were proposed based on basis of international practice [2]. Furthermore, in 2016 the Subcommittee on Handling of the ALPS Treated Water was established to conduct a comprehensive study, including social viewpoints and factors such as reputational damage, based on the output of the Tritiated Water Task Force. [3]

Between 2013 to 2021, the Government of Japan has welcomed five IAEA decommissioning missions, whose opinions and advice have been carefully reflected in the considerations by the Government of Japan about handling of the ALPS treated water. The IAEA missions have pointed to the importance of planning the disposal of the ALPS treated water. The IAEA’s report in 2015 found that tank storage was “at best a temporary measure while, a more sustainable solution was needed”[4]. The IAEA’s report in 2019 advised that “a decision on the disposition path for the stored ALPS treated water containing tritium and other radionuclides, after further treatment as needed, must be taken urgently”[5].

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[4] Mission Report, IAEA International Peer Review Mission on Mid-And-Long-Term Roadmap Towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station Units 1-4, issued 13 May, 2015, p. 13, available at <https://www.iaea.org/sites/default/files/missionreport130515.pdf>.

[5] Mission Report, IAEA International Peer Review Mission on Mid-And-Long-Term Roadmap Towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station Units 1-4, issued 31 January, 2019, p. 8, available at <https://www.iaea.org/sites/default/files/19/01/missionreport-310119.pdf>

Against this backdrop, the Subcommittee on Handling of the ALPS Treated Water compiled a report in February 2020. The Subcommittee concluded that discharge into the sea and vapor release were the only two practical options out of the theoretically available options, and that discharge into the sea could be implemented more reliably than vapor release, as it would allow for greater accuracy of monitoring methods. The Subcommittee also pointed out that space for installing additional tanks, other than those currently planned, was limited[6].

In addition, after the publication of the ALPS Subcommittee's report, the Government of Japan held "Meetings for Hearing Opinions" to hear the opinions of the stakeholders and solicited opinions from the general public. The comments submitted raised, among other issues, concerns about the impact of discharge of ALPS treated water into the sea in the surrounding environment. Based on these studies and comments, the Government of Japan announced its "Basic Policy on handling of ALPS treated water at the Tokyo Electric Power Company Holdings' Fukushima Daiichi Nuclear Power Station", during the meeting of the Ministerial Council Regarding Decommissioning/Contaminated Water/Treated Water on April 13, 2021[4]. In this Basic Policy, the Government of Japan selected handling of the ALPS treated water by discharge into the sea,conditional on ensuring safety as to this method of discharge.

TEPCO has taken this Basic Policy into consideration, and presented "TEPCO's Company Action in Response to the Basic Policy (hereinafter "Company Action in Response to Basic Policy") [5] on April 16th of the same year, the gist of which is as follows.

- In discharging ALPS treated water into the sea, TEPCO shall conform with regulatory requirements as well as relevant international laws and practices. In addition, TEPCO shall take further action to make sure that the water to be discharged is safe, and to ensure the safety of the public, surrounding environment and of agriculture, forestry and fishery products.
  - In order to ensure the safety of the public and the surrounding environment, the concentration of radioactive material such as tritium and other radionuclides in discharged water shall conform with regulatory standards established by the Government of Japan based on internationally recognized technical documents (IAEA Safety Standards, and ICRP Recommendation, etc.), and other laws and ordinances.
  - Prior to initiating necessary licensing procedures with the Nuclear Regulation Authority, a safety assessment shall be conducted to review the radiological impact on humans and the environment when discharge is conducted based on the conditions above. The results shall be disclosed and reviewed by experts such as IAEA.

This report presents the results of an assessment of the radiological impacts on humans and the environment of the discharge of ALPS treated water into the sea, based on the information available at the current design stage of the implementation plan for the discharge, and in accordance with the standards and guidelines established by internationally recognised organizations such as the IAEA and ICRP. TEPCO invited to take part in this assessment external experts of three fields: humans radiological protection, environmental protection and marine dispersion simulation.

It will be reviewed as appropriate in the light of the knowledge obtained through the process of examining the design and operation in accordance with the implementation plan for the discharges, from the opinions of various bodies and persons, from the reviews by IAEA experts, and through the cross-checks conducted by third-party evaluation.

In addition, TEPCO plans to carefully start its discharges with small amounts of water while assessing and confirming the impact on the surrounding environment. If the dilution equipment fails to perform

[6] See References [3], pages 5-7 for a comparative study of the basic requirements (e.g., regulatory feasibility, technological feasibility) and conditions (e.g., duration, cost, scale, secondary waste, and work exposure) for ocean emissions and other alternative disposal methods. The Report of the Subcommittee is available at <https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20200210_alps.pdf >

its functions due to breakdown or loss of power, or if an abnormal value is detected by monitoring, TEPCO will stop discharging ALPS treated water immediately and only resume when until TEPCO confirms that the water can be discharged safely.

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Major point in the assessment of the discharge into the sea

This report, which is based on current plans for the discharge of ALPS treated water into the sea, contains an assessment of the radiation dose to "the representative person" that may be caused through systematic discharge, in accordance with the precepts outlined in the IAEA Safety Standards GSG-9 "Regulatory Control of Radioactive Discharges to the Environment"[6] (hereinafter "GSG-9"), was conducted. The specific procedures undertaken in this assessment were designed in accordance with the IAEA Safety Standards GSG-10 "Prospective Radiological Environment Impact Assessment for Facilities and Activities" [7] (hereinafter "GSG-10"), as international standards for safe discharges. The assessments of potential exposure[7] and environment protection, not subject to GSG-9, were conducted in accordance with GSG-10.

In compiling this report, employees with knowledge on the assessment of radiological impact on the environment were selected and assigned, and experts in the three fields especially important for assessing radiological impact: human radiological protection, environmental protection and marine dispersion simulation, were invited as members from outside the company.

TEPCO seleted a total of 64 radionuclides for assessment: tritium (H-3), carbon 14 (C-14), and 62 radionuclides to be removed by ALPS. Among these nuclides, the concentration of tritium exceeds the regulatory standard of 60,000 Bq/L even after treatment by ALPS, so it shall be diluted until it meets the regulatory standard. The Government of Japan has requested us not only to strictly comply with the regulatory standards, but also to discharge the ALPS treated water below 1,500 Bq/L[8], in order to reassure the public as much as possible. Accordingly, in the "Company Action in Response to Basic Policy", TEPCO determined the concentration indischarged water was set to be less than 1,500Bq/L, and the upper limit for the annual amount discharged was set to be 22 TBq[9] (2.2E + 13Bq)[10].

The radionuclide composition of ALPS treated water differs by each tank group[11]. In order to manage the risk of multiple nuclides discharge, "the sum of the ratios of legally required concentrations" (hereinafter "the sum of the ratios")[12] of radionuclides other than tritium, shall not exceed one. Therefore, for the radionuclide composition of ALPS treated water to be used for the assessment, the following four cases were selected: actual radionuclide composition of the three particular tank groups which have completed measurement and assessment of the 64 radionuclides, and the hypothetical radionuclide composition giving the conservative exposure ("the sum of the ratios" other than tritium is exactly 1).

According to the national regulatory standards set based on the recommendations of ICRP, the concentrations of radionuclides other than tritium in the ALPS treated water can be safely discharged directly to the sea. In order to reduce the tritium concentration to less than 1,500 Bq/L, it is necessary to dilute the water by more than 100 times with seawater, and the sum of the ratios of 63 radionuclides

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[7] Potential exposure: Exposure considering future events that are not guaranteed to occur but can be anticipated as probable events or sequence of events such as operational events, accidents involving radiation source, equipment failure and operational errors.

[8] Similar to the current operational target value for discharge water concentrations from groundwater bypass and subdrain. The value is the same as the operational target value for the effluent concentration of the groundwater bypass and sub-drain, which have already been discharged. This is stated in "Implementation Plan III 3.2.1 Management of Radioactive Waste, etc." and has been approved by the Nuclear Regulation Authority. The tritium concentration of 1,500 Bq/L is 1/40th of the announced concentration limit of 60,000 Bq/L, and approximately 1/7th of the WHO Guidelines for drinking-water quality of 10,000 Bq/L.

[9] The operational target value at FDNPS before the accident.

[10] "E+number" means 10 to the numberth power. 2.2E + 13 indicates 2.2×10^{13}.

[11] Multiple tanks utilized in conjunction.

[12] The sum of the ratios of concentration of radionuclides inside radioactive waste to legally required concentration according to regulatory standard [8] when there are multiple radioactive materials contained. Intake of water, of which "the sum of ratio" is one, over a lifetime will result in the effective dose of 1 mSv/year in average.

other than tritium in the discharged water after dilution with seawater will be less than 0.01, which will further enhance the safety.

The dispersion of the discharged water in the sea was calculated and assessed using a model with a higher-resolution of the sea area near FDNPS, based on one with verified reproducibility through reproduction calculation of the cesium (Cs) concentration in seawater after the accident [9].

The following five pathways for dispersion were considered for the transfer model for radioactive materials discharged into the sea: (i) transfer and dispersion through weather conditions such as sea current,; (ii) transfer and dispersion through weather conditions such as sea current → adhesion to ship hull,; (iii) transfer and dispersion through weather conditions such as sea current → adhesion to sand on the beach,; (iv) transfer and dispersion through weather conditions such as sea current → adhesion to fishing nets,; (v) transfer and dispersion through weather conditions such as sea current → ingestion and concentration of radionuclides to marine life such as fishery.

In the assessment of human exposure pathways, categories were roughly divided into external exposure (i.e., exposure to radiation from a source outside the body) and internal exposure (i.e., exposure to radiation from a source within the body.). For external exposure, the five different pathways indicated by previous studies as particularly important were assessed: (i) external exposure to radiation from sea surface while performing work on the sea,; (ii) external exposure to radiation from radioactive materials adhering to the ship hull while working on the sea,; (iii) external exposure to radiation while swimming and working under water,; (iv) external exposure to radiation from the sand on the beach,; (v) external exposure to radiation from radioactive materials on fishing nets. For internal exposure, the exposure pathway is on the assumption that radioactive materials are transferred from seawater to marine products and taken into the human body as they are ingested.

The characteristics of "the representative person" subject to exposure assessment was set in accordance with "Public dose assessment guideline for safety review of nuclear power light water reactor" [10]. Based on the data referenced from the FY2019 National Health and Nutrition Survey [11] in Japan, assessments were conducted for two groups of persons: (i) individuals who ingest average amounts of marine products,; (ii) individuals who ingest significantly more than average amounts of marine products.

Calculation and assessment of the results involved comparisons with the public dose limit of 1mSv/year, and the target dose value for domestic nuclear power stations, 0.05mSv/year, which is set as the operational target for nuclear power stations in Japan.

In all cases, the cumulative doses of both external and internal exposure through the various pathways were below both the public dose limit and the target dose value for nuclear power stations in japan.

Pursuant to the recommendations in GSG-10 and concurrent with the assessments just described, an additional assessment was conducted based on a hypothetical scenario in which the ALPS treated water was discharged into the sea without dilution. The transfer in this case was assumed to be external exposure from seawater over a short period where exposure cannot be controlled. The assessment was conducted assuming a case where the emission rate of Tellurium 127 (Te-127), which is the radionuclide and has the most impact on external exposure from sea surface, is at a maximum, and the duration of exposure was set to one day (24 hours). On these assumptions, which are considered to be conservative, the assessment showed that the potential effective dose resulting from such uncontrolled exposure was lower than below the levels set in GSG-10 as the levels to be used in planning for accidents.

Furthermore, as part of the assessment regarding environmental protection, an assessment was conducted relating to the protection of animals and plants during normal operation of facilities for discharging ALPS treated water, in accordance with the methodology indicated in Annex I of GSG-10. Four cases were selected: actual radionuclide compositions of three particular tank groups which have completed measurement and assessment of the 64 radionuclides, and the hypothetical radionuclide composition. However, assessment of impacts on animals and plants involves calculation methods for different from those used for the assessment of human exposure, the nuclide composition (“the sum of the ratios” other than tritium is 1) at which the exposure is maximized was newly selected from the nuclide selection (see Ref. B). Based on the list of reference animals and plants[13]identified by ICRP, animals and plants selected for assessment are the flatfish (flounder, fluke), crab (portunus trituberculatus, ovalipes punctatus), and brown seaweed (gulfweed and sea oak) which live in the relevant sea area around FDNPS. Dose assessment was conducted in accordance with the methods presented by ICRP, and the dose rate received by reference animals and plants in their habitat was compared with international guideline, notably the derived consideration reference level (hereinafter “DCRL”)[14]. The estimated dose rate for reference animals and plant in their habitat was low, at or below 1/100 when compared to the lower limit of the DCRL.

The assessment described in this report was conducted based on the information available at the current design stage of the implementation plan for discharge into the sea. It will be reviewed as appropriate in the light of the knowledge obtained through the process of examining the design and operation of the treatment and discharge systems in accordance with the implementation plan, and from the opinions of various bodies/persons, reviews by IAEA experts, and through the cross-checks by third-party evaluation.

The conclusion of the report is that exposure to radioactivity resulting from the implementation of the planned systems for treatment and discharge of treated water from the FDNPS will fall well within established international safety limits (i.e., dose limit and DCRL), based on internationally recognized technical documents.

[13] Reference animals/plants: A specific type of animal or plant assumed to link environmental radiation exposure with dose and its impact.
[14] Derived consideration reference level (DCRL): A band of dose rates with a single-digit range for each species of organisms, defined by the ICRP. In cases where this dose rate level is exceeded, the effect on organism should be considered.

1. Purpose of Evaluation

The purpose of this radiation impact assessment shall be as follows.

Purpose 1: Assess the impact of radiation resulting from the discharge of ALPS treated water conducted by TEPCO while referring to internationally recognized technical documents (IAEA Safety Standards, ICRP Recommendations, etc.).

Purpose 2: Communicate the results of the assessment both domestically and internationally, and based on opinions received from various parties, conduct reviews, etc., as necessary, to consider ways to optimize the risk regarding discharge.

2. Principle for Assessment

Although detailed design of discharge facilities has not yet been finalized, an assessment of the dose to the representative person through systematic discharge shall be conducted in accordance with GSG-9 to confirm risk from the perspective of radiological protection for humans. Specific methodology for assessment shall be in accordance with Figure 2-1 developed by GSG-10.
GSG-10 includes assessment methods for potential exposure and environmental protection not included in GSG-9. Trial calculation of these assessment methods are also presented in Reference A and Reference B.

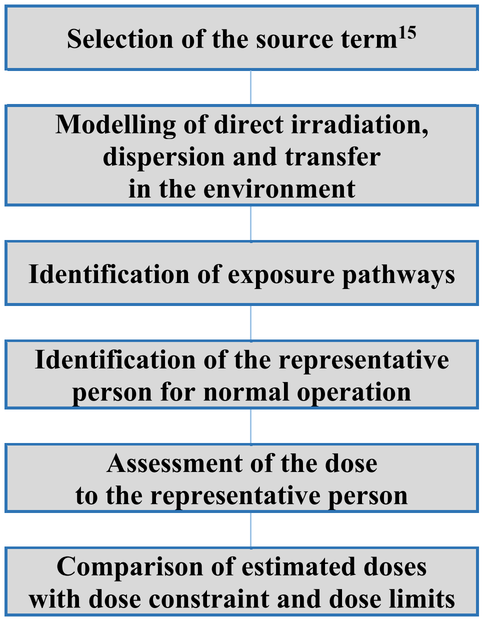


Figure 2-1 Steps for Exposure Assessment (developed from GSG-10)

[15] In this assessment, source term refers to the annual amount (total) of each radionuclide discharged which is contained in diluted ALPS treated water discharged into the sea annually.

3. Water quality and discharge method of ALPS treated water, etc.

3-1. Water quality of ALPS treated water, etc.

The ALPS treated water, etc. currently stored in tanks have been treated by ALPS, designed to remove the 62 radionuclides in contaminated water but tritium and C-14. The principles behind the selection of 62 radionuclides to be removed by ALPS are presented in Reference C.

Although ALPS is capable of treating contaminated water to levels where "the sum of the ratios" of the 62 radioactive materials, other than tritium and C-14, is less than one, approx. 70% of ALPS treated water, etc. (based on inventory of tank groups that were fulled by December 31, 2019) is "treated water to be re-purified" which contains a level of radioactive materials, other than tritium, which exceeds standards for discharge into the environment ("the sum of the ratios" of radionuclides other than tritium is less than one) due to water treated initially prior to performance enhancement being included, and the volume of treating water being prioritized to reduce additional exposure at the site boundary. Treated water to be re-purified shall continue to be treated (secondary treatment) before discharge until "the sum of the ratios" of radionuclides other than tritium is less than one, and shall be discharged after becoming ALPS treated water. The legally required concentrations of the 62 radionuclides to be removed by ALPS, Tritium, and C-14 are presented in Table 3-1.
In conducting secondary treatment using ALPS, the performance test was performed from September 2020 for two tank groups with a total capacity of 2,000m^3, and it was verified that ALPS was capable of bringing "the sum of the ratios" of radionuclides other than tritium in each tank groups to less than one [12]. Water quality of ALPS treated water, etc., including the results of the performance test for secondary treatment, is summarized in Reference D.

Table 3-1 Legally Required Concentrations of 62 radionuclides subject to be removed by ALPS, Tritium, and C-14

	Subjected radionuclides (physical half-life)	Legally required concentrations (Bq/L)		Subjected radionuclides (physical half-life)	Legally required concentrations (Bq/L)
1	H-3 (approx. 12 years)	6.0E+04	33	Te-129m (approx. 34 days)	3.0E+02
2	C-14 (approx. 5,700 years)	2.0E+03	34	I-129 (approx. 16 million years)	9.0E+00
3	Mn-54 (approx. 310 days)	1.0E+03	35	Cs-134 (approx. 2.1 years)	6.0E+01
4	Fe-59 (approx. 44 days)	4.0E+02	36	Cs-135 (approx. 2.3 million years)	6.0E+02
5	Co-58 (approx. 71 days)	1.0E+03	37	Cs-136 (approx. 13 days)	3.0E+02
6	Co-60 (approx. 5.3 years)	2.0E+02	38	Cs-137 (approx. 30 years)	9.0E+01
7	Ni-63 (approx. 100 years)	6.0E+03	39	Ba-137m (approx. 2.6 minutes)	8.0E+05
8	Zn-65 (approx. 240 days)	2.0E+02	40	Ba-140 (approx. 13 days)	3.0E+02
9	Rb-86 (approx. 19 days)	3.0E+02	41	Ce-141 (approx. 33 days)	1.0E+03
10	Sr-89 (approx. 51 days)	3.0E+02	42	Ce-144 (approx. 280 days)	2.0E+02
11	Sr-90 (approx. 29 years)	3.0E+01	43	Pr-144 (approx. 17 minutes)	2.0E+04
12	Y-90 (approx. 64 hours)	3.0E+02	44	Pr-144m (approx. 7.2 minutes)	4.0E+04
13	Y-91 (approx. 59 days)	3.0E+02	45	Pm-146 (approx. 5.5 years)	9.0E+02
14	Nb-95 (approx. 35 days)	1.0E+03	46	Pm-147 (approx. 2.6 years)	3.0E+03
15	Tc-99 (approx. 210,000 years)	1.0E+03	47	Pm-148 (approx. 5.4 days)	3.0E+02
16	Ru-103 (approx. 39 days)	1.0E+03	48	Pm-148m (approx. 41 days)	5.0E+02
17	Ru-106 (approx. 370 days)	1.0E+02	49	Sm-151 (approx. 90 years)	8.0E+03
18	Rh-103m (approx. 56 minutes)	2.0E+05	50	Eu-152 (approx. 14 years)	6.0E+02
19	Rh-106 (approx. 30 seconds)	3.0E+05	51	Eu-154 (approx. 8.6 years)	4.0E+02
20	Ag-110m (approx. 250 days)	3.0E+02	52	Eu-155 (approx. 4.8 years)	3.0E+03
21	Cd-113m (approx. 14 years)	4.0E+01	53	Gd-153 (approx. 240 days)	3.0E+03
22	Cd-115m (approx. 45 days)	3.0E+02	54	Tb-160 (approx. 72 days)	5.0E+02
23	Sn-119m (approx. 290 days)	2.0E+03	55	Pu-238 (approx. 88 years)	4.0E+00
24	Sn-123 (approx. 130 days)	4.0E+02	56	Pu-239 (approx. 24,000 years)	4.0E+00
25	Sn-126 (approx. 230,000 years)	2.0E+02	57	Pu-240 (approx. 6600 years)	4.0E+00
26	Sb-124 (approx. 60 days)	3.0E+02	58	Pu-241 (approx. 14 years)	2.0E+02
27	Sb-125 (approx. 2.8 years)	8.0E+02	59	Am-241 (approx. 430 years)	5.0E+00
28	Te-123m (approx. 120 days)	6.0E+02	60	Am-242m (approx. 140 years)	5.0E+00
29	Te-125m (approx. 57 days)	9.0E+02	61	Am-243 (approx. 7,400 years)	5.0E+00
30	Te-127 (approx. 9.4 hours)	5.0E+03	62	Cm-242 (approx. 160 days)	6.0E+01
31	Te-127m (approx. 110 days)	3.0E+02	63	Cm-243 (approx. 29 years)	6.0E+00
32	Te-129 (approx.. 70 minutes)	1.0E+04	64	Cm-244 (approx. 18 years)	7.0E+00

※The half-lives are quoted from the ICRP Publication 107 “Nuclear Decay Data for Dosimetric Calculations” [13]

Remarks) “E+number” means 10 to the numberth power

3-2. Discharge method

Within TEPCO's Action in Response to the Basic Policy, the following outlines were presented with regard to the discharge into the sea.

- Design and operation of facilities necessary for discharge into the sea shall confirm with regulations and receive necessary authorization by the Nuclear Regulation Authority.
- Treated water to be re-purified shall repeatedly undergo secondary treatment until values are definitely lower than regulatory requirements for safety ("the sum of the ratios" of radionuclides other than tritium falls to less than 1)
- The concentration of radioactive materials in ALPS treated water (tritium, 62 radionuclides and C-14) shall be measured and assessed prior to dilution and discharge, and the results of measurement /assessment shall be disclosed each time, and third party measurement/assessment also shall be conducted and their results are disclosed.
- For tritium that is difficult to remove, a large volume of sea water (at or more than 100 times) shall be used to dilute the water prior to discharge. In this way, "the sum of the ratios" of radionuclides other than tritium, shall fall to less than 0.01.
- Tritium concentration in discharged water shall be well under the Government of Japan's standards for safety regulation (legally required concentration) which is 60,000Bq/L and the World Health Organization's (WHO) guidelines for drinking water which is 10,000Bq/L. Subject concentration shall be less than 1,500Bq/L, similar to the current operational target value for discharge water concentrations from groundwater bypass and subdrain.
- Discharge into the sea shall be initiated carefully in small volumes, and the integrity of facilities, transfer steps for ALPS treated water, measurement process for the concentration of radioactive materials, assessment of diluted tritium in discharged water and status of dispersion in the sea shall be reviewed.
- In the unlikely event that failure or blackout prevents transfer equipment and dilution equipment from performing as expected, discharge shall be stopped immediately. Also, if abnormal values are detected in sea area monitoring, discharge shall be temporarily stopped and a survey shall be conducted to assess the situation. Discharge shall be recommenced only after verifying that safe discharge can be achieved.
- The upper limit for the amount of tritium discharged annually shall, for the time being, be set to 22 TBq per year, (2.2E + 13Bq) which was the operational target value at FDNPS before the accident, and standards shall be set not to exceed this value.

Specific items to be implemented, presented in TEPCO's Action in Response to the Basic Policy, are as presented in Table 3-2.

Table 3-2. Specific Items to be Implemented

Secondary treatment of treated water to be re-purified	・For treated water to be re-purified, secondary treatment shall be conducted and definitely below the regulatory requirements for safety shall be confirmed ("the sum of the ratios" of radionuclides other than tritium is less than one).
Analysis of ALPS treated water	・The results of measurement/assessment regarding concentration of radioactive materials such as tritium, 62radionuclides (radionuclides to be removed by ALPS) and C-14 in ALPS treated water, shall be disclosed each time prior to dilution and discharge, and results of measurement/assessment conducted by third parties shall also be disclosed.
Dilution and discharge (including emergency measures)	・Discharge is conducted after diluting with adequate volume of seawater (at or more than 100 times) so that the tritium concentration is adequately below the legally required concentration. In doing so, "the sum of the ratios" of radionuclides other than tritium, in discharged water shall be less than 0.01. - The tritium concentration shall be the same as the operational target value for discharge water concentration from groundwater bypass and subdrain (less than 1,500Bq per liter). ・The upper limit for the amount of tritium discharged annually shall, for the time being, be set to 22 TBq per year, which was the operational target value at FDNPS before the accident, and the limit shall be set not to exceed this value. The annual amount of tritium discharged shall be reviewed in accordance with the progress of decommissioning. ・In the unlikely event that failure or blackout prevents transfer equipment and dilution equipment from performing as expected, discharge shall be stopped immediately. ・If abnormal values are detected in sea area monitoring, temporarily stop discharge and conduct a survey to assess the situation. Recommence discharge only after verifying that safe discharge can be achieved.
Sea area monitoring	・Initiate sea area monitoring approx. one year prior to the planned period for commencing discharge, and conduct monitoring based on the enhanced plan. ・Strengthen monitoring of seawater, fish and seaweed. -In addition to the monitoring of Cs 137, focus on measuring and assessing tritium as well. -Seawater continues to be the primary sample material, but increase the number of fish and seaweed sampled. ・Disclose the results of radiation measurement taken each time when discharging. -Consider the analysis and disclosure of results by a third party.

To further reduce radiological impact on the environment, autonomous operational control values were established, as operational control prior to initiating discharge of ALPS treated water, for the eight radionuclides, which pose a relatively larger exposure impact on humans due to any cause such as concentration with fish and shellfish, etc. when legally required concentrations of them is the same. Items reviewed for setting the operational control value are presented in Reference E. Radionuclides subject to operational control and their operational control values are presented in Table 3-3.
Additionally, when discharging into the sea, impact on surrounding environment shall be confirmed and it shall be initiated with careful discharge in small scale. In the unlikely event that the dilution equipment malfunctions due to a failure or power outage, or if an abnormal value is detected by monitoring, the discharge should be stopped without fail until verifying that safe discharge can be achieved.

ALPS treated water will be diluted at or over 100 times using seawater when discharging into the sea so the tritium concentration falls to below 1,500Bq/L which is the operational value for groundwater bypass and subdrain; therefore, "the sum of the ratios" of radionuclides other than tritium to the regulatory limits shall fall to below 0.01.

Table 3-3. Operational Control Values

Subject radionuclide	Legally required concentration [Bq/L]	Operational control value [Bq/L]	Ratios of legally required concentration
C-14	2.0E+03	5.0E+02	2.50E-01
Fe-59	4.0E+02	2.0E-01	5.00E-04
Ag-110m	3.0E+02	6.0E-02	2.00E-04
Cd-113m	4.0E+01	2.0E-01	5.00E-03
Cd-115m	3.0E+02	4.0E+00	1.33E-02
Sn-119m	2.0E+03	6.0E+01	3.00E-02
Sn-123	4.0E+02	8.0E+00	2.00E-02
Sn-126	2.0E+02	4.0E-01	2.00E-03

3-3. Discharge facilities

A schematic drawing of facilities used for discharge into the sea (Figure 3-1) is presented in TEPCO's Action in Response to Basic Policy, and a trial calculation was conducted while considering the review status of discharge facilities presented below.

a Dilution/Discharge equipment consist of the sample tank for confirming concentration of radioactive material in "ALPS treated water" prior to dilution, seawater transfer pump and seawater transfer piping used to pump up and discharge sea water, treated water transfer pump and treated water transfer pipe and valves used to transfer "ALPS treated water" from the sample tank to the seawater pipe.

b Tanks installed at the center of the site premises at an elevation of 33.5m near the ALPS are used as sample tanks. One group of tanks shall consist of ten tanks with approx. 10,000m^3 capacity, and each tank shall be equipped with a mixing unit, and each tank group equipped with a circulation unit. The tanks need to function to receive, analyze and discharge simultaneously, so three tank groups are operated in rotation. The maximum discharge volume of ALPS treated water is 500m^3/day.

c The seawater transfer pump and seawater transfer piping shall be installed at 2.5m above sea level on the seaside of Units 5 and 6. To secure that the tritium concentration falls less than 1,500Bq/L through dilution using large volumes of seawater (at or more than 100 times), a flow meter shall be installed on the seawater transfer piping. There shall be three seawater transfer pumps installed to ensure conservative redundancy. In order to conduct the dilution with seawater adequately, the seawater transfer pumps shall be capable of pumping the maximum flow rate which can be measured (approx. 170,000m^3/day/unit).

d The treated water transfer pump shall be installed at 33.5m above sea level near the sample tank. A flow control valve shall be installed to adjust the flow rate when discharging ALPS treated water.

e The treated water transfer pipe shall be installed to connect the sample tank (33.5m above sea level) with the seawater pipe (2.5m above sea level). There shall be two emergency isolation valves installed on the treated water transfer pipes to enable isolation transfer of ALPS treated water in the event of an abnormality. One emergency isolation valve shall be installed near the seawater pipe to minimize the discharge of ALPS treated water in the event of an abnormality, and another valve shall be installed on the inner side of the seawall (EL. 13.5m) in the event that the former emergency isolation valve fails to function due to it becoming submerged from a tsunami, etc.

This assessment is conducted on the assumption that treated water shall be discharged from the seabed where is approx. 1 km off the coast (Figure 3-2).[16]

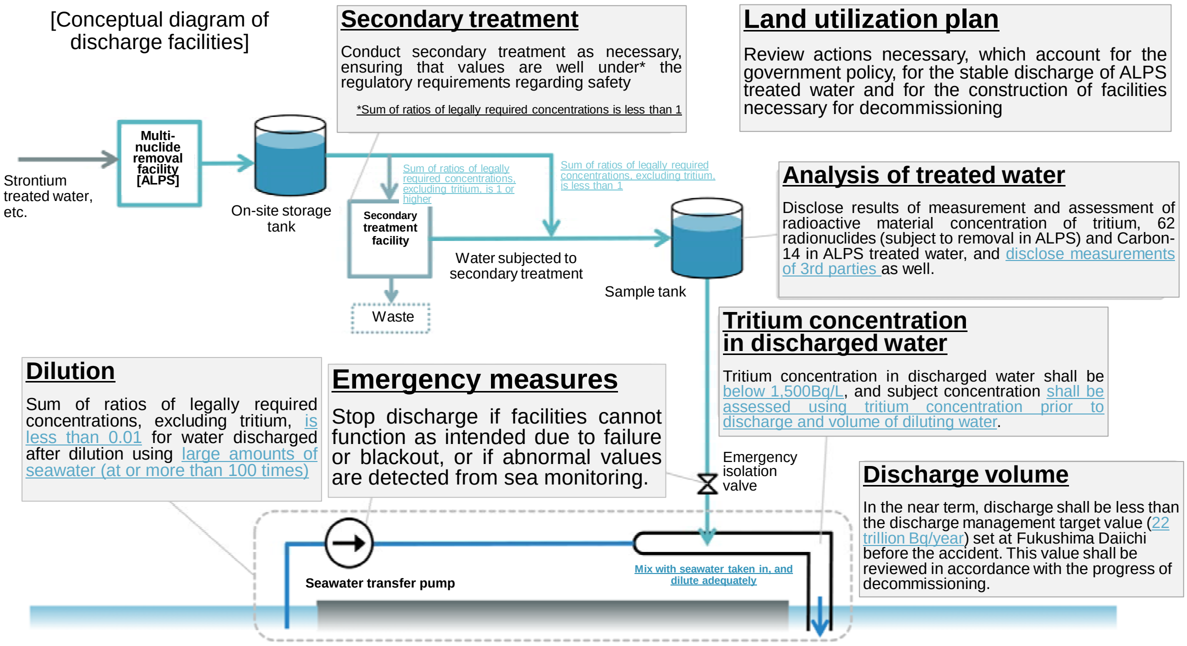
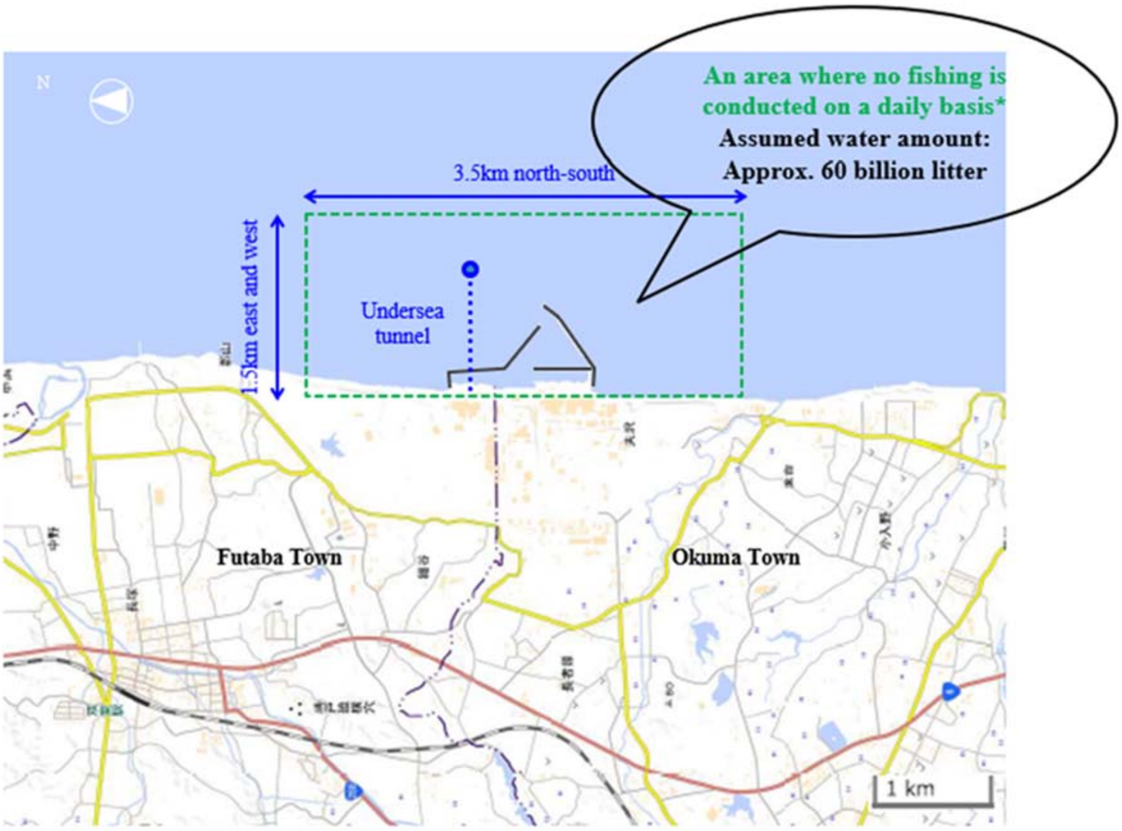


Figure 3-1 Schematic Drawing of Facilities for Discharge into the Sea

[16] This proposal is also advantageous from the viewpoint of seawater ingest for dilution, as the discharged water diffuses off the coast, compared to proposals that use existing discharge outlets.



Source: Prepared by Tokyo Electric Power Company Holdings, Inc. based on the map developed by the Geospatial Information Authority of Japan (Electronic territory web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1

※Areas where common fishery rights are not set

Figure 3-2 Discharge Location (under review)

4. Assessment Method

4-1. Source term (annually discharged amount for each radionuclide)

There are 64 radionuclides subject to radiation impact assessment for the discharge into the sea of ALPS treated water which consist of tritium, C-14 and the 62 radionuclides to be removed by ALPS (Table 3-1). TEPCO's Action in Response to the Government's Policy, the upper limit for annually tritium discharged is set to 2.2 GBq (2.2E + 13Bq), for the time being, which was the target value for discharge at FDNPS prior to the accident.

The discharge amount of 63 radionuclides, excluding tritium, is calculated based on the value calculated by multiplying the radionuclide composition in ALPS treated water (concentration for each radionuclide) and the annual discharge amount. The tritium concentration in ALPS treated water, etc. stored ranges from approx. 150,000 Bq/L to approx. 2.16 million Bq/L, and the annual discharge volume fluctuates depending on the tritium concentration of the ALPS treated water to be discharged. The annual discharge amount is inversely proportional to the tritium concentration, and the discharge amount of the 63 radionuclides other than tritium increases when the tritium concentration is lower.

The composition of radionuclides in ALPS treated water differs for each tank group, so it was decided that the assessment would be conducted assuming the discharge of ALPS treated water with multiple radionuclide compositions.

(1) Measured values of 64 radionuclides

i. K4 tank group ("the sum of the ratios" of radionuclides other than tritium is 0.29)
ii. J1-C tank group ("the sum of the ratios" of radionuclides other than tritium is 0.35)
iii. J1-G tank group ("the sum of the ratios" of radionuclides other than tritium is 0.22)

(2) The hypothetical ALPS treated water
("the sum of the ratios" of radionuclides, only selected relatively significant radionuclides, other than tritium is 1)

Source term shall be set in accordance with one of the two ways below.

(1) Source term based on the measured value of the 64 radionuclides

a The annual amount of tritium discharged shall be its upper limit, 2.2 TBq (2.2E + 13Bq).
b The annual discharge amount shall be calculated based on (1)-a and the actual tritium concentration measured.
c The annual discharge amount for each radionuclide shall be identified based on the value calculated by multiplying the measured concentration of 63 radionuclides and the annual discharge amount. Radionuclides below detectable levels shall also be calculated conservatively using the minimum detection limit.

(2) Source term based on the hypothetical ALPS treated water.

a The annual discharge amount of tritium shall be its upper limit, 2.2 GBq (2.2E + 13Bq).
b By setting the tritium concentration in ALPS treated water used for assessment as a lower value: 100,000Bq/L, which is less than the lowest tritium concentration confirmed so far (approx. 150,000 Bq / L), the annual discharge amount of ALPS treated water shall be estimated at a higher value, 2.2E+0.8L. Consequently, the annual discharge amount for radionuclides other than tritium shall also be estimated at a higher value.
c Within the 63 radionuclides other than tritium, the concentration of eight radionuclides with relatively significant impact on exposure subject to operational control shall be set using the operational control value which is the upper limit. "The sum of the ratios" of eight radionuclides is 0.32.
d For the other 55 radionuclides, Zn-65, the radionuclide with the most significant impact next to the eight radionuclides subject to operational control, shall be used as the representative radionuclide, and the concentration of Zn-65 shall be set to 140Bq/L,

equivalent to 0.68 for its ratio of legally required concentration. "The sum of the ratios" of radionuclides other than tritium becomes one, which is the upper limit for discharge control value.

e The concentration of the eight radionuclides subject to operational control and Zn-65 shall be multiplied with the annual discharge amount in (2)-b to set the annual discharge amount for the nine radionuclides.

As indicated in 3-2., when actually discharging ALPS treated water into the sea, the water shall be diluted at or over 100 times with seawater so the tritium concentration falls to below 1,500Bq/L which is the operational limit for groundwater bypass and subdrain system. Therefore, "the sum of the ratios" of radionuclides other than tritium shall fall to less than 0.01.

4-2. Modelling of dispersion and transfer after discharge,

a Dispersion calculation at the sea area

The regional sea model "ROMS: Regional Ocean Modeling System" applied to the Fukushima coast by the Central Research Institute of Electric Power Industry shall be used. This model has been confirmed to have high reproducibility based on comparisons between reproductive calculation of Cs concentration in the sea from the Fukushima Daiichi accident using past meteorological and hydrographic data, and data from actual measurements. (Tsumune et al., 2020) [9] This model was also used in "TEPCO Draft Study Responding to the Subcommittee Report on Handling ALPS Treated Water" [14] disclosed on March 24, 2020. Based on this model, concentration was calculated using a model with enhanced resolution of the sea area surrounding the FDNPS to precisely set the discharge location and facilities at the power station and harbor. It was confirmed that reproducibility of Cs concentration in the sea due to the accident at FDNPS was enhanced due to the enhancement of resolution.

Key conditions for calculation are as follows.

Flow data for the sea area

- Data interpolating short term weather forecast data from the Meteorological Agency was used for the driving force of the sea surface (Hashimoto et al., 2010) [15].
- Sea reanalysis data (JCOPE2(Miyazawa et al., 2009) [16] was used as original data for the sea boundary conditions and data assimilation (nudging) [17]

Scope of model (refer to figure 4-1)

Resolution (general) : North south abt. 925m x East west abt. 735m (approx. 1km), Vertical direction: 30 layers

Resolution (close-up) : North south abt. 185m x East west abt. 147m (approx. 200m), Vertical direction: 30 layers

Scope of model : North latitude 35.30- 39.71 degrees,
East longitude 140.30 -143.50 degrees (490km x 270km),
North south abt. 22.5m x East west abt. 8.4m around the NPS
The resolution of the sea area between the blue and red lines in Figure 4-1 is gradually increased from abt. 1km mesh so that the sea area, where the red and blue hatches intersect indicating above, are becomes a 200m mesh

[17] Data assimilation: A method of combining actual measured data with a simulation.

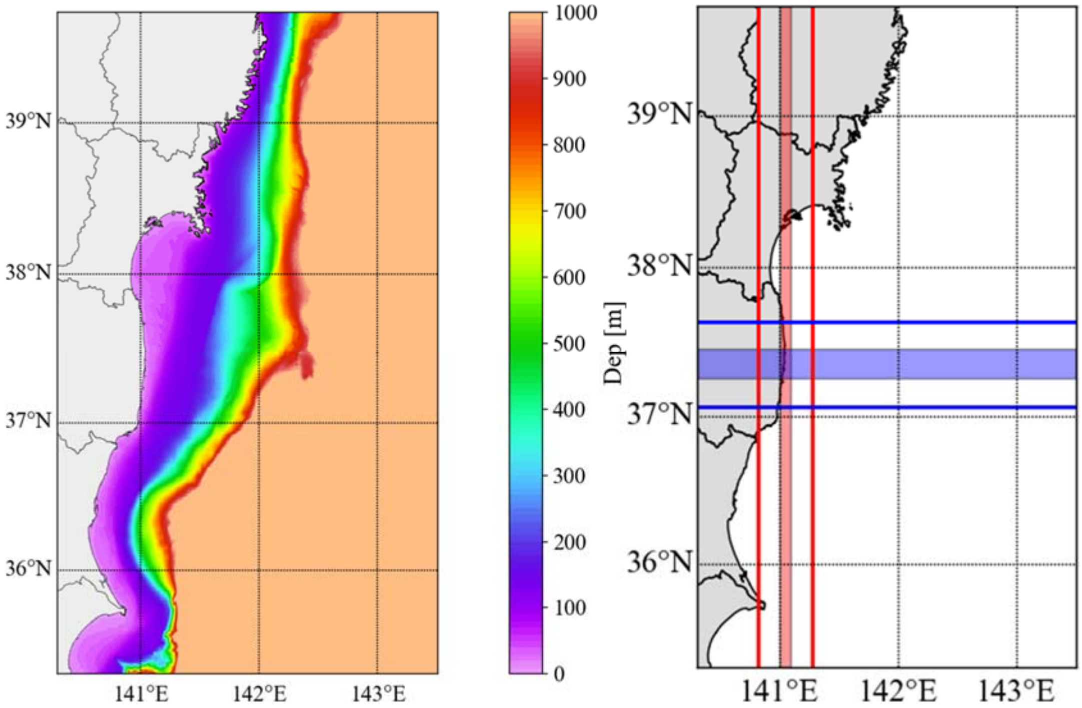


Figure 4-1 Scope of the Model and Distribution of Depth

(The resolution of the sea area between the blue and red lines that intersect indicating above, are becomes a 200m mesh

b Transfer model

The transfer model for radioactive materials discharged into the sea shall be considered with following items.

(1) Transfer and dispersion via sea current
(2) Transfer and dispersion via sea current → Adhesion to ship hull
(3) Transfer and dispersion via sea current → Adhesion to sand on the beach
(4) Transfer and dispersion via sea current → Adhesion to fishing nets
(5) Transfer and dispersion via sea current → Ingestion of marine products such as fishery and concentration

4-3. Identifying exposure pathways

The assessment model and parameters for each exposure pathway are presented below.

a External exposure

(1) External exposure received from sea surface when working on the sea

External exposure received from radioactive materials in seawater when working on the sea shall be assessed using the model presented in Figure 4-2.

The equation for effective dose D_1 (mSv/year) from sea surface radiation is presented in equation (1)

$$D_1 = \sum_i (K_1)_i \cdot (x_1)_i \cdot t_1 \quad (1)$$

In this equation,

$(K_1)_i$ is the effective dose conversion factor ((mSv/h)/(Bq/L)) of gamma rays of the radionuclide *i* from sea surface,

$(x_1)_i$ is the concentration of radionuclide *i* in seawater (Bq/L)

t_1 is the number of hours exposed annually (h/year)

The effective dose conversion factor for gamma rays emitted from sea surface were quoted from the value in the Handbook Assessing the Impact of Decommissioning on the Environment [17] (hereinafter “Decommissioning handbook”). For the calculation of the effective dose conversion factor, the simple shielding calculation code QAD-CGGP2 using the Point-Kernel method is used. For the radionuclides not indicated in the Decommissioning handbook, beta and gamma radionuclides used the largest conservative values for Co-60 and alpha-emitting radionuclides used Am-243 respectively (Table 4-1). The number of hours exposed annually is shown in 4-4.

The assessment point shall be the sea area outside the boundary, where no fishing is conducted in on a daily basis, in front of the power station where general ships such as fishing boats do not regularly enter the area. As the distance to the closest harbor is at or more than 5 km away, the concentration of radioactive materials in the sea used for assessment was set to be the annual average of sea surface (top layer) concentration within an area 10km*10km which includes the area where no fishing is conducted in on a daily basis. A map of the sea area around the power station is presented in Figure 4-3. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

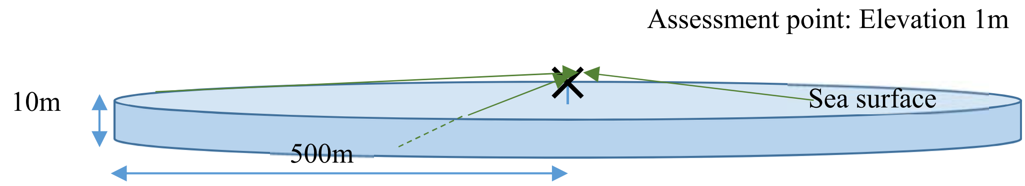


Figure 4-2 Model for Assessment of Exposure from Sea surface, Decommissioning Handbook

Figure 4-3 Area Map for the Calculation of Concentration in Seawater for Assessment
Source: Prepared by Tokyo Electric Power Company Holdings, Inc. based on the map developed by the Geospatial Information Authority of Japan (Electronic territory web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1

(2) External exposure during the work on the sea from radioactive material adhering to ship hull

External exposure during the work on the sea received from radioactive materials that have transferred from seawater to ship hull shall be assessed using the model presented in Figure 4-4.

The equation for effective dose D_2 (mSv/year) from ship hull is presented in equations (2) and (3).

$$D_2 = \sum_i (K_2)_i \cdot (S_2)_i \cdot t_2 \tag{2}$$

$$(S_2)_i = (F_2)_i \cdot (x_2)_i \tag{3}$$

In this equation,

$(K_2)_i$ is the effective dose conversion factor ((mSv/h)/(Bq/m^2)) of gamma rays of the radionuclide *i* adhering to the ship hull

$(S_2)_i$ is the contamination density (Bq/m^2) of radionuclide *i* adhering to the ship hull

t_2 is the number of exposed hours annually (h/year)

$(F_2)_i$ is the transfer factor ((Bq/m^2)/(Bq/L)) of the radionuclide *i* from sea to the ship hull

$(x_2)_i$ is the concentration of the radionuclide *i* in seawater (Bq/L) at the assessment point

The values in the Decommissioning handbook were used for the effective dose conversion factor from gamma rays of radioactive materials adhering to ship hull. For the calculation of the effective dose conversion factor, the simple shielding calculation code QAD-CGGP2 using the Point-Kernel method is used. For the radionuclides not indicated in the Decommissioning handbook, beta and gamma radionuclides used the largest conservative values for Co-60 and alpha-emitting radionuclides used Am-243 respectively (Table 4-2). The number of hours exposed annually is shown in 4-4. The transfer factor to the ship hull was set to 100((Bq/m^2)/(Bq/L)) based on the "Application for reprocessing business" (Japan Nuclear Fuel Service,1989) [18].
The concentration of radioactive materials in seawater at the assessment point and values used for assessment are the same as the values used in (1) External exposure received from sea surface when working on the sea. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

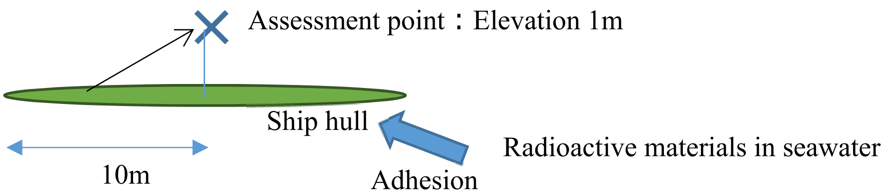


Figure 4-4 Model for Assessment of Exposure from Ship Hull, Decommissioning Handbook

(3) External exposure from swimming and underwater work

Assessment shall be conducted using a submersion model[18] regarding external exposure received from γ rays of radioactive materials in surrounding seawater when swimming and underwater work.

The equation for the effective dose D_3 (mSv/year) received from seawater radiation when swimming and underwater work is presented in equation (4).

$$D_3 = \sum_i (K_3)_i \cdot (x_3)_i \cdot t_3 \quad (4)$$

In this equation,
$(K_3)_i$ is the effective dose conversion factor ((mSv/h)/(Bq/L)) of radionuclide i by gamma rays from seawater
$(x_3)_i$ is the concentration of radionuclide i in seawater (Bq/L)
t_3 is the number of hours exposed annually (h/year)

Values from the Decommissioning handbook were used for the effective dose conversion factor by gamma rays from seawater. For the radionuclides not indicated in the Decommissioning handbook, beta and gamma radionuclides used the largest conservative values for Co-60 and alpha-emitting radionuclides used Am-243 respectively (Table 4-3). The number of hours exposed annually is shown in 4-4.

The concentration of radioactive materials in seawater at the assessment point and values used for assessment is the same as the values used in (1) External exposure received from sea surface when working on the sea, but average concentration for all layers from sea

18 A model that calculates the exposure received from surrounding radioactive materials when the subject is in a situation of being surrounded by radioactive materials

surface to seabed shall be used as exposure takes place from underwater. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

(4) External exposure at the beach

The assessment shall be conducted on the assumption of the model shown in Figure 4-5 for external exposure received when staying on a beach from radioactive materials that have transferred from the surface of seawater to sand on the beach.

The equation for the effective dose D_4 (mSv/year) received by gamma rays from the beach sand is presented in equation (5).

$$D_4 = \sum_i (K_4)_i \cdot (x_4)_i \cdot (F_4)_i \cdot t_4 \quad (5)$$

In this equation,

$(K_4)_i$ is the effective dose conversion factor ((mSv/h)/(Bq/kg)) of radionuclide i by gamma rays from beach sand

$(x_4)_i$ is the concentration of radionuclide i in seawater (Bq/L)

$(F_4)_i$ is the transfer coefficient ((Bq/kg)/(Bq/L)) of radionuclide i from seawater to beach sand

t_4 is the number of hours exposed annually (h/year)

Values from the Decommissioning handbook were used for the effective dose conversion factor by γ rays from seawater. For the calculation of the effective dose conversion factor, the simple shielding calculation code QAD-CGGP2 using the Point-Kernel method is used. For the radionuclides not indicated in the Decommissioning handbook, beta and gamma radionuclides used the largest conservative values for Co-60 and alpha-emitting radionuclides used Am-243 respectively (Table 4-4). The transfer coefficient of radionuclides on beach sand was set at 1,000 ((Bq/kg)/(Bq/L)) for all radionuclides in accordance with “Public dose assessment guideline for safety review of nuclear power light water reactor”. The number of hours exposed annually is shown in 4-4.

The assessment point is located at a beach beyond the boundaries of the area where no fishing is conducted on daily basis indicated in Figure 4-3. The principles for the concentration of radioactive materials in seawater used for assessment are the same as (1) External exposure received from sea surface when working on the sea. The average concentration for all layers shall be used for the coastal area on the assumption that seawater from both shallow and deep areas become mixed. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

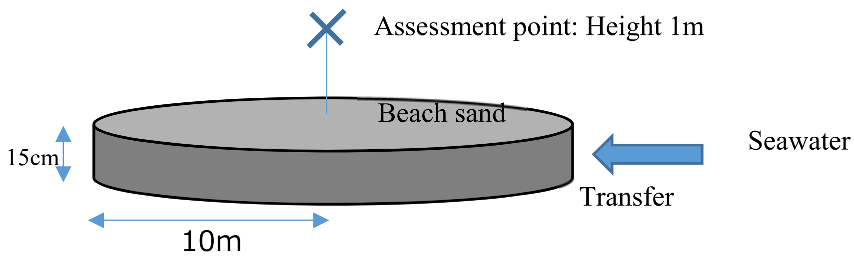


Figure 4-5 Model for Assessment of Exposure from Beach Sand, Decommissioning Handbook

(5) External exposure from radioactive material adhering to fishing net

The assessment shall be conducted on the assumption of the model shown in Figure 4-6 for external exposure during fishing work received from radioactive materials adhering to fishing nets carried on deck or on dry land which have been contaminated with radioactive materials transferred from seawater.

The equation for the effective dose D_5 (mSv/year) from radioactive materials adhering to fishing nets is presented in equations (6) and (7).

$$D_5 = \sum_i (K_5)_i \cdot (S_5)_i \cdot t_5 \quad (6)$$

$$(S_5)_i = (F_5)_i \cdot (x_5)_i \quad (7)$$

In this equation,

$(K_5)_i$ is the effective dose conversion factor ((mSv/h)/(Bq/kg)) of gamma rays of radionuclide i on the fishing net

$(S_5)_i$ is the concentration of radionuclide i on the fishing net (Bq/kg)

t_5 is the number of hours exposed annually (h/year)

$(F_5)_i$ is the transfer coefficient ((Bq/kg)/(Bq/L)) of radionuclide i from seawater to fishing net

$(x_5)_i$ is the underwater concentration (Bq/L) of radionuclide i in the sea area where fishing nets are used

Values from the Decommissioning handbook were used for the effective dose conversion factor. For the calculation of the effective dose conversion factor, the simple shielding calculation code QAD-CGGP2 using the Point-Kernel method is used. For the radionuclides not indicated in the Decommissioning handbook, beta and gamma radionuclides used the largest conservative values for Co-60 and alpha-emitting radionuclides used Am-243 respectively (Table 4-5). The number of hours exposed annually is shown in 4-4. The transfer coefficient was set to 4,000 ((Bq/kg)/(Bq/L)) for all radionuclides except for tritium in accordance with the “Application for Reprocessing Business”.
The assessment point and the principles for the concentration of radioactive materials underwater are the same as (1) External exposure received from sea surface when working on the sea. The average concentration of all layers shall be used as fishing nets subjected to various layers will be used depending the type of fish sampled. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

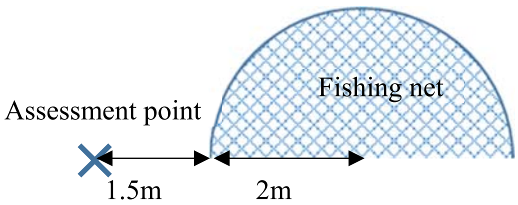


Figure 4-6 Model for Assessment of Exposure from Fishing Net, Decommissioning Handbook

b Internal exposure

The model below shall be used to assess internal exposure due to ingestion of marine products contaminated with radioactive materials transferred from seawater.

The equation for the effective dose D_6 (mSv/year) from radioactive materials due to ingestion of marine products is presented in equations (8) and (9)

$$D_6 = \sum_k \sum_i (K_F^{50})_i \cdot H_{ki} \quad (8)$$

$$H_{ki} = 365 \cdot 10^{-3} \cdot x_i \cdot (CF)_{ki} \cdot F_k \cdot W_k \cdot f_{ki} \quad (9)$$

In this equation,

$(K_F^{50})_i$ is the effective dose coefficient ((mSv)/(Bq)) of ingested radionuclide *i*

H_{ki} is the ingestion rate (Bq/year) of radionuclide *i* based on marine products

x_i is the concentration of radionuclide *i* in seawater

$(CF)_{ki}$ is the concentration factor ((Bq/kg)/(Bq/L))[19] of radionuclide *i* for marine product k

F_k is the dilution factor regarding ratio of marine products contaminated with radioactive materials (hereinafter referred to "market dilution")

W_k is the amount of marine product k ingested (g/day)

f_{ki} is the ratio of attenuation for radionuclide i from gathering to ingestion of marine product k

$365 \cdot 10^{-3}$ is a coefficient based on unit conversion (365 days/year, 10^{-3}kg/g)

The value in ICRP Publication 72 "Age-dependent Doses to Members of the Public from Ingest of Radionuclides; Part 5 Compilation of Ingestion and inhalation Dose Coefficients"[19] was used for the effective dose coefficient by ingestion (Table 4-6).

The distance to the closest fishing port is 5km or more; therefore, the area, where no fishing is conducted on daily basis, is set to be 10km x10km around the power station, and the concentration of radioactive materials underwater was set to be the average concentration in the area 10km x 10km around the power station including the area where common fishery rights are not set. The average concentration of all layers shall be used. (Detail calculation method of concentration in seawater is shown in 5-1, 5-2, 5-3.)

The value in IAEA Technical Reports Series No.422 "Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment" [20] and UCRL-50564 Rev.1 "CONCENTRATION FACTORS OF CHEMICAL ELEMENTS IN EDIBLE AQUATIC ORGANISMS" [21] was used for the concentration factor of marine products (Table 4-7).

The amount of marine product ingestion is shown in 4-4. The attenuation of radionuclide was dismissed for market dilution and the period from gathering to ingestion of marine products.

4-4. Identifying the representative person subject to exposure assessment

Characteristics of the representative person subject to exposure assessment were set as presented below in accordance with the "Public dose assessment guideline for safety review of nuclear power light water reactor", etc.

・Conducts fishing for 120 days (2,880 hours) annually of which 80 days (1,920 hours) are spent working near fishing nets.

・Stays on the beach for 500 hours, and swims 96 hours annually.

・The amount of marine products ingestion was assessed using the two cases below while referring to the amount of ingest by food group in the "FY2019 National Health and Nutrition Survey" disclosed by Ministry of Health、Labour and Welfare.

[19] A convenient factor shows the relationship between the radionuclide concentration (per wet weight) in marine life (edible parts as a rule) with respect to the radionuclide concentration in the living environment. It is used in the assessment model for transfer to life.

(1) Person ingesting an average amount of marine products

The average ingestion amount by persons aged 20 years or older was set as the adult value, and values for children and infants were set at 1/2 and 1/5 the amount consumed by adults respectively in accordance with the “Guidelines for the Assessment of Target Dose Values Around Commercial Light Water Reactor Facilities”[22]

(2) Person ingesting large amounts of marine products

Adult value was set by adding two times the standard deviation value to the average ingestion amount

4-5. Exposure assessment method

The exposure calculation shall be conducted in accordance with the assessment methods described in 4-1 to 4-4.

The calculation result shall be compared with the public dose limit 1mSv/year. Since the concept of dose constraint value is not applied in Japan, the comparison with the target dose value for domestic nuclear power stations, 0.05mSv/year, which is set as the target of optimization, shall be also.

Table 4-1 Effective Dose Conversion Factor of Radiation from Sea Surface

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/L))	Remarks
H-3	5.4E-15	
C-14	3.7E-12	
Mn-54	1.7E-07	
Fe-59	3.2E-11	
Co-58	2.0E-07	
Co-60	5.0E-07	
Ni-63	2.3E-13	
Zn-65	1.2E-07	
Rb-86	5.0E-07	Set to same value as Co-60 conservatively
Sr-89	5.0E-07	Set to same value as Co-60 conservatively
Sr-90	1.6E-09	
Y-90	–	Included in parent radionuclide Sr-90
Y-91	5.0E-07	Set to same value as Co-60 conservatively
Nb-95	5.0E-07	Set to same value as Co-60 conservatively
Tc-99	1.5E-11	
Ru-103	5.0E-07	Set to same value as Co-60 conservatively
Ru-106	4.5E-08	
Rh-103m	–	Included in parent radionuclide Ru-103
Rh-106	–	Included in parent radionuclide Ru-106
Ag-110m	5.0E-07	Set to same value as Co-60 conservatively
Cd-113m	7.4E-11	
Cd-115m	5.0E-07	Set to same value as Co-60 conservatively
Sn-119m	5.0E-07	Set to same value as Co-60 conservatively
Sn-123	5.0E-07	Set to same value as Co-60 conservatively
Sn-126	1.1E-08	
Sb-124	5.0E-07	Set to same value as Co-60 conservatively
Sb-125	8.7E-08	
Te-123m	5.0E-07	Set to same value as Co-60 conservatively
Te-125m	6.6E-09	
Te-127	5.0E-07	Set to same value as Co-60 conservatively
Te-127m	5.0E-07	Set to same value as Co-60 conservatively
Te-129	–	Included in parent radionuclide Te-129m
Te-129m	5.0E-07	Set to same value as Co-60 conservatively
I-129	4.6E-09	
Cs-134	3.1E-07	
Cs-135	5.0E-07	Set to same value as Co-60 conservatively
Cs-136	5.0E-07	Set to same value as Co-60 conservatively

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/L))	Remarks
Cs-137	1.2E-07	
Ba-137m	−	Included in parent radionuclide Cs-137
Ba-140	5.0E-07	Set to same value as Co-60 conservatively
Ce-141	5.0E-07	Set to same value as Co-60 conservatively
Ce-144	1.3E-08	
Pr-144	−	Included in parent radionuclide Ce-144
Pr-144m	−	Included in parent radionuclide Ce-144
Pm-146	5.0E-07	Set to same value as Co-60 conservatively
Pm-147	8.2E-12	
Pm-148	5.0E-07	Set to same value as Co-60 conservatively
Pm-148m	5.0E-07	Set to same value as Co-60 conservatively
Sm-151	1.7E-12	
Eu-152	2.3E-07	
Eu-154	2.5E-07	
Eu-155	5.0E-07	Set to same value as Co-60 conservatively
Gd-153	5.0E-07	Set to same value as Co-60 conservatively
Tb-160	5.0E-07	Set to same value as Co-60 conservatively
Pu-238	4.7E-11	
Pu-239	2.6E-11	
Pu-240	4.6E-11	
Pu-241	2.9E-08	
Am-241	4.6E-09	
Am-242m	3.1E-09	
Am-243	4.4E-08	
Cm-242	4.8E-11	
Cm-243	4.4E-08	Set to same value as Am-243 conservatively
Cm-244	4.5E-11	

Table 4-2 Effective Dose Conversion Factor of γ Ray from Ship

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/m^2))	Remarks
H-3	1.4E-14	
C-14	1.3E-12	
Mn-54	1.4E-09	
Fe-59	4.2E-12	
Co-58	1.6E-09	
Co-60	3.5E-09	

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/m^2))	Remarks
Ni-63	2.5E-13	
Zn-65	1.0E-09	
Rb-86	3.5E-09	Set to same value as Co-60 conservatively
Sr-89	3.5E-09	Set to same value as Co-60 conservatively
Sr-90	5.8E-11	
Y-90	–	Included in parent radionuclide Sr-90
Y-91	3.5E-09	Set to same value as Co-60 conservatively
Nb-95	3.5E-09	Set to same value as Co-60 conservatively
Tc-99	2.8E-12	
Ru-103	3.5E-09	Set to same value as Co-60 conservatively
Ru-106	4.0E-10	
Rh-103m	–	Included in parent radionuclide Ru-103
Rh-106	–	Included in parent radionuclide Ru-106
Ag-110m	3.5E-09	Set to same value as Co-60 conservatively
Cd-113m	7.2E-12	
Cd-115m	3.5E-09	Set to same value as Co-60 conservatively
Sn-119m	3.5E-09	Set to same value as Co-60 conservatively
Sn-123	3.5E-09	Set to same value as Co-60 conservatively
Sn-126	2.3E-10	
Sb-124	3.5E-09	Set to same value as Co-60 conservatively
Sb-125	8.3E-10	
Te-123m	3.5E-09	Set to same value as Co-60 conservatively
Te-125m	4.4E-10	
Te-127	3.5E-09	Set to same value as Co-60 conservatively
Te-127m	3.5E-09	Set to same value as Co-60 conservatively
Te-129	–	Included in parent radionuclide Te-129m
Te-129m	3.5E-09	Set to same value as Co-60 conservatively
I-129	3.0E-10	
Cs-134	2.4E-09	
Cs-135	3.5E-09	Set to same value as Co-60 conservatively
Cs-136	3.5E-09	Set to same value as Co-60 conservatively
Cs-137	9.5E-10	
Ba-137m	–	Included in parent radionuclide Cs-137
Ba-140	3.5E-09	Set to same value as Co-60 conservatively
Ce-141	3.5E-09	Set to same value as Co-60 conservatively
Ce-144	1.6E-10	
Pr-144	–	Included in parent radionuclide Ce-144

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/m^2))	Remarks
Pr-144m	−	Included in parent radionuclide Ce-144
Pm-146	3.5E-09	Set to same value as Co-60 conservatively
Pm-147	1.9E-12	
Pm-148	3.5E-09	Set to same value as Co-60 conservatively
Pm-148m	3.5E-09	Set to same value as Co-60 conservatively
Sm-151	8.7E-13	
Eu-152	1.8E-09	
Eu-154	1.8E-09	
Eu-155	3.5E-09	Set to same value as Co-60 conservatively
Gd-153	3.5E-09	Set to same value as Co-60 conservatively
Tb-160	3.5E-09	Set to same value as Co-60 conservatively
Pu-238	1.1E-10	
Pu-239	3.9E-11	
Pu-240	1.0E-10	
Pu-241	7.7E-10	
Am-241	2.0E-10	
Am-242m	8.3E-10	
Am-243	1.1E-09	
Cm-242	1.1E-10	
Cm-243	1.1E-09	Set to same value as Am-243 conservatively
Cm-244	1.0E-10	

Table 4-3 Effective Dose Conversion Factor for Exposure from Seawater Radiation When Swimming and Underwater Work

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/L))	Remarks
H-3	0.0E+00	
C-14	0.0E+00	
Mn-54	4.8E-07	
Fe-59	6.8E-07	
Co-58	4.7E-07	
Co-60	1.4E-06	
Ni-63	0.0E+00	
Zn-65	3.3E-07	
Rb-86	1.4E-06	Set to same value as Co-60 conservatively
Sr-89	1.4E-06	Set to same value as Co-60 conservatively
Sr-90	7.2E-13	

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/L))	Remarks
Y-90	−	Included in parent radionuclide Sr-90
Y-91	1.4E-06	Set to same value as Co-60 conservatively
Nb-95	1.4E-06	Set to same value as Co-60 conservatively
Tc-99	4.0E-13	
Ru-103	1.4E-06	Set to same value as Co-60 conservatively
Ru-106	1.2E-07	
Rh-103m	−	Included in parent radionuclide Ru-103
Rh-106	−	Included in parent radionuclide Ru-106
Ag-110m	1.4E-06	Set to same value as Co-60 conservatively
Cd-113m	4.2E-11	
Cd-115m	1.4E-06	Set to same value as Co-60 conservatively
Sn-119m	1.4E-06	Set to same value as Co-60 conservatively
Sn-123	1.4E-06	Set to same value as Co-60 conservatively
Sn-126	3.2E-08	
Sb-124	1.4E-06	Set to same value as Co-60 conservatively
Sb-125	2.5E-07	
Te-123m	1.4E-06	Set to same value as Co-60 conservatively
Te-125m	2.0E-08	
Te-127	1.4E-06	Set to same value as Co-60 conservatively
Te-127m	1.4E-06	Set to same value as Co-60 conservatively
Te-129	−	Included in parent radionuclide Te-129m
Te-129m	1.4E-06	Set to same value as Co-60 conservatively
I-129	1.4E-08	
Cs-134	9.0E-07	
Cs-135	1.4E-06	Set to same value as Co-60 conservatively
Cs-136	1.4E-06	Set to same value as Co-60 conservatively
Cs-137	3.4E-07	
Ba-137m	−	Included in parent radionuclide Cs-137
Ba-140	1.4E-06	Set to same value as Co-60 conservatively
Ce-141	1.4E-06	Set to same value as Co-60 conservatively
Ce-144	2.8E-08	
Pr-144	−	Included in parent radionuclide Ce-144
Pr-144m	−	Included in parent radionuclide Ce-144
Pm-146	1.4E-06	Set to same value as Co-60 conservatively
Pm-147	2.5E-12	
Pm-148	1.4E-06	Set to same value as Co-60 conservatively
Pm-148m	1.4E-06	Set to same value as Co-60 conservatively

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/L))	Remarks
Sm-151	8.3E-12	
Eu-152	6.6E-07	
Eu-154	6.4E-07	
Eu-155	1.4E-06	Set to same value as Co-60 conservatively
Gd-153	1.4E-06	Set to same value as Co-60 conservatively
Tb-160	1.4E-06	Set to same value as Co-60 conservatively
Pu-238	1.1E-09	
Pu-239	5.2E-10	
Pu-240	9.9E-10	
Pu-241	8.1E-08	
Am-241	1.9E-08	
Am-242m	1.4E-08	
Am-243	1.4E-07	
Cm-242	1.1E-09	
Cm-243	1.4E-07	Set to same value as Am-243 conservatively
Cm-244	9.0E-10	

Table 4-4 Effective Dose Conversion Factor for γ Ray from Beach Sand

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
H-3	4.3E-15	
C-14	1.4E-12	
Mn-54	1.6E-07	
Fe-59	1.6E-11	
Co-58	1.9E-07	
Co-60	4.7E-07	
Ni-63	1.1E-13	
Zn-65	1.1E-07	
Rb-86	4.7E-07	Set to same value as Co-60 conservatively
Sr-89	4.7E-07	Set to same value as Co-60 conservatively
Sr-90	1.2E-09	
Y-90	−	Included in parent radionuclide Sr-90
Y-91	4.7E-07	Set to same value as Co-60 conservatively
Nb-95	4.7E-07	Set to same value as Co-60 conservatively
Tc-99	6.3E-12	
Ru-103	4.7E-07	Set to same value as Co-60 conservatively
Ru-106	4.3E-08	

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
Rh-103m	−	Included in parent radionuclide Ru-103
Rh-106	−	Included in parent radionuclide Ru-106
Ag-110m	4.7E-07	Set to same value as Co-60 conservatively
Cd-113m	4.1E-11	
Cd-115m	4.7E-07	Set to same value as Co-60 conservatively
Sn-119m	4.7E-07	Set to same value as Co-60 conservatively
Sn-123	4.7E-07	Set to same value as Co-60 conservatively
Sn-126	5.2E-09	
Sb-124	4.7E-07	Set to same value as Co-60 conservatively
Sb-125	8.3E-08	
Te-123m	4.7E-07	Set to same value as Co-60 conservatively
Te-125m	1.9E-09	
Te-127	4.7E-07	Set to same value as Co-60 conservatively
Te-127m	4.7E-07	Set to same value as Co-60 conservatively
Te-129	−	Included in parent radionuclide Te-129m
Te-129m	4.7E-07	Set to same value as Co-60 conservatively
I-129	1.3E-09	
Cs-134	3.1E-07	
Cs-135	4.7E-07	Set to same value as Co-60 conservatively
Cs-136	4.7E-07	Set to same value as Co-60 conservatively
Cs-137	1.2E-07	
Ba-137m	−	Included in parent radionuclide Cs-137
Ba-140	4.7E-07	Set to same value as Co-60 conservatively
Ce-141	4.7E-07	Set to same value as Co-60 conservatively
Ce-144	1.0E-08	
Pr-144	−	Included in parent radionuclide Ce-144
Pr-144m	−	Included in parent radionuclide Ce-144
Pm-146	4.7E-07	Set to same value as Co-60 conservatively
Pm-147	3.5E-12	
Pm-148	4.7E-07	Set to same value as Co-60 conservatively
Pm-148m	4.7E-07	Set to same value as Co-60 conservatively
Sm-151	6.3E-13	
Eu-152	2.1E-07	
Eu-154	2.3E-07	
Eu-155	4.7E-07	Set to same value as Co-60 conservatively
Gd-153	4.7E-07	Set to same value as Co-60 conservatively
Tb-160	4.7E-07	Set to same value as Co-60 conservatively

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
Pu-238	3.6E-11	
Pu-239	2.1E-11	
Pu-240	3.5E-11	
Pu-241	2.0E-08	
Am-241	1.7E-09	
Am-242m	2.0E-09	
Am-243	3.1E-08	
Cm-242	3.7E-11	
Cm-243	3.1E-08	Set to same value as Am-243 conservatively
Cm-244	3.6E-11	

Table 4-5 Effective Dose Conversion Factor for γ Ray from Fishing Nets

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
H-3	1.9E-16	
C-14	1.5E-13	
Mn-54	3.2E-08	
Fe-59	2.2E-12	
Co-58	3.7E-08	
Co-60	9.9E-08	
Ni-63	7.8E-15	
Zn-65	2.3E-08	
Rb-86	9.9E-08	Set to same value as Co-60 conservatively
Sr-89	9.9E-08	Set to same value as Co-60 conservatively
Sr-90	2.1E-10	
Y-90	−	Included in parent radionuclide Sr-90
Y-91	9.9E-08	Set to same value as Co-60 conservatively
Nb-95	9.9E-08	Set to same value as Co-60 conservatively
Tc-99	7.9E-13	
Ru-103	9.9E-08	Set to same value as Co-60 conservatively
Ru-106	8.2E-09	
Rh-103m	−	Included in parent radionuclide Ru-103
Rh-106	−	Included in parent radionuclide Ru-106
Ag-110m	9.9E-08	Set to same value as Co-60 conservatively
Cd-113m	5.9E-12	
Cd-115m	9.9E-08	Set to same value as Co-60 conservatively
Sn-119m	9.9E-08	Set to same value as Co-60 conservatively

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
Sn-123	9.9E-08	Set to same value as Co-60 conservatively
Sn-126	7.0E-10	
Sb-124	9.9E-08	Set to same value as Co-60 conservatively
Sb-125	1.5E-08	
Te-123m	9.9E-08	Set to same value as Co-60 conservatively
Te-125m	2.3E-10	
Te-127	9.9E-08	Set to same value as Co-60 conservatively
Te-127m	9.9E-08	Set to same value as Co-60 conservatively
Te-129	−	Included in parent radionuclide Te-129m
Te-129m	9.9E-08	Set to same value as Co-60 conservatively
I-129	1.6E-10	
Cs-134	5.9E-08	
Cs-135	9.9E-08	Set to same value as Co-60 conservatively
Cs-136	9.9E-08	Set to same value as Co-60 conservatively
Cs-137	2.2E-08	
Ba-137m	−	Included in parent radionuclide Cs-137
Ba-140	9.9E-08	Set to same value as Co-60 conservatively
Ce-141	9.9E-08	Set to same value as Co-60 conservatively
Ce-144	2.0E-09	
Pr-144	−	Included in parent radionuclide Ce-144
Pr-144m	−	Included in parent radionuclide Ce-144
Pm-146	9.9E-08	Set to same value as Co-60 conservatively
Pm-147	4.2E-13	
Pm-148	9.9E-08	Set to same value as Co-60 conservatively
Pm-148m	9.9E-08	Set to same value as Co-60 conservatively
Sm-151	5.8E-14	
Eu-152	4.3E-08	
Eu-154	4.7E-08	
Eu-155	9.9E-08	Set to same value as Co-60 conservatively
Gd-153	9.9E-08	Set to same value as Co-60 conservatively
Tb-160	9.9E-08	Set to same value as Co-60 conservatively
Pu-238	1.7E-12	
Pu-239	1.9E-12	
Pu-240	1.8E-12	
Pu-241	3.1E-09	
Am-241	2.1E-10	
Am-242m	2.7E-10	
Am-243	4.8E-09	

Radionuclide	Effective dose conversion factor ((mSv/h)/(Bq/kg))	Remarks
Cm-242	1.8E-12	
Cm-243	4.8E-09	Set to same value as Am-243 conservatively
Cm-244	2.1E-12	

Table 4-6 Effective Dose Coefficient due to Ingestion

Subject radionuclide	Effective dose coefficient (mSv/Bq)			Remarks
	Adult	Child	Infant	
H-3	1.8E-08	3.1E-08	6.4E-08	
C-14	5.8E-07	9.9E-07	1.4E-06	
Mn-54	7.1E-07	1.9E-06	5.4E-06	
Fe-59	1.8E-06	7.5E-06	3.9E-05	
Co-58	7.4E-07	2.6E-06	7.3E-06	
Co-60	3.4E-06	1.7E-05	5.4E-05	
Ni-63	1.5E-07	4.6E-07	1.6E-06	
Zn-65	3.9E-06	9.7E-06	3.6E-05	
Rb-86	2.8E-06	9.9E-06	3.1E-05	
Sr-89	2.6E-06	8.9E-06	3.6E-05	
Sr-90	2.8E-05	4.7E-05	2.3E-04	
Y-90	–	–	–	Assessed using parent radionuclide Sr-90
Y-91	2.4E-06	8.8E-06	2.8E-05	
Nb-95	5.8E-07	1.8E-06	4.6E-06	
Tc-99	6.4E-07	2.3E-06	1.0E-05	
Ru-103	7.3E-07	2.4E-06	7.1E-06	
Ru-106	7.0E-06	2.5E-05	8.4E-05	
Rh-103m	–	–	–	Assessed using parent radionuclide Ru-103
Rh-106	–	–	–	Assessed using parent radionuclide Ru-106
Ag-110m	2.8E-06	7.8E-06	2.4E-05	
Cd-113m	2.3E-05	3.9E-05	1.2E-04	
Cd-115m	3.3E-06	9.7E-06	4.1E-05	
Sn-119m	3.4E-07	1.3E-06	4.1E-06	
Sn-123	2.1E-06	7.8E-06	2.5E-05	
Sn-126	4.7E-06	1.6E-05	5.0E-05	
Sb-124	2.5E-06	8.4E-06	2.5E-05	
Sb-125	1.1E-06	3.4E-06	1.1E-05	
Te-123m	1.4E-06	4.9E-06	1.9E-05	
Te-125m	8.7E-07	3.3E-06	1.3E-05	
Te-127	1.7E-07	6.2E-07	1.5E-06	

Subject radionuclide	Effective dose coefficient (mSv/Bq)			Remarks
	Adult	Child	Infant	
Te-127m	2.3E-06	9.5E-06	4.1E-05	
Te-129	−	−	−	Assessed using parent radionuclide Te-129m
Te-129m	3.0E-06	1.2E-05	4.4E-05	
I-129	1.1E-04	1.7E-04	1.8E-04	
Cs-134	1.9E-05	1.3E-05	2.6E-05	
Cs-135	2.0E-06	1.7E-06	4.1E-06	
Cs-136	3.0E-06	6.1E-06	1.5E-05	
Cs-137	1.3E-05	9.6E-06	2.1E-05	
Ba-137m	−	−	−	Assessed using parent radionuclide Cs-137
Ba-140	2.6E-06	9.2E-06	3.2E-05	
Ce-141	7.1E-07	2.6E-06	8.1E-06	
Ce-144	5.2E-06	1.9E-05	6.6E-05	
Pr-144	−	−	−	Assessed using parent radionuclide Ce-144
Pr-144m	−	−	−	Assessed using parent radionuclide Ce-144
Pm-146	9.0E-07	2.8E-06	1.0E-05	
Pm-147	2.6E-07	9.6E-07	3.6E-06	
Pm-148	2.7E-06	9.7E-06	3.0E-05	
Pm-148m	1.7E-06	5.5E-06	1.5E-05	
Sm-151	9.8E-08	3.3E-07	1.5E-06	
Eu-152	1.4E-06	4.1E-06	1.6E-05	
Eu-154	2.0E-06	6.5E-06	2.5E-05	
Eu-155	3.2E-07	1.1E-06	4.3E-06	
Gd-153	2.7E-07	9.4E-07	2.9E-06	
Tb-160	1.6E-06	5.4E-06	1.6E-05	
Pu-238	2.3E-04	3.1E-04	4.0E-03	
Pu-239	2.5E-04	3.3E-04	4.2E-03	
Pu-240	2.5E-04	3.3E-04	4.2E-03	
Pu-241	4.8E-06	5.5E-06	5.6E-05	
Am-241	2.0E-04	2.7E-04	3.7E-03	
Am-242m	1.9E-04	2.3E-04	3.1E-03	
Am-243	2.0E-04	2.7E-04	3.6E-03	
Cm-242	1.2E-05	3.9E-05	5.9E-04	
Cm-243	1.5E-04	2.2E-04	3.2E-03	
Cm-244	1.2E-04	1.9E-04	2.9E-03	

Table 4-7 Concentration Factor for Marine Products

Subject radionuclide	Concentration factor ((Bq/kg)/(Bq/L))			Remarks
	Fish	Invertebrates	Seaweed	
H-3	1.0E+00	1.0E+00	1.0E+00	
C-14	2.0E+04	2.0E+04	1.0E+04	
Mn-54	1.0E+03	5.0E+04	6.0E+03	
Fe-59	3.0E+04	5.0E+05	2.0E+04	
Co-58	7.0E+02	2.0E+04	6.0E+03	
Co-60	7.0E+02	2.0E+04	6.0E+03	
Ni-63	1.0E+03	2.0E+03	2.0E+03	
Zn-65	1.0E+03	8.0E+04	2.0E+03	
Rb-86	9.0E+00	1.7E+01	1.7E+01	Referenced from UCRL-50564 Rev.1
Sr-89	3.0E+00	1.0E+01	1.0E+01	
Sr-90	3.0E+00	1.0E+01	1.0E+01	
Y-90	–	–	–	Assessed using parent radionuclide Sr-90
Y-91	2.0E+01	1.0E+03	1.0E+03	
Nb-95	3.0E+01	1.0E+03	3.0E+03	
Tc-99	8.0E+01	5.0E+02	3.0E+04	
Ru-103	2.0E+00	5.0E+02	2.0E+03	
Ru-106	2.0E+00	5.0E+02	2.0E+03	
Rh-103m	–	–	–	Assessed using parent radionuclide Ru-103
Rh-106	–	–	–	Assessed using parent radionuclide Ru-106
Ag-110m	1.0E+04	6.0E+04	5.0E+03	
Cd-113m	5.0E+03	8.0E+04	2.0E+04	
Cd-115m	5.0E+03	8.0E+04	2.0E+04	
Sn-119m	5.0E+05	5.0E+05	2.0E+05	
Sn-123	5.0E+05	5.0E+05	2.0E+05	
Sn-126	5.0E+05	5.0E+05	2.0E+05	
Sb-124	6.0E+02	3.0E+02	2.0E+01	
Sb-125	6.0E+02	3.0E+02	2.0E+01	
Te-123m	1.0E+03	1.0E+03	1.0E+04	
Te-125m	1.0E+03	1.0E+03	1.0E+04	
Te-127	1.0E+03	1.0E+03	1.0E+04	
Te-127m	1.0E+03	1.0E+03	1.0E+04	
Te-129	–	–	–	Assessed using parent radionuclide Te-129m
Te-129m	1.0E+03	1.0E+03	1.0E+04	
I-129	9.0E+00	1.0E+01	1.0E+04	
Cs-134	1.0E+02	6.0E+01	5.0E+01	
Cs-135	1.0E+02	6.0E+01	5.0E+01	
Cs-136	1.0E+02	6.0E+01	5.0E+01	
Cs-137	1.0E+02	6.0E+01	5.0E+01	

Subject radionuclide	Concentration factor ((Bq/kg)/(Bq/L))			Remarks
	Fish	Invertebrates	Seaweed	
Ba-137m	–	–	–	Assessed using parent radionuclide Cs-137
Ba-140	1.0E+01	1.0E+01	7.0E+01	
Ce-141	5.0E+01	2.0E+03	5.0E+03	
Ce-144	5.0E+01	2.0E+03	5.0E+03	
Pr-144	–	–	–	Assessed using parent radionuclide Ce-144
Pr-144m	–	–	–	Assessed using parent radionuclide Ce-144
Pm-146	3.0E+02	7.0E+03	3.0E+03	
Pm-147	3.0E+02	7.0E+03	3.0E+03	
Pm-148	3.0E+02	7.0E+03	3.0E+03	
Pm-148m	3.0E+02	7.0E+03	3.0E+03	
Sm-151	3.0E+02	7.0E+03	3.0E+03	
Eu-152	3.0E+02	7.0E+03	3.0E+03	
Eu-154	3.0E+02	7.0E+03	3.0E+03	
Eu-155	3.0E+02	7.0E+03	3.0E+03	
Gd-153	3.0E+02	7.0E+03	3.0E+03	
Tb-160	6.0E+01	3.0E+03	2.0E+03	
Pu-238	1.0E+02	3.0E+03	4.0E+03	
Pu-239	1.0E+02	3.0E+03	4.0E+03	
Pu-240	1.0E+02	3.0E+03	4.0E+03	
Pu-241	1.0E+02	3.0E+03	4.0E+03	
Am-241	1.0E+02	1.0E+03	8.0E+03	
Am-242m	1.0E+02	1.0E+03	8.0E+03	
Am-243	1.0E+02	1.0E+03	8.0E+03	
Cm-242	1.0E+02	1.0E+03	5.0E+03	
Cm-243	1.0E+02	1.0E+03	5.0E+03	
Cm-244	1.0E+02	1.0E+03	5.0E+03	

*Values for mollusks (excluding cephalopodan) were used for invertebrates.

Table 4-8 Ingestion Amount for Person Ingesting Average Amount of Marine Products (g/day)

	Fishes	Invertebrates	Seaweed
Adult	58	10	11
Child	29	5.1	5.3
Infant	12	2.0	2.1

Table 4-9 Ingestion Amount for Person Ingesting Large Amounts of Marine Products (g/day)

	Fishes	Invertebrates	Seaweed
Adult	190	62	52
Child	97	31	26
Infant	39	12	10

5. Assessment of Exposure

5-1. Selecting source term

The source term (annual discharge, Bq) selected in accordance with steps indicated in 4-1. are presented in Tables 5-1 to 5-4. When actually performing discharge of ALPS treated water, the subject water shall be diluted at or over 100 times using seawater when discharging into the sea so the tritium concentration falls to below 1,500Bq/L which is the operational limit for groundwater bypass and subdrain; therefore, "the sum of the ratios" of radionuclides other than tritium shall fall to below 0.01.

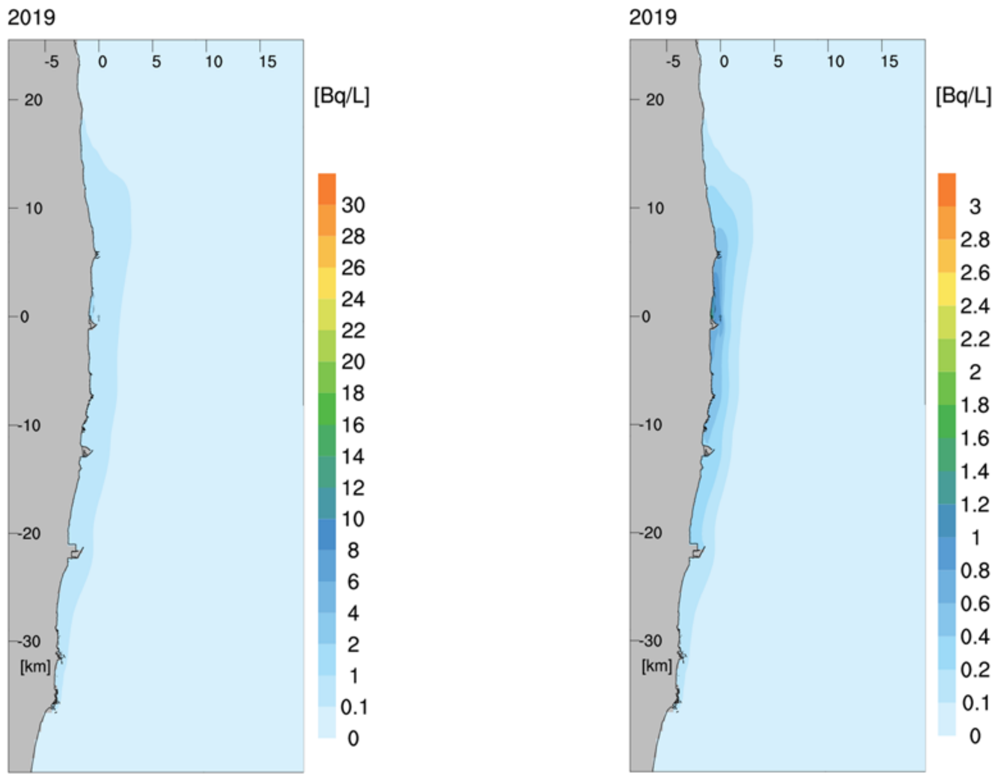
5-2. Assessment of dispersion and transfer

The model presented in 4-2. was used to calculate the changes in tritium concentration in seawater through dispersion and transfer under conditions where an annual total of 22 TBq (2.2E+13Bq) of tritium is discharged evenly throughout the year from the seabed approx. 1 km off the coast of the power station. Data from 2014 and 2019 were used regarding meteorological and sea conditions. The results for the two years are not significantly different. The results of the calculation of the average concentrations around the power plant for meteorogical and sea conditions in 2019, shown in Figures 5-1 to 5, were relatively high. Figure 5-1 presents the annual average concentration on the sea surface over a wide area, and Figure 5-2 presents the annual average concentration on the sea surface near the power station. An area approx. 3 km around FDNPS shows concentration exceeding 1Bq/L on the sea surface.

Figures 5-3 and 5-4 present a cross-section of the annual average concentration in the sea from the east-west direction and north-south direction. Although the concentration exceeds 20Bq/L near the point of discharge at seabed, the concentration rapidly decreases in the surrounding area.

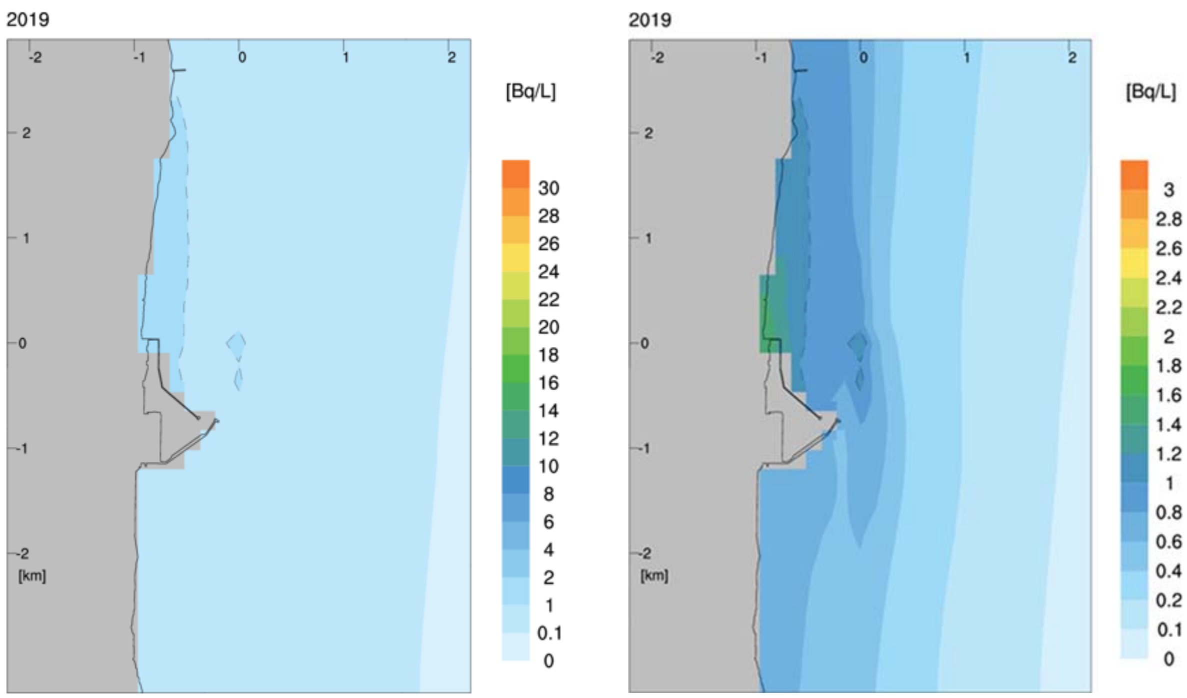
Figure 5-5 presents the seasonal average concentration on the sea surface. An area around FDNPS also shows concentration exceeding 1Bq/L, although the area varies compared to Figure 5-1.

Figure 5-6 and 5-7 illustrates the most northerly, southerly and easterly spreading cases of the daily average concentration distribution at the sea surface throughout the year, respectively. A comparison of the calculation results with those of the coastal discharges that were being compared in the study of the release method is shown in Reference F.



Detailed classification of concentration in the left figure

Figure 5-1 Distribution Map of Annual Average Concentration on Sea Surface
(Even discharge of tritium, 2.2E + 13Bq, throughout the year)



Detailed classification of Concentration in the left figure

Figure 5-2 Distribution Map of Annual Average Concentration on Sea Surface (enlarged, close-up map)
(Even discharge of tritium, 2.2E + 13Bq, throughout the year)

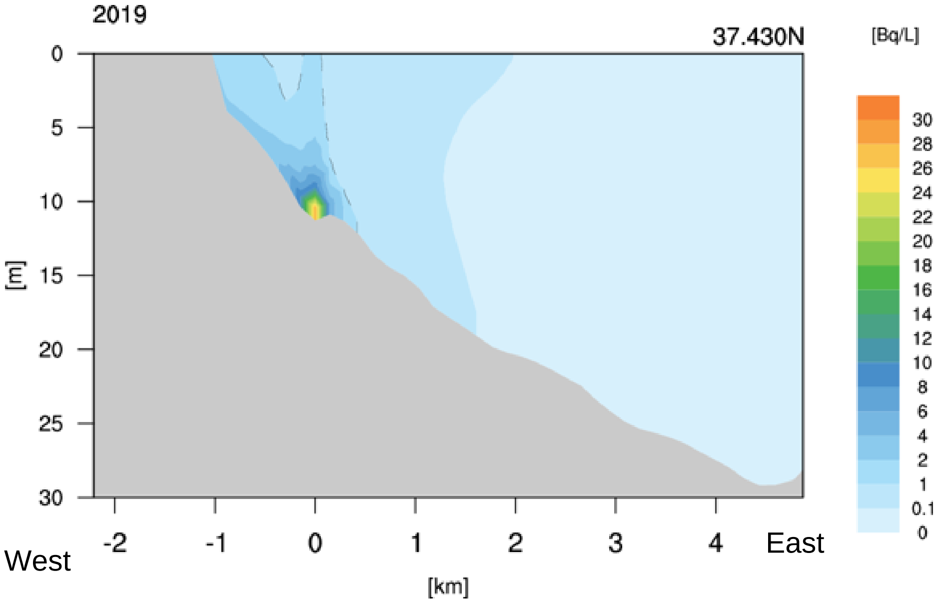


Figure 5-3 Distribution Map of Annual Average Concentration in Seawater (east-west cross-section of discharge location)

(Even discharge of tritium, 2.2E + 13Bq, throughout the year)

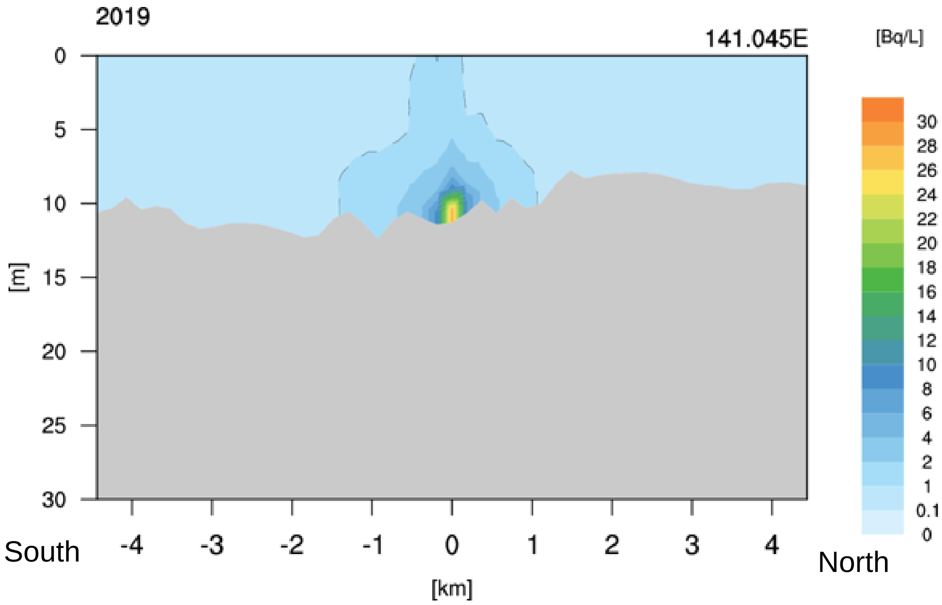
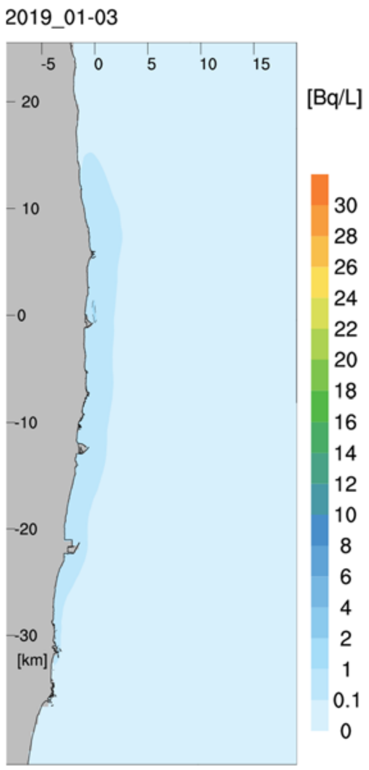
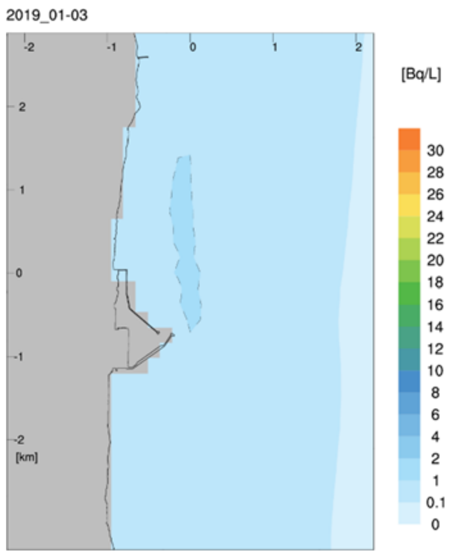


Figure 5-4 Distribution Map of Annual Average Concentration in Seawater (north-south cross-section of discharge location)

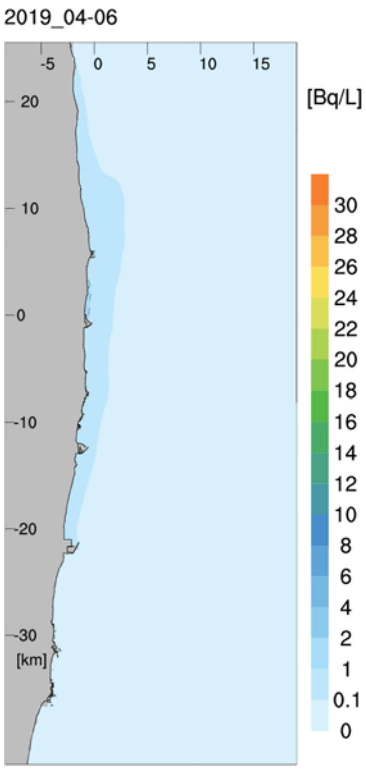
(Even discharge of tritium, 2.2E + 13Bq, throughout the year)

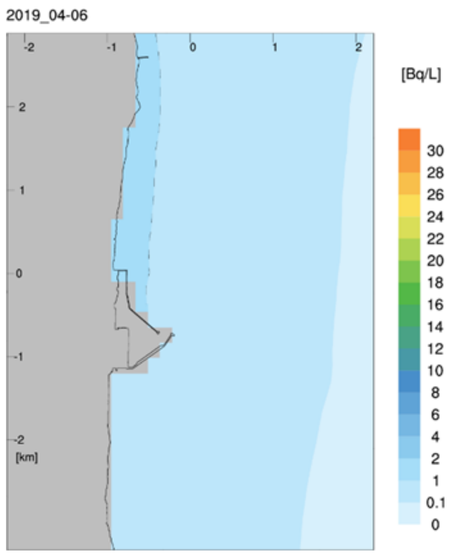




Close-up map of the left figure

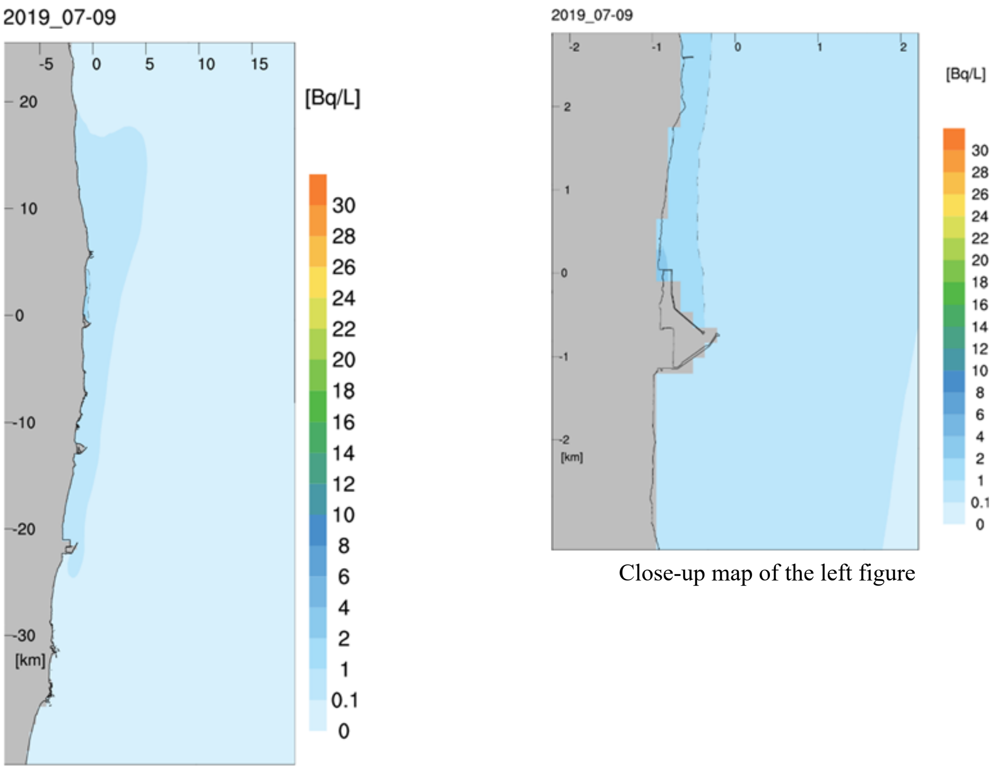
Figure 5-5 (1) Distribution Map of Seasonal Average Concentration on Sea Surface
(Average of January to March)





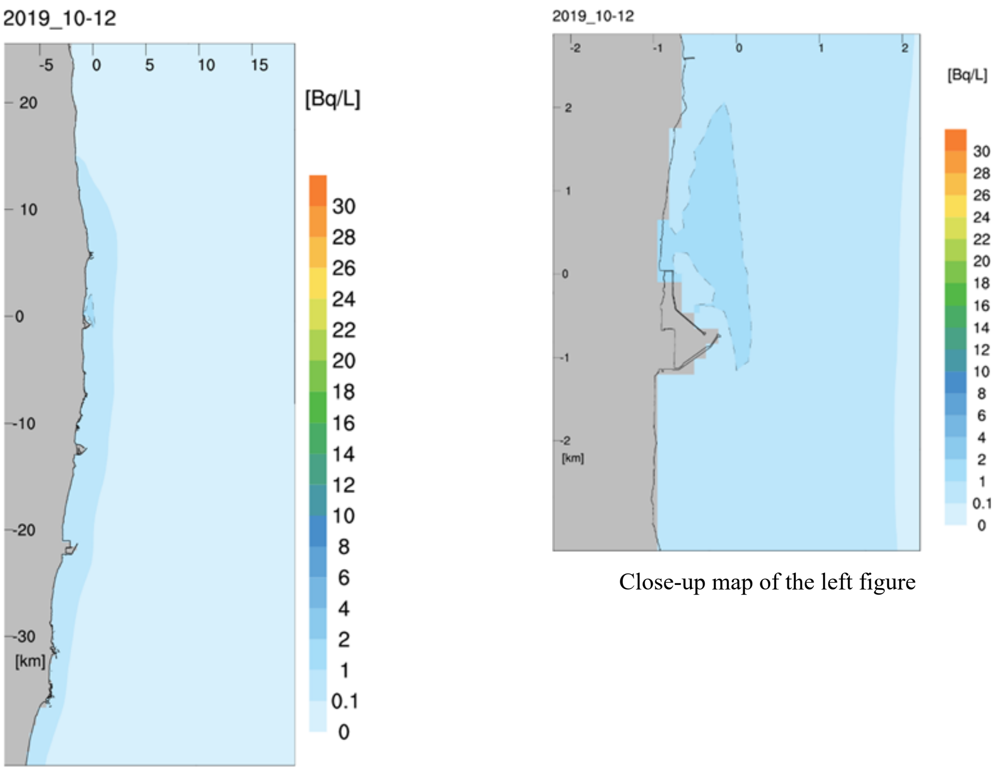
Close-up map of the left figure

Figure 5-5 (2) Distribution Map of Seasonal Average Concentration on Sea Surface
(Average of April to June)



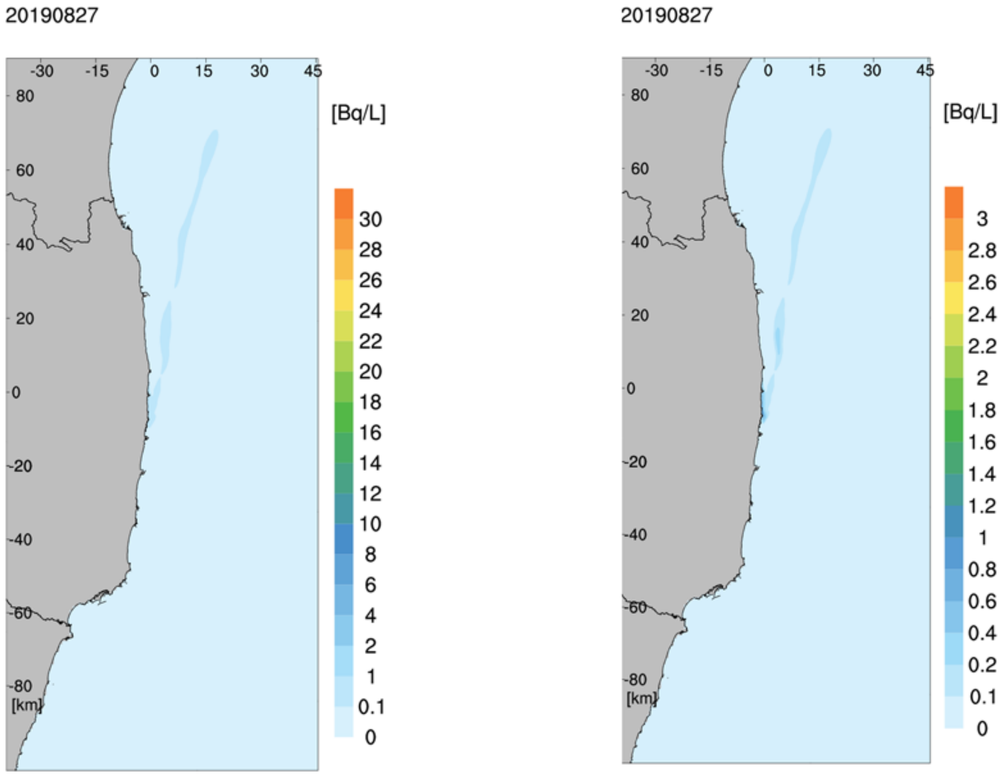
Close-up map of the left figure

Figure 5-5 (3) Distribution Map of Seasonal Average Concentration on Sea Surface
(Average of July to September)



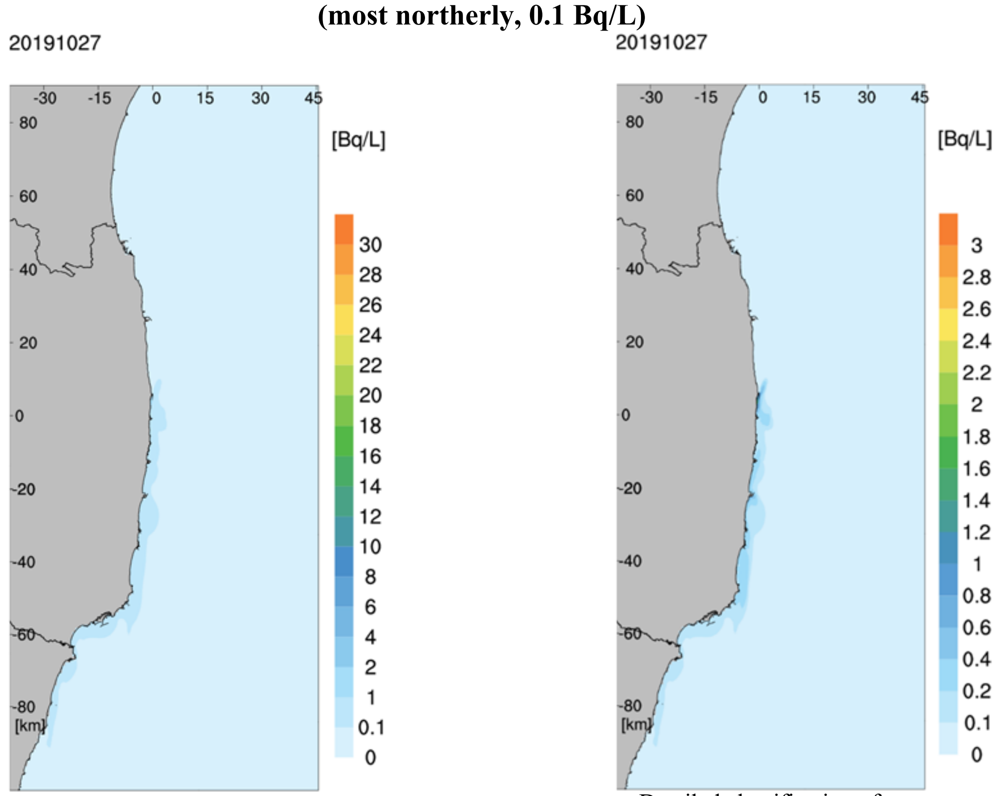
Close-up map of the left figure

Figure 5-5 (4) Distribution Map of Seasonal Average Concentration on Sea Surface
(Average of October to December)



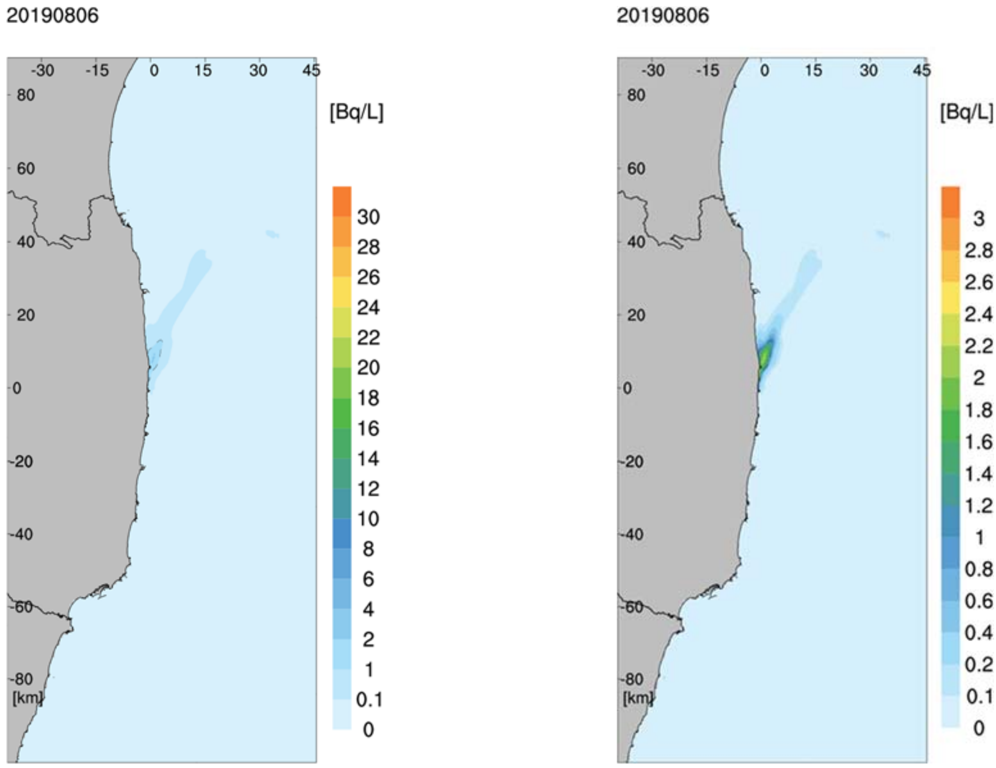
Detailed classification of concentration in the left figure

Figure 5-6 (1) Distribution of daily average concentration at the sea surface (most northerly, 0.1 Bq/L)



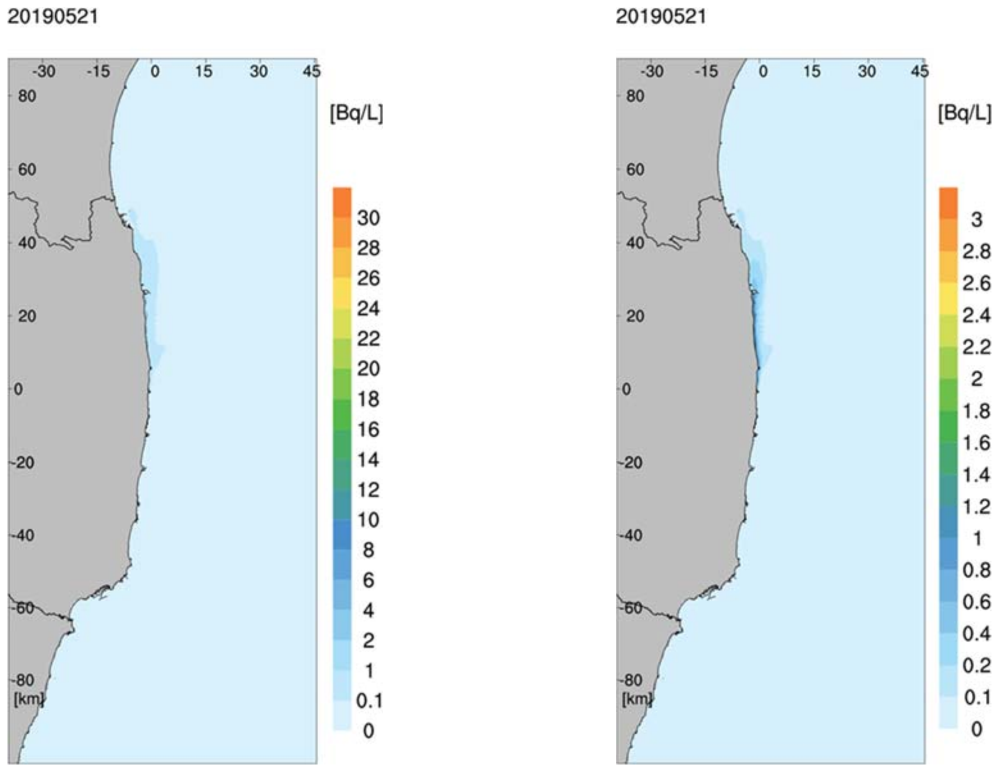
Detailed classification of concentration in the left figure

Figure 5-6 (2) Distribution of daily average concentration at the sea surface (most southerly, 0.1Bq/L)



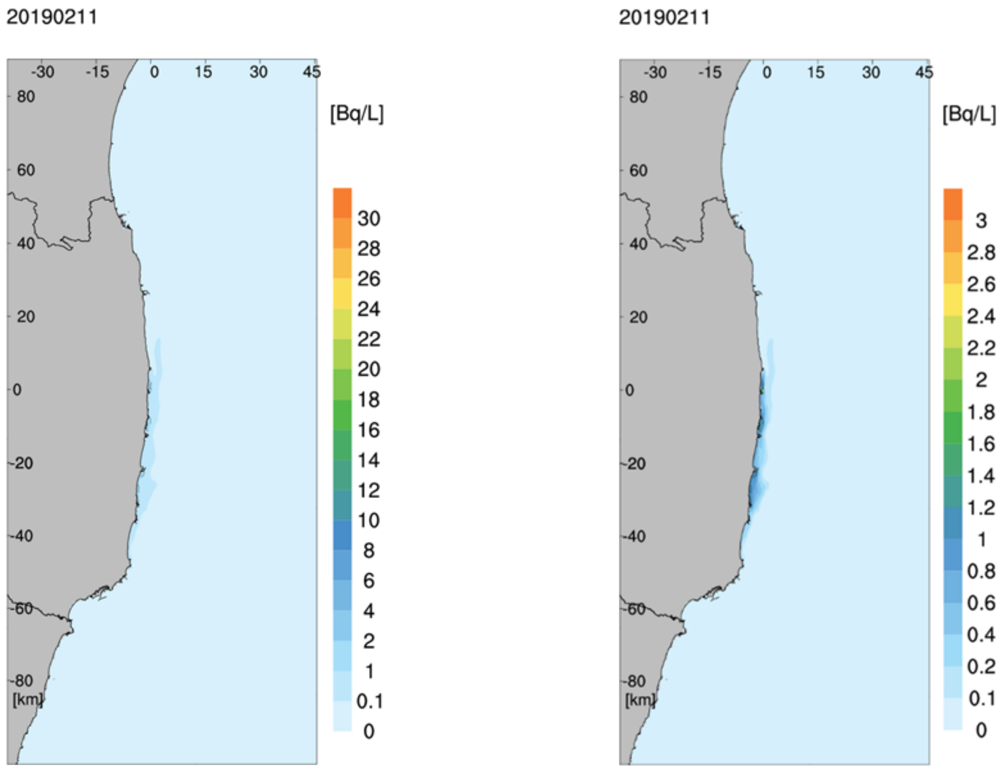
Detailed classification of concentration in the left figure

Figure 5-6 (3) Distribution of daily average concentration at the sea surface (most easterly, 0.1Bq/L)



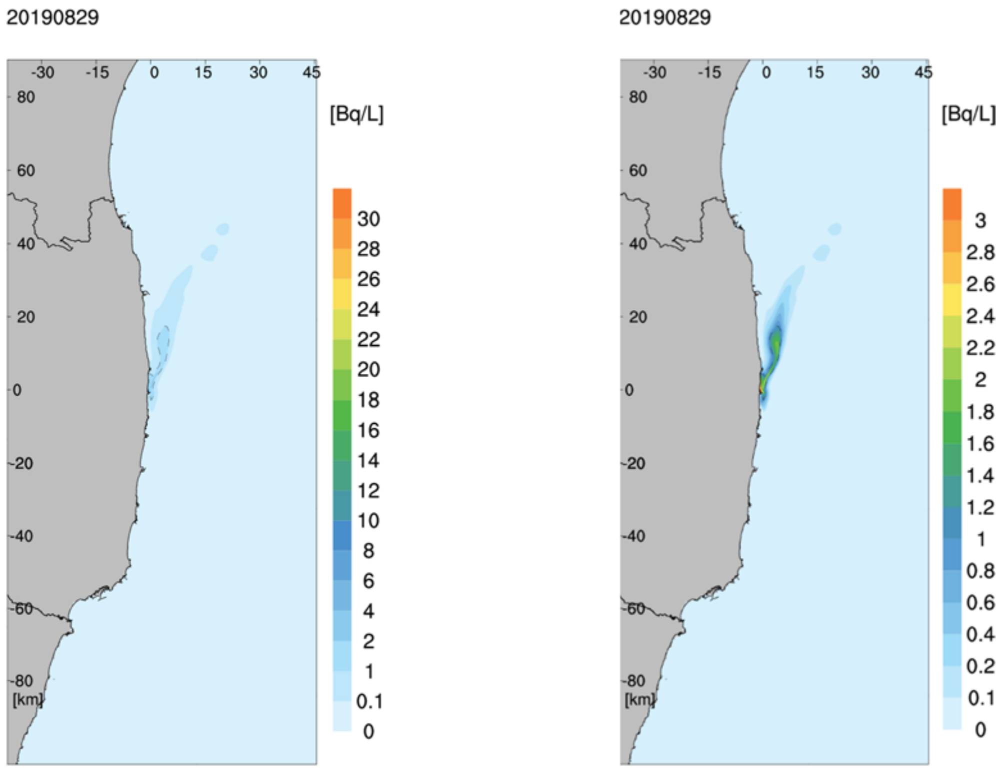
Detailed classification of concentration in the left figure

Figure 5-7 (1) Distribution of daily average concentration at the sea surface (most northerly, 0.1Bq/L)



Detailed classification of concentration in the left figure

Figure 5-7 (2) Distribution of daily average concentration at the sea surface (most southerly, 1Bq/L)



Detailed classification of concentration in the left figure

Figure 5-7 (3) Distribution of daily average concentration at the sea surface (most easterly, 1Bq/L)

5-3. Calculating the seawater concentration of radionuclides used for assessment

Based on the results of dispersion and transfer assessment of tritium, the concentration of other radionuclides is calculated through the ratio of annual discharge of tritium and that of other radionuclides.

The tritium concentration (annual average concentration) in seawater, if tritium is discharged at an annual rate of 22 TBq (2.2E+13Bq), within a 10km*10km area around the power station is presented in Table 5-5. The rate of change in concentrations between 2014 and 2019 was below 20%. Also, in the model used as a basis for the assessment, a reproduction calculation of Cs-137 leaking from the FDNPS was conducted and presented in a dissertation (Tsumune et al., 2020 [13]). The distributions of annual average concentration calculated using meteorological conditions of the four years from 2013 to 2016 were similar, and it is stated that the predictability of the annual average concentration distributions of the subject sea area was high. While the impact of year to year fluctuations in concentration is small, the larger concentration value from the year 2019 was used in this assessment.

The results, and concentration of radioactive material in seawater used for assessment calculated from annual discharge for each radionuclide in tables 5-1 to 5-4, are presented in tables 5-6 to 5-9.

5-4. Results of exposure assessment

The results of exposure assessment conducted regarding the four cases below using the concentrations in seawater presented in tables 5-6 to 5-9 are presented in tables 5-10 and 5-11.

(1) Source term based on the measured value of the 64 radionuclides
   i. K4 tank group ("the sum of the ratios" of radionuclides other than tritium is 0.29)
   ii. J1-C tank group ("the sum of the ratios" of radionuclides other than tritium is 0.35)
   iii. J1-G tank group ("the sum of the ratios" of radionuclides other than tritium is 0.22)

(2) Source term based on the hypothetical ALPS treated water
   ("the sum of the ratios" of radionuclides other than tritium is 1)

The results of assessment using source term by the radionuclide composition of measured values was 0.000017 (1.7E-05) to 0.00031 (3.1E-04) mSv/year, and both values were significantly below not only the public dose limit of 1mSv/year, but also the target dose value for the Domestic Nuclear Power Plant which is 0.05mSv/year. Also, in the assessment conducted under extremely conservative conditions where the source term based on the hypothetical ALPS treated water which "the sum of the ratios" of relatively significant radionuclides is 1, and the subject was assumed to consume large amounts of Marine products, the results of exposure assessment was 0.0021 (2.1E-03) mSv/year, which was significantly lower than not only the dose limit of 1mSv/year, but also the target dose value of 0.05mSv/year. In the evaluation in the source term based on measured values, nuclides below the detection limit (non-detected nuclides) were also evaluated as being included at the detection limit. For this reason, the evaluation results are considered to be conservative. The contribution of non-detected nuclides in the evaluation results is shown in Reference G.

The internal exposure assessment results in infants, where the effective dose coefficient is large and the internal exposure assessment value is high, was within the scope of 0.000029 (2.9E-05mSv/year) for the smallest value from the K4 tank group and 0.0039 (3.9E-03) mSv/year for the results with the largest value using the upper limit for discharge control; and results were significantly lower than not only the dose limit of 1mSv/year, but also the target dose value of 0.05mSv/year.

Details of the assessment results by each radionuclide are presented in Reference H.

Table 5-1 Source Term by Radionuclide Composition of Measured Values (K4 tank group) (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
H-3	1.9E+05	1.2E+08	2.2E+13	・The amount of tritium discharged annually was set to be the upper limit value for annual discharge. ・Discharged water shall be diluted at or over 100 times with seawater so that the tritium concentration falls to below 1500Bq/L.
C-14	1.5E+01		1.7E+09	
Mn-54	6.7E-03		7.8E+05	
Fe-59	1.7E-02		2.0E+06	
Co-58	8.0E-03		9.3E+05	
Co-60	4.4E-01		5.1E+07	
Ni-63	2.2E+00		2.5E+08	
Zn-65	1.5E-02		1.7E+06	
Rb-86	1.9E-01		2.2E+07	
Sr-89	1.0E-01		1.2E+07	
Sr-90	2.2E-01		2.5E+07	
Y-90	2.2E-01		2.5E+07	
Y-91	2.2E+00		2.5E+08	
Nb-95	1.0E-02		1.2E+06	
Tc-99	7.0E-01		8.1E+07	
Ru-103	1.0E-02		1.2E+06	
Ru-106	1.6E+00		1.9E+08	
Rh-103m	1.0E-02		1.2E+06	
Rh-106	1.6E+00		1.9E+08	
Ag-110m	5.6E-03		6.5E+05	
Cd-113m	1.8E-02		2.1E+06	
Cd-115m	6.4E-01		7.4E+07	
Sn-119m	1.7E-01		2.0E+07	
Sn-123	1.2E+00		1.4E+08	
Sn-126	2.7E-02		3.1E+06	
Sb-124	9.5E-03		1.1E+06	
Sb-125	3.3E-01		3.8E+07	
Te-123m	9.2E-03		1.1E+06	
Te-125m	3.3E-01		3.8E+07	
Te-127	3.2E-01		3.7E+07	
Te-127m	3.2E-01		3.7E+07	
Te-129	8.1E-02		9.4E+06	
Te-129m	3.2E-01		3.7E+07	
I-129	2.1E+00		2.4E+08	
Cs-134	4.5E-02		5.2E+06	
Cs-135	2.5E-06		2.9E+02	
Cs-136	3.0E-02		3.5E+06	

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
Cs-137	4.2E-01		4.9E+07	
Ba-137m	4.2E-01		4.9E+07	
Ba-140	9.5E-02		1.1E+07	
Ce-141	2.5E-02		2.9E+06	
Ce-144	6.3E-02		7.3E+06	
Pr-144	6.3E-02		7.3E+06	
Pr-144m	6.3E-02		7.3E+06	
Pm-146	9.8E-02		1.1E+07	
Pm-147	1.9E-01		2.2E+07	
Pm-148	5.0E-01		5.8E+07	
Pm-148m	8.4E-03		9.7E+05	
Sm-151	9.0E-04		1.0E+05	
Eu-152	2.8E-02		3.2E+06	
Eu-154	1.2E-02		1.4E+06	
Eu-155	3.3E-02		3.8E+06	
Gd-153	3.2E-02		3.7E+06	
Tb-160	2.8E-02		3.2E+06	
Pu-238	6.3E-04		7.3E+04	
Pu-239	6.3E-04		7.3E+04	
Pu-240	6.3E-04		7.3E+04	
Pu-241	2.8E-02		3.2E+06	
Am-241	6.3E-04		7.3E+04	
Am-242m	3.9E-05		4.5E+03	
Am-243	6.3E-04		7.3E+04	
Cm-242	6.3E-04		7.3E+04	
Cm-243	6.3E-04		7.3E+04	
Cm-244	6.3E-04		7.3E+04	

Table 5-2 Source Term by Radionuclide Composition of Measured Values (J1-C tank group) (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
H-3	8.2E+05	2.7E+07	2.2E+13	・The amount of tritium discharged annually was set to be the upper limit value for annual discharge. ・Discharged water shall be diluted at or over 100 times with seawater so that the tritium concentration falls to below 1500Bq/L.
C-14	1.8E+01		4.8E+08	
Mn-54	3.8E-02		1.0E+06	
Fe-59	8.7E-02		2.3E+06	
Co-58	4.1E-02		1.1E+06	
Co-60	3.3E-01		8.9E+06	
Ni-63	8.5E+00		2.3E+08	
Zn-65	9.4E-02		2.5E+06	
Rb-86	5.0E-01		1.3E+07	
Sr-89	5.4E-02		1.4E+06	
Sr-90	3.6E-02		9.7E+05	
Y-90	3.6E-02		9.7E+05	
Y-91	1.7E+01		4.6E+08	
Nb-95	5.0E-02		1.3E+06	
Tc-99	1.2E+00		3.2E+07	
Ru-103	5.3E-02		1.4E+06	
Ru-106	1.4E+00		3.8E+07	
Rh-103m	5.3E-02		1.4E+06	
Rh-106	1.4E+00		3.8E+07	
Ag-110m	4.3E-02		1.2E+06	
Cd-113m	8.5E-02		2.3E+06	
Cd-115m	2.7E+00		7.2E+07	
Sn-119m	4.2E+01		1.1E+09	
Sn-123	6.6E+00		1.8E+08	
Sn-126	2.9E-01		7.8E+06	
Sb-124	9.7E-02		2.6E+06	
Sb-125	2.3E-01		6.2E+06	
Te-123m	9.2E-02		2.5E+06	
Te-125m	2.3E-01		6.2E+06	
Te-127	4.7E+00		1.3E+08	
Te-127m	4.9E+00		1.3E+08	
Te-129	6.2E-01		1.7E+07	
Te-129m	1.4E+00		3.8E+07	
I-129	1.2E+00		3.2E+07	
Cs-134	7.6E-02		2.0E+06	
Cs-135	1.2E-06		3.2E+01	
Cs-136	4.7E-02		1.3E+06	

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
Cs-137	1.9E-01		5.1E+06	
Ba-137m	1.9E-01		5.1E+06	
Ba-140	2.0E-01		5.4E+06	
Ce-141	2.6E-01		7.0E+06	
Ce-144	5.7E-01		1.5E+07	
Pr-144	5.7E-01		1.5E+07	
Pr-144m	5.7E-01		1.5E+07	
Pm-146	6.7E-02		1.8E+06	
Pm-147	8.0E-01		2.1E+07	
Pm-148	2.3E-01		6.2E+06	
Pm-148m	4.8E-02		1.3E+06	
Sm-151	1.1E-02		3.0E+05	
Eu-152	2.8E-01		7.5E+06	
Eu-154	1.1E-01		3.0E+06	
Eu-155	3.4E-01		9.1E+06	
Gd-153	2.6E-01		7.0E+06	
Tb-160	1.4E-01		3.8E+06	
Pu-238	3.3E-02		8.9E+05	
Pu-239	3.3E-02		8.9E+05	
Pu-240	3.3E-02		8.9E+05	
Pu-241	1.2E+00		3.2E+07	
Am-241	3.3E-02		8.9E+05	
Am-242m	5.9E-04		1.6E+04	
Am-243	3.3E-02		8.9E+05	
Cm-242	3.3E-02		8.9E+05	
Cm-243	3.3E-02		8.9E+05	
Cm-244	3.3E-02		8.9E+05	

Table 5-3 Source Term by Radionuclide Composition of Measured Values (J1-G tank group) (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
H-3	2.7E+05	8.1E+07	2.2E+13	・The amount of tritium discharged annually was set to be the upper limit value for annual discharge. ・Discharged water shall be diluted at or over 100 times with seawater so
C-14	1.6E+01		1.3E+09	
Mn-54	3.8E-02		3.1E+06	
Fe-59	7.2E-02		5.9E+06	
Co-58	3.7E-02		3.0E+06	
Co-60	2.3E-01		1.9E+07	

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
Ni-63	8.8E+00		7.2E+08	that the tritium concentration falls to below 1500Bq/L.
Zn-65	8.0E-02		6.5E+06	
Rb-86	4.7E-01		3.8E+07	
Sr-89	4.5E-02		3.7E+06	
Sr-90	3.2E-02		2.6E+06	
Y-90	3.2E-02		2.6E+06	
Y-91	1.2E+01		9.8E+08	
Nb-95	4.7E-02		3.8E+06	
Tc-99	1.3E+00		1.1E+08	
Ru-103	5.1E-02		4.2E+06	
Ru-106	4.8E-01		3.9E+07	
Rh-103m	5.1E-02		4.2E+06	
Rh-106	4.8E-01		3.9E+07	
Ag-110m	4.0E-02		3.3E+06	
Cd-113m	8.6E-02		7.0E+06	
Cd-115m	2.3E+00		1.9E+08	
Sn-119m	4.0E+01		3.3E+09	
Sn-123	6.3E+00		5.1E+08	
Sn-126	1.5E-01		1.2E+07	
Sb-124	8.4E-02		6.8E+06	
Sb-125	1.4E-01		1.1E+07	
Te-123m	6.7E-02		5.5E+06	
Te-125m	1.4E-01		1.1E+07	
Te-127	4.3E+00		3.5E+08	
Te-127m	4.5E+00		3.7E+08	
Te-129	5.9E-01		4.8E+07	
Te-129m	1.2E+00		9.8E+07	
I-129	3.3E-01		2.7E+07	
Cs-134	6.7E-02		5.5E+06	
Cs-135	2.1E-06		1.7E+02	
Cs-136	3.6E-02		2.9E+06	
Cs-137	3.3E-01		2.7E+07	
Ba-137m	3.3E-01		2.7E+07	
Ba-140	1.7E-01		1.4E+07	
Ce-141	1.2E-01		9.8E+06	
Ce-144	5.5E-01		4.5E+07	
Pr-144	5.5E-01		4.5E+07	
Pr-144m	5.5E-01		4.5E+07	
Pm-146	6.3E-02		5.1E+06	

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
Pm-147	7.2E-01		5.9E+07	
Pm-148	4.5E-01		3.7E+07	
Pm-148m	4.1E-02		3.3E+06	
Sm-151	1.0E-02		8.1E+05	
Eu-152	1.9E-01		1.5E+07	
Eu-154	1.0E-01		8.1E+06	
Eu-155	1.8E-01		1.5E+07	
Gd-153	1.9E-01		1.5E+07	
Tb-160	1.4E-01		1.1E+07	
Pu-238	2.8E-02		2.3E+06	
Pu-239	2.8E-02		2.3E+06	
Pu-240	2.8E-02		2.3E+06	
Pu-241	1.0E+00		8.1E+07	
Am-241	2.8E-02		2.3E+06	
Am-242m	5.1E-04		4.2E+04	
Am-243	2.8E-02		2.3E+06	
Cm-242	2.8E-02		2.3E+06	
Cm-243	2.8E-02		2.3E+06	
Cm-244	2.8E-02		2.3E+06	

Table 5-4 Source Term based on the hypothetical ALPS treated water (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
H-3	1.0E+05	2.2E+08	2.2E+13	・The amount of tritium discharged annually was set to be the upper limit value for annual discharge. ・Discharged water shall be diluted at or over 100 times with seawater so that the tritium concentration falls to below 1500Bq/L. Therefore, "the sum of the ratios" of radionuclides other than tritium to the regulatory limits is below 0.01.
C-14	5.0E+02		1.1E+11	
Fe-59	2.0E-01		4.4E+07	
Zn-65	1.4E+02		3.1E+10	
Ag-110m	6.0E-02		1.3E+07	
Cd-113m	2.0E-01		4.4E+07	
Cd-115m	4.0E+00		8.8E+08	
Sn-119m	6.0E+01		1.3E+10	
Sn-123	8.0E+00		1.8E+09	
Sn-126	4.0E-01		8.8E+07	

Table 5-5 Tritium Concentration in Seawater if Discharging Tritium at a Rate of 2.2E+13Bq Annually

	Depth	Result of calculation (Bq/L)			Concentration for assessment (Bq/L)
		Meteorological/sea phenomenon in 2014	Meteorological/sea phenomenon in 2019	Difference (%)	
Average concentration in an area 10km*10km around the power station	All layers	4.8E-02	5.6E-02	17	5.6E-02
	Top layer	1.0E-01	1.2E-01	18	1.2E-01

Table 5-6 Concentration in Seawater used for Assessment (source term by radionuclide composition in K4 tank group)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
H-3	2.2E+13	5.6E-02	1.2E-01
C-14	1.7E+09	4.4E-06	9.5E-06
Mn-54	7.8E+05	2.0E-09	4.2E-09
Fe-59	2.0E+06	5.0E-09	1.1E-08
Co-58	9.3E+05	2.4E-09	5.1E-09
Co-60	5.1E+07	1.3E-07	2.8E-07
Ni-63	2.5E+08	6.5E-07	1.4E-06
Zn-65	1.7E+06	4.4E-09	9.5E-09
Rb-86	2.2E+07	5.6E-08	1.2E-07
Sr-89	1.2E+07	2.9E-08	6.3E-08
Sr-90	2.5E+07	6.5E-08	1.4E-07
Y-90	2.5E+07	6.5E-08	1.4E-07
Y-91	2.5E+08	6.5E-07	1.4E-06
Nb-95	1.2E+06	2.9E-09	6.3E-09
Tc-99	8.1E+07	2.1E-07	4.4E-07
Ru-103	1.2E+06	2.9E-09	6.3E-09
Ru-106	1.9E+08	4.7E-07	1.0E-06
Rh-103m	1.2E+06	2.9E-09	6.3E-09
Rh-106	1.9E+08	4.7E-07	1.0E-06
Ag-110m	6.5E+05	1.7E-09	3.5E-09
Cd-113m	2.1E+06	5.3E-09	1.1E-08
Cd-115m	7.4E+07	1.9E-07	4.0E-07
Sn-119m	2.0E+07	5.0E-08	1.1E-07

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
Sn-123	1.4E+08	3.5E-07	7.6E-07
Sn-126	3.1E+06	8.0E-09	1.7E-08
Sb-124	1.1E+06	2.8E-09	6.0E-09
Sb-125	3.8E+07	9.7E-08	2.1E-07
Te-123m	1.1E+06	2.7E-09	5.8E-09
Te-125m	3.8E+07	9.7E-08	2.1E-07
Te-127	3.7E+07	9.4E-08	2.0E-07
Te-127m	3.7E+07	9.4E-08	2.0E-07
Te-129	9.4E+06	2.4E-08	5.1E-08
Te-129m	3.7E+07	9.4E-08	2.0E-07
I-129	2.4E+08	6.2E-07	1.3E-06
Cs-134	5.2E+06	1.3E-08	2.8E-08
Cs-135	2.9E+02	7.4E-13	1.6E-12
Cs-136	3.5E+06	8.8E-09	1.9E-08
Cs-137	4.9E+07	1.2E-07	2.7E-07
Ba-137m	4.9E+07	1.2E-07	2.7E-07
Ba-140	1.1E+07	2.8E-08	6.0E-08
Ce-141	2.9E+06	7.4E-09	1.6E-08
Ce-144	7.3E+06	1.9E-08	4.0E-08
Pr-144	7.3E+06	1.9E-08	4.0E-08
Pr-144m	7.3E+06	1.9E-08	4.0E-08
Pm-146	1.1E+07	2.9E-08	6.2E-08
Pm-147	2.2E+07	5.6E-08	1.2E-07
Pm-148	5.8E+07	1.5E-07	3.2E-07
Pm-148m	9.7E+05	2.5E-09	5.3E-09
Sm-151	1.0E+05	2.7E-10	5.7E-10
Eu-152	3.2E+06	8.3E-09	1.8E-08
Eu-154	1.4E+06	3.5E-09	7.6E-09
Eu-155	3.8E+06	9.7E-09	2.1E-08
Gd-153	3.7E+06	9.4E-09	2.0E-08
Tb-160	3.2E+06	8.3E-09	1.8E-08
Pu-238	7.3E+04	1.9E-10	4.0E-10
Pu-239	7.3E+04	1.9E-10	4.0E-10
Pu-240	7.3E+04	1.9E-10	4.0E-10
Pu-241	3.2E+06	8.3E-09	1.8E-08

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
Am-241	7.3E+04	1.9E-10	4.0E-10
Am-242m	4.5E+03	1.1E-11	2.5E-11
Am-243	7.3E+04	1.9E-10	4.0E-10
Cm-242	7.3E+04	1.9E-10	4.0E-10
Cm-243	7.3E+04	1.9E-10	4.0E-10
Cm-244	7.3E+04	1.9E-10	4.0E-10
Subject for exposure assessment		Swimming Beach sand Fishing nets Ingest of Marine products	Seawater Ship hull

Table 5-7 Concentration in Seawater Used for Assessment (source term by the J1-C tank group water)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
H-3	2.2E+13	5.6E-02	1.2E-01
C-14	4.8E+08	1.2E-06	2.6E-06
Mn-54	1.0E+06	2.6E-09	5.6E-09
Fe-59	2.3E+06	5.9E-09	1.3E-08
Co-58	1.1E+06	2.8E-09	6.0E-09
Co-60	8.9E+06	2.3E-08	4.8E-08
Ni-63	2.3E+08	5.8E-07	1.2E-06
Zn-65	2.5E+06	6.4E-09	1.4E-08
Rb-86	1.3E+07	3.4E-08	7.3E-08
Sr-89	1.4E+06	3.7E-09	7.9E-09
Sr-90	9.7E+05	2.5E-09	5.3E-09
Y-90	9.7E+05	2.5E-09	5.3E-09
Y-91	4.6E+08	1.2E-06	2.5E-06
Nb-95	1.3E+06	3.4E-09	7.3E-09
Tc-99	3.2E+07	8.2E-08	1.8E-07

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
Ru-103	1.4E+06	3.6E-09	7.8E-09
Ru-106	3.8E+07	9.6E-08	2.0E-07
Rh-103m	1.4E+06	3.6E-09	7.8E-09
Rh-106	3.8E+07	9.6E-08	2.0E-07
Ag-110m	1.2E+06	2.9E-09	6.3E-09
Cd-113m	2.3E+06	5.8E-09	1.2E-08
Cd-115m	7.2E+07	1.8E-07	4.0E-07
Sn-119m	1.1E+09	2.9E-06	6.1E-06
Sn-123	1.8E+08	4.5E-07	9.7E-07
Sn-126	7.8E+06	2.0E-08	4.2E-08
Sb-124	2.6E+06	6.6E-09	1.4E-08
Sb-125	6.2E+06	1.6E-08	3.4E-08
Te-123m	2.5E+06	6.3E-09	1.3E-08
Te-125m	6.2E+06	1.6E-08	3.4E-08
Te-127	1.3E+08	3.2E-07	6.9E-07
Te-127m	1.3E+08	3.3E-07	7.2E-07
Te-129	1.7E+07	4.2E-08	9.1E-08
Te-129m	3.8E+07	9.6E-08	2.0E-07
I-129	3.2E+07	8.2E-08	1.8E-07
Cs-134	2.0E+06	5.2E-09	1.1E-08
Cs-135	3.2E+01	8.2E-14	1.8E-13
Cs-136	1.3E+06	3.2E-09	6.9E-09
Cs-137	5.1E+06	1.3E-08	2.8E-08
Ba-137m	5.1E+06	1.3E-08	2.8E-08
Ba-140	5.4E+06	1.4E-08	2.9E-08
Ce-141	7.0E+06	1.8E-08	3.8E-08
Ce-144	1.5E+07	3.9E-08	8.3E-08
Pr-144	1.5E+07	3.9E-08	8.3E-08
Pr-144m	1.5E+07	3.9E-08	8.3E-08
Pm-146	1.8E+06	4.6E-09	9.8E-09
Pm-147	2.1E+07	5.5E-08	1.2E-07
Pm-148	6.2E+06	1.6E-08	3.4E-08
Pm-148m	1.3E+06	3.3E-09	7.0E-09
Sm-151	3.0E+05	7.5E-10	1.6E-09
Eu-152	7.5E+06	1.9E-08	4.1E-08

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
Eu-154	3.0E+06	7.5E-09	1.6E-08
Eu-155	9.1E+06	2.3E-08	5.0E-08
Gd-153	7.0E+06	1.8E-08	3.8E-08
Tb-160	3.8E+06	9.6E-09	2.0E-08
Pu-238	8.9E+05	2.3E-09	4.8E-09
Pu-239	8.9E+05	2.3E-09	4.8E-09
Pu-240	8.9E+05	2.3E-09	4.8E-09
Pu-241	3.2E+07	8.2E-08	1.8E-07
Am-241	8.9E+05	2.3E-09	4.8E-09
Am-242m	1.6E+04	4.0E-11	8.6E-11
Am-243	8.9E+05	2.3E-09	4.8E-09
Cm-242	8.9E+05	2.3E-09	4.8E-09
Cm-243	8.9E+05	2.3E-09	4.8E-09
Cm-244	8.9E+05	2.3E-09	4.8E-09
Subject for exposure assessment		Swimming Beach sand Fishing net Ingest of Marine products	Seawater Ship hull

Table 5-8 Concentration in Seawater Used for Assessment (source term by the J1-G tank group water)

Subject radionuclide	Annual discharge (Bq)	Seawater concentration used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
H-3	2.2E+13	5.6E-02	1.2E-01
C-14	1.3E+09	3.3E-06	7.1E-06
Mn-54	3.1E+06	7.9E-09	1.7E-08
Fe-59	5.9E+06	1.5E-08	3.2E-08
Co-58	3.0E+06	7.7E-09	1.6E-08
Co-60	1.9E+07	4.8E-08	1.0E-07
Ni-63	7.2E+08	1.8E-06	3.9E-06
Zn-65	6.5E+06	1.7E-08	3.6E-08
Rb-86	3.8E+07	9.7E-08	2.1E-07
Sr-89	3.7E+06	9.3E-09	2.0E-08
Sr-90	2.6E+06	6.6E-09	1.4E-08
Y-90	2.6E+06	6.6E-09	1.4E-08
Y-91	9.8E+08	2.5E-06	5.3E-06
Nb-95	3.8E+06	9.7E-09	2.1E-08
Tc-99	1.1E+08	2.7E-07	5.8E-07
Ru-103	4.2E+06	1.1E-08	2.3E-08
Ru-106	3.9E+07	1.0E-07	2.1E-07
Rh-103m	4.2E+06	1.1E-08	2.3E-08
Rh-106	3.9E+07	1.0E-07	2.1E-07
Ag-110m	3.3E+06	8.3E-09	1.8E-08
Cd-113m	7.0E+06	1.8E-08	3.8E-08
Cd-115m	1.9E+08	4.8E-07	1.0E-06
Sn-119m	3.3E+09	8.3E-06	1.8E-05
Sn-123	5.1E+08	1.3E-06	2.8E-06
Sn-126	1.2E+07	3.1E-08	6.7E-08
Sb-124	6.8E+06	1.7E-08	3.7E-08
Sb-125	1.1E+07	2.9E-08	6.2E-08
Te-123m	5.5E+06	1.4E-08	3.0E-08
Te-125m	1.1E+07	2.9E-08	6.2E-08
Te-127	3.5E+08	8.9E-07	1.9E-06
Te-127m	3.7E+08	9.3E-07	2.0E-06
Te-129	4.8E+07	1.2E-07	2.6E-07
Te-129m	9.8E+07	2.5E-07	5.3E-07
I-129	2.7E+07	6.8E-08	1.5E-07

Subject radionuclide	Annual discharge (Bq)	Seawater concentration used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
Cs-134	5.5E+06	1.4E-08	3.0E-08
Cs-135	1.7E+02	4.4E-13	9.3E-13
Cs-136	2.9E+06	7.5E-09	1.6E-08
Cs-137	2.7E+07	6.8E-08	1.5E-07
Ba-137m	2.7E+07	6.8E-08	1.5E-07
Ba-140	1.4E+07	3.5E-08	7.6E-08
Ce-141	9.8E+06	2.5E-08	5.3E-08
Ce-144	4.5E+07	1.1E-07	2.4E-07
Pr-144	4.5E+07	1.1E-07	2.4E-07
Pr-144m	4.5E+07	1.1E-07	2.4E-07
Pm-146	5.1E+06	1.3E-08	2.8E-08
Pm-147	5.9E+07	1.5E-07	3.2E-07
Pm-148	3.7E+07	9.3E-08	2.0E-07
Pm-148m	3.3E+06	8.5E-09	1.8E-08
Sm-151	8.1E+05	2.1E-09	4.4E-09
Eu-152	1.5E+07	3.9E-08	8.4E-08
Eu-154	8.1E+06	2.1E-08	4.4E-08
Eu-155	1.5E+07	3.7E-08	8.0E-08
Gd-153	1.5E+07	3.9E-08	8.4E-08
Tb-160	1.1E+07	2.9E-08	6.2E-08
Pu-238	2.3E+06	5.8E-09	1.2E-08
Pu-239	2.3E+06	5.8E-09	1.2E-08
Pu-240	2.3E+06	5.8E-09	1.2E-08
Pu-241	8.1E+07	2.1E-07	4.4E-07
Am-241	2.3E+06	5.8E-09	1.2E-08
Am-242m	4.2E+04	1.1E-10	2.3E-10
Am-243	2.3E+06	5.8E-09	1.2E-08
Cm-242	2.3E+06	5.8E-09	1.2E-08
Cm-243	2.3E+06	5.8E-09	1.2E-08
Cm-244	2.3E+06	5.8E-09	1.2E-08
Subject for exposure assessment		Swimming Beach sand Fishing nets Ingest of Marine products	Sea surface Ship hull

Table 5-9 Concentration in Seawater Used for Assessment (source term based on the hypothetical ALPS treated water)

Subject radionuclide	Annual discharge (Bq)	Seawater concentration used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
H-3	2.2E+13	5.6E-02	1.2E-01
C-14	1.1E+11	2.8E-04	6.0E-04
Fe-59	4.4E+07	1.1E-07	2.4E-07
Zn-65	3.1E+10	7.8E-05	1.7E-04
Ag-110m	1.3E+07	3.4E-08	7.2E-08
Cd-113m	4.4E+07	1.1E-07	2.4E-07
Cd-115m	8.8E+08	2.2E-06	4.8E-06
Sn-119m	1.3E+10	3.4E-05	7.2E-05
Sn-123	1.8E+09	4.5E-06	9.6E-06
Sn-126	8.8E+07	2.2E-07	4.8E-07
Subject exposure assessment		Swimming Beach sand Fishing nets Ingest of Marine products	Sea surface Ship hull

Table 5-10 Results of Assessment Regarding Exposure of Humans

Case assessed	Source term	(1) Source term based on measured value						(2) Source term based on the hypothetical ALPS treated water	
		i. K4 tank group		ii. J1-C tank group		iii. J1-G tank group			
	Marine products ingest	Average amount	Large amount	Average amount	Large amount	Average amount	Large amount	Average amount	Large amount
External exposure (mSv/year)	Sea surface	6.5E-09		1.7E-08		4.7E-08		1.8E-07	
	Ship hull	5.2E-09		1.3E-08		3.4E-08		1.4E-07	
	Swimming	2.8E-10		7.6E-10		2.0E-09		7.9E-09	
	Beach sand	5.0E-07		1.3E-06		3.6E-06		1.4E-05	
	Fishing nets	1.6E-06		4.3E-06		1.2E-05		4.5E-05	
Internal exposure (mSv/year)		1.5E-05	6.1E-05	2.8E-05	1.1E-04	7.9E-05	3.0E-04	4.8E-04	2.0E-03
Total (mSv/year)		1.7E-05	6.3E-05	3.4E-05	1.1E-04	9.4E-05	3.1E-04	5.4E-04	2.1E-03

Table 5-11 Results of Assessment Regarding Internal Exposure by Age

Case assessed	Source term	(1) Source term based on the measured value				(2) Source term based on the hypothetical ALPS treated water			
		i. K4 tank group		ii. J1-C tank group	iii. J1-G tank group				
	Marine products ingest	Average amount	Large amount	Average amount	Large amount	Average amount	Large amount	Average amount	Large amount
Internal exposure (mSv/year)	Adult	1.5E-05	6.1E-05	2.8E-05	1.1E-04	7.9E-05	3.0E-04	4.8E-04	2.0E-03
	Child	2.4E-05	9.4E-05	5.1E-05	2.0E-04	1.5E-04	5.6E-04	7.5E-04	3.1E-03
	Infant	2.9E-05	1.1E-04	6.7E-05	2.5E-04	1.9E-04	7.1E-04	9.4E-04	3.9E-03

6. Summary

Human exposure assessment of the planned sea discharge of ALPS treated water at FDNPS was evaluated based on the information at the design process. As a result of the calculations with multiple source terms and multiple food ingests, the annual exposure doses ranged from 1.7E-05mSv/year to 2.1E-03mSv/year, which is significantly lower than the ICRP recommendation of 1mSv/year for the general public as well as the Domestic Nuclear Power Plant dose target of 0.05mSv/year in Japan.

Uncertainties in the results of this assessment are shown in Reference I.

This report will be disseminated both domestically and internationally, reviewed by various fields/persons, reviews by IAEA experts, and cross-checks by third party evaluation. While appropriately reflecting the opinions received from various parties, to optimize the risks associated with the disposal as needed. The evaluation of this report is also planned to be revised accordingly.

Reference Documents

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[3] Subcommittee on the Handling of Treated Water from Radionuclide Removal Facilities, "Report of the Subcommittee on the Handling of Treated Water from Radionuclide Removal Facilities", 2020.

[4] Council of Ministers for Decommissioning and Contaminated Water Management, "Basic Policy on Disposal of Treated Water from Radionuclide Removal Facilities at TEPCO's Fukushima Daiichi Nuclear Power Station", 2021.

[5] Tokyo Electric Power Company Holdings, Inc., Action in Response to the Government’s Policy on the Handling of ALPS Treated Water from the Fukushima Daiichi Nuclear Power Station, 2021.

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[7] IAEA, IAEA SAFETY STANDARD SERIES No.GSG-10 “Prospective Radiological Environmental Impact Assessment for Facilities and Activities”, 2018.

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[19] ICRP, “ICRP Publication72 “Age-dependent Doses to the Members of the Public from Intake of Radionuclide - Part 5 Compilation of Ingestion and Inhalation Dose Coefficients” ”, ICRP, 1995.

[20] IAEA, “Technical Reports Series No.422 “Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment” ”, 2004.

[21] Stanley E. Thompson, C. Ann Burton, Dorothy J. Quinn, Yook C. Ng, “CONCENTRATION FACTORS OF CHEMICAL ELEMENTS IN EDIBLE AQUATIC ORGANISM”, LAWRENCE LIVERMORE LABORATORY, 1972.

[22] Japan Atomic Energy Commission Decision, “Guidelines for the Assessment of Target Dose Values Around Commercial Light Water Reactor Facilities”, 1976.

Reference A Assessment of Potential Exposure

As the first step to applying the three principles for radiological protection (justification, optimization and dose limitation) to the act of discharging radioactive material into the environment, the IAEA Safety Standards GSG-9 "Regulatory Control of Radioactive Discharges to the Environment"[A1] refers only to protecting the public from the discharge of radioactive materials from facilities under normal operation.

Only the exposure assessment for humans under normal operation is subject in the main text of this report, but in the [Digest version] TEPCO's Action in Response to the Government's Policy on the Handling of ALPS Treated Water [A2], 2. Design and Operation of Necessary Facilities, the conceptual diagram states that discharge will be stopped if the facilities cannot perform their expected functions due to failure or outages, and an emergency isolation valve is installed. Thus, assessment of potential exposure[20] was conducted assuming shutdown of seawater pump for dilution and failure of the emergency isolation valve.

The assumed event was the shutdown of the seawater transfer pump used for dilution during normal discharge, and ALPS treated water continuously being discharged from the sample tank into the sea without dilution due to the emergency isolation valve failing to actuate. The Handbook Assessing the Impact of Decommissioning on the Environment [A3], 5. Environmental Impact Assessment Model for Accidents, 1) Principles for assumed environmental transition pathways, was referred to for the transition pathway. External exposure from sea surface which cannot be controlled and causes short term impact was the subject. Specific methods for exposure assessment and their results are as follows.

a Source term

ALPS treated water to be discharged has been transferred to the sample tank prior to discharge, and has the concentration of radioactive material checked. The subject event only involves the shutdown of the dilution sea water pump; therefore, the discharge rate of radionuclides does not fluctuate from normal operation, and only the concentration in discharged water becomes higher.

Assessment was limited to external exposure from the sea surface, and the case resulting in the most significant impact with the discharge rate of Te-127 being the highest (when H-3 concentration is 100,000Bq/L), was assessed.

- Subject radionuclide Te-127 (half-life approx. 9 hours)
- Concentration 5,000Bq/L (legally required concentration)
- Based on the flow rate of ALPS treated water of 5,100m^3/day when diluting (67 times) the H-3 concentration at 100,000Bq/L to 1,500Bq/L using 340,000m^3/day seawater for dilution, the discharge rate is 5,000Bq/L×5,100m^3/day = 2.6E+10Bq/day.

b Dispersion assessment

Data from meteorological and sea phenomenon in 2014 and 2019 were used to calculate dispersion in accordance with the regional sea modeling system used for assessing exposure to humans.

Sea current travelling parallel to the coastline in the north south direction is predominant in the sea area in front of FDNPS. Therefore, the point near the boundary for the area where fishery is not conducted on a daily basis (approx. 1 km to the north), where general ships

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[20] Potential Exposure：Exposure considering future events that are not guaranteed to occur but can be anticipated as probable events or sequence of events such as operational events, accidents involving radiation source, equipment failure and operational errors.

performed work in the north south direction from the discharge point, was set as the assessment point.

Sea dispersion simulation using actual meteorological conditions is subject to changes in the current direction; therefore, the sea surface concentration in various points within 1 km radius from the point of discharge was averaged daily, and the largest value throughout the year was used as the seawater concentration in the assessment.

Of the annual fluctuations in the years 2014 and 2019, the maximum concentration recorded was 6.1Bq/L.

c Exposure assessment

A system of sample tanks consists of ten connected tanks. Therefore, it is possible for the discharge to continue for about 2 days at maximum; however, the exposed time shall be set to one day (24 hours) as ships can be evacuated for the subject sea area, and further entry could be restricted.

The dose conversion factor for Te-127 is 5.0E-07[(mSv/h)/(Bq/L)]; therefore, the effective dose of external exposure received from sea surface based on concentration and duration is as follows.

Effective dose＝6.1[Bq/L]×5.0E-07[(mSv/h)/(Bq/L)]×24[h]

＝7.3E-05[mSv]

Therefore, the value was extremely small when compared to the diagnostic criteria of estimated dose during accident presented in GSG-10 which is 5mSv.

As indicated above, while the hypothetical shutdown of dilution seawater pump would temporarily increase the concentration of radioactive material in seawater, the exposure result is small which compared to diagnostic criteria for accidents.

End

Reference

[A1] Regulatory Control of Radioactive Discharges to the Environment, IAEA General Safety Guide No.GSG-9, 2018

[A2] [Digest Version] TEPCO’s Action in Response to the Government’s Policy on the Handling of ALPS Treated Water, April 16, 2021

[A3] FY2006 Technical Survey to Assess the Environmental Impact from Decommissioning a Commercial Nuclear Reactor- Research（Research and Study of Parameters for Assessing Environmental Impact） Attachment Handbook Assessing the Impact of Decommissioning on the Environment (3rd edition), Central Research Institute of Electric Power Industry, March 2007

Reference B Assessment Regarding Environmental Protection

In the IAEA Safety Standard GSG-10 “Prospective Radiological Environmental Impact Assessment for Facilities and Activities”, assessment regarding environmental protection is mentioned not in the main text, but in Attachment I. Procedures listed in Annex I of GSG-10 were used as reference in assessing environmental protection in this report.

B1. Principle for assessment
Conduct assessment for the protection of animals and plants during normal operation as indicated in the IAEA Safety Standard GSG-10 Annex I.

B2. Assessment procedures
Assessment shall be conducted in accordance with the procedure presented in Figure B-1.

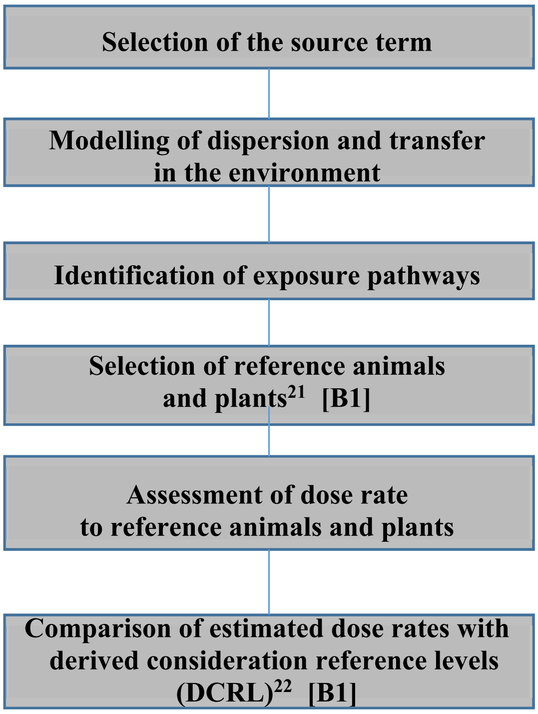


Figure B-1 Steps for the Assessment of Environmental Protection (developed based on GSG-10)

[21] Reference animals and plants: A specific type of animals and plants hypothesized to link the dose and impact regarding exposure to background radiation

[22] Derived consideration reference levels (DCRL): A band of dose rates with a single-digit range for each species of organisms, defined by the ICRP. In cases where this dose rate level is exceeded, the effect on organism should be considered.

B3. Assessment method

a. Source term

Source term shall be set with the same principle as 4-1. Source term. The source term by the measured value for 64 radionuclides shall use the values presented in tables 5-1 to 5-3. Regarding the upper limit for discharge control, Table E-5 shall be referred to for setting the annual discharge amount based on ALPS treated water ("the sum of the ratios" of radionuclides other than tritium is 1) which includes the two radionuclides (Fe-59 and Sn-126), subject to operational control due to its relatively significant impact on exposure, at the highest operation control value ("the sum of the ratios" of Fe-59 and Sn-126 is 0.0025) and Pm-148m at 499Bq/L (the ratio to legally required concentration of Pm-148m is 0.9975), representing the other 61 radionuclides.

b. Modelling dispersion and transition after discharge

(i) Sea dispersion model

Use the same model as the one used to assess protection of humans.

(ii)Transfer model

Consider the items below regarding the transfer models of radioactive material discharged into the sea.

(1) Dispersion and transfer by sea current, etc.

(2) Dispersion and transfer by sea current, etc. → transition to marine sediments on undersea

c. Identifying exposure pathways

The model below shall be used to calculate internal exposure received by reference animals and plants from radioactive materials ingested from seawater, and external exposure form radioactive materials in seawater and radioactive material that transitioned to marine sediment.

The equation for absorbed dose rate D_E (mGy/day) is indicated in equation (B1).

$$D_E = \sum_i (DCF_{int})_{ki} \cdot (x_7)_i \cdot (CR)_{ki} + 0.5 \cdot \left\{ \sum_i (DCF_{ext})_{ki} \cdot (x_7)_i \cdot (1 + (K_d)_i) \right\} \quad \text{(B1)}$$

In this equation

$(DCF_{int})_{ki}$ is the dose conversion factor ((mGy/day)/(Bq/kg)) for internal exposure of marine products k from radionuclide i

$(x_7)_i$ is the concentration of radionuclide i in seawater (Bq/L) at the sea area subject to assessment

$(CR)_{ki}$ is the concentration ratio of radionuclide i between marine products k and seawater ((Bq/kg)/(Bq/L))

$(DCF_{ext})_{ki}$ is the dose conversion factor ((mGy/day)/(Bq/kg)) for external exposure of marine products k from radionuclide i

$(K_d)_i$ is the concentration distribution coefficient (((Bq/kg)/(Bq/L)) of radionuclide i from seawater to sediment

Small scale brown seaweed, primarily consisting of the perennial algae sea oak, are widely distributed along the coast of Fukushima Prefecture where the power station is located [B2]. There are no special sea areas around the power station such as habitats of marine products designated as natural treasure [B3]; therefore, the concentration of radioactive material in seawater used for assessment shall be the average concentration in an area 10km*10km around the power station, similar to assessment for the protection of humans. However, concentration at the undersea (bottom layer) shall be used to assess external exposure through sediments.

The ICRP Publication 136 “Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation”(ICRP, 2017) [B4] and the ICRP BiotaDC program [B5] were referenced for the internal exposure dose conversion factor and external exposure dose conversion factors[23] for animals and plants (indicated in tables B-1 and B-2). The dose conversion factor for Sn-126 could not be calculated using BiotaDC, so internal/external dose conversion factor for Ru-106 and Ag-110m were used respectively as conservative values.

ICRP Publication 114 “Environmental Protection: Transfer Parameters for Reference Animals and Plants” (ICRP, 2009) [B6] was referred to for the concentration ratio of animals/plants and seawater[24]. For elements not included in the publication, the concentration factor for IAEA TRS-422 “Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment” (IAEA, 2004) [B7] was referenced (indicated in Table B-3). The concentration distribution factors for seawater and marine sediment are established in 2.3.OCEAN MARGIN Kds of IAEA TRS-422 (shown in Table B-4).

d. Selection of reference animals and plants (organism subject to assessment)

Reference animals and plants indicated in ICRP Publication 136 were selected as listed below while considering the animals and plants present in the peripheral sea area.

- flat fish (flounders and flukes are widely distributed in the sea area around the power station)
- crab (portunus trituberculatus and ovalipes punctatus are widely distributed in the sea area around the power station)
- brown seaweed (gulfweed and sea oak are widely distributed in the sea area around the power station)

e. Dose assessment

Dose assessment shall be conducted for each type of reference animals and plants by comparing with the derived consideration reference levels (DCRL) presented in the ICRP Publication 124 “Protection of the Environment under Different Exposure Situations”.

[23] Dose conversion factor for animals/plants: A conversion coefficient used for the simplified calculation of internal exposure and external exposure received by an organism through environmental radionuclides.

[24] Concentration ratio (CR): A transfer coefficient which empirically derives the ratio between radionuclide concentration in marine products with radionuclide concentration in the environment seawater for the purpose of use in the review of exposure in animals and plants from background radiation (ICRP, 2009). Not limited to edible parts as in concentration factor.

Table B-1 Internal Exposure Dose Conversion Factors for Animals and plants

	Subject radionuclide	Internal exposure dose conversion factor ((mGy/day) /(Bq/kg))			Remarks
		Flat fish	Crab	Brown seaweed	
1	H-3	7.9E-08	7.9E-08	7.9E-08	
2	C-14	7.0E-07	7.0E-07	7.0E-07	
3	Mn-54	1.1E-06	1.4E-06	9.4E-07	
4	Fe-59	2.9E-06	3.4E-06	2.0E-06	
5	Co-58	1.6E-06	2.1E-06	1.5E-06	
6	Co-60	3.8E-06	5.0E-06	3.6E-06	
7	Ni-63	2.4E-07	2.4E-07	2.4E-07	
8	Zn-65	7.7E-07	1.0E-06	7.0E-07	
9	Rb-86	8.8E-06	9.1E-06	6.9E-06	
10	Sr-89	7.7E-06	7.9E-06	7.7E-06	
11	Sr-90	1.4E-05	1.5E-05	1.4E-05	
12	Y-90	—	—	—	Included in parent radionuclide Sr-90
13	Y-91	8.0E-06	8.1E-06	6.4E-06	
14	Nb-95	1.5E-06	1.9E-06	1.4E-06	
15	Tc-99	1.4E-06	1.4E-06	1.4E-06	
16	Ru-103	2.1E-06	2.3E-06	2.0E-06	
17	Ru-106	1.7E-05	1.9E-05	1.7E-05	
18	Rh-103m	—	—	—	Included in parent radionuclide Ru-103
19	Rh-106	—	—	—	Included in parent radionuclide Ru-106
20	Ag-110m	4.3E-06	5.5E-06	4.1E-06	
21	Cd-113m	2.5E-06	2.5E-06	2.4E-06	
22	Cd-115m	8.0E-06	8.2E-06	6.4E-06	
23	Sn-119m	1.2E-06	1.2E-06	1.1E-06	
24	Sn-123	7.0E-06	7.1E-06	5.8E-06	
25	Sn-126	1.7E-05	1.9E-05	1.7E-05	Used values for Ru-106
26	Sb-124	7.0E-06	7.9E-06	6.7E-06	
27	Sb-125	2.0E-06	2.2E-06	1.9E-06	
28	Te-123m	1.6E-06	1.7E-06	1.4E-06	
29	Te-125m	1.7E-06	1.8E-06	1.6E-06	
30	Te-127	3.1E-06	3.1E-06	2.9E-06	
31	Te-127m	4.2E-06	4.2E-06	4.0E-06	
32	Te-129	—	—	—	Included in parent radionuclide Te-129m
33	Te-129m	8.4E-06	8.6E-06	8.2E-06	
34	I-129	1.0E-06	1.1E-06	1.0E-06	
35	Cs-134	4.1E-06	4.8E-06	3.8E-06	

	Subject radionuclide	Internal exposure dose conversion factor ((mGy/day) /(Bq/kg))			Remarks
		Flat fish	Crab	Brown seaweed	
36	Cs-135	1.2E-06	1.2E-06	1.2E-06	
37	Cs-136	4.3E-06	5.3E-06	4.1E-06	
38	Cs-137	4.1E-06	4.3E-06	4.1E-06	
39	Ba-137m	—	—	—	Included in parent radionuclide Cs-137
40	Ba-140	1.4E-05	1.5E-05	1.4E-05	
41	Ce-141	2.4E-06	2.6E-06	2.4E-06	
42	Ce-144	1.6E-05	1.7E-05	1.6E-05	
43	Pr-144	—	—	—	Included in parent radionuclide Cs-144
44	Pr-144m	—	—	—	Included in parent radionuclide Cs-144
45	Pm-146	2.3E-06	2.6E-06	1.5E-06	
46	Pm-147	8.6E-07	8.6E-07	8.5E-07	
47	Pm-148	9.9E-06	1.1E-05	7.3E-06	
48	Pm-148m	5.2E-06	6.1E-06	3.3E-06	
49	Sm-151	2.8E-07	2.8E-07	2.8E-07	
50	Eu-152	3.1E-06	3.6E-06	2.9E-06	
51	Eu-154	5.0E-06	5.8E-06	5.0E-06	
52	Eu-155	1.0E-06	1.0E-06	9.8E-07	
53	Gd-153	8.5E-07	9.2E-07	7.0E-07	
54	Tb-160	4.8E-06	5.4E-06	3.7E-06	
55	Pu-238	7.7E-05	7.7E-05	7.7E-05	
56	Pu-239	7.2E-05	7.2E-05	7.2E-05	
57	Pu-240	7.2E-05	7.2E-05	7.2E-05	
58	Pu-241	7.4E-08	7.4E-08	7.4E-08	
59	Am-241	7.7E-05	7.7E-05	7.7E-05	
60	Am-242m	3.6E-06	3.6E-06	3.4E-06	
61	Am-243	7.9E-05	7.9E-05	7.8E-05	
62	Cm-242	8.6E-05	8.6E-05	8.6E-05	
63	Cm-243	8.4E-05	8.4E-05	8.4E-05	
64	Cm-244	8.2E-05	8.2E-05	8.2E-05	

Table B-2 External Exposure Dose Conversion Factor for Animals and plants

	Subject radionuclide	External exposure dose conversion factor ((mGy/day) /(Bq/kg))			Remarks
		Flat fish	Crab	Brown seaweed	
1	H-3	1.9E-14	2.4E-16	2.4E-16	
2	C-14	4.3E-10	5.3E-10	5.3E-10	
3	Mn-54	1.1E-05	1.0E-05	1.1E-05	
4	Fe-59	1.5E-05	1.5E-05	1.6E-05	
5	Co-58	1.2E-05	1.2E-05	1.2E-05	
6	Co-60	3.1E-05	3.1E-05	3.4E-05	
7	Ni-63	2.6E-11	4.1E-11	4.1E-11	
8	Zn-65	7.4E-06	7.2E-06	7.4E-06	
9	Rb-86	1.7E-06	1.4E-06	3.7E-06	
10	Sr-89	3.6E-07	2.0E-07	4.1E-07	
11	Sr-90	1.2E-06	5.5E-07	1.2E-06	
12	Y-90	—	—	—	Included in parent radionuclide Sr-90
13	Y-91	4.4E-07	2.5E-07	2.0E-06	
14	Nb-95	9.6E-06	9.4E-06	9.8E-06	
15	Tc-99	3.1E-09	3.4E-09	3.6E-09	
16	Ru-103	6.2E-06	6.0E-06	6.2E-06	
17	Ru-106	5.3E-06	3.8E-06	5.3E-06	
18	Rh-103m	—	—	—	Included in parent radionuclide Ru-103
19	Rh-106	—	—	—	Included in parent radionuclide Ru-106
20	Ag-110m	3.6E-05	3.4E-05	3.6E-05	
21	Cd-113m	1.7E-08	1.6E-08	1.4E-07	
22	Cd-115m	8.2E-07	6.2E-07	2.4E-06	
23	Sn-119m	1.0E-07	8.0E-08	1.7E-07	
24	Sn-123	3.7E-07	2.5E-07	1.6E-06	
25	Sn-126	3.6E-05	3.4E-05	3.6E-05	Used values for Ag-110m
26	Sb-124	2.4E-05	2.3E-05	2.4E-05	
27	Sb-125	5.5E-06	5.3E-06	5.5E-06	
28	Te-123m	1.8E-06	1.7E-06	2.0E-06	
29	Te-125m	2.9E-07	2.4E-07	4.3E-07	
30	Te-127	8.9E-08	8.3E-08	2.9E-07	
31	Te-127m	1.8E-07	1.6E-07	4.2E-07	
32	Te-129	—	—	—	Included in parent radionuclide Te-129m
33	Te-129m	1.2E-06	1.1E-06	1.3E-06	
34	I-129	2.2E-07	1.9E-07	2.4E-07	

	Subject radionuclide	External exposure dose conversion factor ((mGy/day) /(Bq/kg))			Remarks
		Flat fish	Crab	Brown seaweed	
35	Cs-134	2.0E-05	1.9E-05	2.0E-05	
36	Cs-135	2.2E-09	2.6E-09	2.6E-09	
37	Cs-136	2.6E-05	2.6E-05	2.6E-05	
38	Cs-137	7.2E-06	7.0E-06	7.2E-06	
39	Ba-137m	—	—	—	Included in parent radionuclide Cs-137
40	Ba-140	3.1E-05	3.1E-05	3.4E-05	
41	Ce-141	9.6E-07	9.1E-07	9.8E-07	
42	Ce-144	2.6E-06	1.5E-06	2.6E-06	
43	Pr-144	—	—	—	Included in parent radionuclide Cs-144
44	Pr-144m	—	—	—	Included in parent radionuclide Cs-144
45	Pm-146	9.5E-06	9.1E-06	1.0E-05	
46	Pm-147	9.9E-10	1.1E-09	1.0E-08	
47	Pm-148	8.1E-06	7.5E-06	1.1E-05	
48	Pm-148m	2.5E-05	2.4E-05	2.7E-05	
49	Sm-151	7.7E-11	8.4E-11	7.6E-10	
50	Eu-152	1.5E-05	1.4E-05	1.5E-05	
51	Eu-154	1.6E-05	1.5E-05	1.6E-05	
52	Eu-155	7.4E-07	7.0E-07	7.4E-07	
53	Gd-153	1.2E-06	1.1E-06	1.4E-06	
54	Tb-160	1.4E-05	1.4E-05	1.5E-05	
55	Pu-238	4.6E-09	3.8E-09	5.5E-09	
56	Pu-239	2.6E-09	2.3E-09	3.1E-09	
57	Pu-240	4.3E-09	3.6E-09	5.3E-09	
58	Pu-241	1.9E-11	1.9E-11	2.0E-11	
59	Am-241	2.9E-07	2.6E-07	2.9E-07	
60	Am-242m	2.4E-07	2.3E-07	4.2E-07	
61	Am-243	2.9E-06	2.8E-06	3.2E-06	
62	Cm-242	5.3E-09	4.3E-09	6.2E-09	
63	Cm-243	1.6E-06	1.5E-06	1.6E-06	
64	Cm-244	4.8E-09	3.8E-09	5.5E-09	

Table B-3 Concentration Ratio for Animals and plants

	Subject radionuclide	Concentration ratio ((Bq/kg) /(Bq/L))			Remarks
		Flat fish	Crab	Brown seaweed	
1	H-3	1.0E+00	1.0E+00	3.7E-01	
2	C-14	1.2E+04	1.0E+04	8.0E+03	
3	Mn-54	2.5E+02	2.5E+03	1.1E+04	
4	Fe-59	3.0E+04	5.0E+05	2.0E+04	Referenced from TRS422
5	Co-58	3.3E+02	4.7E+03	6.8E+02	
6	Co-60	3.3E+02	4.7E+03	6.8E+02	
7	Ni-63	2.7E+02	9.1E+02	2.0E+03	
8	Zn-65	2.2E+04	3.0E+05	1.3E+04	
9	Rb-86	3.6E+01	1.4E+01	1.2E+01	Used homologous Cs value
10	Sr-89	1.0E+01	2.4E+00	4.3E+01	
11	Sr-90	1.0E+01	2.4E+00	4.3E+01	
12	Y-90	—	—	—	Assessed using values for parent nuclide Sr-90
13	Y-91	2.0E+01	1.0E+03	1.0E+03	Referenced from TRS422
14	Nb-95	3.0E+01	1.0E+02	8.1E+01	
15	Tc-99	8.0E+01	1.9E+02	3.7E+04	
16	Ru-103	1.6E+01	1.0E+02	2.9E+02	
17	Ru-106	1.6E+01	1.0E+02	2.9E+02	
18	Rh-103m	—	—	—	Assessed using values for parent nuclide Ru-103
19	Rh-106	—	—	—	Assessed using values for parent nuclide Ru-106
20	Ag-110m	8.1E+03	2.0E+05	1.9E+03	
21	Cd-113m	1.3E+04	1.2E+04	1.6E+03	
22	Cd-115m	1.3E+04	1.2E+04	1.6E+03	
23	Sn-119m	5.0E+05	5.0E+05	2.0E+05	Referenced from TRS422
24	Sn-123	5.0E+05	5.0E+05	2.0E+05	Referenced from TRS422
25	Sn-126	5.0E+05	5.0E+05	2.0E+05	Referenced from TRS422
26	Sb-124	6.0E+02	3.0E+02	1.5E+03	
27	Sb-125	6.0E+02	3.0E+02	1.5E+03	
28	Te-123m	1.0E+03	1.0E+03	1.0E+04	
29	Te-125m	1.0E+03	1.0E+03	1.0E+04	
30	Te-127	1.0E+03	1.0E+03	1.0E+04	
31	Te-127m	1.0E+03	1.0E+03	1.0E+04	
32	Te-129	—	—	—	Assessed using values for parent nuclide Te-129m
33	Te-129m	1.0E+03	1.0E+03	1.0E+04	

	Subject radionuclide	Concentration ratio ((Bq/kg) /(Bq/L))			Remarks
		Flat fish	Crab	Brown seaweed	
34	I-129	9.0E+00	3.0E+00	1.4E+03	
35	Cs-134	3.6E+01	1.4E+01	1.2E+01	
36	Cs-135	3.6E+01	1.4E+01	1.2E+01	
37	Cs-136	3.6E+01	1.4E+01	1.2E+01	
38	Cs-137	3.6E+01	1.4E+01	1.2E+01	
39	Ba-137m	—	—	—	Assessed using values for parent nuclide Cs-137
40	Ba-140	9.6E+00	8.0E+02	1.6E+03	
41	Ce-141	2.1E+02	1.0E+02	9.5E+02	
42	Ce-144	2.1E+02	1.0E+02	9.5E+02	
43	Pr-144	—	—	—	Assessed using values for parent nuclide Ce-144
44	Pr-144m	—	—	—	Assessed using values for parent nuclide Ce-144
45	Pm-146	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
46	Pm-147	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
47	Pm-148	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
48	Pm-148m	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
49	Sm-151	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
50	Eu-152	7.3E+02	2.4E+04	1.1E+03	
51	Eu-154	7.3E+02	2.4E+04	1.1E+03	
52	Eu-155	7.3E+02	2.4E+04	1.1E+03	
53	Gd-153	7.3E+02	2.4E+04	5.9E+03	Used values from homologous Eu (fish, crab), La (brown seaweed)
54	Tb-160	6.0E+01	4.0E+03	2.0E+03	Referenced from TRS422
55	Pu-238	2.1E+01	3.8E+01	2.4E+03	
56	Pu-239	2.1E+01	3.8E+01	2.4E+03	
57	Pu-240	2.1E+01	3.8E+01	2.4E+03	
58	Pu-241	2.1E+01	3.8E+01	2.4E+03	
59	Am-241	1.9E+02	5.0E+02	7.7E+01	
60	Am-242m	1.9E+02	5.0E+02	7.7E+01	
61	Am-243	1.9E+02	5.0E+02	7.7E+01	

	Subject radionuclide	Concentration ratio ((Bq/kg) /(Bq/L))			Remarks
		Flat fish	Crab	Brown seaweed	
62	Cm-242	1.9E+02	5.0E+02	8.4E+03	
63	Cm-243	1.9E+02	5.0E+02	8.4E+03	
64	Cm-244	1.9E+02	5.0E+02	8.4E+03	

Table B-4 Distribution Coefficient of Seawater and Marine Sediment

	Subject radionuclide	Concentration distribution coefficient ((Bq/kg) /(Bq/L))	Remarks
1	H-3	1.0E+00	
2	C-14	1.0E+03	
3	Mn-54	2.0E+06	
4	Fe-59	3.0E+08	
5	Co-58	3.0E+05	
6	Co-60	3.0E+05	
7	Ni-63	2.0E+04	
8	Zn-65	7.0E+04	
9	Rb-86	4.0E+03	Used homologous Cs value
10	Sr-89	8.0E+00	
11	Sr-90	8.0E+00	
12	Y-90	—	Assessed using values for parent nuclide Sr-90
13	Y-91	9.0E+05	
14	Nb-95	8.0E+05	
15	Tc-99	1.0E+02	
16	Ru-103	4.0E+04	
17	Ru-106	4.0E+04	
18	Rh-103m	—	Assessed using values for parent nuclide Ru-103
19	Rh-106	—	Assessed using values for parent nuclide Ru-106
20	Ag-110m	1.0E+04	
21	Cd-113m	3.0E+04	
22	Cd-115m	3.0E+04	
23	Sn-119m	4.0E+06	
24	Sn-123	4.0E+06	
25	Sn-126	4.0E+06	
26	Sb-124	2.0E+03	
27	Sb-125	2.0E+03	

	Subject radionuclide	Concentration distribution coefficient ((Bq/kg) /(Bq/L))	Remarks
28	Te-123m	1.0E+03	
29	Te-125m	1.0E+03	
30	Te-127	1.0E+03	
31	Te-127m	1.0E+03	
32	Te-129	—	Assessed using values for parent nuclide Te-129m
33	Te-129m	1.0E+03	
34	I-129	7.0E+01	
35	Cs-134	4.0E+03	
36	Cs-135	4.0E+03	
37	Cs-136	4.0E+03	
38	Cs-137	4.0E+03	
39	Ba-137m	—	Assessed using values for parent nuclide Cs-137
40	Ba-140	2.0E+03	
41	Ce-141	3.0E+06	
42	Ce-144	3.0E+06	
43	Pr-144	—	Assessed using values for parent nuclide Ce-144
44	Pr-144m	—	Assessed using values for parent nuclide Ce-144
45	Pm-146	2.0E+06	
46	Pm-147	2.0E+06	
47	Pm-148	2.0E+06	
48	Pm-148m	2.0E+06	
49	Sm-151	3.0E+06	
50	Eu-152	2.0E+06	
51	Eu-154	2.0E+06	
52	Eu-155	2.0E+06	
53	Gd-153	2.0E+06	
54	Tb-160	2.0E+06	
55	Pu-238	1.0E+05	
56	Pu-239	1.0E+05	
57	Pu-240	1.0E+05	
58	Pu-241	1.0E+05	
59	Am-241	2.0E+06	
60	Am-242m	2.0E+06	
61	Am-243	2.0E+06	
62	Cm-242	2.0E+06	
63	Cm-243	2.0E+06	

	Subject radionuclide	Concentration distribution coefficient ((Bq/kg) /(Bq/L))	Remarks
64	Cm-244	2.0E+06	

B4. Assessment results

a. Source term

As indicated in B3, tables 5-1 to 5-3 shall be used for the source term by the measured value.

The assessment results of ALPS treated water being discharged for each radionuclide at the legally required concentration, are presented in Table B-5. After the radionuclides Fe-59 and Sn-126 subject to operational control, Pm-148m had the most significant relative impact on exposure.

Based on the results, the source term based on the hypothetical ALPS treated water was obtained by multiplying the ALPS treated water with "the sum of the ratios" of radionuclides other than tritium is 1 by the annual discharged amount. Fe-59 and Sn-126 are included in the source term with the concentration of the operational control value ("the sum of the ratios" of Fe-59 and Sn-126 is 0.0025), and Pm-148m is included as a representative nuclide of the other 61 nuclides with 499 Bq/L (the ratio to legally required concentration of Pm-148m is 0.9975). The source term set is presented in Table B-6.

b. Result of assessing dispersion and transfer

Seawater concentration used for exposure assessment was calculated using the same method implemented in the assessment for protecting humans, through the dispersion and transfer calculation results and source term. Exposure assessment shall consider the impact of marine sediment, so concentration at the bottom layer shall be used.

Table B-7 presents the tritium concentration (average annual concentration) in seawater at the bottom layer in an area 10km*10km around the power station if tritium is discharged at a rate of 22 TBq (2.2E+13Bq) annually. The concentration used for assessment was the same as used for the assessment of human exposure: the meteorological and sea phenomenon in 2019.

The results of this assessment and the seawater concentration used in the exposure assessment for each radionuclide derived from source term in tables 5-1 to 5-3 and Table B-6 are presented in tables B-8 to B-11.

c. Results of exposure assessment

The assessment results of exposure for reference animals and plants are presented in Table B-12. Both results demonstrated low dose rate, at or below 1/100 the value when compared to the lower limit of the derived consideration reference levels.

Table B-5 Result of Exposure Assessment Regarding Environmental Protection if Discharge is Conducted With Each Radionuclide Being at the Legally required concentration Limits

No.	Subject radionuclide	Flat fish [mGy/day]	Crab [mGy/day]	Brown seaweed [mGy/day]	Remarks
1	Fe-59	5.4E-01	5.4E-01	5.8E-01	Subject to operational control
2	Sn-126	9.7E-03	9.3E-03	9.0E-03	Subject to operational control
3	Pm-148m	7.5E-03	7.2E-03	8.1E-03	Representative radionuclide
4	Mn-54	6.6E-03	6.0E-03	6.6E-03	
5	Eu-152	5.4E-03	5.1E-03	5.4E-03	
6	Pm-146	5.1E-03	4.9E-03	5.4E-03	
7	Tb-160	4.2E-03	4.2E-03	4.5E-03	
8	Eu-154	3.8E-03	3.6E-03	3.8E-03	
9	Nb-95	2.3E-03	2.3E-03	2.4E-03	
10	Gd-153	2.2E-03	2.3E-03	2.5E-03	
11	Pm-148	1.5E-03	1.4E-03	2.0E-03	
12	Eu-155	1.3E-03	1.3E-03	1.3E-03	
13	Co-58	1.1E-03	1.1E-03	1.1E-03	
14	Sn-123	1.0E-03	9.7E-04	1.0E-03	Subject to operational control
15	Sn-119m	9.6E-04	9.1E-04	6.7E-04	Subject to operational control
16	Ce-141	8.6E-04	8.2E-04	8.8E-04	
17	Co-60	5.6E-04	5.6E-04	6.1E-04	
18	Ce-144	4.7E-04	2.7E-04	4.7E-04	
19	Ru-103	7.4E-05	7.2E-05	7.5E-05	
20	Ag-110m	3.9E-05	2.3E-04	3.4E-05	Subject to operational control
21	Y-91	3.6E-05	2.2E-05	1.6E-04	
22	Zn-65	3.1E-05	6.6E-05	3.1E-05	
23	Cd-115m	2.1E-05	1.9E-05	8.3E-06	Subject to operational control
24	C-14	1.0E-05	8.4E-06	6.7E-06	Subject to operational control
25	Te-127	9.4E-06	9.4E-06	8.7E-05	
26	Cs-136	9.4E-06	9.4E-06	9.4E-06	
27	Am-243	8.7E-06	8.5E-06	9.6E-06	
28	Ru-106	6.4E-06	4.7E-06	6.7E-06	
29	Cm-243	5.8E-06	5.6E-06	8.3E-06	

No.	Subject radionuclide	Flat fish [mGy/day]	Crab [mGy/day]	Brown seaweed [mGy/day]	Remarks
30	Ba-140	5.6E-06	7.7E-06	1.0E-05	
31	Sb-124	5.1E-06	4.6E-06	6.1E-06	
32	Sb-125	3.2E-06	2.9E-06	4.0E-06	
33	Pm-147	2.2E-06	8.2E-06	2.3E-05	
34	Te-129m	1.6E-06	1.6E-06	1.5E-05	
35	Cs-134	1.4E-06	1.4E-06	1.4E-06	
36	Sm-151	1.0E-06	6.9E-06	6.4E-06	
37	Te-125m	1.0E-06	1.0E-06	8.8E-06	
38	Am-241	9.1E-07	9.0E-07	8.9E-07	
39	Te-123m	9.0E-07	9.2E-07	5.4E-06	
40	Cd-113m	7.9E-07	7.3E-07	1.4E-07	Subject to operational control
41	Cs-137	7.9E-07	7.6E-07	7.8E-07	
42	Cm-242	7.8E-07	1.7E-06	2.6E-05	
43	Te-127m	7.7E-07	7.7E-07	7.2E-06	
44	Am-242m	7.2E-07	7.0E-07	1.3E-06	
45	Rb-86	6.7E-07	5.3E-07	1.3E-06	
46	Ni-63	2.3E-07	7.9E-07	1.7E-06	
47	Cm-244	8.6E-08	1.9E-07	2.9E-06	
48	Tc-99	6.7E-08	1.6E-07	3.1E-05	
49	Cs-135	1.7E-08	7.9E-09	7.1E-09	
50	Sr-89	1.4E-08	3.6E-09	6.0E-08	
51	H-3	4.7E-09	4.7E-09	1.8E-09	
52	Pu-238	4.4E-09	7.5E-09	4.4E-07	
53	Pu-240	4.1E-09	7.0E-09	4.2E-07	
54	Pu-239	3.9E-09	6.8E-09	4.2E-07	
55	Sr-90	2.6E-09	6.9E-10	1.1E-08	
56	Pu-241	3.0E-10	4.5E-10	2.1E-08	
57	I-129	9.1E-11	5.4E-11	7.6E-09	
58	Y-90	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
59	Rh-103m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
60	Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
61	Te-129	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results

No.	Subject radionuclide	Flat fish [mGy/day]	Crab [mGy/day]	Brown seaweed [mGy/day]	Remarks
62	Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
63	Pr-144	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
64	Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results

Table B-6 Source Term based on the hypothetical ALPS treated water (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)
H-3	1.0E+05	2.2E+08	2.2E+13
Fe-59	2.0E-01		4.4E+07
Sn-126	4.0E-01		8.8E+07
Pm-148m	5.0E+02		1.1E+11

Table B-7 Tritium Concentration in Seawater if 2.2E+13Bq of Tritium is Discharged Annually

Assessment point	Depth	Calculation Results (Bq/L)			Concentration for assessment (Bq/L)
		Meteorological/sea phenomenon in 2014	Meteorological/sea phenomenon in 2019	Difference (%)	
Average concentration in an area 10km*10km around the power station	Bottom layer	5.0E-02	6.0E-02	19	6.0E-02

Table B-8 Concentration in Seawater Used for Assessment (source term by the radionuclide composition in K4 tank group)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
H-3	2.2E+13	6.0E-02
C-14	1.7E+09	4.7E-06
Mn-54	7.8E+05	2.1E-09
Fe-59	2.0E+06	5.4E-09
Co-58	9.3E+05	2.5E-09
Co-60	5.1E+07	1.4E-07
Ni-63	2.5E+08	6.9E-07

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
Zn-65	1.7E+06	4.7E-09
Rb-86	2.2E+07	6.0E-08
Sr-89	1.2E+07	3.2E-08
Sr-90	2.5E+07	6.9E-08
Y-90	2.5E+07	6.9E-08
Y-91	2.5E+08	6.9E-07
Nb-95	1.2E+06	3.2E-09
Tc-99	8.1E+07	2.2E-07
Ru-103	1.2E+06	3.2E-09
Ru-106	1.9E+08	5.1E-07
Rh-103m	1.2E+06	3.2E-09
Rh-106	1.9E+08	5.1E-07
Ag-110m	6.5E+05	1.8E-09
Cd-113m	2.1E+06	5.7E-09
Cd-115m	7.4E+07	2.0E-07
Sn-119m	2.0E+07	5.4E-08
Sn-123	1.4E+08	3.8E-07
Sn-126	3.1E+06	8.5E-09
Sb-124	1.1E+06	3.0E-09
Sb-125	3.8E+07	1.0E-07
Te-123m	1.1E+06	2.9E-09
Te-125m	3.8E+07	1.0E-07
Te-127	3.7E+07	1.0E-07
Te-127m	3.7E+07	1.0E-07
Te-129	9.4E+06	2.6E-08
Te-129m	3.7E+07	1.0E-07
I-129	2.4E+08	6.6E-07
Cs-134	5.2E+06	1.4E-08
Cs-135	2.9E+02	7.9E-13
Cs-136	3.5E+06	9.5E-09
Cs-137	4.9E+07	1.3E-07
Ba-137m	4.9E+07	1.3E-07
Ba-140	1.1E+07	3.0E-08
Ce-141	2.9E+06	7.9E-09
Ce-144	7.3E+06	2.0E-08
Pr-144	7.3E+06	2.0E-08
Pr-144m	7.3E+06	2.0E-08
Pm-146	1.1E+07	3.1E-08

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
Pm-147	2.2E+07	6.0E-08
Pm-148	5.8E+07	1.6E-07
Pm-148m	9.7E+05	2.7E-09
Sm-151	1.0E+05	2.8E-10
Eu-152	3.2E+06	8.8E-09
Eu-154	1.4E+06	3.8E-09
Eu-155	3.8E+06	1.0E-08
Gd-153	3.7E+06	1.0E-08
Tb-160	3.2E+06	8.8E-09
Pu-238	7.3E+04	2.0E-10
Pu-239	7.3E+04	2.0E-10
Pu-240	7.3E+04	2.0E-10
Pu-241	3.2E+06	8.8E-09
Am-241	7.3E+04	2.0E-10
Am-242m	4.5E+03	1.2E-11
Am-243	7.3E+04	2.0E-10
Cm-242	7.3E+04	2.0E-10
Cm-243	7.3E+04	2.0E-10
Cm-244	7.3E+04	2.0E-10
Subject exposure assessment		Environmental protection

Table B-9 Concentration in Seawater Used for Assessment (source term by the radionuclide composition in J1-C tank group)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
H-3	2.2E+13	6.0E-02
C-14	4.8E+08	1.3E-06
Mn-54	1.0E+06	2.8E-09
Fe-59	2.3E+06	6.4E-09
Co-58	1.1E+06	3.0E-09
Co-60	8.9E+06	2.4E-08
Ni-63	2.3E+08	6.2E-07
Zn-65	2.5E+06	6.9E-09
Rb-86	1.3E+07	3.7E-08
Sr-89	1.4E+06	4.0E-09
Sr-90	9.7E+05	2.6E-09
Y-90	9.7E+05	2.6E-09
Y-91	4.6E+08	1.2E-06
Nb-95	1.3E+06	3.7E-09
Tc-99	3.2E+07	8.8E-08
Ru-103	1.4E+06	3.9E-09
Ru-106	3.8E+07	1.0E-07
Rh-103m	1.4E+06	3.9E-09
Rh-106	3.8E+07	1.0E-07
Ag-110m	1.2E+06	3.1E-09
Cd-113m	2.3E+06	6.2E-09
Cd-115m	7.2E+07	2.0E-07
Sn-119m	1.1E+09	3.1E-06
Sn-123	1.8E+08	4.8E-07
Sn-126	7.8E+06	2.1E-08
Sb-124	2.6E+06	7.1E-09
Sb-125	6.2E+06	1.7E-08
Te-123m	2.5E+06	6.7E-09
Te-125m	6.2E+06	1.7E-08
Te-127	1.3E+08	3.4E-07
Te-127m	1.3E+08	3.6E-07
Te-129	1.7E+07	4.5E-08
Te-129m	3.8E+07	1.0E-07
I-129	3.2E+07	8.8E-08
Cs-134	2.0E+06	5.6E-09
Cs-135	3.2E+01	8.8E-14

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
Cs-136	1.3E+06	3.4E-09
Cs-137	5.1E+06	1.4E-08
Ba-137m	5.1E+06	1.4E-08
Ba-140	5.4E+06	1.5E-08
Ce-141	7.0E+06	1.9E-08
Ce-144	1.5E+07	4.2E-08
Pr-144	1.5E+07	4.2E-08
Pr-144m	1.5E+07	4.2E-08
Pm-146	1.8E+06	4.9E-09
Pm-147	2.1E+07	5.9E-08
Pm-148	6.2E+06	1.7E-08
Pm-148m	1.3E+06	3.5E-09
Sm-151	3.0E+05	8.0E-10
Eu-152	7.5E+06	2.0E-08
Eu-154	3.0E+06	8.0E-09
Eu-155	9.1E+06	2.5E-08
Gd-153	7.0E+06	1.9E-08
Tb-160	3.8E+06	1.0E-08
Pu-238	8.9E+05	2.4E-09
Pu-239	8.9E+05	2.4E-09
Pu-240	8.9E+05	2.4E-09
Pu-241	3.2E+07	8.8E-08
Am-241	8.9E+05	2.4E-09
Am-242m	1.6E+04	4.3E-11
Am-243	8.9E+05	2.4E-09
Cm-242	8.9E+05	2.4E-09
Cm-243	8.9E+05	2.4E-09
Cm-244	8.9E+05	2.4E-09
Subject exposure assessment		Environmental protection

Table B-10 Concentration in Seawater Used for Assessment (source term by the radionuclide composition in J1-G tank group)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
H-3	2.2E+13	6.0E-02
C-14	1.3E+09	3.6E-06

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
Mn-54	3.1E+06	8.4E-09
Fe-59	5.9E+06	1.6E-08
Co-58	3.0E+06	8.2E-09
Co-60	1.9E+07	5.1E-08
Ni-63	7.2E+08	2.0E-06
Zn-65	6.5E+06	1.8E-08
Rb-86	3.8E+07	1.0E-07
Sr-89	3.7E+06	1.0E-08
Sr-90	2.6E+06	7.1E-09
Y-90	2.6E+06	7.1E-09
Y-91	9.8E+08	2.7E-06
Nb-95	3.8E+06	1.0E-08
Tc-99	1.1E+08	2.9E-07
Ru-103	4.2E+06	1.1E-08
Ru-106	3.9E+07	1.1E-07
Rh-103m	4.2E+06	1.1E-08
Rh-106	3.9E+07	1.1E-07
Ag-110m	3.3E+06	8.9E-09
Cd-113m	7.0E+06	1.9E-08
Cd-115m	1.9E+08	5.1E-07
Sn-119m	3.3E+09	8.9E-06
Sn-123	5.1E+08	1.4E-06
Sn-126	1.2E+07	3.3E-08
Sb-124	6.8E+06	1.9E-08
Sb-125	1.1E+07	3.1E-08
Te-123m	5.5E+06	1.5E-08
Te-125m	1.1E+07	3.1E-08
Te-127	3.5E+08	9.6E-07
Te-127m	3.7E+08	1.0E-06
Te-129	4.8E+07	1.3E-07
Te-129m	9.8E+07	2.7E-07
I-129	2.7E+07	7.3E-08
Cs-134	5.5E+06	1.5E-08
Cs-135	1.7E+02	4.7E-13
Cs-136	2.9E+06	8.0E-09
Cs-137	2.7E+07	7.3E-08
Ba-137m	2.7E+07	7.3E-08
Ba-140	1.4E+07	3.8E-08

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
Ce-141	9.8E+06	2.7E-08
Ce-144	4.5E+07	1.2E-07
Pr-144	4.5E+07	1.2E-07
Pr-144m	4.5E+07	1.2E-07
Pm-146	5.1E+06	1.4E-08
Pm-147	5.9E+07	1.6E-07
Pm-148	3.7E+07	1.0E-07
Pm-148m	3.3E+06	9.1E-09
Sm-151	8.1E+05	2.2E-09
Eu-152	1.5E+07	4.2E-08
Eu-154	8.1E+06	2.2E-08
Eu-155	1.5E+07	4.0E-08
Gd-153	1.5E+07	4.2E-08
Tb-160	1.1E+07	3.1E-08
Pu-238	2.3E+06	6.2E-09
Pu-239	2.3E+06	6.2E-09
Pu-240	2.3E+06	6.2E-09
Pu-241	8.1E+07	2.2E-07
Am-241	2.3E+06	6.2E-09
Am-242m	4.2E+04	1.1E-10
Am-243	2.3E+06	6.2E-09
Cm-242	2.3E+06	6.2E-09
Cm-243	2.3E+06	6.2E-09
Cm-244	2.3E+06	6.2E-09
Subject exposure assessment		Environmental protection

Table B-11 Concentration in Seawater Used for Assessment (source term based on the hypothetical ALPS treated water)

Subject radionuclide	Annual discharge (Bq)	Concentration in seawater used for assessment (within an area of 10km*10km)
		Average concentration of bottom layer (Bq/L)
H-3	2.2E+13	6.0E-02
Fe-59	4.4E+07	1.2E-07
Sn-126	8.8E+07	2.4E-07
Pm-148m	1.1E+11	3.0E-04
Subject exposure assessment		Environmental protection

Table B-12 Results of Assessment Regarding Environmental Protection

Assessment case		(1) Source term by measured value			(2) Source term based on the hypothetical ALPS treated water
		i. K4 tank group	ii. J1-C tank group	iii. J1-G tank group	
Exposure (mGy/day)	Flat fish	1.7E-05	2.2E-05	5.6E-05	7.8E-03
	Crab	1.7E-05	2.2E-05	5.5E-05	7.5E-03
	Brown seaweed	1.9E-05	2.3E-05	5.9E-05	8.4E-03
Derived consideration reference levels (DCRL) Flat fish：1-10 mGy/day　Crab：10-100 mGy/day　Brown seaweed：1-10 mGy/day					

Reference

[B1] ICRP, ICRP Publication 124 “Protection of the Environment under Different Exposure Situations” ,2013

[B2] Ministry of the Environment, The Report of the Marine Biotic Environment Survey in the 4th National Survey on the Natural Environment (survey of dry beach, sea-grass bed, coral reef), 1994

[B3] Agency for Cultural Affairs, Emergency Survey of Natural Treasures, Vegetation Map/Key Animals and plants Map, Fukushima Prefecture, 1971

[B4] ICRP, ICRP Publication 136 "Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation", 2017

[B5] ICRP, BiotaDC v.1.5.1 http://biotadc.icrp.org/, 2017

[B6] ICRP, ICRP Publication 114 "Environmental Protection : Transfer Parameters for Reference Animals and Plants", 2009

[B7] IAEA, Technical Reports Series No.422 ”Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment”, 2004

Reference C Principles for the Selection of Radionuclides Subject to Removal by ALPS

C1. Strategy for selecting radionuclides to removal

Water treatment by the ALPS (fresh water, RO concentrated salt water and water at the outlet of treatment equipment) is assumed to contain radioactive material from fuel in the reactors of Units 1-3 (hereinafter FP radionuclide) and radioactive material from corrosion products contained in water from when the plant was operating (hereinafter CP radionuclide). As part of the design of the ALPS, it is necessary to estimate the FP and CP radionuclides in water to treat that exist at a high concentration which should be removed to reduce the risk of the public becoming exposed to radiation in the unlikely event that the water treatment leaks out into the environment.

Therefore, in estimating the concentration of radioactive materials contained in the water to be treated, FP nuclides were selected those that were assumed to be present in significant concentrations based on the evaluation results of the core inventory. For those nuclides that had been measured in March 2011, the concentrations in the stagnant water were estimated based on the measurement results. For the nuclides that had not been measured, the concentrations in the retained water were estimated based on the evaluation results of the core inventory.

Regarding the CP nuclides, it is considered that the nuclides contained in the reactor retained water at the time of plant operation have transferred to the accumulated water, and that the nuclides contained in the retained water in the concentrated waste tank were mixed in when the accumulated water was transferred to the high temperature incinerator building.
The concentrations of the nuclides in the retained water were estimated using the results of the measurement of CP nuclides in the retained water of the reactor and the concentrated liquid waste tank during the plant operation.

As it was assumed that the operation of the ALPS was to commence one year after (365 days after) reactor shutdown, the half-life of both FP and CP radionuclides were considered, and the concentration in accumulated water 365 days after reactor shutdown was estimated after applying decay correction. The radionuclide with concentration, calculated through decay correction, exceeding 1/100 of the legally required concentration were considered to exist in significant concentrations in accumulated water 365 days after reactor shutdown, and selected as being subject to removal by ALPS. As the values are at or below 1/100, “the sum of ratios” of excluded radionuclides is approx. 0.05 at maximum. Therefore, the concentrations of excluded radionuclides are considered to be sufficiently low.

C2. Method for selecting radionuclides subject to removal and its results

(1) Method for selecting FP radionuclides subject to removal and its results
Selection of FP radionuclides to be removed was conducted in accordance with the flow chart in Figure C-1. Consequently, 56 radionuclides were selected for removal.

(2) Method for selecting CP radionuclides subject to removal and its results
Selection of CP radionuclides to be removed was conducted in accordance with the flow chart in Figure C-2. Consequently, 6 radionuclides were selected for removal.

(3) Summary of selecting radionuclides subject to removal
A total of 62 radionuclides, 56 FP radionuclides and 6 CP radionuclides were selected to be subject to removal (refer to Table C-1).

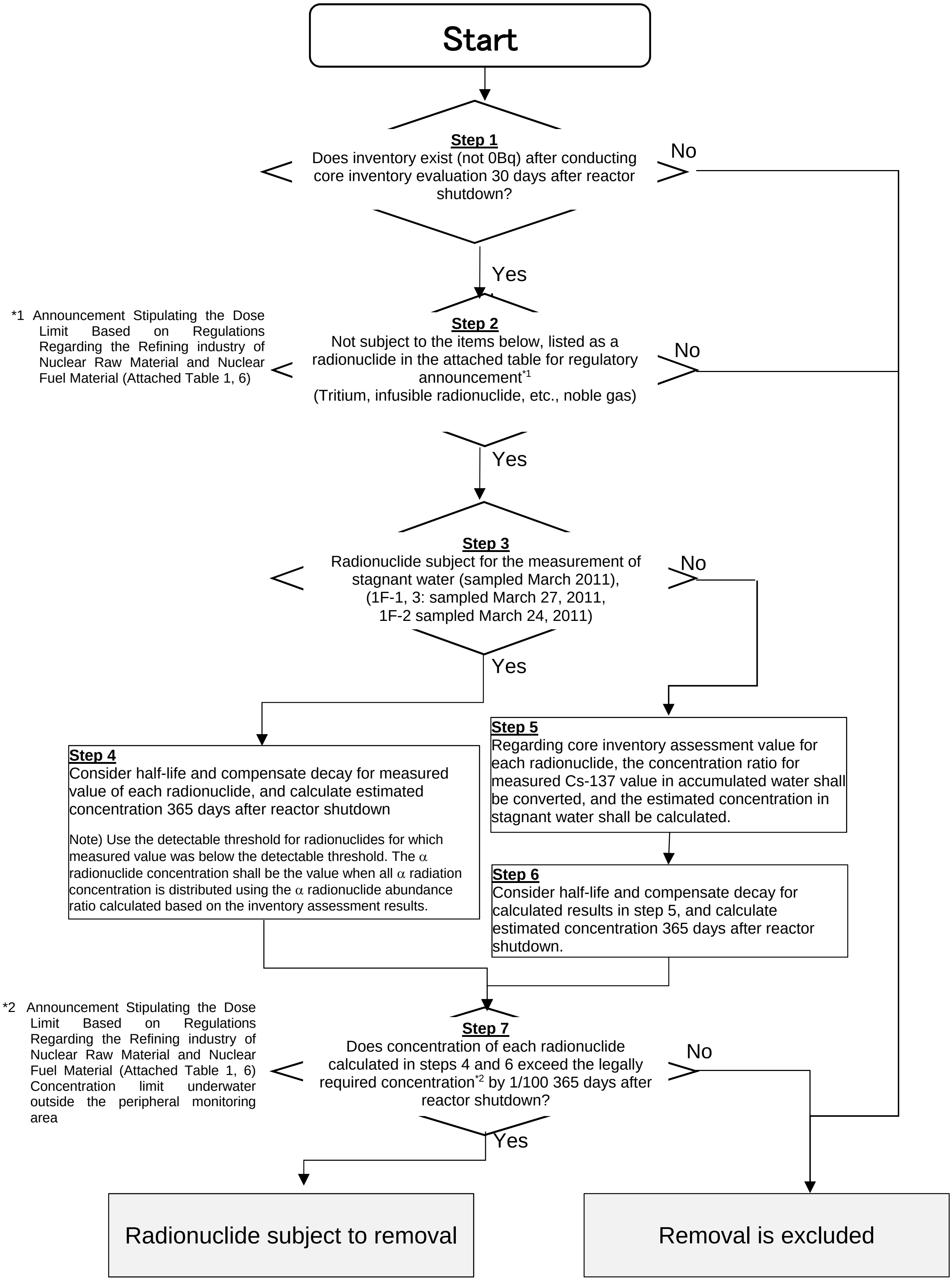


Figure C-1: Flow Chart for the Selection of FP Radionuclide Subject to Removal

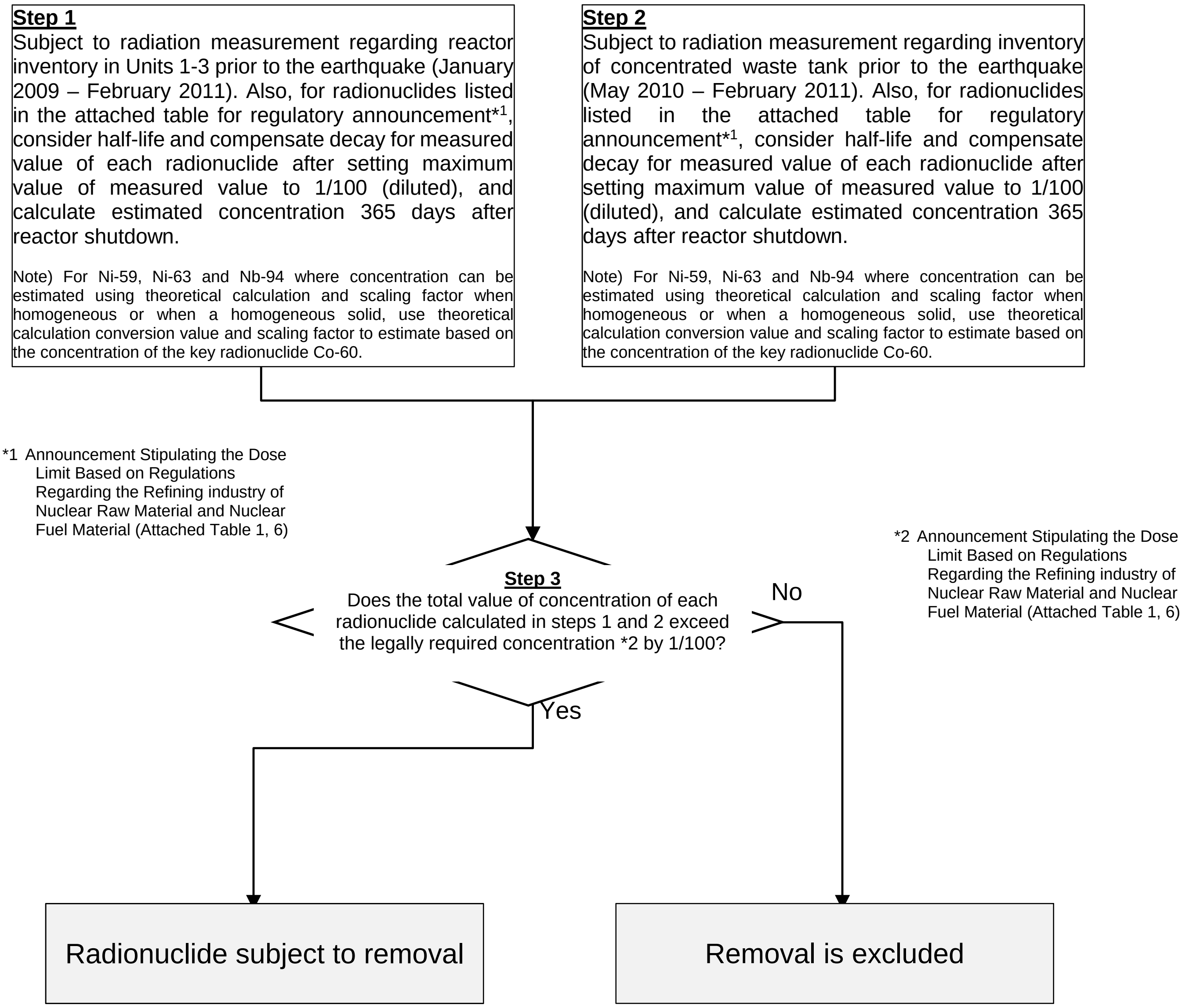


Figure C-2 Flow Chart for the Selection of CP Radionuclides Subject to Removal

Table C-1 List of Radionuclides Subject to Removal

No.	Radionuclide	Physical half-life	Radiation type	No	Radionuclide	Physical half-life	Radiation type
1	Mn-54	310d	γ	32	I-129	1.6E+07y	βγ
2	Fe-59	44 d	γ	33	Cs-134	2.1y	βγ
3	Co-58	71d	γ	34	Cs-135	2.3E+06y	β
4	Co-60	5.3y	βγ	35	Cs-136	13d	βγ
5	Ni-63	100y	β	36	Cs-137	30y	βγ
6	Zn-65	240d	βγ	37	Ba-137m	2.6m	γ
7	Rb-86	19d	βγ	38	Ba-140	13d	βγ
8	Sr-89	51d	β	39	Ce-141	33d	βγ
9	Sr-90	29y	β	40	Ce-144	280d	βγ
10	Y-90	64h	β	41	Pr-144	17m	βγ
11	Y-91	59d	βγ	42	Pr-144m	7.2m	γ
12	Nb-95	35d	βγ	43	Pm-146	5.5y	βγ
13	Tc-99	2.1E+05y	β	44	Pm-147	2.6y	βγ
14	Ru-103	39d	βγ	45	Pm-148	5.4d	βγ
15	Ru-106	370d	β	46	Pm-148m	41d	γ
16	Rh-103m	56m	βγ	47	Sm-151	90y	βγ
17	Rh-106	30s	γ	48	Eu-152	14y	βγ
18	Ag-110m	250d	βγ	49	Eu-154	8.6y	βγ
19	Cd-113m	14 y	γ	50	Eu-155	4.8y	βγ
20	Cd-115m	45d	βγ	51	Gd-153	240d	γ
21	Sn-119m	290d	γ	52	Tb-160	72d	βγ
22	Sn-123	130d	βγ	53	Pu-238	88y	α
23	Sn-126	2.3E+05y	βγ	54	Pu-239	2.4E+04y	α
24	Sb-124	60d	βγ	55	Pu-240	6.6E+03y	α
25	Sb-125	2.8y	βγ	56	Pu-241	14y	β
26	Te-123m	120d	γ	57	Am-241	430y	α
27	Te-125m	57d	γ	58	Am-242m	140y	α
28	Te-127	9.4h	βγ	59	Am-243	7.4E+03y	α
29	Te-127m	110d	βγ	60	Cm-242	160d	α
30	Te-129	70m	βγ	61	Cm-243	29y	α
31	Te-129m	34d	βγ	62	Cm-244	18y	α

Reference D Regarding the Water Quality of ALPS Treated Water, etc.

D1. Regarding water quality of ALPS treated water, etc., in tank groups where “the sum of the ratios” of radionuclides other than tritium can be estimated to be less than one.

The key seven radionuclides (the seven radionuclides, Cs-137, Cs-134, Co-60, Sb-125, Ru-106, Sr-90, I-129 detected at significant levels when being treated by ALPS), tritium, and all β rays were measured for each tank group (five to ten units of tanks connected when receiving water from ALPS) that had become full. Samples were collected at a rate of one to two samples per tank group, and in addition to the above, C-14, Tc-99 and all α rays were measured in some tank groups.

Based on the data below disclosed by TEPCO, the analysis results of tank groups for which “the sum of the ratios” of radionuclides other than tritium can be estimated to be less than 1 that were extracted, and the concentration distribution of the key seven radionuclides were organized in Figure D-1*. In the actual discharge, analysis shall be conducted of the 64 radionuclides prior to discharge (62 radionuclides subject to removal +, C-14, tritium), and the legally required concentration except for tritium shall be confirmed to be less than 1.)

Measured radioactivity concentration in each tank group (excluding reused tanks) (as of 31 March 2021) [D1]

Test water for secondary treatment
https://www.tepco.co.jp/decommission/information/newsrelease/reference/pdf/2020/2h/rf_20201224_1.pdf

*The equation for estimating “the sum of the ratios” of radionuclides other than tritium in water stored at each tank group is presented below. Based on past records, “the sum of the ratios” of 56 radionuclides, excluding the key seven radionuclides, is expected to be around 0.41. Therefore, if “the sum of the ratios” of the seven key radionuclides was less than 0.59, subject water was categorized as having “the sum of the ratios” of radionuclides other than tritium below one.

“The sum of the ratios” of the seven key radionuclides (Measured value)	+	ratio to the legally reuired concentration of C-14 (Maximum value: 0.11*1)	+	“The sum of the ratios” of the other 55 radionuclides (Estimated value：0.30*2)

*1: Maximum 215 Bq/L (refer to Figure D-2)
*2: Estimated at 0.3 based on “the sum of the ratios” of the other 55 radionuclides derived from the results of analysis regarding 62 radionuclides at the outlet of ALPS from FY2015-2017 (refer to Reference 2, 10th Subcommittee Regarding the Handling of Water Treated with ALPS, etc. [D2])

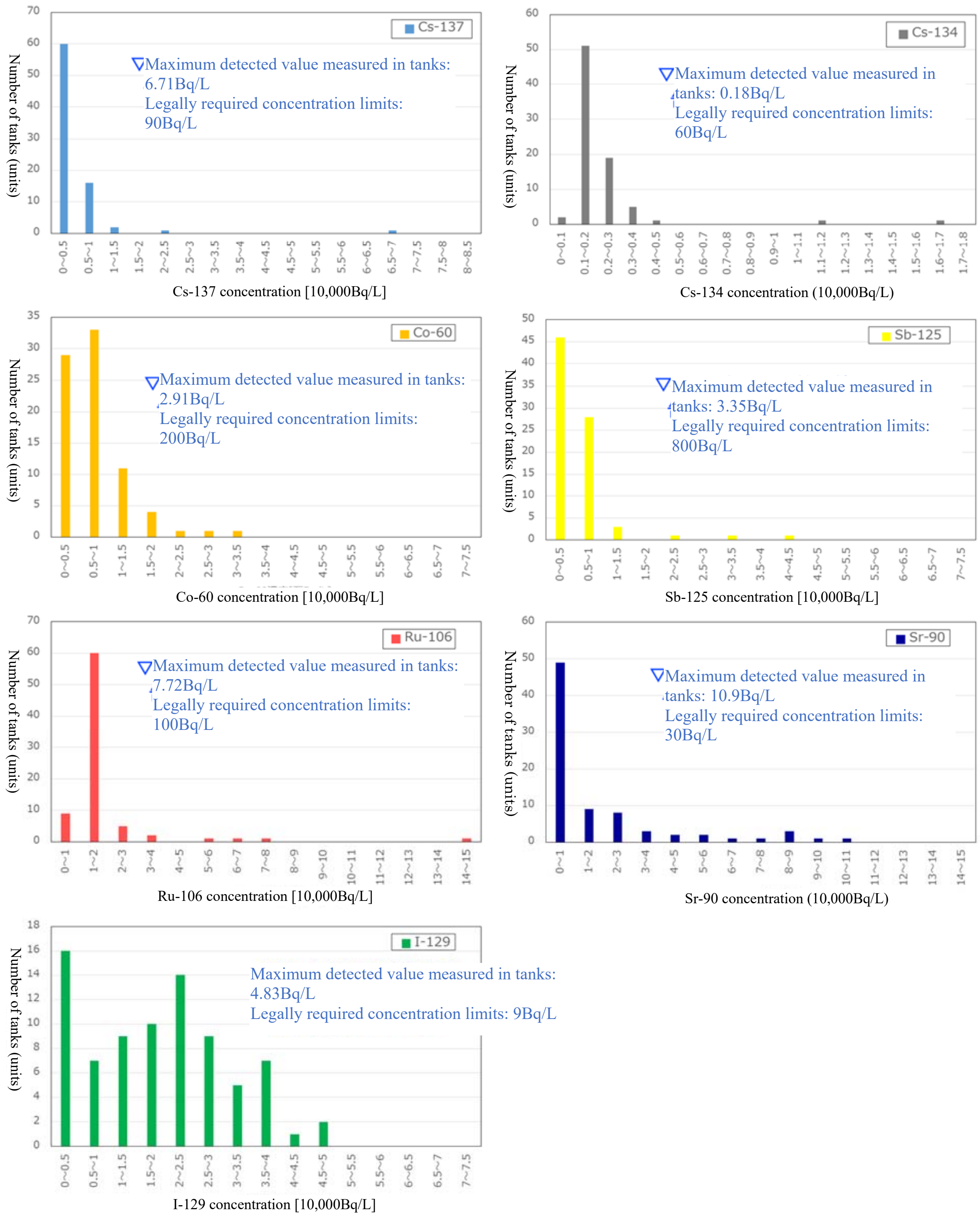
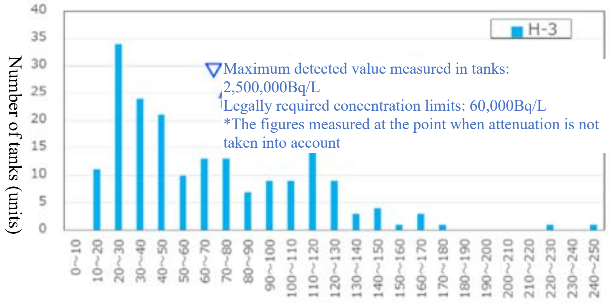


Figure D-1 Distribution of Concentration of the Seven Key Radionuclides in the Analysis Results of ALPS Treated Water, etc.

*Plotted the analysis results (for 80 units) for "the sum of the ratios" of the seven key radionuclides being below 0.59 (excluding test water for secondary treatment)

*The vertical axis indicates the number of tanks

Also, past tank analysis results [D1] were identified for tritium and C-14 not subject to removal by ALPS, and the created distribution of concentration based on analysis results is presented in Figure D-2.



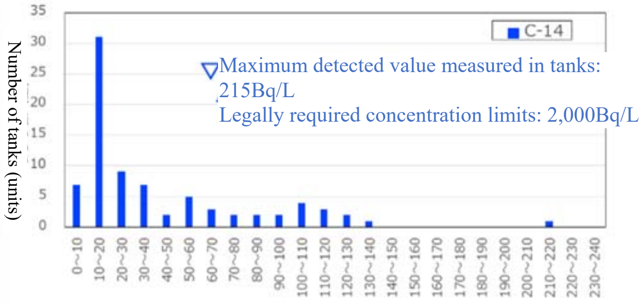


Figure D-2 Distribution of Concentration of Tritium and C-14 in the Analysis Results of ALPS Treated Water, etc.

*Plotted the analysis results for tank groups (189 units for tritium and 81 units for C-14) (excluding test water for secondary treatment)

*The vertical axis indicates the number of tanks

D2. Analysis results of the 64 radionuclides

Analysis results for the K4 tank group [D1] [D3], where complete analysis results for all 64 radionuclides are available, and the analysis results of the two tank groups [D4] subjected to performance tests for secondary treatment, are presented in tables D-1 to D-3.

Table D-1 Analysis Results from the K4 Tank Group

Radionuclide	Legally required concentration limits [Bq/L]	Analysis results [Bq/L]	Ratio of legally required concentration	Remarks
H-3	6.0E+04	1.9E+05	3.2E+00	Discharge after diluting to below 1,500Bq/L
C-14	2.0E+03	1.5E+01	7.5E-03	
Mn-54	1.0E+03	< 6.7E-03	6.7E-06	
Fe-59	4.0E+02	< 1.7E-02	4.3E-05	
Co-58	1.0E+03	< 8.0E-03	8.0E-06	
Co-60	2.0E+02	4.4E-01	2.2E-03	
Ni-63	6.0E+03	2.2E+00	3.7E-04	
Zn-65	2.0E+02	< 1.5E-02	7.5E-05	
Rb-86	3.0E+02	< 1.9E-01	6.3E-04	
Sr-89	3.0E+02	< 1.0E-01	3.3E-04	
Sr-90	3.0E+01	2.2E-01	7.3E-03	
Y-90	3.0E+02	2.2E-01	7.3E-04	Radiation equilibrium with Sr-90
Y-91	3.0E+02	< 2.2E+00	7.3E-03	
Nb-95	1.0E+03	< 1.0E-02	1.0E-05	
Tc-99	1.0E+03	7.0E-01	7.0E-04	
Ru-103	1.0E+03	< 1.0E-02	1.0E-05	
Ru-106	1.0E+02	1.6E+00	1.6E-02	
Rh-103m	2.0E+05	< 1.0E-02	5.0E-08	Radiation equilibrium with Ru-103
Rh-106	3.0E+05	1.6E+00	5.3E-06	Radiation equilibrium with Ru-106

Radionuclide	Legally required concentration limits [Bq/L]	Analysis results [Bq/L]	Ratio of legally required concentration	Remarks
Ag-110m	3.0E+02	< 5.6E-03	1.9E-05	
Cd-113m	4.0E+01	< 1.8E-02	4.5E-04	
Cd-115m	3.0E+02	< 6.4E-01	2.1E-03	
Sn-119m	2.0E+03	< 1.7E-01	8.5E-05	Assessed based on radiation concentration of Sn-123
Sn-123	4.0E+02	< 1.2E+00	3.0E-03	
Sn-126	2.0E+02	< 2.7E-02	1.4E-04	
Sb-124	3.0E+02	< 9.5E-03	3.2E-05	
Sb-125	8.0E+02	3.3E-01	4.1E-04	
Te-123m	6.0E+02	< 9.2E-03	1.5E-05	
Te-125m	9.0E+02	3.3E-01	3.7E-04	Radiation equilibrium with Sb-125
Te-127	5.0E+03	< 3.2E-01	6.4E-05	
Te-127m	3.0E+02	< 3.2E-01	1.1E-03	Assessed based on radiation concentration of Te-127
Te-129	1.0E+04	< 8.1E-02	8.1E-06	
Te-129m	3.0E+02	< 3.2E-01	1.1E-03	
I-129	9.0E+00	2.1E+00	2.3E-01	
Cs-134	6.0E+01	4.5E-02	7.5E-04	
Cs-135	6.0E+02	2.5E-06	4.2E-09	Assessed based on radiation concentration of Cs-137
Cs-136	3.0E+02	< 3.0E-02	1.0E-04	
Cs-137	9.0E+01	4.2E-01	4.7E-03	
Ba-137m	8.0E+05	4.2E-01	5.3E-07	Radiation equilibrium with Cs-137

Radionuclide	Legally required concentration limits [Bq/L]	Analysis results [Bq/L]	Ratio of legally required concentration	Remarks
Ba-140	3.0E+02	< 9.5E-02	3.2E-04	
Ce-141	1.0E+03	< 2.5E-02	2.5E-05	
Ce-144	2.0E+02	< 6.3E-02	3.2E-04	
Pr-144	2.0E+04	< 6.3E-02	3.2E-06	Radiation equilibrium with Ce-144
Pr-144m	4.0E+04	< 6.3E-02	1.6E-06	Radiation equilibrium with Ce-144
Pm-146	9.0E+02	< 9.8E-02	1.1E-04	
Pm-147	3.0E+03	< 1.9E-01	6.3E-05	Assessed based on radiation concentration of Eu-154
Pm-148	3.0E+02	< 5.0E-01	1.7E-03	
Pm-148m	5.0E+02	< 8.4E-03	1.7E-05	
Sm-151	8.0E+03	< 9.0E-04	1.1E-07	Assessed based on radiation concentration of Eu-154
Eu-152	6.0E+02	< 2.8E-02	4.7E-05	
Eu-154	4.0E+02	< 1.2E-02	3.0E-05	
Eu-155	3.0E+03	< 3.3E-02	1.1E-05	
Gd-153	3.0E+03	< 3.2E-02	1.1E-05	
Tb-160	5.0E+02	< 2.8E-02	5.6E-05	
Pu-238	4.0E+00	< 6.3E-04	1.6E-04	Assessed enveloped by measured value of all α rays
Pu-239	4.0E+00	< 6.3E-04	1.6E-04	Assessed enveloped by measured value of all α rays
Pu-240	4.0E+00	< 6.3E-04	1.6E-04	Assessed enveloped by measured value of all α rays

Radionuclide	Legally required concentration limits [Bq/L]	Analysis results [Bq/L]	Ratio of legally required concentration	Remarks
Pu-241	2.0E+02	< 2.8E-02	1.4E-04	Assessed based on radiation concentration of Pu-238
Am-241	5.0E+00	< 6.3E-04	1.3E-04	Assessed enveloped by measured value of all α rays
Am-242m	5.0E+00	< 3.9E-05	7.8E-06	Assessed based on radiation concentration of Am-241
Am-243	5.0E+00	< 6.3E-04	1.3E-04	Assessed enveloped by measured value of all α rays
Cm-242	6.0E+01	< 6.3E-04	1.1E-05	Assessed enveloped by measured value of all α rays
Cm-243	6.0E+00	< 6.3E-04	1.1E-04	Assessed enveloped by measured value of all α rays
Cm-244	7.0E+00	< 6.3E-04	9.0E-05	Assessed enveloped by measured value of all α rays
"The sum of the ratios" of radionuclides other than tritium			2.9E-01	

*The average value of the measurement results for five tanks were used for C-14, the average value of the measurement results for seven tanks were used for H-3 [D1]; the analysis results of composites were used for other radionuclides [D3]

Table D-2 Analysis Results of Test to Verify Performance of Secondary Treatment (J1-C group)

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
H-3	6.0E+04	8.51E+05	1.4E+01	8.22E+05	1.4E+01	Discharge after diluting to below 1,500Bq/L
C-14	2.0E+03	1.53E+01	7.6E-03	1.76E+01	8.8E-03	
Mn-54	1.0E+03	< 3.62E-01	3.6E-04	< 3.83E-02	3.8E-05	

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Fe-59	4.0E+02	< 6.41E-01	1.6E-03	< 8.66E-02	2.2E-04	
Co-58	1.0E+03	< 3.44E-01	3.4E-04	< 4.11E-02	4.1E-05	
Co-60	2.0E+02	3.63E+01	1.8E-01	3.33E-01	1.7E-03	
Ni-63	6.0E+03	5.19E+01	8.6E-03	< 8.45E+00	1.4E-03	
Zn-65	2.0E+02	< 7.19E-01	3.6E-03	< 9.41E-02	4.7E-04	
Rb-86	3.0E+02	< 4.11E+00	1.4E-02	< 4.97E-01	1.7E-03	
Sr-89	3.0E+02	< 6.72E+03	2.2E+01	< 5.37E-02	1.8E-04	
Sr-90	3.0E+01	6.46E+04	2.2E+03	3.57E-02	1.2E-03	
Y-90	3.0E+02	6.46E+04	2.2E+02	3.57E-02	1.2E-04	Radiation equilibrium with Sr-90
Y-91	3.0E+02	< 8.45E+01	2.8E-01	< 1.65E+01	5.5E-02	
Nb-95	1.0E+03	< 3.50E-01	3.5E-04	< 4.96E-02	5.0E-05	
Tc-99	1.0E+03	1.74E+01	1.7E-02	< 1.23E+00	1.2E-03	
Ru-103	1.0E+03	< 7.21E-01	7.2E-04	< 5.27E-02	5.3E-05	
Ru-106	1.0E+02	< 5.00E+00	5.0E-02	1.43E+00	1.4E-02	
Rh-103m	2.0E+05	< 7.21E-01	3.6E-06	< 5.27E-02	2.6E-07	Radiation equilibrium with Ru-103
Rh-106	3.0E+05	< 5.00E+00	1.7E-05	1.43E+00	4.8E-06	Radiation equilibrium with Ru-106
Ag-110m	3.0E+02	< 5.41E-01	1.8E-03	< 4.26E-02	1.4E-04	
Cd-113m	4.0E+01	< 2.05E+01	5.1E-01	< 8.52E-02	2.1E-03	

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Cd-115m	3.0E+02	< 2.26E+01	7.5E-02	< 2.70E+00	9.0E-03	
Sn-119m	2.0E+03	< 3.90E+02	1.9E-01	< 4.24E+01	2.1E-02	Assessed based on radiation concentration of Sn-123
Sn-123	4.0E+02	< 6.06E+01	1.5E-01	< 6.59E+00	1.6E-02	
Sn-126	2.0E+02	< 2.88E+00	1.4E-02	< 2.92E-01	1.5E-03	
Sb-124	3.0E+02	< 2.79E-01	9.3E-04	< 9.67E-02	3.2E-04	
Sb-125	8.0E+02	8.30E+01	1.0E-01	2.26E-01	2.8E-04	
Te-123m	6.0E+02	< 8.32E-01	1.4E-03	< 9.19E-02	1.5E-04	
Te-125m	9.0E+02	8.30E+01	9.2E-02	2.26E-01	2.5E-04	Radiation equilibrium with Sb-125
Te-127	5.0E+03	< 7.25E+01	1.5E-02	< 4.69E+00	9.4E-04	
Te-127m	3.0E+02	< 7.53E+01	2.5E-01	< 4.87E+00	1.6E-02	Assessed based on radiation concentration of Te-127
Te-129	1.0E+04	< 1.27E+01	1.3E-03	< 6.15E-01	6.1E-05	
Te-129m	3.0E+02	< 1.31E+01	4.4E-02	< 1.37E+00	4.6E-03	
I-129	9.0E+00	2.99E+01	3.3E+00	1.16E+00	1.3E-01	
Cs-134	6.0E+01	2.93E+01	4.9E-01	< 7.60E-02	1.3E-03	
Cs-135	6.0E+02	3.81E-03	6.4E-06	1.18E-06	2.0E-09	Assessed based on radiation concentration of Cs-137
Cs-136	3.0E+02	< 3.77E-01	1.3E-03	< 4.68E-02	1.6E-04	
Cs-137	9.0E+01	5.99E+02	6.7E+00	1.85E-01	2.1E-03	

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Ba-137m	8.0E+05	5.99E+02	7.5E-04	1.85E-01	2.3E-07	Radiation equilibrium with Cs-137
Ba-140	3.0E+02	< 2.40E+00	8.0E-03	< 2.02E-01	6.7E-04	
Ce-141	1.0E+03	< 1.51E+00	1.5E-03	< 2.62E-01	2.6E-04	
Ce-144	2.0E+02	< 6.84E+00	3.4E-02	< 5.69E-01	2.8E-03	
Pr-144	2.0E+04	< 6.84E+00	3.4E-04	< 5.69E-01	2.8E-05	Radiation equilibrium with Ce-144
Pr-144m	4.0E+04	< 6.84E+00	1.7E-04	< 5.69E-01	1.4E-05	Radiation equilibrium with Ce-144
Pm-146	9.0E+02	< 1.23E+00	1.4E-03	< 6.66E-02	7.4E-05	
Pm-147	3.0E+03	< 4.08E+00	1.4E-03	< 8.04E-01	2.7E-04	Assessed based on radiation concentration of Eu-154
Pm-148	3.0E+02	< 6.49E-01	2.2E-03	< 2.33E-01	7.8E-04	
Pm-148m	5.0E+02	< 6.34E-01	1.3E-03	< 4.84E-02	9.7E-05	
Sm-151	8.0E+03	< 5.77E-02	7.2E-06	< 1.14E-02	1.4E-06	Assessed based on radiation concentration of Eu-154
Eu-152	6.0E+02	< 2.70E+00	4.5E-03	< 2.84E-01	4.7E-04	
Eu-154	4.0E+02	< 5.77E-01	1.4E-03	< 1.14E-01	2.8E-04	
Eu-155	3.0E+03	< 3.43E+00	1.1E-03	< 3.36E-01	1.1E-04	
Gd-153	3.0E+03	< 3.17E+00	1.1E-03	< 2.64E-01	8.8E-05	
Tb-160	5.0E+02	< 1.66E+00	3.3E-03	< 1.43E-01	2.9E-04	
Pu-238	4.0E+00	5.70E-01	1.4E-01	< 3.25E-02	8.1E-03	Assessed enveloped by measured value of all α rays

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Pu-239	4.0E+00	5.70E-01	1.4E-01	< 3.25E-02	8.1E-03	Assessed enveloped by measured value of all α rays
Pu-240	4.0E+00	5.70E-01	1.4E-01	< 3.25E-02	8.1E-03	Assessed enveloped by measured value of all α rays
Pu-241	2.0E+02	2.07E+01	1.0E-01	< 1.18E+00	5.9E-03	Assessed based on radiation concentration of Pu-238
Am-241	5.0E+00	5.70E-01	1.1E-01	< 3.25E-02	6.5E-03	Assessed enveloped by measured value of all α rays
Am-242m	5.0E+00	1.03E-02	2.1E-03	< 5.87E-04	1.2E-04	Assessed based on radiation concentration of Am-241
Am-243	5.0E+00	5.70E-01	1.1E-01	< 3.25E-02	6.5E-03	Assessed enveloped by measured value of all α rays
Cm-242	6.0E+01	5.70E-01	9.5E-03	< 3.25E-02	5.4E-04	Assessed enveloped by measured value of all α rays
Cm-243	6.0E+00	5.70E-01	9.5E-02	< 3.25E-02	5.4E-03	Assessed enveloped by measured value of all α rays
Cm-244	7.0E+00	5.70E-01	8.1E-02	< 3.25E-02	4.6E-03	Assessed enveloped by measured value of all α rays
"The sum of the ratios" of radionuclides other than tritium		-	2.4E+03	-	3.5E-01	

Table D-3 Analysis Results of Test to Verify Performance of Secondary Treatment (J1-G group)

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
H-3	6.0E+04	2.73E+05	4.6E+00	2.72E+05	4.5E+00	Discharge after diluting to below 1,500Bq/L
C-14	2.0E+03	1.26E+01	6.3E-03	1.56E+01	7.8E-03	
Mn-54	1.0E+03	< 2.02E-01	2.0E-04	< 3.79E-02	3.8E-05	
Fe-59	4.0E+02	< 3.51E-01	8.8E-04	< 7.17E-02	1.8E-04	
Co-58	1.0E+03	< 2.11E-01	2.1E-04	< 3.74E-02	3.7E-05	
Co-60	2.0E+02	1.31E+01	6.5E-02	2.33E-01	1.2E-03	
Ni-63	6.0E+03	< 1.84E+01	3.1E-03	< 8.84E+00	1.5E-03	
Zn-65	2.0E+02	< 4.35E-01	2.2E-03	< 7.97E-02	4.0E-04	
Rb-86	3.0E+02	< 2.56E+00	8.5E-03	< 4.67E-01	1.6E-03	
Sr-89	3.0E+02	< 7.87E+02	2.6E+00	< 4.52E-02	1.5E-04	
Sr-90	3.0E+01	1.04E+04	3.5E+02	< 3.18E-02	1.1E-03	
Y-90	3.0E+02	1.04E+04	3.5E+01	< 3.18E-02	1.1E-04	Radiation equilibrium with Sr-90
Y-91	3.0E+02	< 4.82E+01	1.6E-01	< 1.18E+01	3.9E-02	
Nb-95	1.0E+03	< 2.56E-01	2.6E-04	< 4.70E-02	4.7E-05	
Tc-99	1.0E+03	1.20E+00	1.2E-03	< 1.29E+00	1.3E-03	
Ru-103	1.0E+03	< 3.39E-01	3.4E-04	< 5.06E-02	5.1E-05	
Ru-106	1.0E+02	< 2.27E+00	2.3E-02	4.83E-01	4.8E-03	
Rh-103m	2.0E+05	< 3.39E-01	1.7E-06	< 5.06E-02	2.5E-07	Radiation equilibrium with Ru-103

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Rh-106	3.0E+05	< 2.27E+00	7.6E-06	4.83E-01	1.6E-06	Radiation equilibrium with Ru-106
Ag-110m	3.0E+02	< 2.92E-01	9.7E-04	< 4.00E-02	1.3E-04	
Cd-113m	4.0E+01	< 2.04E+01	5.1E-01	< 8.55E-02	2.1E-03	
Cd-115m	3.0E+02	< 1.16E+01	3.9E-02	< 2.29E+00	7.6E-03	
Sn-119m	2.0E+03	< 2.13E+02	1.1E-01	< 4.03E+01	2.0E-02	Assessed based on radiation concentration of Sn-123
Sn-123	4.0E+02	< 3.31E+01	8.3E-02	< 6.26E+00	1.6E-02	
Sn-126	2.0E+02	< 1.16E+00	5.8E-03	< 1.47E-01	7.3E-04	
Sb-124	3.0E+02	< 2.20E-01	7.3E-04	< 8.42E-02	2.8E-04	
Sb-125	8.0E+02	3.23E+01	4.0E-02	1.37E-01	1.7E-04	
Te-123m	6.0E+02	< 3.83E-01	6.4E-04	< 6.67E-02	1.1E-04	
Te-125m	9.0E+02	3.23E+01	3.6E-02	1.37E-01	1.5E-04	Radiation equilibrium with Sb-125
Te-127	5.0E+03	< 3.53E+01	7.1E-03	< 4.33E+00	8.7E-04	
Te-127m	3.0E+02	< 3.67E+01	1.2E-01	< 4.50E+00	1.5E-02	Assessed based on radiation concentration of Te-127
Te-129	1.0E+04	< 4.71E+00	4.7E-04	< 5.94E-01	5.9E-05	
Te-129m	3.0E+02	< 6.61E+00	2.2E-02	< 1.21E+00	4.0E-03	
I-129	9.0E+00	2.79E+00	3.1E-01	3.28E-01	3.6E-02	
Cs-134	6.0E+01	5.94E+00	9.9E-02	< 6.65E-02	1.1E-03	
Cs-135	6.0E+02	7.51E-04	1.3E-06	2.10E-06	3.5E-09	Assessed based on radiation concentration of Cs-137

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Cs-136	3.0E+02	< 1.96E-01	6.5E-04	< 3.63E-02	1.2E-04	
Cs-137	9.0E+01	1.18E+02	1.3E+00	3.29E-01	3.7E-03	
Ba-137m	8.0E+05	1.18E+02	1.5E-04	3.29E-01	4.1E-07	Radiation equilibrium with Cs-137
Ba-140	3.0E+02	< 1.22E+00	4.1E-03	< 1.73E-01	5.8E-04	
Ce-141	1.0E+03	< 9.39E-01	9.4E-04	< 1.19E-01	1.2E-04	
Ce-144	2.0E+02	< 3.02E+00	1.5E-02	< 5.53E-01	2.8E-03	
Pr-144	2.0E+04	< 3.02E+00	1.5E-04	< 5.53E-01	2.8E-05	Radiation equilibrium with Ce-144
Pr-144m	4.0E+04	< 3.02E+00	7.6E-05	< 5.53E-01	1.4E-05	Radiation equilibrium with Ce-144
Pm-146	9.0E+02	< 5.26E-01	5.8E-04	< 6.30E-02	7.0E-05	
Pm-147	3.0E+03	< 2.53E+00	8.4E-04	< 7.20E-01	2.4E-04	Assessed based on radiation concentration of Eu-154
Pm-148	3.0E+02	< 5.19E-01	1.7E-03	< 4.52E-01	1.5E-03	
Pm-148m	5.0E+02	< 2.76E-01	5.5E-04	< 4.09E-02	8.2E-05	
Sm-151	8.0E+03	< 3.57E-02	4.5E-06	< 1.02E-02	1.3E-06	Assessed based on radiation concentration of Eu-154
Eu-152	6.0E+02	< 1.21E+00	2.0E-03	< 1.90E-01	3.2E-04	
Eu-154	4.0E+02	< 3.57E-01	8.9E-04	< 1.02E-01	2.5E-04	
Eu-155	3.0E+03	< 1.38E+00	4.6E-04	< 1.75E-01	5.8E-05	
Gd-153	3.0E+03	< 1.21E+00	4.0E-04	< 1.85E-01	6.2E-05	
Tb-160	5.0E+02	< 6.88E-01	1.4E-03	< 1.35E-01	2.7E-04	

Radionuclide (half-life)	Legally required concentration limits [Bq/L]	Before secondary treatment		After secondary treatment		Remarks
		Analysis results [Bq/L]	Ratio of legally required concentration	Analysis results [Bq/L]	Ratio of legally required concentration	
Pu-238	4.0E+00	< 3.19E-02	8.0E-03	< 2.80E-02	7.0E-03	Assessed enveloped by measured value of all α rays
Pu-239	4.0E+00	< 3.19E-02	8.0E-03	< 2.80E-02	7.0E-03	Assessed enveloped by measured value of all α rays
Pu-240	4.0E+00	< 3.19E-02	8.0E-03	< 2.80E-02	7.0E-03	Assessed enveloped by measured value of all α rays
Pu-241	2.0E+02	< 1.16E+00	5.8E-03	< 1.02E+00	5.1E-03	Assessed based on radiation concentration of Pu-238
Am-241	5.0E+00	< 3.19E-02	6.4E-03	< 2.80E-02	5.6E-03	Assessed enveloped by measured value of all α rays
Am-242m	5.0E+00	< 5.77E-04	1.2E-04	< 5.05E-04	1.0E-04	Assessed based on radiation concentration of Am-241
Am-243	5.0E+00	< 3.19E-02	6.4E-03	< 2.80E-02	5.6E-03	Assessed enveloped by measured value of all α rays
Cm-242	6.0E+01	< 3.19E-02	5.3E-04	< 2.80E-02	4.7E-04	Assessed enveloped by measured value of all α rays
Cm-243	6.0E+00	< 3.19E-02	5.3E-03	< 2.80E-02	4.7E-03	Assessed enveloped by measured value of all α rays
Cm-244	7.0E+00	< 3.19E-02	4.6E-03	< 2.80E-02	4.0E-03	Assessed enveloped by measured value of all α rays
"The sum of the ratios" of radionuclides other than tritium		-	3.9E+02	-	2.2E-01	

Reference
[D1] Estimated Radiation Concentration for Each Tank Group (as of March 31, 2021) (Tokyo Electric Power Company Holdings, Inc., 2021)
[D2] 10th Subcommittee Regarding the Handling of Water Treated with ALPS, Reference 2 ALPS treated water data collection (assessment results for 62 radionuclides) (Tokyo Electric Power Company Holdings, Inc., 2018)
[D3] 10th Subcommittee Regarding the Handling of Water Treated with ALPS, Reference 3 Data collection for ALPS treated water (for each tank group) (Tokyo Electric Power Company Holdings, Inc., 2018)
[D4] Status Regarding the Performance Test for the Secondary Treatment of ALPS Treated Water, etc. (Tokyo Electric Power Company Holdings, Inc., December 21, 2020)

Reference E Setting Operational Control Value

Sufficient safety will be ensured by confirming "the sum of the ratios" of radionuclides other than tritium is less than one in the case of the discharge of ALPS treated water into the sea, and the water will be diluted by 100 times or more using seawater to ensure that the tritium concentration falls significantly below the legally required concentration. In addition, in order to optimize radiation protection by further reducing the impact on the external environment, TEPCO decided to implement individual operational control for important nuclides in terms of exposure. The following procedure was used to set the operational control values.

1. Selecting radionuclides significant for exposure
2. Set operational control value of radionuclides selected

If concentration exceeds the operational control value, discharge must be stopped and the water will transfer to the storage tanks.

E1. Selection of radionuclides subject to operational control

The legally required concentration is set so that continuous daily ingestion of radioactive material in liquid does not result in annual exposure exceeding 1mSv. Therefore, the annual radiation exposed through direct ingestion remains about the same for different radionuclides if the ratio to legally required concentration is the same. Even if there are multiple radionuclides involved, if "the sum of ratios" is less than one, the annual exposure will not exceed 1mSv.

On the other hand, the behavior in the environment differs depending on the element, such as transfer to organisms. The effects of exposure to radiation are different depending on the nuclides, even when emitted at the same ratio to legally required concentration.

Therefore, to confirm the impact of each radionuclide discharged with the same ratio of legally required concentration, exposure assessment was conducted using a hypothetical ALPS treated water discharge for each radionuclide at the legally required concentration ("the sum of ratios" is one), and radionuclides significant for exposure were selected.

a. Source term

The annual drainage for each radionuclide was set as presented in Table E-1, in accordance with the conditions below.

・The annual drainage for tritium was set to the upper limit, 22 TBq (2.2E+13Bq).

・From the perspective of verifying the impact of radionuclides other than tritium with significant impact on exposure, the tritium concentration in ALPS treated water to be discharged was set to 100,000Bq/L, lower than the tritium concentration in ALPS treated water (approx. 150,000Bq/L-2.5 million Bq/L), and annual drainage was set at a conservatively high value of 220 million L (2.2E+0.8 L).

・Annual amount discharged was set based on the product of the legally required concentration limits and annual drainage for each radionuclide.

b. Concentration of each radionuclide in seawater used for exposure assessment

Based on the tritium concentration in seawater (at all layers) presented in Table 5-5, the concentration of each radionuclide in seawater to be used for exposure assessment was calculated based on the ratio of tritium and the annual discharge of each radionuclide. The concentration of each radionuclide in seawater used for assessment is presented in Table E-2.

c. Results of exposure assessment and selection of radionuclides for operational control

The assessment method for internal exposure received through ingestion of marine products is the same method employed in the 4-3.b, and the person subject to exposure assessment was set to ingest a large amount of marine products.

The assessment results regarding internal exposure received by adults in the case where discharge of each radionuclide is conducted at the legally required concentration limits is presented in Table E-3 in descending order. The eight radionuclides causing exposure exceeding 0.001mSv/year, if discharged at the legally required concentration limits, were selected as radionuclides for operational control due to the significant impact on exposure assessment.

Regarding external exposure, there are radionuclides which cause exposure exceeding 0.001mSv/year when considering transition to fishing nets. However, as presented in Table E-4, these radionuclides all use the dose conversion factor for Co-60, and there is little impact to actual external exposure when compared to Co-60, due to the photon energy released from each radionuclide as well as its emission rate. Therefore, it was decided that there was no need to subject these radionuclides to operational control.

d. Confirmation regarding environmental protection

Previous reviews focused on the impact on human exposure. Further reviews were conducted to confirm if there were other radionuclides to be subjected to operational control from the perspective of environmental protection.

Specifically, a. Source term was used to assess the impact that each radionuclide has on marine products using the assessment method presented in Reference B. The assessment results are presented in Table E-5 (Same Table as Table B-5 is shown) in descending order.

The most significant impact radionuclide is Fe-59, but the results were lower than the lower limit of the derived consideration reference levels. Due to Fe-59 already has been subjected to operational control from the perspective of reducing human exposure, and the assessment value of other radionuclides was smaller by one digit or more when compared to Fe-59, TEPCO decided that Fe-59 was not be subjected to operational control from the perspective of environmental protection.

Table E-1 Source Term for Confirming the Impact of the 63 Radionuclides Other Than Tritium (annual discharge)

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
H-3	1.0E+05	2.2E+08	2.2E+13	・The amount of tritium discharged annually was set to be the upper limit. ・Tritium concentration was set to be lower than the concentration in stored ALPS treated water, etc. so that the annual drainage can be set at a higher value. ・Subject source term is only set for assessment purposes when conducting hypothetical discharge of ALPS treated water to verify the impact of exposure for each radionuclide subject to the legally required concentration limits (" the sum of ratios" is one). In reality, water of such quality will not be discharged.
C-14	2.0E+03	2.2E+08	4.4E+11	
Mn-54	1.0E+03	2.2E+08	2.2E+11	
Fe-59	4.0E+02	2.2E+08	8.8E+10	
Co-58	1.0E+03	2.2E+08	2.2E+11	
Co-60	2.0E+02	2.2E+08	4.4E+10	
Ni-63	6.0E+03	2.2E+08	1.3E+12	
Zn-65	2.0E+02	2.2E+08	4.4E+10	
Rb-86	3.0E+02	2.2E+08	6.6E+10	
Sr-89	3.0E+02	2.2E+08	6.6E+10	
Sr-90	3.0E+01	2.2E+08	6.6E+09	
Y-90	3.0E+02	2.2E+08	6.6E+10	
Y-91	3.0E+02	2.2E+08	6.6E+10	
Nb-95	1.0E+03	2.2E+08	2.2E+11	
Tc-99	1.0E+03	2.2E+08	2.2E+11	
Ru-103	1.0E+03	2.2E+08	2.2E+11	
Ru-106	1.0E+02	2.2E+08	2.2E+10	
Rh-103m	2.0E+05	2.2E+08	4.4E+13	
Rh-106	3.0E+05	2.2E+08	6.6E+13	
Ag-110m	3.0E+02	2.2E+08	6.6E+10	
Cd-113m	4.0E+01	2.2E+08	8.8E+09	
Cd-115m	3.0E+02	2.2E+08	6.6E+10	
Sn-119m	2.0E+03	2.2E+08	4.4E+11	
Sn-123	4.0E+02	2.2E+08	8.8E+10	
Sn-126	2.0E+02	2.2E+08	4.4E+10	
Sb-124	3.0E+02	2.2E+08	6.6E+10	
Sb-125	8.0E+02	2.2E+08	1.8E+11	
Te-123m	6.0E+02	2.2E+08	1.3E+11	
Te-125m	9.0E+02	2.2E+08	2.0E+11	
Te-127	5.0E+03	2.2E+08	1.1E+12	
Te-127m	3.0E+02	2.2E+08	6.6E+10	
Te-129	1.0E+04	2.2E+08	2.2E+12	
Te-129m	3.0E+02	2.2E+08	6.6E+10	
I-129	9.0E+00	2.2E+08	2.0E+09	

Subject radionuclide	Radionuclide concentration (Bq/L)	Annual drainage (L)	Annual discharge (Bq)	Remarks
Cs-134	6.0E+01	2.2E+08	1.3E+10	
Cs-135	6.0E+02	2.2E+08	1.3E+11	
Cs-136	3.0E+02	2.2E+08	6.6E+10	
Cs-137	9.0E+01	2.2E+08	2.0E+10	
Ba-137m	8.0E+05	2.2E+08	1.8E+14	
Ba-140	3.0E+02	2.2E+08	6.6E+10	
Ce-141	1.0E+03	2.2E+08	2.2E+11	
Ce-144	2.0E+02	2.2E+08	4.4E+10	
Pr-144	2.0E+04	2.2E+08	4.4E+12	
Pr-144m	4.0E+04	2.2E+08	8.8E+12	
Pm-146	9.0E+02	2.2E+08	2.0E+11	
Pm-147	3.0E+03	2.2E+08	6.6E+11	
Pm-148	3.0E+02	2.2E+08	6.6E+10	
Pm-148m	5.0E+02	2.2E+08	1.1E+11	
Sm-151	8.0E+03	2.2E+08	1.8E+12	
Eu-152	6.0E+02	2.2E+08	1.3E+11	
Eu-154	4.0E+02	2.2E+08	8.8E+10	
Eu-155	3.0E+03	2.2E+08	6.6E+11	
Gd-153	3.0E+03	2.2E+08	6.6E+11	
Tb-160	5.0E+02	2.2E+08	1.1E+11	
Pu-238	4.0E+00	2.2E+08	8.8E+08	
Pu-239	4.0E+00	2.2E+08	8.8E+08	
Pu-240	4.0E+00	2.2E+08	8.8E+08	
Pu-241	2.0E+02	2.2E+08	4.4E+10	
Am-241	5.0E+00	2.2E+08	1.1E+09	
Am-242m	5.0E+00	2.2E+08	1.1E+09	
Am-243	5.0E+00	2.2E+08	1.1E+09	
Cm-242	6.0E+01	2.2E+08	1.3E+10	
Cm-243	6.0E+00	2.2E+08	1.3E+09	
Cm-244	7.0E+00	2.2E+08	1.5E+09	

Table E-2 Concentration of Seawater Used for Assessment

Subject radionuclide	Annual discharge (Bq)	Concentration of seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
H-3	2.2E+13	5.6E-02	1.2E-01
C-14	4.4E+11	1.1E-03	2.4E-03
Mn-54	2.2E+11	5.6E-04	1.2E-03
Fe-59	8.8E+10	2.2E-04	4.8E-04
Co-58	2.2E+11	5.6E-04	1.2E-03
Co-60	4.4E+10	1.1E-04	2.4E-04
Ni-63	1.3E+12	3.4E-03	7.2E-03
Zn-65	4.4E+10	1.1E-04	2.4E-04
Rb-86	6.6E+10	1.7E-04	3.6E-04
Sr-89	6.6E+10	1.7E-04	3.6E-04
Sr-90	6.6E+09	1.7E-05	3.6E-05
Y-90	6.6E+10	1.7E-04	3.6E-04
Y-91	6.6E+10	1.7E-04	3.6E-04
Nb-95	2.2E+11	5.6E-04	1.2E-03
Tc-99	2.2E+11	5.6E-04	1.2E-03
Ru-103	2.2E+11	5.6E-04	1.2E-03
Ru-106	2.2E+10	5.6E-05	1.2E-04
Rh-103m	4.4E+13	1.1E-01	2.4E-01
Rh-106	6.6E+13	1.7E-01	3.6E-01
Ag-110m	6.6E+10	1.7E-04	3.6E-04
Cd-113m	8.8E+09	2.2E-05	4.8E-05
Cd-115m	6.6E+10	1.7E-04	3.6E-04
Sn-119m	4.4E+11	1.1E-03	2.4E-03
Sn-123	8.8E+10	2.2E-04	4.8E-04
Sn-126	4.4E+10	1.1E-04	2.4E-04
Sb-124	6.6E+10	1.7E-04	3.6E-04
Sb-125	1.8E+11	4.5E-04	9.6E-04
Te-123m	1.3E+11	3.4E-04	7.2E-04
Te-125m	2.0E+11	5.0E-04	1.1E-03
Te-127	1.1E+12	2.8E-03	6.0E-03
Te-127m	6.6E+10	1.7E-04	3.6E-04
Te-129	2.2E+12	5.6E-03	1.2E-02
Te-129m	6.6E+10	1.7E-04	3.6E-04

Subject radionuclide	Annual discharge (Bq)	Concentration of seawater used for assessment (within an area of 10km*10km)	
		Average concentration of all layers (Bq/L)	Average concentration of top layer (Bq/L)
I-129	2.0E+09	5.0E-06	1.1E-05
Cs-134	1.3E+10	3.4E-05	7.2E-05
Cs-135	1.3E+11	3.4E-04	7.2E-04
Cs-136	6.6E+10	1.7E-04	3.6E-04
Cs-137	2.0E+10	5.0E-05	1.1E-04
Ba-137m	1.8E+14	4.5E-01	9.6E-01
Ba-140	6.6E+10	1.7E-04	3.6E-04
Ce-141	2.2E+11	5.6E-04	1.2E-03
Ce-144	4.4E+10	1.1E-04	2.4E-04
Pr-144	4.4E+12	1.1E-02	2.4E-02
Pr-144m	8.8E+12	2.2E-02	4.8E-02
Pm-146	2.0E+11	5.0E-04	1.1E-03
Pm-147	6.6E+11	1.7E-03	3.6E-03
Pm-148	6.6E+10	1.7E-04	3.6E-04
Pm-148m	1.1E+11	2.8E-04	6.0E-04
Sm-151	1.8E+12	4.5E-03	9.6E-03
Eu-152	1.3E+11	3.4E-04	7.2E-04
Eu-154	8.8E+10	2.2E-04	4.8E-04
Eu-155	6.6E+11	1.7E-03	3.6E-03
Gd-153	6.6E+11	1.7E-03	3.6E-03
Tb-160	1.1E+11	2.8E-04	6.0E-04
Pu-238	8.8E+08	2.2E-06	4.8E-06
Pu-239	8.8E+08	2.2E-06	4.8E-06
Pu-240	8.8E+08	2.2E-06	4.8E-06
Pu-241	4.4E+10	1.1E-04	2.4E-04
Am-241	1.1E+09	2.8E-06	6.0E-06
Am-242m	1.1E+09	2.8E-06	6.0E-06
Am-243	1.1E+09	2.8E-06	6.0E-06
Cm-242	1.3E+10	3.4E-05	7.2E-05
Cm-243	1.3E+09	3.4E-06	7.2E-06
Cm-244	1.5E+09	3.9E-06	8.4E-06

<table>
<tr><td rowspan="2">Subject radionuclide</td><td rowspan="2">Annual discharge (Bq)</td><td colspan="2">Concentration of seawater used for assessment (within an area of 10km*10km)</td></tr>
<tr><td>Average concentration of all layers (Bq/L)</td><td>Average concentration of top layer (Bq/L)</td></tr>
<tr><td colspan="2">Subject exposure pathway</td><td>Swimming
Beach sand
Fishing net
Ingesting marine products</td><td>Seawater
Ship hull</td></tr>
</table>

Table E-3 Results of Assessment Regarding Internal Exposure (for adults)
When Discharging With Each Radionuclide at the Legally required concentration Limits
(Eight radionuclides exceeding 0.001mSv/year selected as subjects to operational control)

No.	Subject radionuclide	Legally required concentration limits [Bq/L]	Internal exposure dose received through ingesting marine products (mSv/year)	Remarks
1	Sn-126	2.0E+02	2.6E-02	Subject to operational control
2	Sn-123	4.0E+02	2.3E-02	Subject to operational control
3	Sn-119m	2.0E+03	1.9E-02	Subject to operational control
4	Fe-59	4.0E+02	5.6E-03	Subject to operational control
5	Cd-115m	3.0E+02	1.4E-03	Subject to operational control
6	C-14	2.0E+03	1.3E-03	Subject to operational control
7	Cd-113m	4.0E+01	1.3E-03	Subject to operational control
8	Ag-110m	3.0E+02	1.0E-03	Subject to operational control
9	Zn-65	2.0E+02	8.4E-04	
10	Mn-54	1.0E+03	5.2E-04	
11	Co-58	1.0E+03	2.5E-04	
12	Co-60	2.0E+02	2.3E-04	
13	Tc-99	1.0E+03	2.1E-04	
14	Te-129m	3.0E+02	1.4E-04	
15	Te-127	5.0E+03	1.3E-04	
16	Te-123m	6.0E+02	1.3E-04	
17	Eu-155	3.0E+03	1.3E-04	
18	Te-125m	9.0E+02	1.2E-04	
19	Pm-148m	5.0E+02	1.1E-04	
20	Eu-152	6.0E+02	1.1E-04	
21	Te-127m	3.0E+02	1.1E-04	
22	Gd-153	3.0E+03	1.1E-04	
23	Pm-146	9.0E+02	1.1E-04	
24	Pm-148	3.0E+02	1.1E-04	
25	Eu-154	4.0E+02	1.1E-04	

No.	Subject radionuclide	Legally required concentration limits [Bq/L]	Internal exposure dose received through ingesting marine products (mSv/year)	Remarks
26	I-129	9.0E+00	1.1E-04	
27	Sm-151	8.0E+03	1.0E-04	
28	Pm-147	3.0E+03	1.0E-04	
29	Am-241	5.0E+00	1.0E-04	
30	Am-243	5.0E+00	1.0E-04	
31	Te-129	1.0E+04	9.9E-05	
32	Am-242m	5.0E+00	9.7E-05	
33	Pu-239	4.0E+00	8.4E-05	
34	Pu-240	4.0E+00	8.4E-05	
35	Ce-144	2.0E+02	8.4E-05	
36	Pu-241	2.0E+02	8.1E-05	
37	Pu-238	4.0E+00	7.8E-05	
38	Ni-63	6.0E+03	7.7E-05	
39	Pr-144	2.0E+04	6.7E-05	
40	Cm-243	6.0E+00	6.3E-05	
41	Cm-244	7.0E+00	5.9E-05	
42	Ce-141	1.0E+03	5.7E-05	
43	Cm-242	6.0E+01	5.0E-05	
44	Tb-160	5.0E+02	4.9E-05	
45	Rh-103m	2.0E+05	3.6E-05	
46	Nb-95	1.0E+03	2.7E-05	
47	Sb-125	8.0E+02	2.4E-05	
48	Sb-124	3.0E+02	2.0E-05	
49	Ru-103	1.0E+03	2.0E-05	
50	Y-90	3.0E+02	2.0E-05	
51	Ru-106	1.0E+02	1.9E-05	
52	Y-91	3.0E+02	1.7E-05	
53	Cs-135	6.0E+02	6.2E-06	
54	Cs-137	9.0E+01	6.1E-06	
55	Cs-134	6.0E+01	5.9E-06	
56	Cs-136	3.0E+02	4.7E-06	
57	Ba-140	3.0E+02	9.8E-07	
58	Rb-86	3.0E+02	6.3E-07	
59	Sr-90	3.0E+01	2.9E-07	
60	Sr-89	3.0E+02	2.7E-07	
61	H-3	6.0E+04	1.1E-07	

No.	Subject radionuclide	Legally required concentration limits [Bq/L]	Internal exposure dose received through ingesting marine products (mSv/year)	Remarks
62	Rh-106	3.0E+05	0.0E+00	See parent radionuclide for assessment results
63	Ba-137m	8.0E+05	0.0E+00	See parent radionuclide for assessment results
64	Pr-144m	4.0E+04	0.0E+00	See parent radionuclide for assessment results

Table E-4 Results of Assessment Regarding External Exposure Received From Fishing Nets When Discharging With Each Radionuclide at the Legally required concentration Limits

	Radionuclide	Legally required concentration limits [Bq/L]	Exposure from fishing net [mSv/year]	Remarks
1	Te-127	5.0E+03	2.1E-03	Referred to Co-60 for dose conversion factor
2	Eu-155	3.0E+03	1.3E-03	Referred to Co-60 for dose conversion factor
3	Gd-153	3.0E+03	1.3E-03	Referred to Co-60 for dose conversion factor
4	Sn-119m	2.0E+03	8.5E-04	Referred to Co-60 for dose conversion factor
5	Nb-95	1.0E+03	4.3E-04	Referred to Co-60 for dose conversion factor
6	Ru-103	1.0E+03	4.3E-04	Referred to Co-60 for dose conversion factor
7	Ce-141	1.0E+03	4.3E-04	Referred to Co-60 for dose conversion factor
8	Pm-146	9.0E+02	3.8E-04	Referred to Co-60 for dose conversion factor
9	Te-123m	6.0E+02	2.6E-04	Referred to Co-60 for dose conversion factor
10	Cs-135	6.0E+02	2.6E-04	Referred to Co-60 for dose conversion factor
11	Pm-148m	5.0E+02	2.1E-04	Referred to Co-60 for dose conversion factor
12	Tb-160	5.0E+02	2.1E-04	Referred to Co-60 for dose conversion factor
13	Sn-123	4.0E+02	1.7E-04	Referred to Co-60 for dose conversion factor
14	Co-58	1.0E+03	1.6E-04	
15	Mn-54	1.0E+03	1.4E-04	
16	Rb-86	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
17	Sr-89	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
18	Y-91	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor

	Radionuclide	Legally required concentration limits [Bq/L]	Exposure from fishing net [mSv/year]	Remarks
19	Ag-110m	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
20	Cd-115m	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
21	Sb-124	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
22	Te-127m	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
23	Te-129m	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
24	Cs-136	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
25	Ba-140	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
26	Pm-148	3.0E+02	1.3E-04	Referred to Co-60 for dose conversion factor
27	Eu-152	6.0E+02	1.1E-04	
28	Co-60	2.0E+02	8.5E-05	
29	Eu-154	4.0E+02	8.1E-05	
30	Sb-125	8.0E+02	5.2E-05	
31	Zn-65	2.0E+02	2.0E-05	
32	Cs-134	6.0E+01	1.5E-05	
33	Cs-137	9.0E+01	8.5E-06	
34	Ru-106	1.0E+02	3.5E-06	
35	Pu-241	2.0E+02	2.7E-06	
36	Ce-144	2.0E+02	1.7E-06	
37	Te-125m	9.0E+02	8.9E-07	
38	Sn-126	2.0E+02	6.0E-07	
39	Cm-243	6.0E+00	1.2E-07	Referred to Am-243 for dose conversion factor
40	Am-243	5.0E+00	1.0E-07	
41	Sr-90	3.0E+01	2.7E-08	
42	I-129	9.0E+00	6.2E-09	
43	Am-242m	5.0E+00	5.8E-09	
44	Pm-147	3.0E+03	5.4E-09	
45	Am-241	5.0E+00	4.5E-09	
46	Fe-59	4.0E+02	3.8E-09	
47	Tc-99	1.0E+03	3.4E-09	
48	Sm-151	8.0E+03	2.0E-09	
49	C-14	2.0E+03	1.3E-09	
50	Cd-113m	4.0E+01	1.0E-09	
51	Cm-242	6.0E+01	4.6E-10	

	Radionuclide	Legally required concentration limits [Bq/L]	Exposure from fishing net [mSv/year]	Remarks
52	Ni-63	6.0E+03	2.0E-10	
53	H-3	6.0E+04	8.2E-11	
54	Cm-244	7.0E+00	6.3E-11	
55	Pu-239	4.0E+00	3.3E-11	
56	Pu-240	4.0E+00	3.1E-11	
57	Pu-238	4.0E+00	2.9E-11	
58	Y-90	3.0E+02	0.0E+00	See parent radionuclide for assessment results
59	Rh-103m	2.0E+05	0.0E+00	See parent radionuclide for assessment results
60	Rh-106	3.0E+05	0.0E+00	See parent radionuclide for assessment results
61	Te-129	1.0E+04	0.0E+00	See parent radionuclide for assessment results
62	Ba-137m	8.0E+05	0.0E+00	See parent radionuclide for assessment results
63	Pr-144	2.0E+04	0.0E+00	See parent radionuclide for assessment results
64	Pr-144m	4.0E+04	0.0E+00	See parent radionuclide for assessment results

*Hatching indicates radionuclides subject to operational control

Table E-5 Results of Assessment Regarding Environmental Protection When Discharging With Each Radionuclide at the Legally required concentration Limits

	Radionuclide	Legally required concentration limits [Bq/L]	Results of exposure assessment (mGy/day)			Remarks
			Flat fish	Crab	Brown seaweed	
1	Fe-59	4.0.E+02	5.4.E-01	5.4.E-01	5.8.E-01	
2	Sn-126	2.0.E+02	9.7.E-03	9.3.E-03	9.0.E-03	
3	Pm-148m	5.0.E+02	7.5.E-03	7.2.E-03	8.1.E-03	
4	Mn-54	1.0.E+03	6.6.E-03	6.0.E-03	6.6.E-03	
5	Eu-152	6.0.E+02	5.4.E-03	5.1.E-03	5.4.E-03	
6	Pm-146	9.0.E+02	5.1.E-03	4.9.E-03	5.4.E-03	
7	Tb-160	5.0.E+02	4.2.E-03	4.2.E-03	4.5.E-03	
8	Eu-154	4.0.E+02	3.8.E-03	3.6.E-03	3.8.E-03	
9	Nb-95	1.0.E+03	2.3.E-03	2.3.E-03	2.4.E-03	
10	Gd-153	3.0.E+03	2.2.E-03	2.3.E-03	2.5.E-03	
11	Pm-148	3.0.E+02	1.5.E-03	1.4.E-03	2.0.E-03	
12	Eu-155	3.0.E+03	1.3.E-03	1.3.E-03	1.3.E-03	
13	Co-58	1.0.E+03	1.1.E-03	1.1.E-03	1.1.E-03	
14	Sn-123	4.0.E+02	1.0.E-03	9.7.E-04	1.0.E-03	

	Radionuclide	Legally required concentration limits [Bq/L]	Results of exposure assessment (mGy/day)			Remarks
			Flat fish	Crab	Brown seaweed	
15	Sn-119m	2.0.E+03	9.6.E-04	9.1.E-04	6.7.E-04	
16	Ce-141	1.0.E+03	8.6.E-04	8.2.E-04	8.8.E-04	
17	Co-60	2.0.E+02	5.6.E-04	5.6.E-04	6.1.E-04	
18	Ce-144	2.0.E+02	4.7.E-04	2.7.E-04	4.7.E-04	
19	Ru-103	1.0.E+03	7.4.E-05	7.2.E-05	7.5.E-05	
20	Ag-110m	3.0.E+02	3.9.E-05	2.3.E-04	3.4.E-05	
21	Y-91	3.0.E+02	3.6.E-05	2.2.E-05	1.6.E-04	
22	Zn-65	2.0.E+02	3.1.E-05	6.6.E-05	3.1.E-05	
23	Cd-115m	3.0.E+02	2.1.E-05	1.9.E-05	8.3.E-06	
24	C-14	2.0.E+03	1.0.E-05	8.4.E-06	6.7.E-06	
25	Te-127	5.0.E+03	9.4.E-06	9.4.E-06	8.7.E-05	
26	Cs-136	3.0.E+02	9.4.E-06	9.4.E-06	9.4.E-06	
27	Am-243	5.0.E+00	8.7.E-06	8.5.E-06	9.6.E-06	
28	Ru-106	1.0.E+02	6.4.E-06	4.7.E-06	6.7.E-06	
29	Cm-243	6.0.E+00	5.8.E-06	5.6.E-06	8.3.E-06	
30	Ba-140	3.0.E+02	5.6.E-06	7.7.E-06	1.0.E-05	
31	Sb-124	3.0.E+02	5.1.E-06	4.6.E-06	6.1.E-06	
32	Sb-125	8.0.E+02	3.2.E-06	2.9.E-06	4.0.E-06	
33	Pm-147	3.0.E+03	2.2.E-06	8.2.E-06	2.3.E-05	
34	Te-129m	3.0.E+02	1.6.E-06	1.6.E-06	1.5.E-05	
35	Cs-134	6.0.E+01	1.4.E-06	1.4.E-06	1.4.E-06	
36	Sm-151	8.0.E+03	1.0.E-06	6.9.E-06	6.4.E-06	
37	Te-125m	9.0.E+02	1.0.E-06	1.0.E-06	8.8.E-06	
38	Am-241	5.0.E+00	9.1.E-07	9.0.E-07	8.9.E-07	
39	Te-123m	6.0.E+02	9.0.E-07	9.2.E-07	5.4.E-06	
40	Cd-113m	4.0.E+01	7.9.E-07	7.3.E-07	1.4.E-07	
41	Cs-137	9.0.E+01	7.9.E-07	7.6.E-07	7.8.E-07	
42	Cm-242	6.0.E+01	7.8.E-07	1.7.E-06	2.6.E-05	
43	Te-127m	3.0.E+02	7.7.E-07	7.7.E-07	7.2.E-06	
44	Am-242m	5.0.E+00	7.2.E-07	7.0.E-07	1.3.E-06	
45	Rb-86	3.0.E+02	6.7.E-07	5.3.E-07	1.3.E-06	
46	Ni-63	6.0.E+03	2.3.E-07	7.9.E-07	1.7.E-06	
47	Cm-244	7.0.E+00	8.6.E-08	1.9.E-07	2.9.E-06	
48	Tc-99	1.0.E+03	6.7.E-08	1.6.E-07	3.1.E-05	
49	Cs-135	6.0.E+02	1.7.E-08	7.9.E-09	7.1.E-09	
50	Sr-89	3.0.E+02	1.4.E-08	3.6.E-09	6.0.E-08	
51	H-3	6.0.E+04	4.7.E-09	4.7.E-09	1.8.E-09	
52	Pu-238	4.0.E+00	4.4.E-09	7.5.E-09	4.4.E-07	

	Radionuclide	Legally required concentration limits [Bq/L]	Results of exposure assessment (mGy/day)			Remarks
			Flat fish	Crab	Brown seaweed	
53	Pu-240	4.0.E+00	4.1.E-09	7.0.E-09	4.2.E-07	
54	Pu-239	4.0.E+00	3.9.E-09	6.8.E-09	4.2.E-07	
55	Sr-90	3.0.E+01	2.6.E-09	6.9.E-10	1.1.E-08	
56	Pu-241	2.0.E+02	3.0.E-10	4.5.E-10	2.1.E-08	
57	I-129	9.0.E+00	9.1.E-11	5.4.E-11	7.6.E-09	
58	Y-90	3.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
59	Rh-103m	2.0.E+05	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
60	Rh-106	3.0.E+05	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
61	Te-129	1.0.E+04	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
62	Ba-137m	8.0.E+05	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
63	Pr-144	2.0.E+04	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results
64	Pr-144m	4.0.E+04	0.0.E+00	0.0.E+00	0.0.E+00	See parent radionuclide for assessment results

*Hatching indicates radionuclides subject to operational control

E2. Setting operational control value

The seven radionuclides, except for C-14, subject to operational control were undetected in the analysis conducted for tanks and outlet water of ALPS. Operational control value for undetected radionuclide were set by adding concentration increased by 20%, accounting for errors, to the lowest detection limit (the group out of the two tank groups with the larger value in the result) of the performance test for secondary treatment and rounding off the value. Operational control value for C-14 with detected levels were set as two times the maximum value for concentration rounded off.

The flow chart for setting operational control value is presented in Figure E-1, and operational control value is presented in Table E-6.

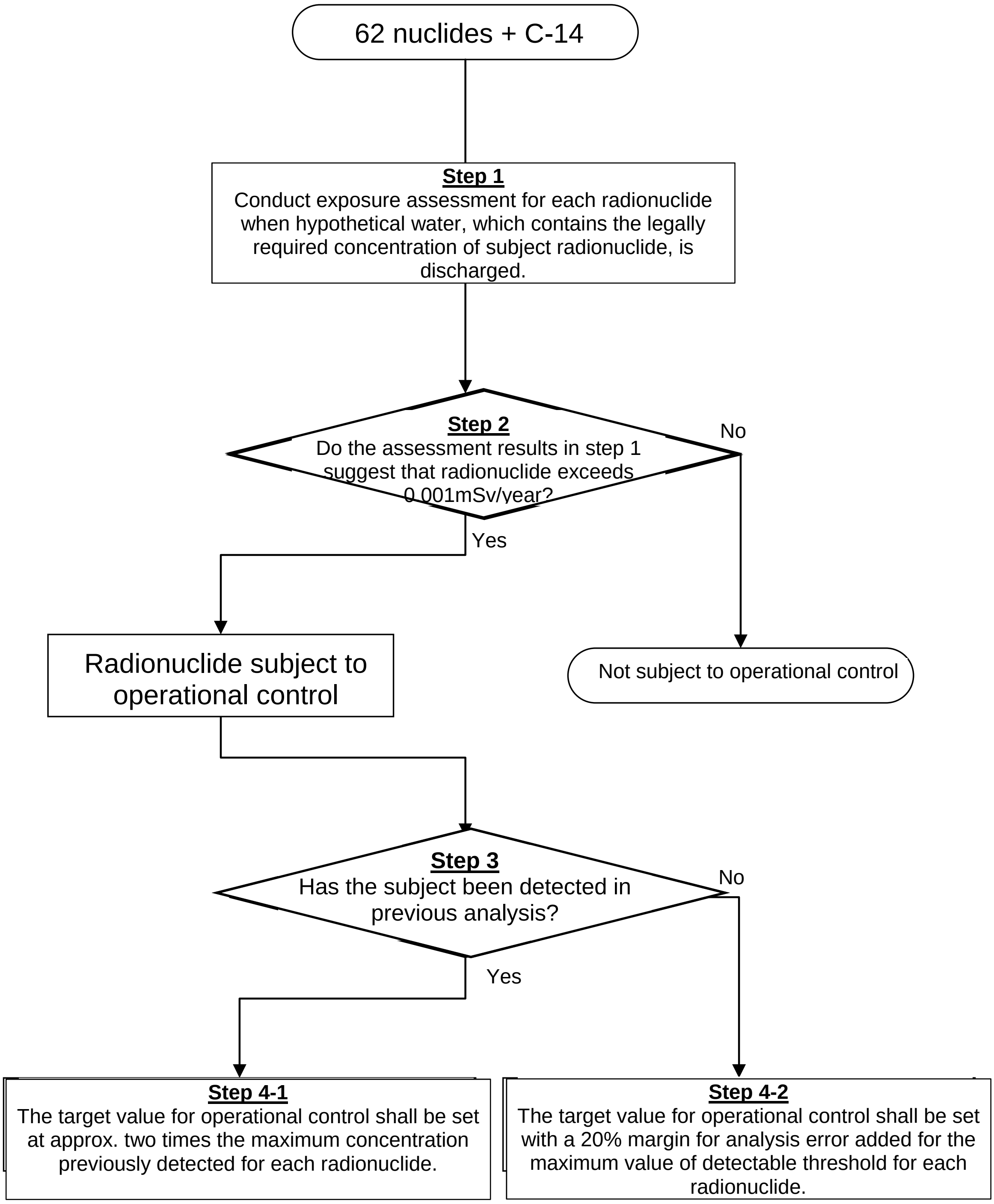


Figure E-1 Flowchart for Setting Operational Control Value

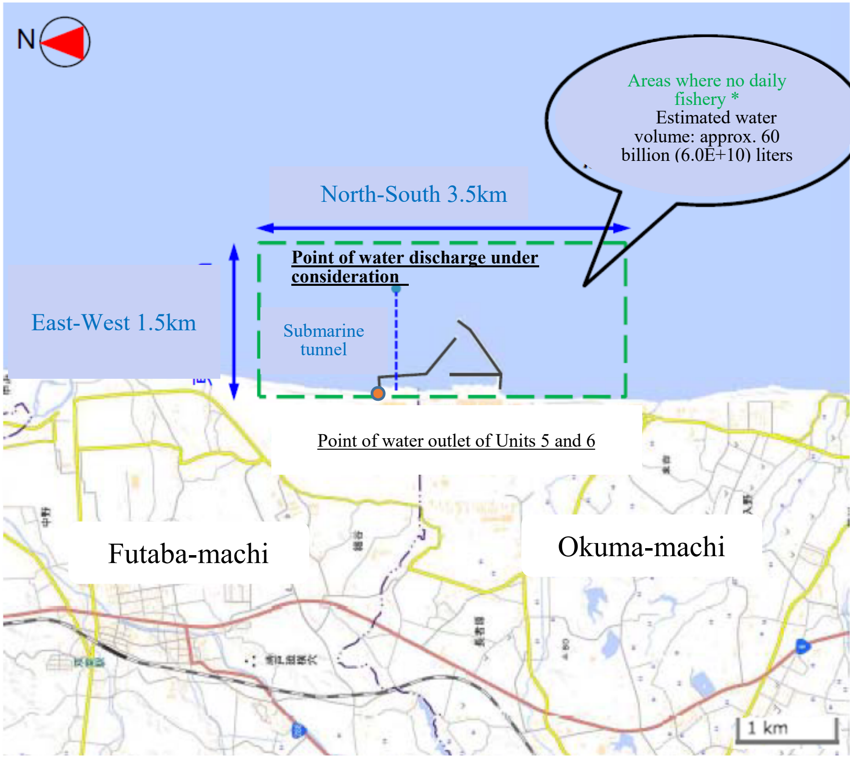
Table E-6 Operational Control Values

	Radionuclides	Legally required concentration [Bq/L]	Lowest detection limit [Bq/L]	Lowest detection limit×1.2 [Bq/L]	Operational control value [Bq/L]	Ratio of legally required concentration
Undetected radionuclides	Fe-59	4.0E+02	8.66E-02	1.04E-01	2.0E-01	5.0E-04
	Ag-110m	3.0E+02	4.26E-02	5.11E-02	6.0E-02	2.0E-04
	Cd-113m	4.0E+01	8.55E-02	1.03E-01	2.0E-01	5.0E-03
	Cd-115m	3.0E+02	2.70E+00	3.24E+00	4.0E+00	1.3E-02
	Sn-119m	2.0E+03	4.24E+01	5.09E+01	6.0E+01	3.0E-02
	Sn-123	4.0E+02	6.59E+00	7.91E+00	8.0E+00	2.0E-02
	Sn-126	2.0E+02	2.92E-01	3.50E-01	4.0E-01	2.0E-03
Detected radionuclides	Radionuclide	Legally required concentration [Bq/L]	Highest detection limit [Bq/L]	Highest detection limit×2 [Bq/L]	Operational control value [Bq/L]	Ratio of legally required concentration
	C-14	2.0E+03	2.15E+02	4.30E+02	5.0E+02	2.5E-01
	Total ratio of legally required concentration					3.2E-01

Reference F Differences in dispersion range depending on water discharge point

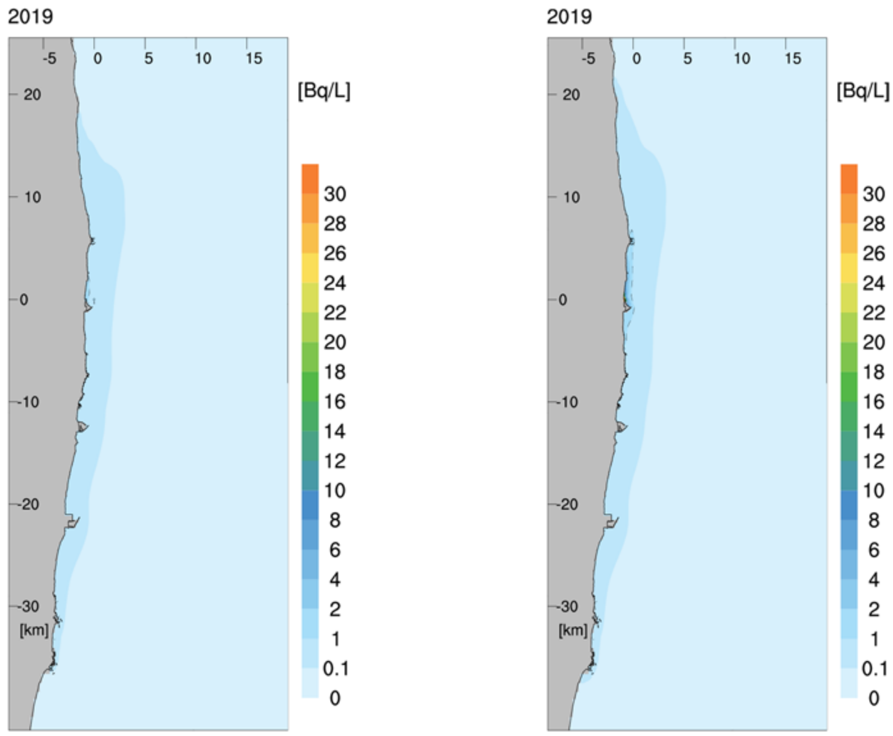
In considering the method of discharging the ALPS treated water, TEPCO initially considered the proposal to discharge the water from the Units 5 and 6 water outlet in NPS, as was when Units 5 and 6 were in regular operation. The location of the water discharge point under consideration and the water outlet of Units 5 and 6 are shown in Figure F-1.

A comparison of the results of the dispersion simulations for the different discharge points is shown in Figures F-2 to F-4. There is no significant difference in the concentration range of 0.1 Bq/L, but the concentration around NPS is lower when the water is discharged from 1km offshore.



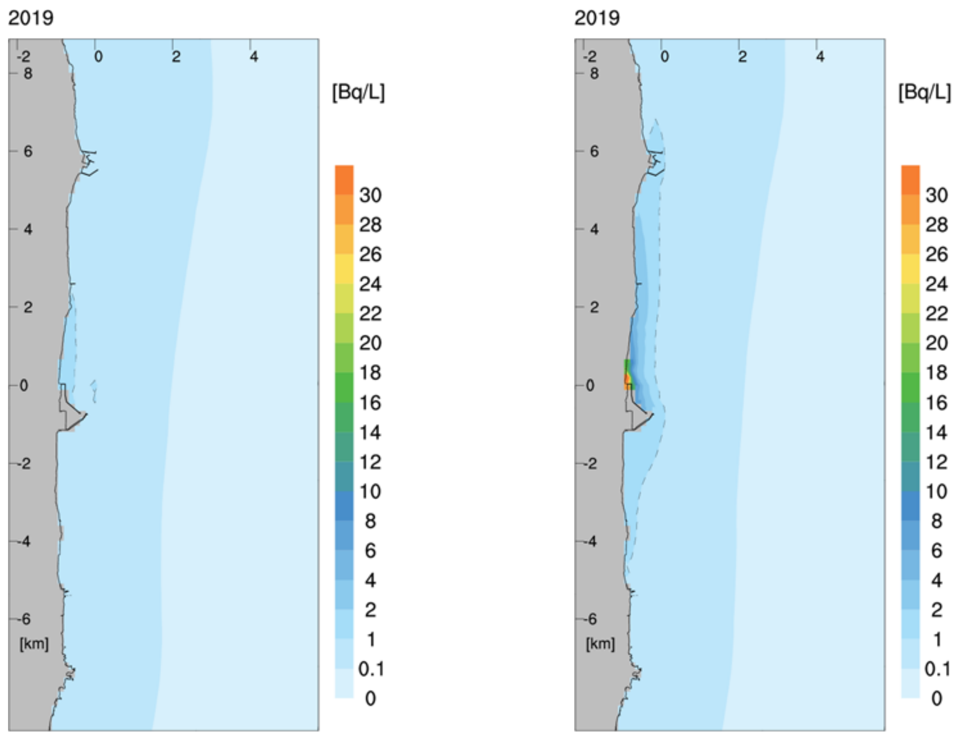
Source: TEPCO Holdings, Inc. based on Geographical Survey Institute map (Electronic National Land Web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1
※共同漁業権非設定区域

Figure F-1　Point of the water discharge in the consideration plan and point of the water outlet of Units 5 and 6



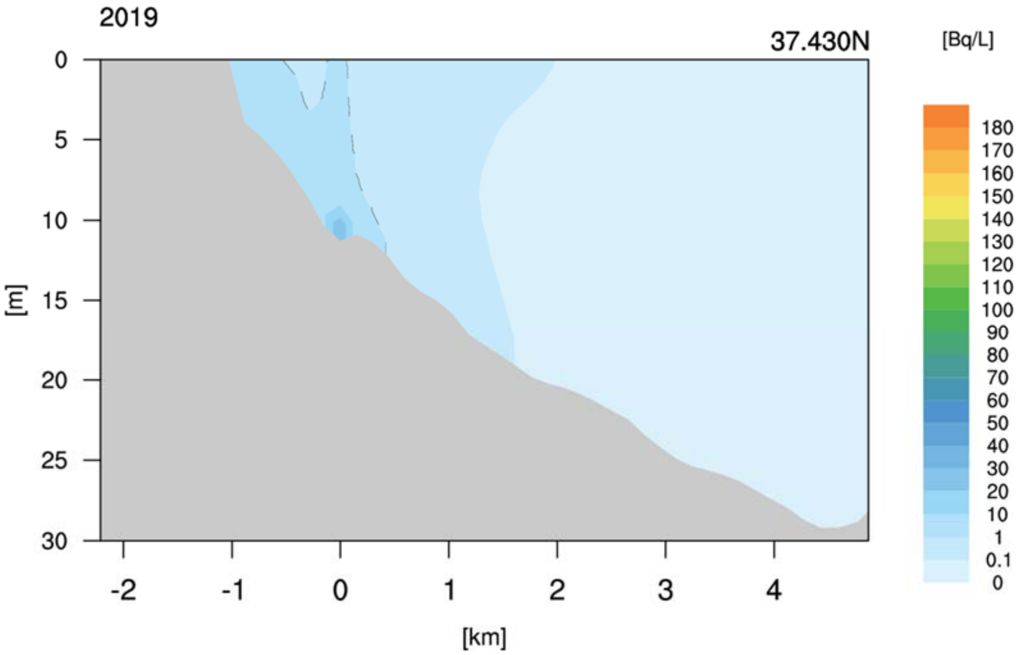
(Water discharged from 1km offshore) (Water discharged from the water outlet of Units 5 and 6)

FigureF-2 Comparison of the annual average concentration distribution on the sea surface due to different discharge points (Wide area)

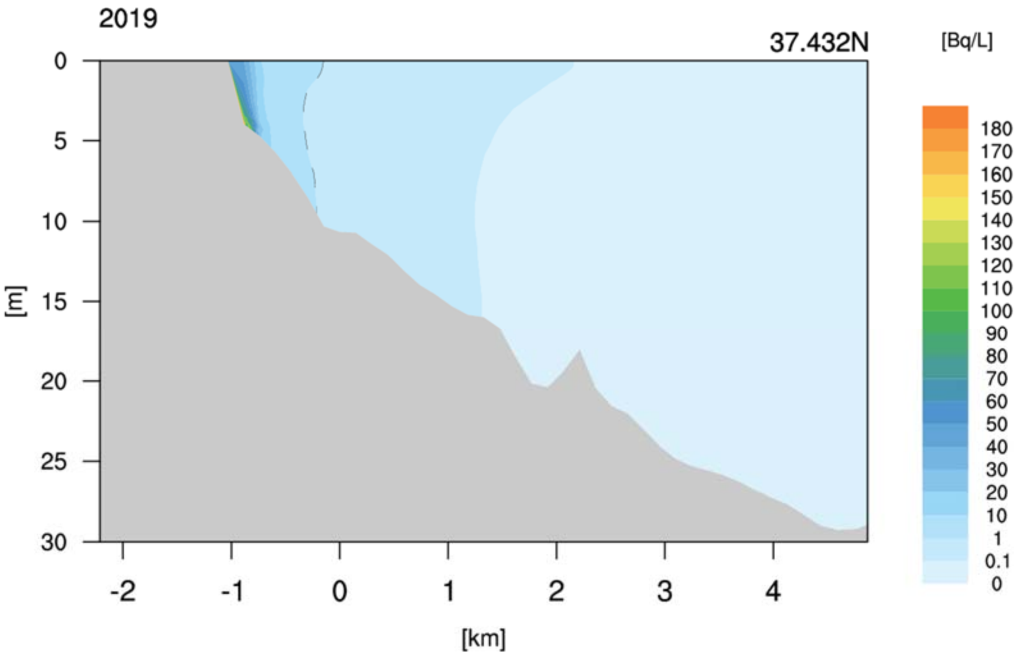


(Water discharged from 1km offshore) (Water discharged from the water outlet of Units 5 and 6)

FigureF-3 Comparison of the annual average concentration distribution on the sea surface due to different discharge points (Enlarged view)



(Water discharged from 1km offshore)



(Water discharged from the water outlet of Units 5 and 6)

FigureF-4 Comparison of the annual average concentration distribution on the sea surface due to different discharge points (Cross-sectional view)

Reference G Attribution of undetected nuclides to the source term based on measured values

The 64 nuclides included in this assessment include many undetected nuclides that have never been detected in previous analytical evaluations. As shown in 4-1, based on measured values, the annual discharge amount is conservatively set assuming that even nuclides below the detection limit are included at the detection limit. However, it is presumed that many of the nuclides that have never been detected are actually much lower concentrations than the detection limits, taking into account their half-life and other factors.

In order to confirm the conservativeness of the exposure assessment results, the results of exposure assessment for each nuclide were tabulated separately for detected and undetected nuclides. The results are shown in Tables G-1 to G-4.
In all cases, the attribution of undetected nuclides is significant, and the assessment results are considered to contain a considerable degree of conservatism.

Table G-1 Attribution of detected and undetected nuclides (human exposure)

Assessment case	Source term	(1) Source term based on actual measurement					
		i. K4 tank group		ii. J1-C tank group		iii. J1-G tank group	
	Marine products ingestion	average	More than average	average	More than average	average	More than average
Exposure* (mSv/year)	Detected nuclides	4.5E-06	1.9E-05	8.3E-07	3.4E-06	1.5E-06	5.7E-06
	Undetected nuclides	1.3E-05	4.4E-05	3.3E-05	1.1E-04	9.2E-05	3.1E-04
	Total	1.7E-05	6.3E-05	3.4E-05	1.1E-04	9.4E-05	3.1E-04
Proportion of undetected nuclides in total		74%	70%	98%	97%	98%	98%

＊ Exposure is the sum of external and internal exposures

Table G-2 Attribution of detected and undetected nuclides (environmental protection, K4 tank group)

Assessment case		K4 tank group		
		Flat fish	Crab	Blown seaweed
Exposure (mGy/day)	Detected nuclides	7.5E-07	7.3E-07	8.1E-07
	Undetected nuclides	1.7E-05	1.6E-05	1.8E-05
	Total	1.7E-05	1.7E-05	1.9E-05
Proportion of undetected nuclides in total		96%	96%	96%

Table G-3 Attribution of detected and undetected nuclides (environmental protection, J1-C tank group)

Assessment case		J1-C tank group		
		Flat fish	Crab	Blown seaweed
Exposure (mGy/day	Detected nuclides	1.5E-05	1.5E-05	1.5E-05
	Undetected nuclides	7.6E-06	7.1E-06	7.8E-06
	Total	2.2E-05	2.2E-05	2.3E-05
Proportion of undetected nuclides in total		34%	33%	33%

Table G-4 Attribution of detected and undetected nuclides (environmental protection, J1-G tank group)

Assessment case		J1-G tank group		
		Flat fish	Crab	Blown seaweed
Exposure (mGy/day	Detected nuclides	2.9E-07	2.8E-07	3.0E-07
	Non-detected nuclides	5.6E-05	5.4E-05	5.8E-05
	Total	5.6E-05	5.5E-05	5.9E-05
Proportion of undetected nuclides in total		99%	99%	99%

Reference H Details of Exposure Assessment Results per Radionuclide

H1. Assessment of internal exposure in humans
The results of internal exposure assessment presented in 5-4 are presented in tables H-1 to H-8 by each radionuclide.

(1) Source term based on measured value of the 64 radionuclides
  i. K4 tank group ("the sum of the ratios"of radionuclides other than tritium is 0.29)
  ii. J1-C tank group ("the sum of the ratios"of radionuclides other than tritium is 0.35)
  iii. J1-G tank group ("the sum of the ratios"of radionuclides other than tritium is 0.22)

(2) Source term based on the hypothetical ALPS treated water
  ("the sum of the ratios"of radionuclides other than tritium is 1)

Table H-1 Results of Assessment Regarding Internal Exposure of Humans (Measured value (K4 tank group), average amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-123	9.8E-06	1.8E-05	2.4E-05	Radionuclide subject to operational control
I-129	2.7E-06	2.0E-06	8.6E-07	
C-14	1.4E-06	1.2E-06	6.8E-07	Radionuclide subject to operational control
Sn-126	4.9E-07	8.4E-07	1.1E-06	Radionuclide subject to operational control
Cd-115m	3.0E-07	4.4E-07	7.4E-07	Radionuclide subject to operational control
Sn-119m	2.3E-07	4.3E-07	5.6E-07	Radionuclide subject to operational control
Cd-113m	5.8E-08	5.0E-08	6.1E-08	Radionuclide subject to operational control
Co-60	4.9E-08	1.2E-07	1.6E-07	
Ru-106	3.3E-08	5.7E-08	7.6E-08	
H-3	2.9E-08	2.5E-08	2.1E-08	
Fe-59	2.3E-08	4.8E-08	1.0E-07	Radionuclide subject to operational control
Te-129m	1.8E-08	3.6E-08	5.3E-08	
Pm-148	1.7E-08	3.1E-08	3.9E-08	
Tc-99	1.6E-08	2.8E-08	4.9E-08	
Te-127m	1.4E-08	2.8E-08	4.9E-08	
Y-91	1.3E-08	2.3E-08	2.9E-08	
Zn-65	5.5E-09	7.0E-09	1.0E-08	
Te-125m	5.5E-09	1.0E-08	1.6E-08	
Cs-137	4.1E-09	1.5E-09	1.4E-09	
Ni-63	3.6E-09	5.4E-09	7.6E-09	
Ce-144	2.7E-09	4.9E-09	6.8E-09	
Ag-110m	2.1E-09	2.9E-09	3.6E-09	Radionuclide subject to operational control
Sb-125	1.5E-09	2.3E-09	3.1E-09	
Y-90	1.4E-09	2.6E-09	3.2E-09	
Am-241	1.4E-09	9.2E-10	5.0E-09	
Am-243	1.4E-09	9.2E-10	4.9E-09	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Pu-239	1.4E-09	8.8E-10	4.4E-09	
Pu-240	1.4E-09	8.8E-10	4.4E-09	
Pu-238	1.2E-09	8.3E-10	4.2E-09	
Pu-241	1.2E-09	6.5E-10	2.6E-09	
Pm-146	1.1E-09	1.8E-09	2.5E-09	
Te-127	1.0E-09	1.9E-09	1.8E-09	
Cm-243	7.2E-10	5.1E-10	3.0E-09	
Pm-147	6.4E-10	1.2E-09	1.8E-09	
Cs-134	6.4E-10	2.2E-10	1.8E-10	
Cm-244	5.8E-10	4.4E-10	2.7E-09	
Eu-152	5.1E-10	7.4E-10	1.2E-09	
Mn-54	3.2E-10	4.3E-10	4.8E-10	
Eu-154	3.1E-10	5.1E-10	7.7E-10	
Tb-160	2.7E-10	4.5E-10	5.3E-10	
Sr-90	2.5E-10	2.1E-10	4.2E-10	
Te-123m	2.5E-10	4.2E-10	6.6E-10	
Co-58	2.0E-10	3.4E-10	3.8E-10	
Pm-148m	1.8E-10	3.0E-10	3.2E-10	
Ce-141	1.5E-10	2.7E-10	3.3E-10	
Eu-155	1.4E-10	2.4E-10	3.6E-10	
Gd-153	1.1E-10	2.0E-10	2.4E-10	
Te-129	9.8E-11	1.6E-10	2.3E-10	
Sb-124	9.7E-11	1.6E-10	2.0E-10	
Am-242m	8.3E-11	4.9E-11	2.6E-10	
Cs-136	6.7E-11	6.8E-11	6.9E-11	
Cm-242	5.8E-11	9.1E-11	5.5E-10	
Rb-86	5.0E-11	8.9E-11	1.1E-10	
Ba-140	3.9E-11	6.7E-11	9.4E-11	
Nb-95	2.8E-11	4.2E-11	4.3E-11	
Pr-144	2.3E-11	3.7E-11	5.6E-11	
Ru-103	2.1E-11	3.4E-11	4.0E-11	
Sr-89	1.1E-11	1.8E-11	3.0E-11	
Sm-151	1.1E-12	1.9E-12	3.5E-12	
Rh-103m	1.7E-13	2.9E-13	4.2E-13	
Cs-135	3.7E-15	1.6E-15	1.6E-15	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	1.5E-05	2.4E-05	2.9E-05	

Table H-2 Results of Assessment Regarding Internal Exposure of Humans (Measured value (K4 tank group), large amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-123	3.7E-05	7.0E-05	8.9E-05	Radionuclide subject to operational control
I-129	1.3E-05	1.0E-05	4.1E-06	
C-14	5.2E-06	4.5E-06	2.5E-06	Radionuclide subject to operational control
Sn-126	1.9E-06	3.2E-06	4.0E-06	Radionuclide subject to operational control
Cd-115m	1.6E-06	2.3E-06	3.8E-06	Radionuclide subject to operational control
Sn-119m	8.5E-07	1.6E-06	2.1E-06	Radionuclide subject to operational control
Cd-113m	3.1E-07	2.6E-07	3.1E-07	Radionuclide subject to operational control
Co-60	2.7E-07	6.8E-07	8.4E-07	
Ru-106	1.6E-07	2.9E-07	3.8E-07	
Fe-59	1.2E-07	2.6E-07	5.3E-07	Radionuclide subject to operational control
H-3	1.1E-07	9.8E-08	8.0E-08	
Pm-148	9.4E-08	1.7E-07	2.0E-07	
Te-129m	8.0E-08	1.6E-07	2.3E-07	
Tc-99	7.7E-08	1.4E-07	2.3E-07	
Y-91	6.7E-08	1.2E-07	1.5E-07	
Te-127m	6.1E-08	1.3E-07	2.1E-07	
Zn-65	3.3E-08	4.1E-08	5.9E-08	
Te-125m	2.4E-08	4.5E-08	7.0E-08	
Cs-137	1.5E-08	5.6E-09	4.9E-09	
Ni-63	1.5E-08	2.3E-08	3.1E-08	
Ce-144	1.4E-08	2.5E-08	3.4E-08	
Ag-110m	9.9E-09	1.4E-08	1.7E-08	Radionuclide subject to operational control
Y-90	7.5E-09	1.4E-08	1.7E-08	
Pu-239	7.0E-09	4.6E-09	2.3E-08	
Pu-240	7.0E-09	4.6E-09	2.3E-08	
Am-241	6.7E-09	4.6E-09	2.4E-08	
Am-243	6.7E-09	4.6E-09	2.3E-08	
Pu-238	6.4E-09	4.3E-09	2.2E-08	
Pm-146	6.1E-09	9.6E-09	1.3E-08	
Pu-241	6.0E-09	3.4E-09	1.3E-08	
Sb-125	5.2E-09	8.2E-09	1.1E-08	
Te-127	4.5E-09	8.3E-09	7.8E-09	
Cm-243	3.5E-09	2.5E-09	1.4E-08	
Pm-147	3.4E-09	6.4E-09	9.2E-09	
Cm-244	2.8E-09	2.2E-09	1.3E-08	
Eu-152	2.7E-09	4.0E-09	6.1E-09	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Cs-134	2.3E-09	8.1E-10	6.4E-10	
Mn-54	1.8E-09	2.5E-09	2.7E-09	
Eu-154	1.7E-09	2.7E-09	4.1E-09	
Tb-160	1.5E-09	2.5E-09	2.8E-09	
Sr-90	1.1E-09	9.6E-10	1.8E-09	
Co-58	1.1E-09	1.9E-09	2.1E-09	
Te-123m	1.1E-09	1.9E-09	2.8E-09	
Pm-148m	9.9E-10	1.6E-09	1.7E-09	
Ce-141	7.5E-10	1.4E-09	1.7E-09	
Eu-155	7.4E-10	1.3E-09	1.9E-09	
Gd-153	6.0E-10	1.0E-09	1.3E-09	
Te-129	4.2E-10	7.1E-10	9.9E-10	
Am-242m	4.0E-10	2.4E-10	1.2E-09	
Sb-124	3.4E-10	5.8E-10	6.9E-10	
Cm-242	2.8E-10	4.5E-10	2.6E-09	
Cs-136	2.5E-10	2.5E-10	2.5E-10	
Rb-86	2.1E-10	3.7E-10	4.6E-10	
Ba-140	1.6E-10	2.9E-10	4.0E-10	
Nb-95	1.4E-10	2.2E-10	2.1E-10	
Pr-144	1.1E-10	1.9E-10	2.7E-10	
Ru-103	1.1E-10	1.7E-10	2.0E-10	
Sr-89	4.8E-11	8.2E-11	1.3E-10	
Sm-151	6.1E-12	1.0E-11	1.8E-11	
Rh-103m	9.4E-13	1.6E-12	2.2E-12	
Cs-135	1.4E-14	5.9E-15	5.6E-15	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	6.1E-05	9.4E-05	1.1E-04	

Table H-3 Results of Assessment Regarding Internal Exposure of Humans (Measured value (J1-C tank group), average amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-119m	1.3E-05	2.5E-05	3.2E-05	Radionuclide subject to operational control
Sn-123	1.3E-05	2.3E-05	3.1E-05	Radionuclide subject to operational control

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-126	1.2E-06	2.1E-06	2.7E-06	Radionuclide subject to operational control
C-14	3.8E-07	3.3E-07	1.9E-07	Radionuclide subject to operational control
I-129	3.6E-07	2.7E-07	1.1E-07	
Cd-115m	2.9E-07	4.3E-07	7.2E-07	Radionuclide subject to operational control
Cd-113m	6.4E-08	5.4E-08	6.7E-08	Radionuclide subject to operational control
Te-127m	5.0E-08	1.0E-07	1.8E-07	
H-3	2.9E-08	2.5E-08	2.1E-08	
Fe-59	2.7E-08	5.7E-08	1.2E-07	Radionuclide subject to operational control
Y-91	2.3E-08	4.1E-08	5.1E-08	
Te-129m	1.9E-08	3.6E-08	5.4E-08	
Am-241	1.7E-08	1.1E-08	6.1E-08	
Am-243	1.7E-08	1.1E-08	5.9E-08	
Pu-239	1.6E-08	1.1E-08	5.4E-08	
Pu-240	1.6E-08	1.1E-08	5.4E-08	
Pu-238	1.5E-08	1.0E-08	5.1E-08	
Pu-241	1.1E-08	6.5E-09	2.6E-08	
Cm-243	8.7E-09	6.2E-09	3.6E-08	
Co-60	8.6E-09	2.2E-08	2.7E-08	
Zn-65	8.0E-09	1.0E-08	1.5E-08	
Cm-244	7.0E-09	5.4E-09	3.3E-08	
Ru-106	6.6E-09	1.2E-08	1.5E-08	
Tc-99	6.5E-09	1.1E-08	1.9E-08	
Ce-144	5.8E-09	1.0E-08	1.4E-08	
Ag-110m	3.7E-09	5.2E-09	6.4E-09	Radionuclide subject to operational control
Te-127	3.5E-09	6.3E-09	6.2E-09	
Ni-63	3.2E-09	4.9E-09	6.8E-09	
Pm-148	1.9E-09	3.4E-09	4.1E-09	
Eu-152	1.2E-09	1.7E-09	2.7E-09	
Te-125m	8.9E-10	1.6E-09	2.6E-09	
Cm-242	7.0E-10	1.1E-09	6.6E-09	
Eu-154	6.6E-10	1.1E-09	1.6E-09	
Pm-147	6.2E-10	1.2E-09	1.7E-09	
Te-123m	5.7E-10	9.8E-10	1.5E-09	
Cs-137	4.3E-10	1.6E-10	1.4E-10	
Mn-54	4.2E-10	5.7E-10	6.4E-10	
Ce-141	3.6E-10	6.4E-10	7.9E-10	
Eu-155	3.3E-10	5.6E-10	8.7E-10	
Tb-160	3.1E-10	5.2E-10	6.1E-10	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Am-242m	2.9E-10	1.7E-10	9.1E-10	
Cs-134	2.5E-10	8.5E-11	7.0E-11	
Pm-148m	2.4E-10	4.0E-10	4.3E-10	
Sb-125	2.4E-10	3.7E-10	4.9E-10	
Co-58	2.3E-10	4.1E-10	4.6E-10	
Sb-124	2.3E-10	3.9E-10	4.7E-10	
Gd-153	2.1E-10	3.7E-10	4.5E-10	
Pm-146	1.8E-10	2.8E-10	4.0E-10	
Te-129	1.7E-10	2.8E-10	4.1E-10	
Y-90	5.4E-11	9.9E-11	1.2E-10	
Pr-144	4.7E-11	7.8E-11	1.2E-10	
Nb-95	3.2E-11	4.9E-11	5.0E-11	
Rb-86	3.1E-11	5.4E-11	6.9E-11	
Ru-103	2.6E-11	4.2E-11	4.9E-11	
Cs-136	2.4E-11	2.5E-11	2.5E-11	
Ba-140	1.9E-11	3.3E-11	4.6E-11	
Sr-90	9.6E-12	8.1E-12	1.6E-11	
Sm-151	3.2E-12	5.5E-12	9.8E-12	
Sr-89	1.3E-12	2.3E-12	3.7E-12	
Rh-103m	2.1E-13	3.6E-13	5.2E-13	
Cs-135	4.2E-16	1.8E-16	1.7E-16	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	2.8E-05	5.1E-05	6.7E-05	

Table H-4 Results of Assessment Regarding Internal Exposure of Humans
(Measured value (J1-Ctank group), large amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-119m	4.9E-05	9.4E-05	1.2E-04	Radionuclide subject to operational control
Sn-123	4.7E-05	8.9E-05	1.1E-04	Radionuclide subject to operational control
Sn-126	4.6E-06	8.0E-06	9.9E-06	Radionuclide subject to operational control
I-129	1.7E-06	1.3E-06	5.4E-07	
Cd-115m	1.5E-06	2.3E-06	3.7E-06	Radionuclide subject to operational control
C-14	1.4E-06	1.3E-06	7.0E-07	Radionuclide subject to operational control
Cd-113m	3.4E-07	2.9E-07	3.4E-07	Radionuclide subject to operational control
Te-127m	2.2E-07	4.5E-07	7.6E-07	
Fe-59	1.5E-07	3.1E-07	6.2E-07	Radionuclide subject to operational control
Y-91	1.2E-07	2.2E-07	2.7E-07	
H-3	1.1E-07	9.8E-08	8.0E-08	
Pu-239	8.5E-08	5.6E-08	2.8E-07	
Pu-240	8.5E-08	5.6E-08	2.8E-07	
Am-241	8.2E-08	5.5E-08	2.9E-07	
Am-243	8.2E-08	5.5E-08	2.8E-07	
Te-129m	8.1E-08	1.6E-07	2.3E-07	
Pu-238	7.8E-08	5.3E-08	2.6E-07	
Pu-241	5.9E-08	3.4E-08	1.3E-07	
Zn-65	4.8E-08	6.0E-08	8.6E-08	
Co-60	4.7E-08	1.2E-07	1.5E-07	
Cm-243	4.2E-08	3.1E-08	1.7E-07	
Cm-244	3.4E-08	2.7E-08	1.6E-07	
Ru-106	3.3E-08	5.9E-08	7.6E-08	
Tc-99	3.1E-08	5.5E-08	9.2E-08	
Ce-144	2.9E-08	5.3E-08	7.1E-08	
Ag-110m	1.8E-08	2.5E-08	3.0E-08	Radionuclide subject to operational control
Te-127	1.5E-08	2.8E-08	2.7E-08	
Ni-63	1.3E-08	2.1E-08	2.8E-08	
Pm-148	1.0E-08	1.8E-08	2.2E-08	
Eu-152	6.3E-09	9.3E-09	1.4E-08	
Te-125m	3.9E-09	7.3E-09	1.1E-08	
Eu-154	3.5E-09	5.8E-09	8.6E-09	
Cm-242	3.4E-09	5.5E-09	3.2E-08	
Pm-147	3.4E-09	6.2E-09	9.0E-09	
Te-123m	2.5E-09	4.4E-09	6.6E-09	
Mn-54	2.4E-09	3.2E-09	3.6E-09	
Ce-141	1.8E-09	3.3E-09	4.0E-09	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Eu-155	1.8E-09	3.0E-09	4.6E-09	
Tb-160	1.7E-09	2.8E-09	3.3E-09	
Cs-137	1.6E-09	5.8E-10	5.1E-10	
Am-242m	1.4E-09	8.4E-10	4.4E-09	
Pm-148m	1.3E-09	2.1E-09	2.3E-09	
Co-58	1.3E-09	2.2E-09	2.4E-09	
Gd-153	1.1E-09	2.0E-09	2.4E-09	
Pm-146	9.7E-10	1.5E-09	2.1E-09	
Cs-134	9.1E-10	3.2E-10	2.5E-10	
Sb-125	8.4E-10	1.3E-09	1.7E-09	
Sb-124	8.1E-10	1.4E-09	1.6E-09	
Te-129	7.5E-10	1.3E-09	1.8E-09	
Y-90	2.9E-10	5.3E-10	6.3E-10	
Pr-144	2.3E-10	3.9E-10	5.7E-10	
Nb-95	1.6E-10	2.5E-10	2.5E-10	
Ru-103	1.3E-10	2.1E-10	2.4E-10	
Rb-86	1.3E-10	2.3E-10	2.8E-10	
Cs-136	8.9E-11	9.2E-11	9.0E-11	
Ba-140	8.0E-11	1.4E-10	1.9E-10	
Sr-90	4.3E-11	3.6E-11	7.0E-11	
Sm-151	1.7E-11	2.9E-11	5.2E-11	
Sr-89	6.0E-12	1.0E-11	1.6E-11	
Rh-103m	1.2E-12	2.0E-12	2.8E-12	
Cs-135	1.5E-15	6.5E-16	6.3E-16	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	1.1E-04	2.0E-04	2.5E-04	

Table H-5 Results of Assessment Regarding Internal Exposure of Humans (Measured value (J1-G tank group), average amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-119m	3.7E-05	7.1E-05	9.2E-05	Radionuclide subject to operational control
Sn-123	3.6E-05	6.7E-05	8.8E-05	Radionuclide subject to operational control
Sn-126	1.9E-06	3.3E-06	4.2E-06	Radionuclide subject to operational control
C-14	1.0E-06	8.8E-07	5.1E-07	Radionuclide subject to operational control
Cd-115m	7.5E-07	1.1E-06	1.9E-06	Radionuclide subject to operational control

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
I-129	3.0E-07	2.3E-07	9.5E-08	
Cd-113m	2.0E-07	1.7E-07	2.0E-07	Radionuclide subject to operational control
Te-127m	1.4E-07	2.8E-07	4.9E-07	
Fe-59	6.8E-08	1.4E-07	3.0E-07	Radionuclide subject to operational control
Te-129m	4.9E-08	9.5E-08	1.4E-07	
Y-91	4.8E-08	8.8E-08	1.1E-07	
Am-241	4.4E-08	2.9E-08	1.6E-07	
Am-243	4.4E-08	2.9E-08	1.5E-07	
Pu-239	4.2E-08	2.8E-08	1.4E-07	
Pu-240	4.2E-08	2.8E-08	1.4E-07	
Pu-238	3.9E-08	2.6E-08	1.3E-07	
H-3	2.9E-08	2.5E-08	2.1E-08	
Pu-241	2.9E-08	1.6E-08	6.6E-08	
Cm-243	2.3E-08	1.6E-08	9.3E-08	
Tc-99	2.1E-08	3.7E-08	6.4E-08	
Zn-65	2.1E-08	2.6E-08	3.8E-08	
Co-60	1.8E-08	4.6E-08	5.7E-08	
Cm-244	1.8E-08	1.4E-08	8.4E-08	
Ce-144	1.7E-08	3.0E-08	4.1E-08	
Pm-148	1.1E-08	2.0E-08	2.4E-08	
Ag-110m	1.0E-08	1.5E-08	1.8E-08	Radionuclide subject to operational control
Ni-63	1.0E-08	1.5E-08	2.2E-08	
Te-127	9.9E-09	1.8E-08	1.7E-08	
Ru-106	6.9E-09	1.2E-08	1.6E-08	
Eu-152	2.4E-09	3.6E-09	5.5E-09	
Cs-137	2.3E-09	8.3E-10	7.5E-10	
Eu-154	1.8E-09	3.0E-09	4.5E-09	
Cm-242	1.8E-09	2.9E-09	1.7E-08	
Pm-147	1.7E-09	3.2E-09	4.7E-09	
Te-125m	1.6E-09	3.0E-09	4.8E-09	
Mn-54	1.3E-09	1.7E-09	1.9E-09	
Te-123m	1.3E-09	2.2E-09	3.4E-09	
Tb-160	9.4E-10	1.6E-09	1.9E-09	
Am-242m	7.6E-10	4.5E-10	2.4E-09	
Cs-134	6.7E-10	2.3E-10	1.9E-10	
Co-58	6.4E-10	1.1E-09	1.2E-09	
Pm-148m	6.4E-10	1.0E-09	1.1E-09	
Sb-124	6.0E-10	1.0E-09	1.2E-09	
Eu-155	5.3E-10	9.0E-10	1.4E-09	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Pm-146	5.2E-10	8.1E-10	1.1E-09	
Ce-141	5.0E-10	9.0E-10	1.1E-09	
Te-129	5.0E-10	8.2E-10	1.2E-09	
Gd-153	4.7E-10	8.2E-10	1.0E-09	
Sb-125	4.4E-10	6.9E-10	9.1E-10	
Y-90	1.4E-10	2.7E-10	3.3E-10	
Pr-144	1.4E-10	2.3E-10	3.4E-10	
Nb-95	9.2E-11	1.4E-10	1.4E-10	
Rb-86	8.8E-11	1.5E-10	2.0E-10	
Ru-103	7.6E-11	1.2E-10	1.4E-10	
Cs-136	5.7E-11	5.8E-11	5.8E-11	
Ba-140	4.9E-11	8.4E-11	1.2E-10	
Sr-90	2.6E-11	2.2E-11	4.3E-11	
Sm-151	8.9E-12	1.5E-11	2.7E-11	
Sr-89	3.4E-12	5.8E-12	9.4E-12	
Rh-103m	6.2E-13	1.1E-12	1.5E-12	
Cs-135	2.2E-15	9.4E-16	9.3E-16	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	7.9E-05	1.5E-04	1.9E-04	

Table H-6 Results of Assessment Regarding Internal Exposure of Humans (Measured value (J1-G tank group), large amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-119m	1.4E-04	2.7E-04	3.4E-04	Radionuclide subject to operational control
Sn-123	1.4E-04	2.6E-04	3.3E-04	Radionuclide subject to operational control
Sn-126	7.3E-06	1.3E-05	1.6E-05	Radionuclide subject to operational control
Cd-115m	4.0E-06	5.9E-06	9.7E-06	Radionuclide subject to operational control
C-14	3.9E-06	3.4E-06	1.9E-06	Radionuclide subject to operational control
I-129	1.4E-06	1.1E-06	4.5E-07	
Cd-113m	1.0E-06	8.8E-07	1.1E-06	Radionuclide subject to operational control
Te-127m	6.0E-07	1.3E-06	2.1E-06	
Fe-59	3.7E-07	7.7E-07	1.6E-06	Radionuclide subject to operational control
Y-91	2.6E-07	4.7E-07	5.8E-07	
Pu-239	2.2E-07	1.4E-07	7.1E-07	
Pu-240	2.2E-07	1.4E-07	7.1E-07	
Am-241	2.1E-07	1.4E-07	7.5E-07	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Am-243	2.1E-07	1.4E-07	7.3E-07	
Te-129m	2.1E-07	4.2E-07	6.0E-07	
Pu-238	2.0E-07	1.4E-07	6.8E-07	
Pu-241	1.5E-07	8.6E-08	3.4E-07	
Zn-65	1.2E-07	1.5E-07	2.2E-07	
H-3	1.1E-07	9.8E-08	8.0E-08	
Cm-243	1.1E-07	8.0E-08	4.5E-07	
Tc-99	1.0E-07	1.8E-07	3.0E-07	
Co-60	1.0E-07	2.5E-07	3.1E-07	
Cm-244	8.7E-08	6.9E-08	4.1E-07	
Ce-144	8.5E-08	1.6E-07	2.1E-07	
Pm-148	6.0E-08	1.1E-07	1.3E-07	
Ag-110m	5.0E-08	7.0E-08	8.4E-08	Radionuclide subject to operational control
Te-127	4.3E-08	7.8E-08	7.4E-08	
Ni-63	4.2E-08	6.5E-08	8.8E-08	
Ru-106	3.4E-08	6.1E-08	8.0E-08	
Eu-152	1.3E-08	1.9E-08	2.9E-08	
Eu-154	9.8E-09	1.6E-08	2.4E-08	
Pm-147	9.2E-09	1.7E-08	2.5E-08	
Cm-242	8.7E-09	1.4E-08	8.2E-08	
Cs-137	8.2E-09	3.1E-09	2.7E-09	
Mn-54	7.4E-09	9.9E-09	1.1E-08	
Te-125m	7.1E-09	1.4E-08	2.1E-08	
Te-123m	5.5E-09	9.6E-09	1.5E-08	
Tb-160	5.1E-09	8.6E-09	9.9E-09	
Am-242m	3.6E-09	2.2E-09	1.1E-08	
Co-58	3.5E-09	6.1E-09	6.7E-09	
Pm-148m	3.4E-09	5.5E-09	5.9E-09	
Eu-155	2.8E-09	4.9E-09	7.4E-09	
Pm-146	2.8E-09	4.3E-09	6.0E-09	
Ce-141	2.5E-09	4.6E-09	5.6E-09	
Gd-153	2.5E-09	4.4E-09	5.2E-09	
Cs-134	2.4E-09	8.5E-10	6.8E-10	
Te-129	2.2E-09	3.6E-09	5.1E-09	
Sb-124	2.1E-09	3.6E-09	4.3E-09	
Sb-125	1.6E-09	2.5E-09	3.2E-09	
Y-90	7.7E-10	1.4E-09	1.7E-09	
Pr-144	6.8E-10	1.2E-09	1.7E-09	
Nb-95	4.6E-10	7.2E-10	7.1E-10	

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Ru-103	3.8E-10	6.3E-10	7.1E-10	
Rb-86	3.6E-10	6.5E-10	8.0E-10	
Cs-136	2.1E-10	2.1E-10	2.1E-10	
Ba-140	2.1E-10	3.7E-10	5.0E-10	
Sr-90	1.2E-10	9.8E-11	1.9E-10	
Sm-151	4.8E-11	8.1E-11	1.4E-10	
Sr-89	1.5E-11	2.6E-11	4.1E-11	
Rh-103m	3.4E-12	5.8E-12	8.1E-12	
Cs-135	8.1E-15	3.5E-15	3.3E-15	
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	3.0E-04	5.6E-04	7.1E-04	

Table H-7 Results of Assessment Regarding Internal Exposure of Humans (the hypothetical ALPS treated water, average amount of marine products ingested)

Radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Sn-119m	1.5E-04	2.9E-04	3.7E-04	Radionuclide subject to operational control
Sn-123	1.2E-04	2.3E-04	3.0E-04	Radionuclide subject to operational control
Zn-65	9.8E-05	1.2E-04	1.8E-04	
C-14	8.7E-05	7.4E-05	4.3E-05	Radionuclide subject to operational control
Sn-126	1.4E-05	2.4E-05	3.0E-05	Radionuclide subject to operational control
Cd-115m	3.5E-06	5.2E-06	8.8E-06	Radionuclide subject to operational control
Cd-113m	9.2E-07	7.9E-07	9.6E-07	Radionuclide subject to operational control
Fe-59	5.1E-07	1.1E-06	2.2E-06	Radionuclide subject to operational control
Ag-110m	7.1E-08	9.9E-08	1.2E-07	Radionuclide subject to operational control
H-3	2.9E-08	2.5E-08	2.1E-08	
Total	4.8E-04	7.5E-04	9.4E-04	

Table H-8 Results of Assessment Regarding Internal Exposure of Humans (the hypothetical ALPS treated water, large amount of marine products ingested)

Subject radionuclide	Result of exposure assessment (mSv/year)			Remarks
	Adult	Child	Infant	
Zn-65	5.9E-04	7.3E-04	1.0E-03	
Sn-119m	5.7E-04	1.1E-03	1.4E-03	Radionuclide subject to operational control
Sn-123	4.7E-04	8.8E-04	1.1E-03	Radionuclide subject to operational control
C-14	3.3E-04	2.9E-04	1.6E-04	Radionuclide subject to operational control
Sn-126	5.2E-05	9.1E-05	1.1E-04	Radionuclide subject to operational control
Cd-115m	1.9E-05	2.8E-05	4.5E-05	Radionuclide subject to operational control
Cd-113m	6.5E-06	5.6E-06	6.6E-06	Radionuclide subject to operational control
Fe-59	2.8E-06	5.8E-06	1.2E-05	Radionuclide subject to operational control
Ag-110m	2.0E-07	2.8E-07	3.4E-07	Radionuclide subject to operational control
H-3	1.1E-07	9.8E-08	8.0E-08	
Total	2.0E-03	3.1E-03	3.9E-03	

H2. Results of assessment regarding environmental protection

The results of exposure assessment presented in Reference B are presented in tables F-9 to F-12 by each radionuclide.

(1) Source term based on the measured value for 64 radionuclides

i. K4 tank group (“the sum of the ratios”of radionuclides other than tritium is 0.29)

ii. J1-C tank group (“the sum of the ratios”of radionuclides other than tritium is 0.35)

iii. J1-G tank group (“the sum of the ratios”of radionuclides other than tritium is 0.22)

(2) Source term based on the hypothetical ALPS treated water

(“the sum of the ratios”of radionuclides other than tritium is 1)

Table H-9 Result of Assessment for Environmental Protection
(source term by measured value (K4 tank group)

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Fe-59	1.2E-05	1.2E-05	1.3E-05	Radionuclide subject to operational control
Sn-123	1.6E-06	1.5E-06	1.7E-06	Radionuclide subject to operational control
Pm-148	1.3E-06	1.2E-06	1.7E-06	
Sn-126	6.9E-07	6.6E-07	6.4E-07	Radionuclide subject to operational control
Co-60	6.5E-07	6.5E-07	7.1E-07	
Pm-146	2.9E-07	2.8E-07	3.1E-07	
Y-91	1.4E-07	8.4E-08	6.3E-07	
Eu-152	1.3E-07	1.2E-07	1.3E-07	
Tb-160	1.2E-07	1.2E-07	1.3E-07	
Ce-144	7.8E-08	4.5E-08	7.8E-08	
Pm-148m	6.6E-08	6.4E-08	7.2E-08	
Eu-154	6.1E-08	5.7E-08	6.1E-08	
Ru-106	5.4E-08	3.9E-08	5.6E-08	
Sn-119m	4.3E-08	4.1E-08	3.0E-08	Radionuclide subject to operational control
C-14	4.0E-08	3.3E-08	2.7E-08	Radionuclide subject to operational control
Cd-115m	2.4E-08	2.2E-08	9.3E-09	Radionuclide subject to operational control
Mn-54	2.3E-08	2.1E-08	2.3E-08	
Gd-153	1.2E-08	1.3E-08	1.4E-08	
Nb-95	1.2E-08	1.2E-08	1.2E-08	
Ce-141	1.1E-08	1.1E-08	1.2E-08	
Eu-155	7.7E-09	7.5E-09	7.7E-09	
H-3	4.7E-09	4.7E-09	1.8E-09	
Co-58	4.5E-09	4.6E-09	4.5E-09	
Cs-137	1.9E-09	1.9E-09	1.9E-09	
Zn-65	1.2E-09	2.6E-09	1.2E-09	
Ba-140	9.3E-10	1.3E-09	1.7E-09	
Te-129m	9.1E-10	9.2E-10	8.4E-09	

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Sb-125	7.0E-10	6.2E-10	8.7E-10	
Am-243	5.8E-10	5.6E-10	6.4E-10	
Cs-134	5.7E-10	5.4E-10	5.7E-10	
Cs-136	4.9E-10	4.9E-10	4.9E-10	
Te-127m	4.3E-10	4.3E-10	4.1E-09	
Ru-103	3.9E-10	3.8E-10	3.9E-10	
Ag-110m	3.8E-10	2.2E-09	3.3E-10	Radionuclide subject to operational control
Cm-243	3.2E-10	3.1E-10	4.6E-10	
Te-127	3.2E-10	3.2E-10	2.9E-09	
Rb-86	2.2E-10	1.8E-10	4.5E-10	
Te-125m	1.9E-10	2.0E-10	1.7E-09	
Cd-113m	1.9E-10	1.7E-10	3.4E-11	Radionuclide subject to operational control
Sb-124	8.5E-11	7.6E-11	1.0E-10	
Pm-147	7.5E-11	2.7E-10	7.5E-10	
Am-241	6.1E-11	5.9E-11	5.9E-11	
Ni-63	4.5E-11	1.5E-10	3.3E-10	
Tc-99	2.5E-11	5.9E-11	1.1E-08	
I-129	1.1E-11	6.7E-12	9.3E-10	
Sr-90	1.0E-11	2.7E-12	4.2E-11	
Te-123m	7.3E-12	7.4E-12	4.4E-11	
Cm-242	4.3E-12	9.4E-12	1.4E-10	
Cm-244	4.1E-12	8.9E-12	1.4E-10	
Am-242m	3.0E-12	2.9E-12	5.2E-12	
Sr-89	2.5E-12	6.3E-13	1.1E-11	
Pu-238	3.7E-13	6.2E-13	3.7E-11	
Pu-240	3.4E-13	5.8E-13	3.4E-11	
Pu-239	3.3E-13	5.7E-13	3.4E-11	
Sm-151	5.9E-14	4.1E-13	3.8E-13	
Pu-241	2.2E-14	3.3E-14	1.6E-12	
Cs-135	3.8E-17	1.7E-17	1.5E-17	
Y-90	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-103m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Te-129	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	1.7E-05	1.7E-05	1.9E-05	

Table H-10 Result of Assessment for Environmental Protection (source term by measured value (J1-C tank group)

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Fe-59	1.4E-05	1.4E-05	1.5E-05	Radionuclide subject to operational control
Sn-119m	2.5E-06	2.3E-06	1.7E-06	Radionuclide subject to operational control
Sn-123	2.0E-06	2.0E-06	2.1E-06	Radionuclide subject to operational control
Sn-126	1.7E-06	1.6E-06	1.6E-06	Radionuclide subject to operational control
Eu-152	3.1E-07	2.9E-07	3.1E-07	
Y-91	2.5E-07	1.5E-07	1.1E-06	
Ce-144	1.6E-07	9.4E-08	1.6E-07	
Tb-160	1.4E-07	1.4E-07	1.5E-07	
Pm-148	1.4E-07	1.3E-07	1.9E-07	
Eu-154	1.3E-07	1.2E-07	1.3E-07	
Co-60	1.1E-07	1.1E-07	1.2E-07	
Pm-148m	8.8E-08	8.4E-08	9.5E-08	
Pm-146	4.7E-08	4.5E-08	4.9E-08	
Mn-54	3.1E-08	2.8E-08	3.1E-08	
Ce-141	2.7E-08	2.6E-08	2.8E-08	
Cd-115m	2.3E-08	2.1E-08	9.1E-09	Radionuclide subject to operational control
Gd-153	2.3E-08	2.4E-08	2.7E-08	
Eu-155	1.8E-08	1.8E-08	1.8E-08	
Nb-95	1.4E-08	1.4E-08	1.4E-08	
C-14	1.1E-08	9.2E-09	7.4E-09	Radionuclide subject to operational control
Ru-106	1.1E-08	8.0E-09	1.1E-08	
Am-243	7.0E-09	6.9E-09	7.7E-09	
Co-58	5.4E-09	5.4E-09	5.4E-09	
H-3	4.7E-09	4.7E-09	1.8E-09	
Cm-243	3.9E-09	3.7E-09	5.6E-09	
Zn-65	1.8E-09	3.8E-09	1.8E-09	
Te-127m	1.5E-09	1.5E-09	1.4E-08	
Te-127	1.1E-09	1.1E-09	1.0E-08	
Te-129m	9.2E-10	9.4E-10	8.5E-09	
Am-241	7.4E-10	7.2E-10	7.1E-10	
Ag-110m	6.8E-10	4.0E-09	5.9E-10	Radionuclide subject to operational control
Ru-103	4.8E-10	4.7E-10	4.8E-10	
Ba-140	4.6E-10	6.3E-10	8.5E-10	
Cs-134	2.2E-10	2.1E-10	2.2E-10	
Cd-113m	2.0E-10	1.9E-10	3.7E-11	Radionuclide subject to operational control
Cs-137	2.0E-10	2.0E-10	2.0E-10	

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Sb-124	2.0E-10	1.8E-10	2.4E-10	
Cs-136	1.8E-10	1.8E-10	1.8E-10	
Rb-86	1.4E-10	1.1E-10	2.7E-10	
Sb-125	1.1E-10	1.0E-10	1.4E-10	
Pm-147	7.3E-11	2.7E-10	7.3E-10	
Cm-242	5.2E-11	1.1E-10	1.8E-09	
Cm-244	4.9E-11	1.1E-10	1.7E-09	
Ni-63	4.0E-11	1.4E-10	3.0E-10	
Te-125m	3.1E-11	3.2E-11	2.7E-10	
Te-123m	1.7E-11	1.7E-11	1.0E-10	
Am-242m	1.0E-11	1.0E-11	1.8E-11	
Tc-99	9.8E-12	2.3E-11	4.5E-09	
Pu-238	4.5E-12	7.5E-12	4.5E-10	
Pu-240	4.2E-12	7.0E-12	4.2E-10	
Pu-239	4.0E-12	6.9E-12	4.2E-10	
I-129	1.5E-12	8.8E-13	1.2E-10	
Sr-90	3.8E-13	1.0E-13	1.6E-12	
Sr-89	3.1E-13	7.8E-14	1.3E-12	
Pu-241	2.2E-13	3.3E-13	1.6E-11	
Sm-151	1.7E-13	1.2E-12	1.1E-12	
Cs-135	4.2E-18	1.9E-18	1.7E-18	
Y-90	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-103m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Te-129	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	2.2E-05	2.2E-05	2.3E-05	

Table H-11 Result of Assessment for Environmental Protection (source term by measured value (J1-G tank group)

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Fe-59	3.6E-05	3.6E-05	3.8E-05	Radionuclide subject to operational control
Sn-119m	7.1E-06	6.8E-06	5.0E-06	Radionuclide subject to operational control
Sn-123	5.9E-06	5.7E-06	6.1E-06	Radionuclide subject to operational control
Sn-126	2.7E-06	2.6E-06	2.5E-06	Radionuclide subject to operational control
Pm-148	8.1E-07	7.5E-07	1.1E-06	
Eu-152	6.3E-07	5.9E-07	6.3E-07	
Y-91	5.3E-07	3.2E-07	2.4E-06	
Ce-144	4.8E-07	2.8E-07	4.8E-07	
Tb-160	4.4E-07	4.4E-07	4.7E-07	
Eu-154	3.6E-07	3.4E-07	3.6E-07	
Co-60	2.4E-07	2.4E-07	2.6E-07	
Pm-148m	2.3E-07	2.2E-07	2.5E-07	
Pm-146	1.3E-07	1.3E-07	1.4E-07	
Mn-54	9.3E-08	8.4E-08	9.3E-08	
Cd-115m	5.9E-08	5.5E-08	2.4E-08	Radionuclide subject to operational control
Gd-153	5.1E-08	5.4E-08	5.9E-08	
Nb-95	4.0E-08	3.9E-08	4.1E-08	
Ce-141	3.8E-08	3.6E-08	3.9E-08	
C-14	3.0E-08	2.5E-08	2.0E-08	Radionuclide subject to operational control
Eu-155	3.0E-08	2.9E-08	3.0E-08	
Am-243	1.8E-08	1.8E-08	2.0E-08	
Co-58	1.5E-08	1.5E-08	1.5E-08	
Ru-106	1.1E-08	8.3E-09	1.2E-08	
Cm-243	1.0E-08	9.6E-09	1.4E-08	
H-3	4.7E-09	4.7E-09	1.8E-09	
Zn-65	4.6E-09	9.8E-09	4.6E-09	
Te-127m	4.3E-09	4.3E-09	4.0E-08	
Te-127	3.0E-09	3.0E-09	2.8E-08	
Te-129m	2.4E-09	2.4E-09	2.2E-08	
Ag-110m	1.9E-09	1.1E-08	1.7E-09	Radionuclide subject to operational control
Am-241	1.9E-09	1.9E-09	1.8E-09	
Ru-103	1.4E-09	1.4E-09	1.4E-09	
Ba-140	1.2E-09	1.6E-09	2.2E-09	
Cs-137	1.1E-09	1.0E-09	1.1E-09	
Cd-113m	6.3E-10	5.8E-10	1.1E-10	Radionuclide subject to operational control
Cs-134	6.0E-10	5.7E-10	6.0E-10	
Sb-124	5.3E-10	4.7E-10	6.4E-10	

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Cs-136	4.2E-10	4.2E-10	4.2E-10	
Rb-86	3.9E-10	3.1E-10	7.8E-10	
Sb-125	2.1E-10	1.9E-10	2.6E-10	
Pm-147	2.0E-10	7.3E-10	2.0E-09	
Cm-242	1.3E-10	2.9E-10	4.5E-09	
Ni-63	1.3E-10	4.3E-10	9.4E-10	
Cm-244	1.3E-10	2.8E-10	4.3E-09	
Te-125m	5.7E-11	6.0E-11	5.0E-10	
Te-123m	3.7E-11	3.8E-11	2.2E-10	
Tc-99	3.2E-11	7.7E-11	1.5E-08	
Am-242m	2.7E-11	2.6E-11	4.8E-11	
Pu-238	1.1E-11	1.9E-11	1.2E-09	
Pu-240	1.1E-11	1.8E-11	1.1E-09	
Pu-239	1.0E-11	1.8E-11	1.1E-09	
I-129	1.2E-12	7.4E-13	1.0E-10	
Sr-90	1.0E-12	2.7E-13	4.3E-12	
Sr-89	7.9E-13	2.0E-13	3.3E-12	
Pu-241	5.6E-13	8.4E-13	4.0E-11	
Sm-151	4.6E-13	3.2E-12	3.0E-12	
Cs-135	2.2E-17	1.0E-17	9.1E-18	
Y-90	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-103m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Rh-106	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Te-129	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Ba-137m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Pr-144m	0.0E+00	0.0E+00	0.0E+00	See parent radionuclide for assessment results
Total	5.6E-05	5.5E-05	5.9E-05	

Table H-12 Result of Assessment for Environmental Protection (source term based on the hypothetical ALPS treated water)

Radionuclide	Result of exposure assessment [mGy/day]			Remarks
	Flat fish	Crab	Brown seaweed	
Pm-148m	7.5E-03	7.2E-03	8.1E-03	
Fe-59	2.7E-04	2.7E-04	2.9E-04	Radionuclide subject to operational control
Sn-126	1.9E-05	1.9E-05	1.8E-05	Radionuclide subject to operational control
H-3	4.7E-09	4.7E-09	1.8E-09	
Total	7.8E-03	7.5E-03	8.4E-03	

Reference I. Uncertainties in this assessment

This section summarizes the implications for assessing this report of the uncertainties that may arise concerning the discharge plan and methodology for this assessment.

I 1. Uncertainties associated with the discharge plan

Regarding the facilities and method of discharge of this plan, there is a possibility that the discharge plan may be subject to change due to local approval, regulatory review, and review by the relevant authorities.

In the event of any changes to the discharge plan, the content of the radiation impact assessment will be reviewed, and a revised version of the report will be prepared. The parameters that directly affect the exposure assessment, such as the water quality of the ALPS treated water ("the sum of the ratios" of radionuclides other than tritium is less than one) indicated in "TEPCO's Action in Response to the Government's Policy", the upper limit of the tritium discharge amount (2.2E+13Bq), and the tritium concentration after dilution (1,500 Bq/L), will not be changed so as to increase the exposure assessment results. Therefore, these parameters are not exposed to have a significant impact on the result of this assessment.

I 2. Uncertainties associated with the assessment conditions

The data, parameters, and assumptions used in this report are subject to uncertainty. However, due to the setting of the source term and conservative assumptions, it is considered that there is no significant likelihood that the assessment results in this report will exceed the dose limits or other criteria for assessment (Table I-1).

Table I-1 Uncertainties associated with the assessment conditions

Item	Details of uncertainty	Impact on assessment
Source term	New nuclides may be added to the list of nuclides to be assessed	If a new nuclide is added, the radiation effect assessment will be carried out again, and the report will be revised if necessary. Based on the past analysis results, there is hardly possibility that new nuclides with high concentrations will be added. Therefore, it is considered that there is no significant likelihood that the assessment results in this report will exceed the dose limits or other criteria for assessment.
Source term	There are few measurement results of nuclides other than tritium, and each nuclide's concentration (nuclide composition) has not been determined	A preliminary assessment of the case where each nuclide is discharged at the legally required concentration is conducted for each nuclide, and only the nuclide with the significant impact is assessed using the source term based on the upper limit for discharge control (the ratio of the legally required concentration is 1). So it is assumed that there is no need to revise the source term for any future measurement results. On the other hand, the source term may be set too high for the actual discharge.
Dispersion and transfer assessment	Actual weather and ocean conditions are likely to have annual and long-term variations	The assessment was carried out using two years of weather and ocean data, and the data of the year with the higher average concentration was used in the evaluation. In addition, the model used in this assessment is based on that verified the annual variations were not significant with the cesium dispersion calculations carried out for four years from 2013 to 2016. Therefore, it is considered that there is no significant likelihood that the assessment results in this report will exceed the dose limits or other criteria for assessment.

Item	Details of uncertainty	Impact on assessment
		Long-term variations will be confirmed and addressed in the environmental monitoring after the start of the discharge into the sea.
Assent of transfer and dispersion	Uncertainty of dispersion and transfer by nuclide	The dispersion and transfer calculations in this report do not consider the settling of particles or their migration to the marine sediment, which is a conservative assumption for the assessment of seawater concentrations. In evaluating the exposure of animals and plants, the migration to the marine sediment is assessed using distribution coefficients based on the calculation results of seawater concentrations with the assumption mentioned above. The assessment is conservative assumption, therefore it is considered that there is no significant likelihood that the assessment results in this report will exceed the dose limits or other criteria for assessment.
Migration of nuclides	There is uncertainty in parameters such as enrichment factors and distribution coefficients themselves. There is also uncertainty in the differences due to fish and the nature of the marine sediment.	The enrichment and partition coefficients are taken from internationally recognized IAEA documents. The transfer coefficients are also taken from data used in Japan's safety reviews. Although there are uncertainties in these coefficients, our reports state that there is no significant possibility that the assessment results in this report will exceed the criteria for assessing dose limits, etc., because conservative assessments have been made in source terms, etc.
Representative individuals	The data on lifestyle does not reflect regional data.	For marine products ingesting, national statistical data were used as the ingest of adults. Although there is data by district, not by age, the difference between the national statistical data and the Tohoku district is about 10%. In addition, although the lifestyle data used were set by surveying the whole country for dose assessment at NPS, the conservative estimation was conducted for other parameters such as source term. Therefore it is considered that there is no significant likelihood that the assessment results in this report will exceed the dose limits or other criteria for assessment.
External exposure assessment	Dose conversion coefficients for all 64 nuclides are not available.	For those nuclides for which dose conversion coefficients are not available, the maximum conversion coefficients for βγ and α nuclides are used, and a conservative assessment is carried out. Therefore, it is considered that the evaluation results in this report are unlikely to exceed the criteria for evaluation of dose limits, etc.

Terminology

Term	Definition
Multi-nuclide removal facility（ALPS）	Water treatment system which removes the 62 radioactive materials other than tritium inside contaminated water to a level which satisfies regulatory requirements (Advanced Liquid Process System).
ALPS treated water	Water treated using the ALPS until radioactive material other than tritium definitely falls below standards stipulated in safety regulations. (“the sum of the ratios”of radionuclides other than tritium is less than 1)
Treated water to be purified	Water treated using the ALPS, etc. which does not meet standards stipulated in safety regulations (“the sum of the ratios”of radionuclides other than tritium is less than 1).
ALPS treated water, etc.	A collective term for ALPS treated water and treated water to be purified.
Strontium removed water	Water which has had most of its contaminants, cesium and strontium, removed.
Secondary treatment	Repeated treatment of treated water using the ALPS, etc. to be purified which the “the sum of the ratios”of radionuclides other than tritium is not less than 1
Groundwater bypass	A measure implemented to reduce the volume of ground water coming close to the Reactor Building by pumping up ground water flowing from the mountain out to sea up a well located away from the Reactor Building, and discharging to the sea after verifying that discharge standards are met.
Subdrain	A measure implemented to reduce contaminated water resulting from ground water flowing into the Reactor Building by pumping ground water up a subdrain (a well near the building), treating it, and discharging to the sea after verifying that discharge standards are met.
Legally required concentration	The criteria for discharging the radioactive materials into the environment, stipulated in “Announcement Stipulating the Dose Limit Based on Regulations Regarding the Refining Business of Nuclear Raw Material and Nuclear Fuel Material”. The sum of the ratios to legally required concentration must be less than 1.
Target value for discharge	A target value stipulated for each nuclide discharged to control the amount of radioactive material released annually from the nuclear power station. FDNPS had stipulated 22 TBq(2.2E +13Bq) as the target value for discharge regarding tritium prior to the accident.
Operational control value	A concentration limit value, stipulated autonomously by TEPCO from the perspective of exposure reduction, for the eight nuclides with significant impact on exposure when discharging ALPS treated water. Detection of densities exceeding the subject value result in the discharge being stopped and the water will be transferred to the storage tank.
World Health Organization’s (WHO) guidelines regarding water quality for drinking	Guideline regarding water quality for drinking stipulated by the World Health Organization. The guideline stipulates parameters for water quality acceptable for continued consumption from the perspective radioactive materials, microorganisms, chemicals, etc. Values for radioactive material stipulated are 10Bq/L for Cs-137 and 10,000Bq/L for tritium.
International Commission on	ICRP Guidance are documents that set out the basic concepts and essential numerical criteria for radiation protection.

Term	Definition
Radiological Protection (ICRP) Guidance	
International Atomic Energy Agency (IAEA) Safety Standards	A document stipulated by IAEA as standards to protect the safety of health, lives and property of people when using radiation and radioactive material as part of activities relevant for securing nuclear safety. The document consists of safety fundamentals, safety requirements and safety guides which present principles and standards to be adhered to. The IAEA Safety Standards Document has been developed based on comments from all IAEA members' countries.
Representative person	A hypothetical individual subjected to exposure when evaluating exposure of the public in the review of radiological protection. Environment and lifestyle which could contribute to increased dose are considered.
Potential exposure	Exposure considering future events that are not guaranteed to occur but can be anticipated as probable events or sequence of events such as operational events, accidents involving radiation source, equipment failure and operational errors. Used in the review of radiological protection.
Area which no fishing is conducted in on a daily basis	An area in which the right of members of a fishery cooperative to jointly use a certain area for fishing (joint fishery right) has not been established. Area where the right to fish is not established.
Regional Sea Modeling System	A numerical analysis model for studying sea currents developed by Rutgers University.
Submersion model	A model for calculating dose from external exposure assuming a situation where a person is surrounded by radioactive material (submersion).
Concentration factor	An expedient coefficient representing the relationship between the radionuclide concentration (wet weight) in marine products (edible parts) and radionuclide concentration in the environment seawater. Used in the model to evaluate transfer to organisms.
Effective dose conversion coefficient	A conversion coefficient used to evaluate the amount of exposure a person receives from radioactive material.
Effective dose coefficient	A conversion coefficient used to evaluate the amount of internal exposure a person receives through the respiratory ingest and general ingest of radionuclide.
Environmental protection	Protection of non-human organisms from the hazardous impact of ionized radiation.
Reference animals and plants	A specific type of animals and plants hypothesized to link the dose and impact regarding exposure to background radiation.
Animals and plants dose conversion coefficient	A conversion coefficient used for the simplified calculation of internal exposure and external exposure received by an organism through environmental radionuclides.
Derived consideration reference levels (DCRL)	A band of dose rates with a single-digit range for each species of organisms, defined by the ICRP. In cases where this dose rate level is exceeded, the effect on organism should be considered.
Concentration ratio	A transfer coefficient which empirically derives the ratio between radionuclide concentration in marine products (overall) with radionuclide concentration in the environment seawater for the purpose of use in the review of exposure in animals and plants from background radiation.
Distribution (or partition) coefficient	The ratio when the concentration of radioactive material in seawater (Bq/L) and marine sediment (Bq/kg) is at an equilibrium. Used to evaluate the transfer of radioactive material from seawater to marine sediment.

Development members

In compiling this report, employees with knowledge on the assessment of radiological impact on the environment were selected and assigned, and experts in the three fields especially important for assessing radiological impact: human radiological protection, environmental protection and marine dispersion simulation, were invited as members from outside the company.

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  TATEDA Yutaka (Guest Research Fellow, Sustainable System Resarch Laboratory, Central Research Institute of Electric Power Industry, marine animals and plants exposure assessment)
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  MASUMOTO Yukio (Professor, The University of Tokyo, dispersion calculation)
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- Observers
  KOYAMA Tadafumi (Distinguished Research Scientist, Central Research Institute of Electric Power Industry)

- Secretariat
  SATO Gaku (Tokyo Electric Power Company Holdings, Inc.)
  MATSUZAKI Katsuhisa (Tokyo Electric Power Company Holdings, Inc.)

End

3.1.4 Reduction of radioactive materials in seawater, seabed soil, groundwater and drainage channels in ports and harbors

（Refer to comparison table for any amendments）

Annexes of the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility

These documents are supplementary information on "the Implementation Plan for Fukushima Daiichi Nuclear Power Station as Specified Nuclear Facility".

Tokyo Electric Power Company Holdings Inc.

The Japanese version shall prevail.

Table of Contents

(Refer to comparison table for any amendments)

The Japanese version shall prevail.

Annex 27

Supplementary information on the ALPS Treated Water Dilution/Discharge Facilities

I. Structural Strength of ALPS Treated Water Dilution/Discharge Facilities

1.1 Main pipe (steel pipe)

The structural evaluation points are shown in Fig. 1 to 4.

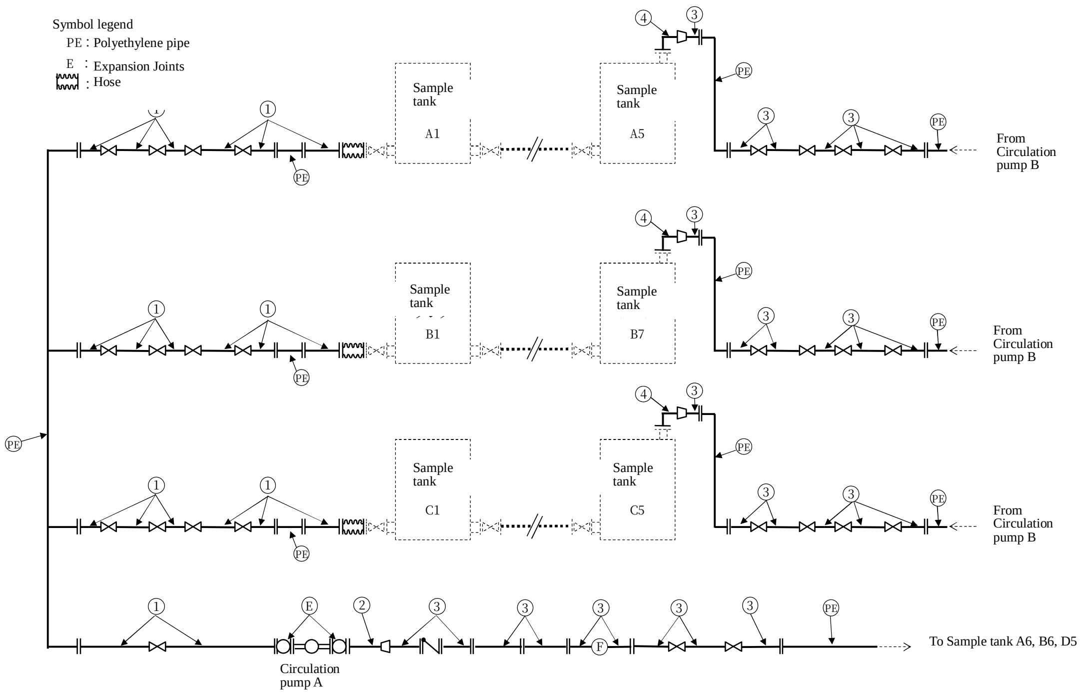

Fig. 1 Schematic diagram of pipe (1/4)

(Facility for measuring and checking)

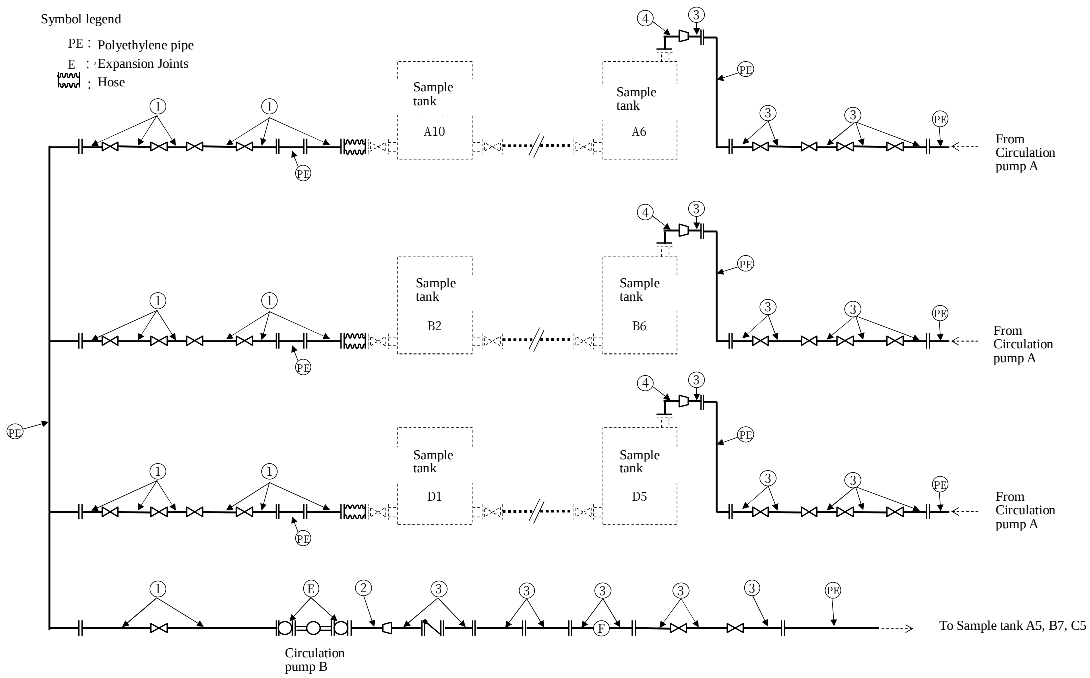

Fig. 2 Schematic diagram of pipe (2/4)

(Facility for measuring and checking)

The Japanese version shall prevail.

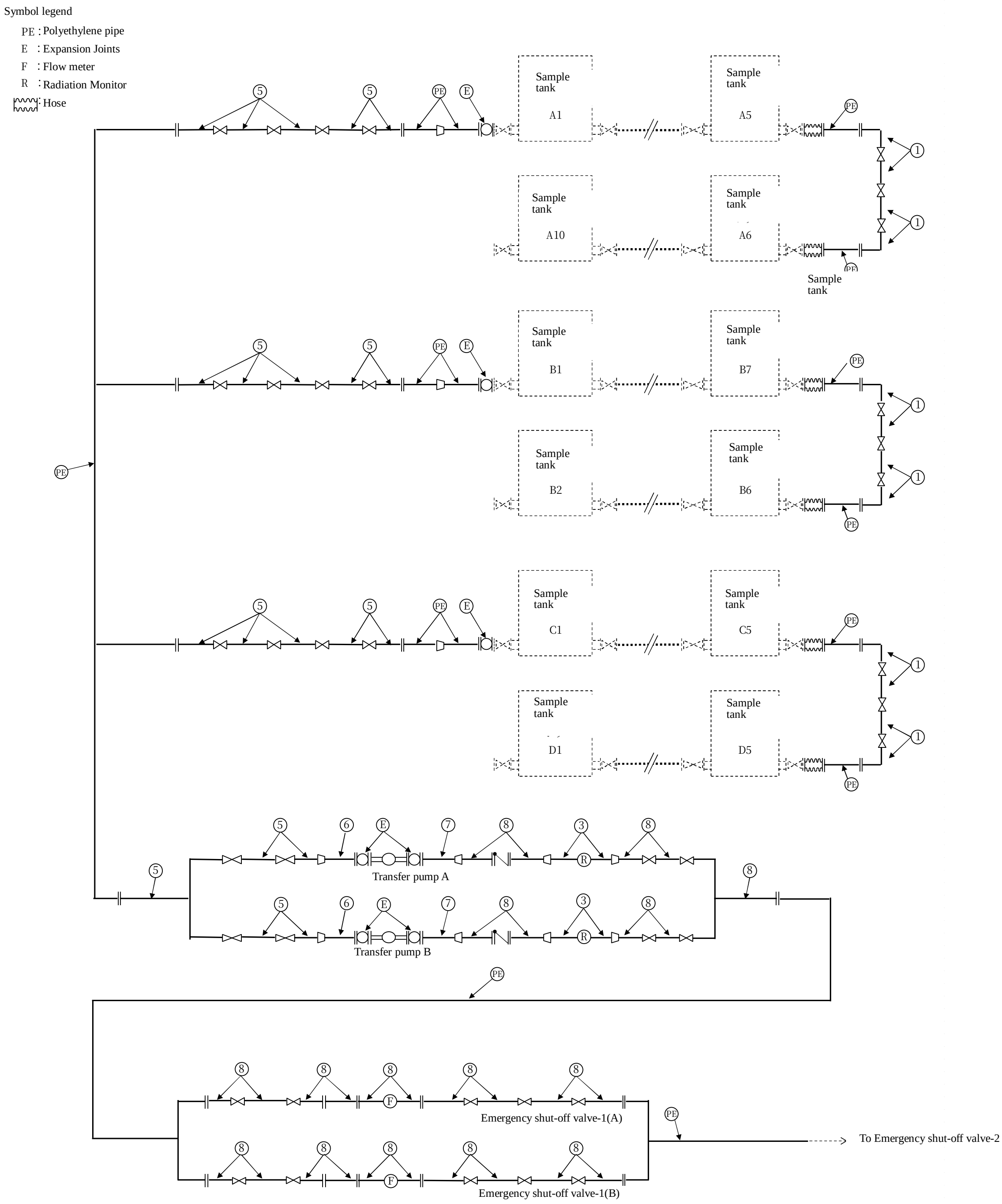

Fig. 3 Schematic diagram of pipe (3/4)

(Transfer Facility)

The Japanese version shall prevail.

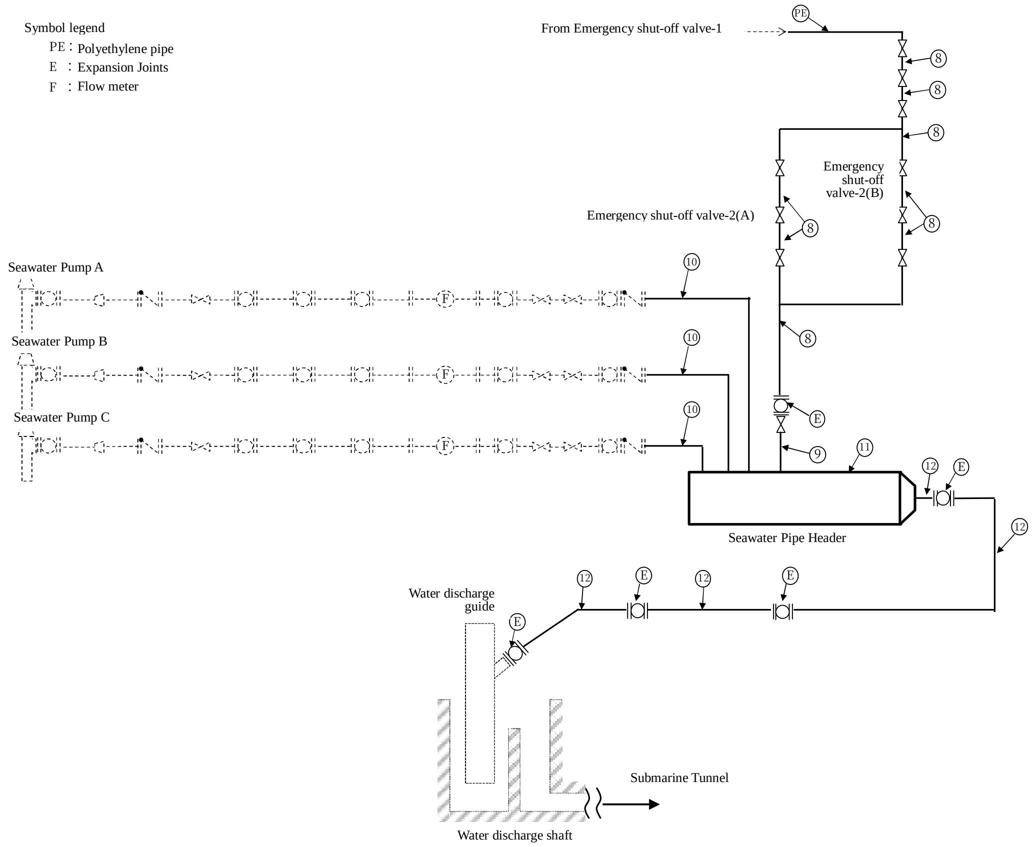

Fig. 4 Schematic diagram of pipe (4/4)
(Transfer Facility, Dilution Facility)

The Japanese version shall prevail.

1.2 Evaluation method

The required thickness of the pipe shall be the greater of the following values:

a. Pipe subjected to pressure on the inner surface

Required thickness for pipe calculation: $t = \frac{PD_0}{2S\eta + 0.8P}$

P	: Max. operating pressure (MPa)
D_0	: Outer diameter of pipe (mm)
S	: Allowable tensile stress of material at maximum operating temperature (MPa)
η	: Efficiency of the longitudinal joint

b.

Minimum required thickness for carbon steel pipes according to design and construction standards: t_r

Values obtained from Table PPD-3411-1 of Design/Construction Standards PPD-3411 (3)

1.3 Evaluation results

Table-1 Evaluation results of structural strength of main pipe (steel pipe)

Evaluation Facility	Outer diameter (mm)	Material	Max. operating pressure (MPa)	Allowable tensile stress of material at maximum operating temperature (MPa)	Efficiency of the longitudinal joint	Max. operating temperature (℃)	Tolerance	Nominal thickness (mm)	Required thickness (mm)	Minimum thickness (mm)
Pipe ①	216.3	SUS316LTP	0.49	[redacted]	[redacted]	40	[redacted]	6.5	0.46	5.68
Pipe ②	139.8	SUS316LTP	0.98	[redacted]	[redacted]	40	[redacted]	5.0	0.59	4.37
Pipe ③	165.2	SUS316LTP	0.98	[redacted]	[redacted]	40	[redacted]	5.0	0.69	4.37
Pipe ④	216.3	SUS316LTP	0.98	[redacted]	[redacted]	40	[redacted]	6.5	0.91	5.68
Pipe ⑤	165.2	SUS316LTP	0.49	[redacted]	[redacted]	40	[redacted]	5.0	0.35	4.37
Pipe ⑥	114.3	SUS316LTP	0.49	[redacted]	[redacted]	40	[redacted]	4.0	0.24	3.50
Pipe ⑦	76.3	SUS316LTP	0.98	[redacted]	[redacted]	40	[redacted]	3.5	0.32	3.00
Pipe ⑧	114.3	SUS316LTP	0.98	[redacted]	[redacted]	40	[redacted]	4.0	0.48	3.50
Pipe ⑨	114.3	STPG370	0.98	[redacted]	[redacted]	40	[redacted]	6.0	3.40	5.25
Pipe ⑩	914.4	STPY400	0.60	[redacted]	[redacted]	40	[redacted]	12.7	4.56	11.45
Pipe ⑪	2235.2	SM400B	0.60	[redacted]	[redacted]	40	[redacted]	16.0	11.14	15.00
Pipe ⑫	1828.8	SM400B	0.60	[redacted]	[redacted]	40	[redacted]	13.0	9.11	12.00

II. Permissible level of nominal values for ALPS Treated Water Dilution/Discharge Facility

Table-1 Permissible level of water discharge guide

Major dimensions (mm)		Permissible level	Basis
Vertical	2,100	[redacted]	Manufacturing tolerances according to JIS
Width	2,100	[redacted]	Manufacturing tolerances according to JIS
Height	7,096	[redacted]	Manufacturer's standard considering manufacturing capacity and experience

Major dimensions (mm)		Permissible level	Basis
Vertical	2,140	[redacted]	Manufacturing tolerances according to JIS
Width	2,140	[redacted]	Manufacturing tolerances according to JIS
Height	11,144	[redacted]	Manufacturer's standard considering manufacturing capacity and experience

Table-2 Permissible level of seawater pipe

Pipe⑪※

Major dimensions (mm)		Permissible level	Basis
Outer diameter	2235.2	[redacted]	Manufacturer's standard considering manufacturing capacity and experience
Thickness	16.0	[redacted]	Material tolerance according to JIS

Pipe⑫※

Major dimensions (mm)		Permissible level	Basis
Outer diameter	1828.8	[redacted]	Manufacturer's standard considering manufacturing capacity and experience
Thickness	13.0	[redacted]	Material tolerance according to JIS

※: Referring to the numbers shown in Fig. 4.