Document 1-1 for the 8th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

# Installation of New ALPS Treated Water Dilution/ Discharge Facilities and the Related Facility

February 7, 2022

TEPCO

Tokyo Electric Power Company Holdings, Inc.

The Japanese version shall prevail.

## Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS treated water into the sea

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water


(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(2) Security measures

[1] Analysis method and Framework for Concentration of Nuclides in ALPS Treated Water

(1) Discharge Facilities of ALPS Treated Water into the Sea

[3] Methods of seawater intake and discharging ALPS treated water after dilution

[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.

**Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS treated water into the sea**

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

## (2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

## (2) Security measures

### [1] Analysis method and Framework for Concentration of Nuclides in ALPS Treated Water

# 2-1 (2) [1] Analysis method and framework for radioactivity concentration of nuclides in ALPS treated water

## 1. Layout of analysis facilities

- Select for an adequate analysis facility on the basis of the target sample of radio radioactivity concentration level

### Environmental management building
For Pretreatment (pretreatment of fish)

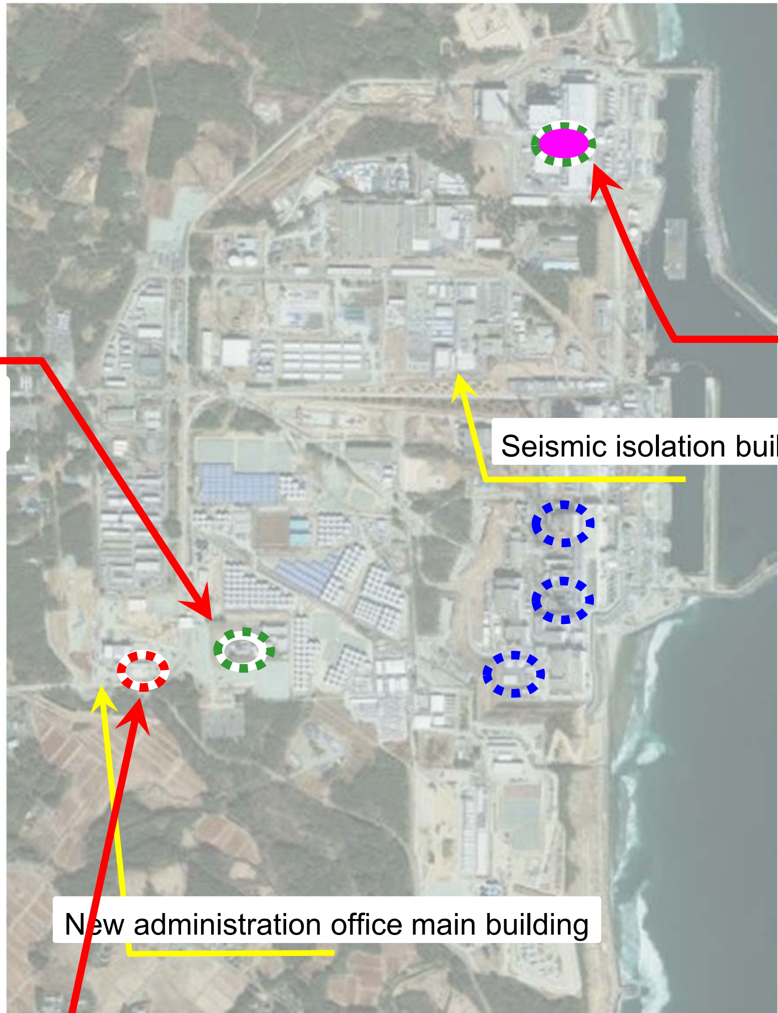
Analysis room + Measurement room: 480 $m^2$
Laboratory table: 4

- The functions were transferred to the chemical analysis building or the units 5 and 6 analysis room.
- Operating under limited function

### Chemical analysis building
For samples with low level concentration

Analysis room + Measurement room: 1,000 $m^2$
Laboratory table: 15, Fume hood: 35

- This facility has been using since 2013.




### Units 5 and 6 analysis room
For samples with high level concentration

Analysis room + Measurement room: 850 $m^2$
Laboratory table: 23, Fume hood: 26

- The facility has been used since before the Earthquake, expanded in 2016.

Legend:
- Facilities used since before the Earthquake
- Facilities became unusable due to the Earthquake
- The new facility was constructed and in operation after the Earthquake
- The existing facility was renovated and expanded after the 3.11 Earthquake

Provided by: JAPAN SPACE IMAGING CORPORATION, © Digital Globe

## 2.1.1 Analysis Framework

TEPCO

### Overview of the Analysis Framework

- The ALPS Treated Water Program Department formulates analysis plans, including implementation plans.
- The Disaster Prevention & Radiation Center prepares resources required to implement the plan and analysis work, etc.

**Treated Water Chemical Analysis & Evaluation Group of the ALPS Treated Water Program**

- Project planning and progress management
- Planning for the discharge of ALPS treated water
  - ALPS treated water analysis conditions*1
  - Sea area monitoring analysis conditions*1
  - Conditions for analytical functions
    Presenting required resources, etc.
  - Participating in Monitoring Coordination Meetings and adjusting plans as necessary
- Research and development of analytical technologies

*1: Sampling points, sampling frequency, analytical precision and accuracy

**Disaster Prevention & Radiation Center**

- Competence management of contract workers
- Competence management of supervisors
- Quality control

**Chemical Analysis & Evaluation Group**

- Operation of analysis facilities
- Management of analysis equipment
- Management of analysis work
- Assessment and management of analytical data
- Preparation of analysis environment

**Discharge & Environmental Radiation Monitoring Group**

- Management of sampling work
- Sea area monitoring and assessment
- Deciding go or no-go of discharge
- Management and disclosure of drainage water data
- Monitoring of land and sea environment

**Contractor*2**

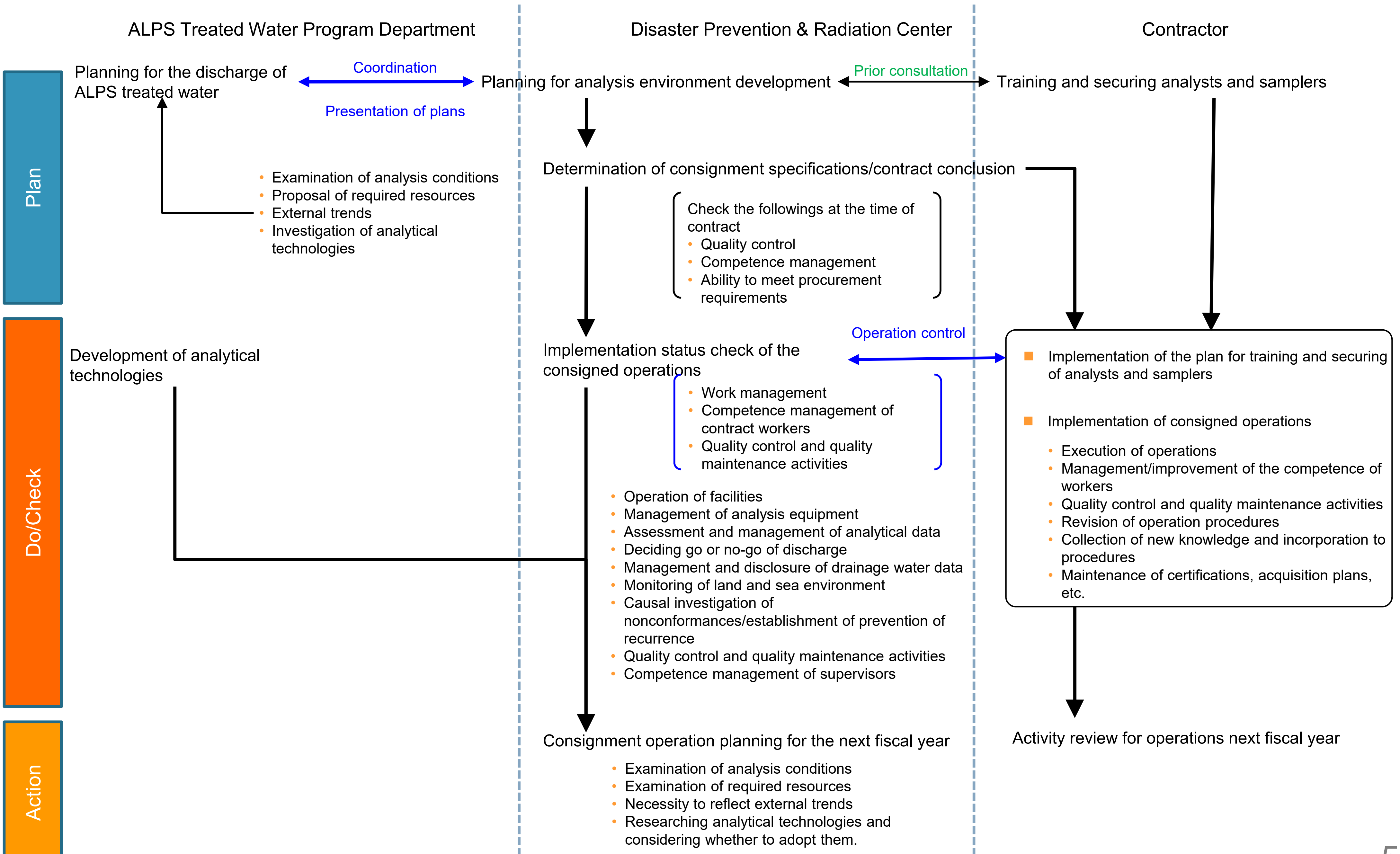
- Development of analysis procedures
- Analysis work
- Skill test
- Acquisition of certification
- Development of sampling procedures
- Sampling work
- Training and securing analysts and samplers

*2: Contractor: Tokyo Power Technology Ltd. (TPT)
TPT has been engaged in sampling and radiochemical analysis works at the Fukushima Daiichi and Daini NPSs and Kashiwazaki-Kariwa NPS since before the Earthquake.

# 2-1 (2) [1] Analysis method and Framework for Concentration of Nuclides in ALPS Treated Water

## 2.1.2 Analysis Framework

TEPCO



## Understanding the competence of analysis supervisors (TEPCO employees)

- The in-house Technique and Skill Certification System certifies the Employees' skills and techniques.
- Conducting competence assessment regularly and effectiveness reviews to improve systematically the lack of their competence.

## Competence of analysts

- Securing high-skilled analysts and increasing the number of them assures to analyze nuclides that requires higher measurement skills (hereinafter referred to as "difficult-to-measure nuclides"), such as C-14, and maintain the normal analysis functions together with the competence.
- In addition to the on-site inter-analysis-room analysis skill test, employees are working to pass analysis skill tests both of domestic and overseas analysis organizations so that they can objectively assess their capabilities from a third-party perspective.
  - Proficiency Test Exercise (organized by the IAEA)
  - Cross-check Japan Environmental Measurement and Chemical Analysis Association, Japan Chemical Analysis Center, and KAKEN Co., Ltd., etc.

## Understanding the competence of individual analysts

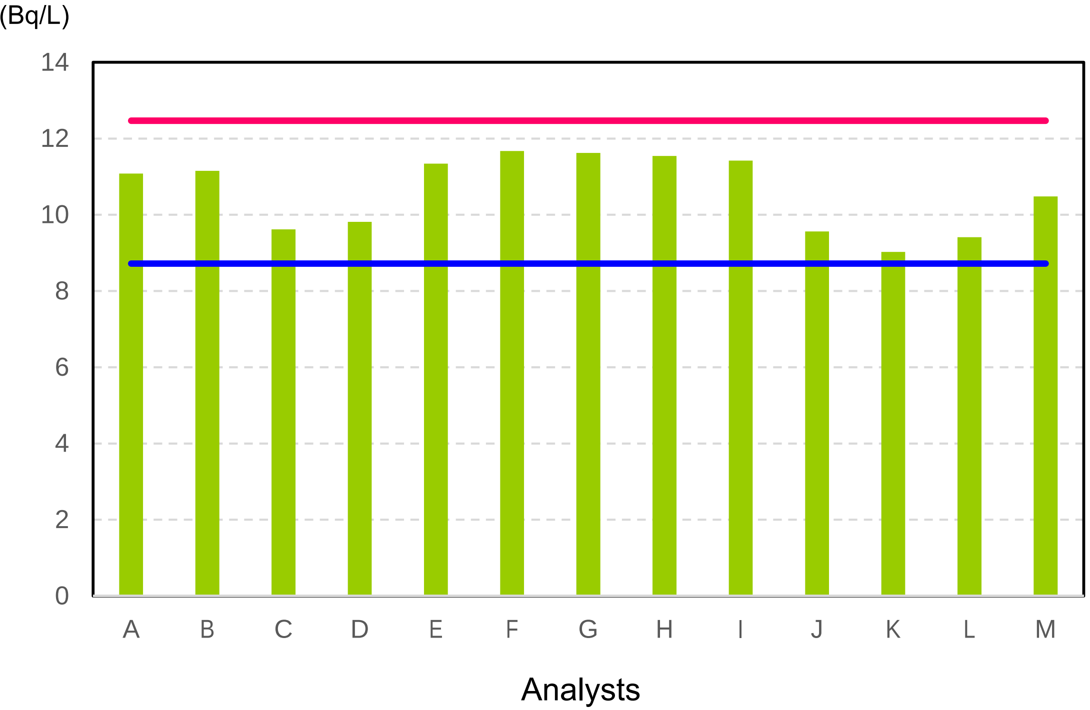
- The number of analysts who can handle difficult-to-measure nuclides shall be increased through OJT, and make them routinely train.
- The competence of analysts working at the chemical analysis building is checked using samples whose concentrations are known (once a year for nuclides subject to ISO/IEC-17025 certification) (See the next page).
- TEPCO checks the implementation status to obtain information about competent personnel (to be reviewed quarterly from FY 2022).

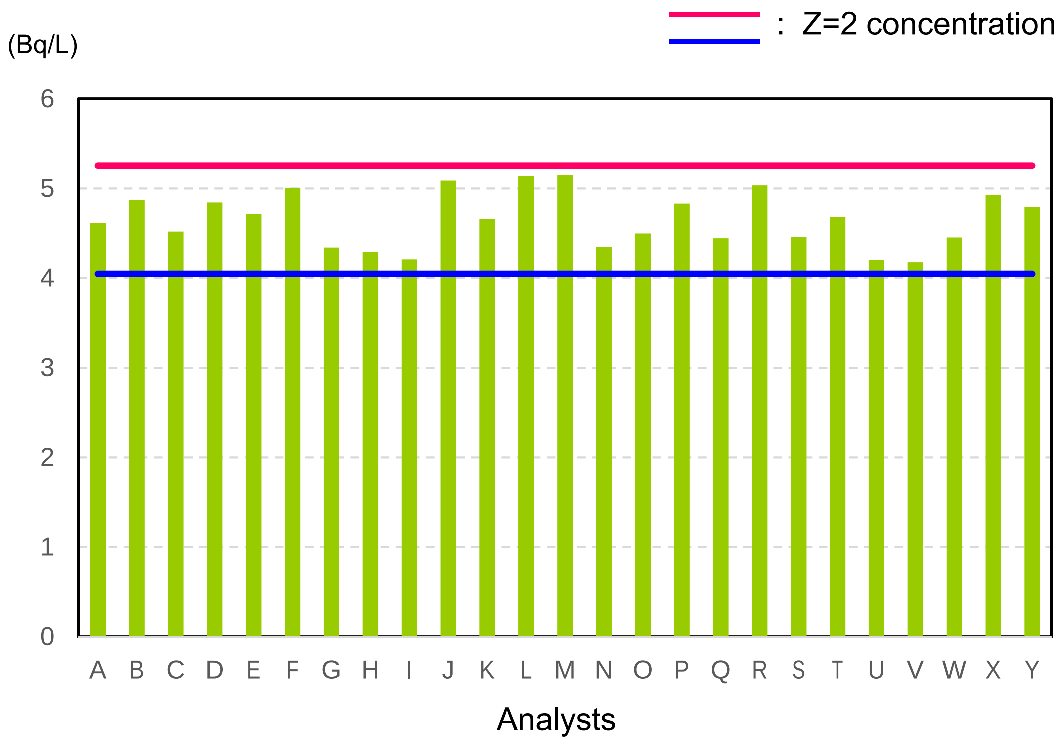
## Quality assurance

- The chemical analysis building, where sea area monitoring is performed, is certified with ISO/IEC-17025 for Cs-134, Cs-137, and H-3 and is subject to periodic inspections.
- The validity of the wastewater data is confirmed by comparing it with the analytical values obtained by a third party. Although tritium is now determined to be acceptable if it is within ± 10%, the validity will be reviewed as well as the measured result while taking into consideration the uncertainty.

## 2.3 Analysis resources

- The competence of analysts working at the chemical analysis building is checked every year using samples whose concentrations are known.
- In the competence check (skill test) conducted in FY 2020, all analysts satisfied the Z-score of 2.
- If an analysist fails to satisfy the Z-score of 2, the result will be verified, and their competence will be rechecked in the presence of the Technical Manager.




Analysts subject to H-3 skill test: 13 analysts
Concentration of the sample: 10.2 Bq/L
The median value of 10 measurements of 3 samples by the person who made the sample
Test period: October 9 to 29 of 2020
Location: Chemical analysis building
Judgment method: Z-score (ISO inspection method)
Judgment value: $|Z| \leq 2$

Analysts subject to Cs-137 skill test: 25 analysts
Concentration of the sample: 4.5 Bq/L
The median value of 10 measurements by the person who made the sample
Test period: July 29 to August 6 of 2020
Location: Chemical analysis building
Judgment method: Z-score (ISO inspection method)
Judgment value: $|Z| \leq 2$

The Japanese version shall prevail.

## 2.4 Quality of analysis data

TEPCO

- Being certified with the ISO/IEC-17025 accreditation for Cs-134/137 and H-3, the same level of analysis will be rolled out to the analysis of other nuclides.
- To obtain the accreditation for the analysis Sr-90 is in planning.

PERRY JOHNSON LABORATORY ACCREDITATION, INC.

*Certificate of Accreditation*

*Perry Johnson Laboratory Accreditation, Inc. has assessed the Laboratory of:*

***Tokyo Power Technology Ltd. FUKUSHIMA Nuclear Power Branch***
***Environmental Chemistry Department: 182-1 Nishikidai Kuma Okumamachi Futaba-gun, Fukushima 979-1305***
***Chemical Analysis Department / Environmental Control Department: Fukushima Daiichi Nuclear Power Station Chemical Analysis Building/Environmental Control Building***
***22 Kitahara Ottozawa Okumamachi Futaba-gun, Fukushima 979-1301***

*(Hereinafter called the Organization) and hereby declares that Organization is accredited in accordance with the recognized International Standard:*

**ISO/IEC 17025:2017**

This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (as outlined by the joint ISO-ILAC-IAF Communiqué dated April 2017):

***Analytical test of radionuclide (including Cs134/Cs137 and H-3) in public waters, wastewater, soil, ash and sludge (As detailed in the supplement)***

Accreditation claims for such testing and/or calibration services shall only be made from addresses referenced within this certificate. This Accreditation is granted subject to the system rules governing the Accreditation referred to above, and the Organization hereby covenants with the Accreditation body's duty to observe and comply with the said rules.

For PJLA:

Tracy Szerszen
President

Perry Johnson Laboratory Accreditation, Inc. (PJLA)
755 W. Big Beaver, Suite 1325
Troy, Michigan 48084

| *Initial Accreditation Date:* | *Issue Date:* | *Expiration Date:* |
|---|---|---|
| June 13, 2016 | June 26, 2020 | June 30, 2022 |
| *Revision Date:* | *Accreditation No.:* | *Certificate No.:* |
| June 28, 2021 | 89362 | L20-355-R1 |

*The validity of this certificate is maintained through ongoing assessments based on a continuous accreditation cycle. The validity of this certificate should be confirmed through the PJLA website: www.pjlabs.com*

*Page 1 of 3*

ペリージョンソン ラボラトリー アクレディテーション インク

認　定　証

ペリージョンソン ラボラトリー アクレディテーション インクは、
下記の試験所を審査しました。

**東京パワーテクノロジー株式会社　原子力事業部　福島原子力事業所**
環境化学部：〒979-1305 福島県双葉郡大熊町大字熊字錦台 182-1
化学分析棟/環境管理棟：〒979-1301 福島県双葉郡大熊町大字夫沢字北原 22
福島第一原子力発電所　化学分析棟/環境管理棟

ここに本組織が、以下の認知された国際規格に基づき、認定されたことを証します。

***ISO/IEC 17025:2017***

本認定により、以下の範囲及び試験所品質マネジメントシステムの運営における技術的能力を実証するものとします。(2017 年 4 月発行 ISO-ILAC-IAF 共同コミュニケに準ずる)

公共水域水、排水、土壌、灰及び汚泥の
放射性核種（Cs134/Cs137 及び H-3 を含む）分析試験
(詳細は付属書に記述)

上記試験及び／又は校正サービスに対する認定資格は本認定証内で言及された住所のみを対象とする。本認定は、上記規格の認定を管理するシステム規定に従い授与され、組織はその規定を遵守し、認定機関の任務を尊重することをここに誓約する。

PJLA

| 初回認定日 | 発行日 | 認定証有効期限 |
|---|---|---|
| 2016 年 6 月 13 日 | 2020 年 6 月 26 日 | 2022 年 6 月 30 日 |
| 改定日 | 認定番号 | 認定証番号 |
| 2021 年 6 月 28 日 | 89362 | L21-355-R1 |

トレーシー　サーツェン
プレジデント
Perry Johnson Laboratory
Accreditation, Inc. (PJLA)
755 W. Big Beaver Rd., Suite 1325
Troy, Michigan 48084

この認定証の有効性は、持続された認定に基づく継続審査を通して維持されています。
PJLA ウェブサイト (www.pjlabs.com)でご確認いただけます。

尚、本認定証は日本語翻訳版であり、英文の認定証を正式のものとする。

1/3 頁

The Japanese version shall prevail.

## 2.5 Quality of analysis data

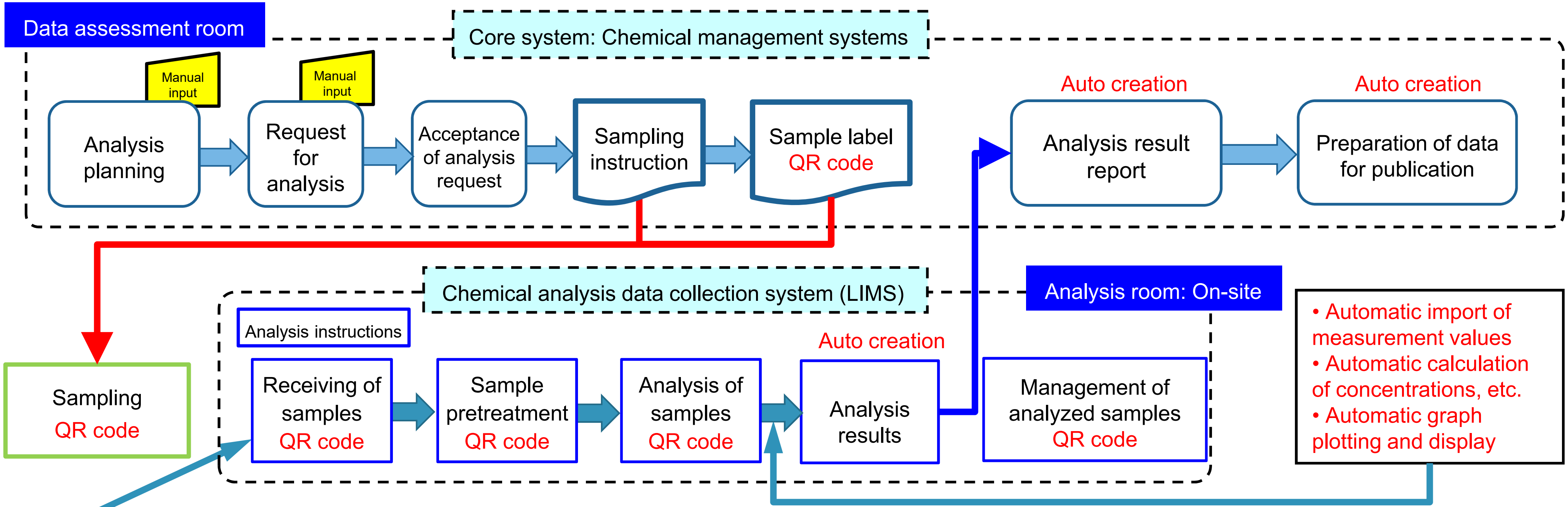
TEPCO

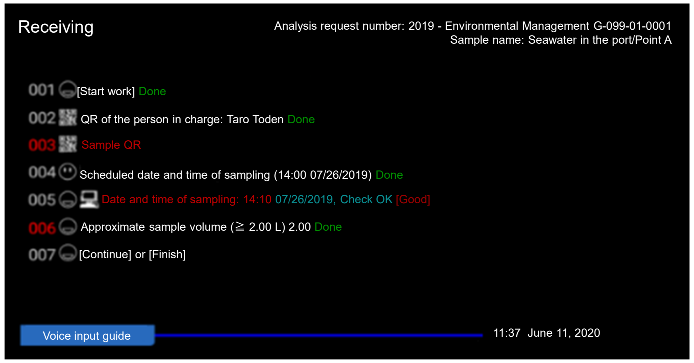
- TEPCO has been controlling the data in line with the Quality Control Standards and Regulations.
  - Based on Article 3 of the Implementation Plan (Quality Management System Plan), contractors are required to adhere to the prescribed analysis procedures and to secure the competence of analysts, and the analysis procedures and competence management records are submitted and checked.
- The third-party organizations are selected based on the accreditations they have obtained, such as ISO/IEC-17025.

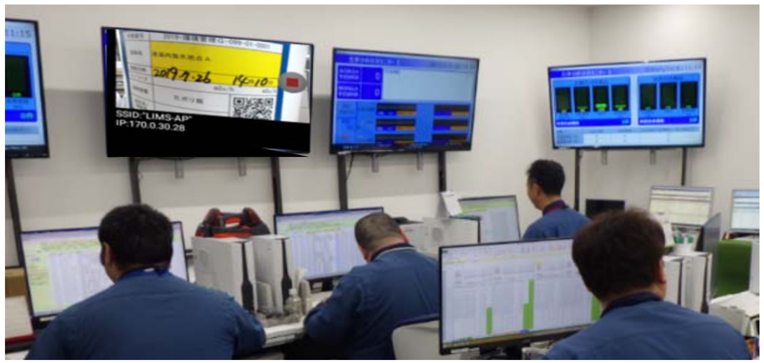
| Organization | Accreditation | Accreditation obtained (17025) |
|---|---|---|
| TPT (Fukushima Daiichi) | ISO/IEC17025<br>ISO9001 | (Chemical analysis building) Cs-134, Cs-137, H-3 |
| KAKEN | ISO/IEC17025 | Cs-134,Cs-137<br>I-131<br>Sr-90<br>H-3 |
| Japan Chemical Analysis Center | ISO/IEC17025<br>ISO9001 | Gamma-emitting nuclides<br>H-3<br>Radioactive strontium<br>Plutonium, etc. |
| Tohoku Ryokka Kankyohozen | ISO/IEC17025<br>ISO9001 | Cs-134,Cs-137<br>I-131<br>H-3 |

## 3.1 Quality control of the analysis process

- Establishment of a mechanism on keeping the analysis process at a certain quality and the detection mechanism on abnormalities of data



<Analysis room: On-site>
Input voice and send images following the instructions displayed on smart glasses

<Data assessment room>
Input data to LIMS terminals from camera images

[Register sample data when the data of the analyst matches the data confirmed by the supervisor in the assessment room]

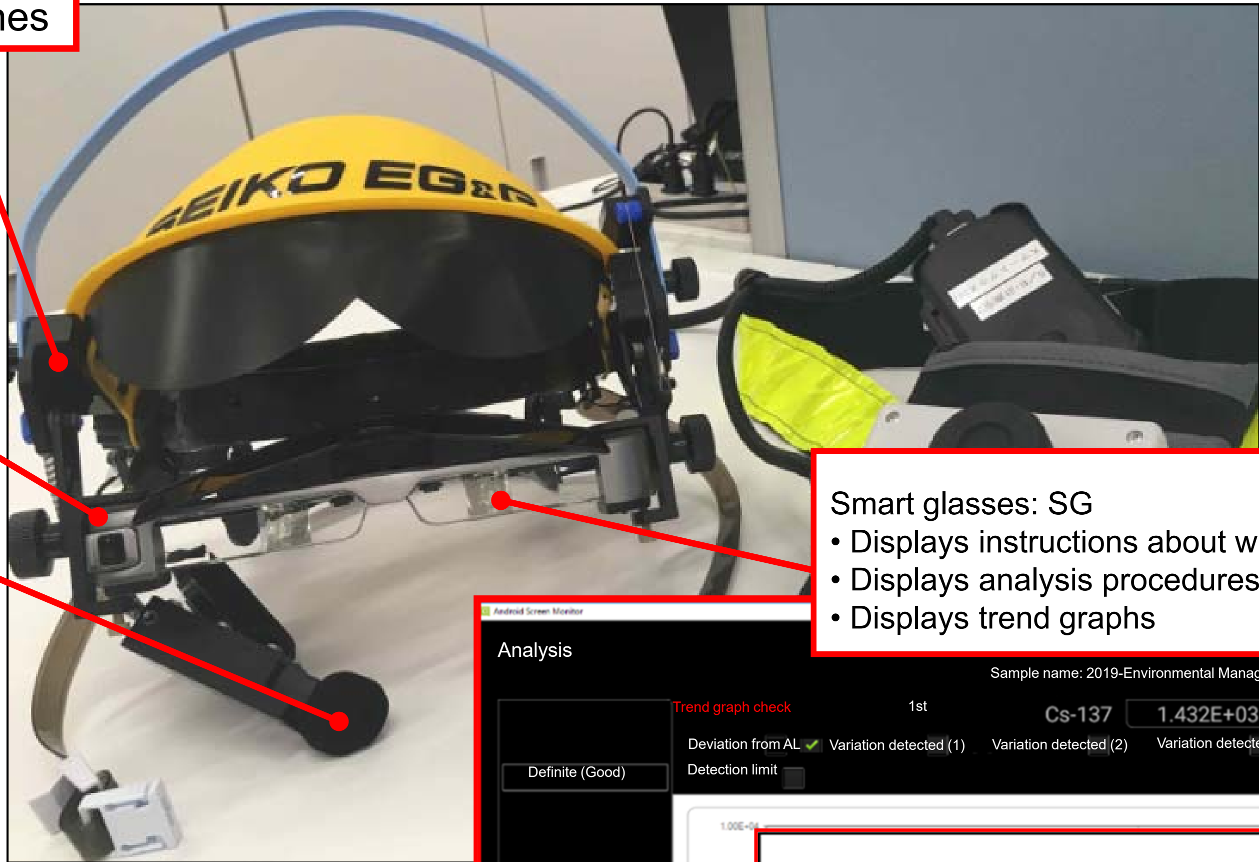
### 3.2 Quality control of the analysis process

TEPCO

- Smart glasses are used as on-site control terminals of the chemical analysis data collection system (LIMS).

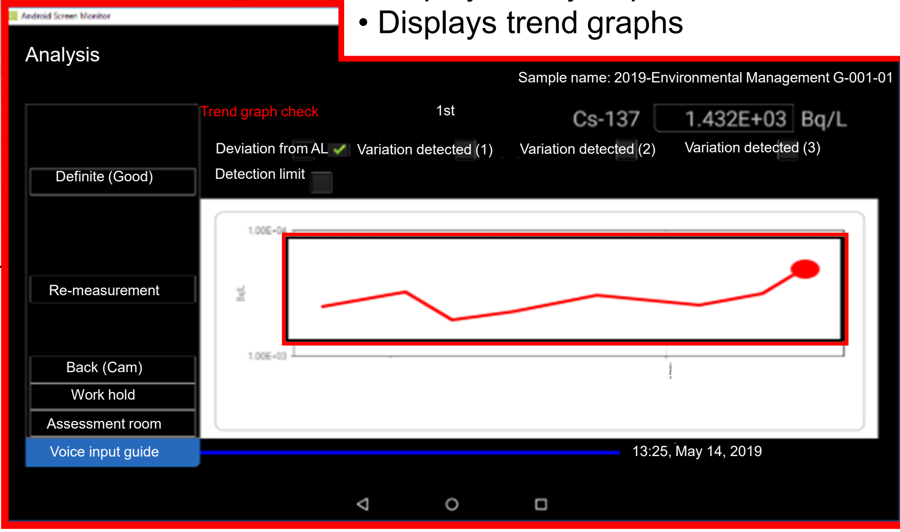
Camera
- Reads QR codes
- Sends video images


Headphones




Microphone
- Conversation with staff in the assessment room
- Responds to instructions given by the SG

Smart glasses: SG
- Displays instructions about what to do
- Displays analysis procedures
- Displays trend graphs




Sharing of sounds and images

Data assessment room
(New office main building)

## 3.3 Quality control of the analysis process

TEPCO

### Activities at TEPCO

- Since FY 2020, the usage of procedures and compliance with specifications have been regularly checked at the on-site analysis room (This initiative is being rolled out targeting all analysis work performed in the 1F site).
- In order to ensure the quality and safety of work, all analysts are required to follow the same procedures even when they take turns: Ensure the continuity of data.
- The method to check procedures is standardized.
- Even third-party companies are required to submit work procedures by the specifications so that TEPCO will be further involved in the quality control of work processes.
- The following efforts are being made to prevent quality assurance activities and safety management from stagnating.
  - Contractors are instructed to identify risks through pre-work safety assessments before starting operations. TEPCO explains past nonconformance cases, reminds them to adhere to rules, and provides guidance.
  - With the aim of maintaining performances, meetings are held every month with contractors to discuss issues in analysis work and the implementation status of measures to prevent recurrence of past nonconformance.
  - With the aim of ensuring safety in the field and the quality of work, field patrols are performed every month with contractors to check analysis work, and unsafe conditions are extracted.
  - Last fiscal year, TEPCO started to check the implementation status of analysis procedures established by contractors; TEPCO identifies areas for improvement regarding operations and instructs them to take corrective actions.

### Activities at contractors

- Procedures will be improved to become easier to use, such as by describing applicable official laws and publicly available literature.
- In order to ensure the quality and safety of work, a system is established to enable all analysts to follow the same procedures even when they take turns: Ensure the continuity of data.

## 4.1 Response to abnormalities

TEPCO

- In addition to measures to respond to new or added sea area monitoring, the following preparations are being made.

  - Analysts are stationed on a 24-hour basis in case of an abnormality, such as water leakage from the system, so emergency analyses can be performed at any time of day or night.
  - In order to enable swift response to the need for an emergency analysis, some measurement instruments are selected and excluded from those used in regular analyses.

- Specific system examples

  - Response to emergency analysis of γ-ray emitting nuclides and tritium
  - Assuming emergency analyses during nighttime, two analyzers are stationed in the units 5 and 6 analysis room at all times (9 analysts in total).
  - When a radiochemical analysis of extremely low concentrations is required to be performed urgently, analyzers move to the chemical analysis building to protect samples from contamination.
  - One person is assigned exclusively to the analysis of γ-ray emitting nuclides and one person to the tritium analysis.

## 4.2 Response to abnormalities

TEPCO

- The power source for the chemical analysis building, where emergency analyses are performed, is duplexed, and infrastructures are reinforced to ensure the analyses of γ-ray emitting nuclides and tritium.
- When an emergency analysis arises during the daytime, analysts in the chemical analysis building handle it. During the nighttime, analysts in the units 5 and 6 analysis rooms move to the chemical analysis building to perform the measurement work.
  Analysts who work in nighttime shifts (Units 5 and 6 analysis room) keep a certain competence to ensure analyze, organizing improvement plan for analysis skills on low level radioactive concentrationsamples.
- Supervisors prepare to organize a framework at a nighttime emergency, that employees living in the Okuma dormitory respond to emergency analyses. A competence improvement assistances on analysis response shall be systematically given for newly assigned employees, those who will be able to deal with the situation independently.

| | Affiliation | Number of employees | Daytime on business days (Maximum) | Nonbusiness days | Nighttime | Remarks |
|---|---|---|---|---|---|---|
| Analysts | Chemical analysis building | 34 persons | 34 persons | 5 persons | 0 persons | Day duty only |
| | | | | | ↑ Emergency analysis during nighttime Move to the chemical analysis building | |
| | Units 5 and 6 analysis room | 59 persons | 37 persons | 21 persons[*1]<br>*1: Total number of staff members | 2 persons | Shift work and day duty |
| Supervisors | Chemical Analysis & Evaluation Group | 15 persons | 15 persons | 2 persons | 0 persons (7 persons[*2]) | Day duty only |

*2: Night shift staff are selected

The Japanese version shall prevail.

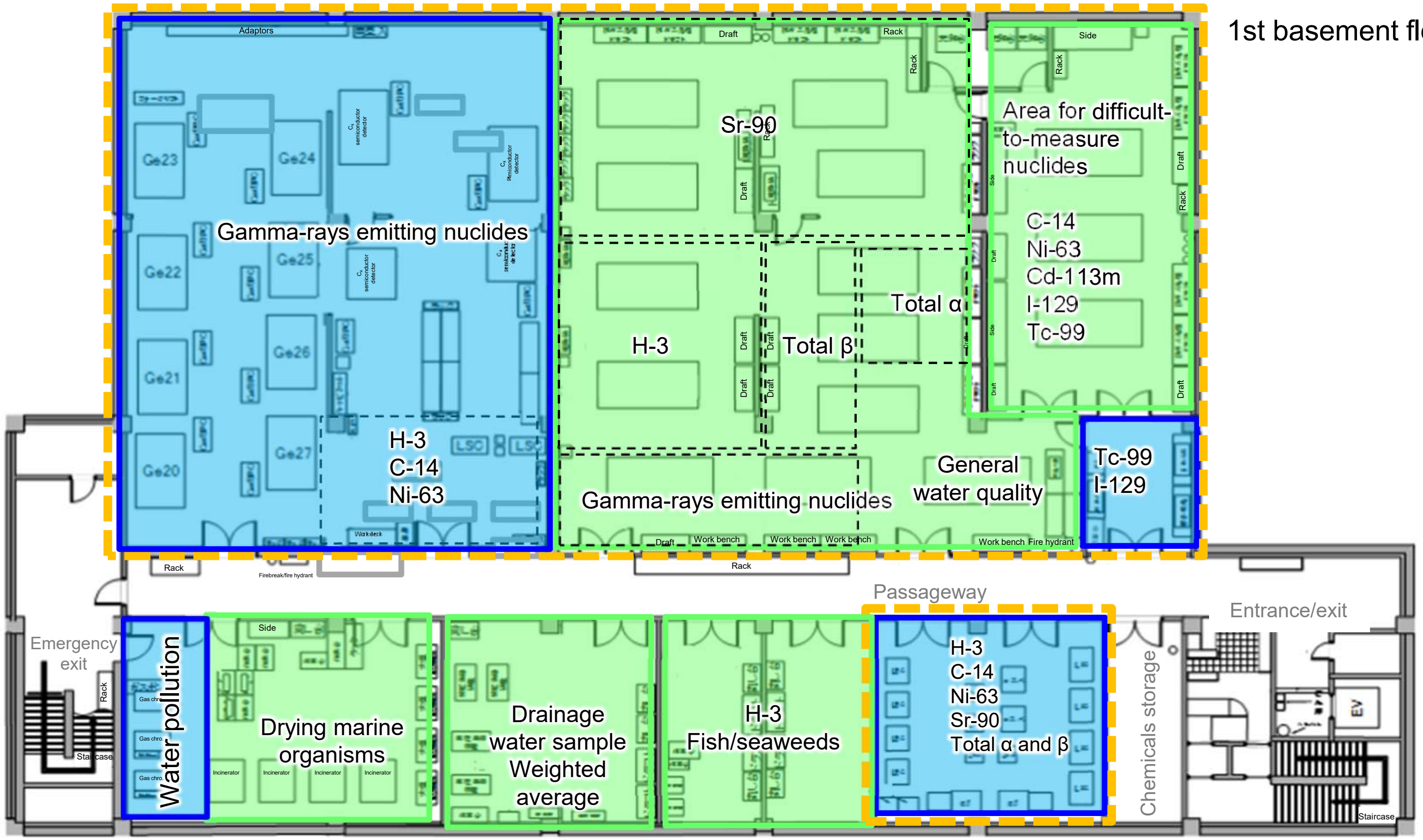
# 5. Functions of the chemical analysis building

TEPCO

■ The layout featuring to ensure the analyses samples of lower level radio activity concentrations

Entire area: Area handling sea area samples

1st basement floor

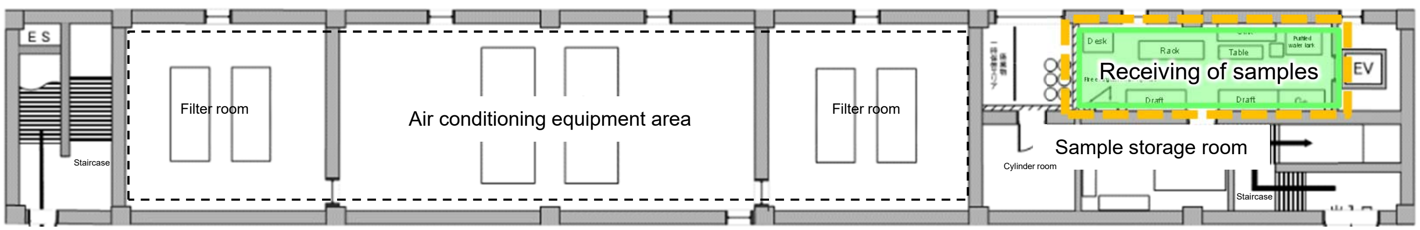



: ALPS treated water handling area

: Pre-treatment area

: Measurement area

1st floor




■ Measures to handle samples with lower radio active concentration

- Measurement areas are installed underground to reduce the impacts of environmental doses (ex. surrounding 50 cm-thick concrete).
- Samples brought in are limited, only when they are clearly with low activity concentrations, such as seawater (Other samples are to be brought into the units 5 and 6 analysis rooms).
- Before entering rooms, the staff must put on additional socks and undergo a survey for their bodies and items.
- Rooms are checked for contamination regularly and cleaned as necessary (floor surfaces at entrances and exits, etc.)

| | Area ($m^2$) |
|---|---|
| Analysis area | 936 |
| Sample storage area | 24 |
| Air conditioning equipment area | 207 |
| Passageway and others | 333 |
| Total floor area of the building | 1,500 |

The Japanese version shall prevail.

## Preparation of analysis environment

- Since the 3.11 Earthquake, maximum efforts have been focused on handling samples with high level radio activity concentrations.
- After establishing an environment for the analysis of environmental samples (as mentioned above, the chemical analysis building was constructed in July 2013), personnel training was promoted as well for the analysis of samples in which radio radioactive concentration are clearly low, such as seawater.
- As the development of groundwater bypass and sub-drain system progressed, efforts were focused on the training of workers in the chemical analysis building along with the training of workers in the units 5 and 6 analysis room.
- With a view to the start of the discharge of ALPS treated water, the layout of the chemical analysis building has been improved (as mentioned above), and the analysis framework has been strengthened.
- In the chemical analysis building, in addition to (1) the establishment of an analysis environment for ALPS treated water, (2) the development of an environment to respond to the strengthened sea area monitoring (announced on August 25, 2021) has been promoted.

## 6.2.1 Handling of ALPS treated water

TEPCO

- Samples of ALPS treated water are samples with low radio activity concentrations. Therefore, the nuclides in the table below **(tentative)** are analyzed and evaluated in the chemical analysis building the same way as samples for the sea area monitoring.

| | Nuclide | Analysis method | | Nuclide | Analysis method | | Nuclide | Analysis method |
|---|---|---|---|---|---|---|---|---|
| 1 | H-3 | LSC | 23 | Sn-119m | Evaluated value | 45 | Pm-146 | Ge |
| 2 | C-14 | LSC | 24 | Sn-123 | Ge | 46 | Pm-147 | Evaluated value |
| 3 | Mn-54 | Ge | 25 | Sn-126 | Ge | 47 | Pm-148 | Ge |
| 4 | Fe-59 | Ge | 26 | Sb-124 | Ge | 48 | Pm-148m | Ge |
| 5 | Co-58 | Ge | 27 | Sb-125 | Ge | 49 | Sm-151 | Evaluated value |
| 6 | Co-60 | Ge | 28 | Te-123m | Ge | 50 | Eu-152 | Ge |
| 7 | Ni-63 | LSC | 29 | Te-125m | Evaluated value | 51 | Eu-154 | Ge |
| 8 | Zn-65 | Ge | 30 | Te-127 | Ge | 52 | Eu-155 | Ge |
| 9 | Rb-86 | Ge | 31 | Te-127m | Evaluated value | 53 | Gd-153 | Ge |
| 10 | Sr-89 | β-Spec | 32 | Te-129 | Ge | 54 | Tb-160 | Ge |
| 11 | Sr-90 | β-Spec | 33 | Te-129m | Ge | 55 | Pu-238 | ZnS |
| 12 | Y-90 | Evaluated value | 34 | I-129 | ICP-MS | 56 | Pu-239 | ZnS |
| 13 | Y-91 | Ge | 35 | Cs-134 | Ge | 57 | Pu-240 | ZnS |
| 14 | Nb-95 | Ge | 36 | Cs-135 | Evaluated value | 58 | Pu-241 | Evaluated value |
| 15 | Tc-99 | ICP-MS | 37 | Cs-136 | Ge | 59 | Am-241 | ZnS |
| 16 | Ru-103 | Ge | 38 | Cs-137 | Ge | 60 | Am-242m | Evaluated value |
| 17 | Ru-106 | Ge | 39 | Ba-137m | Evaluated value | 61 | Am-243 | ZnS |
| 18 | Rh-103m | Evaluated value | 40 | Ba-140 | Ge | 62 | Cm-242 | ZnS |
| 19 | Rh-106 | Evaluated value | 41 | Ce-141 | Ge | 63 | Cm-243 | ZnS |
| 20 | Ag-110m | Ge | 42 | Ce-144 | Ge | 64 | Cm-244 | ZnS |
| 21 | Cd-113m | LSC | 43 | Pr-144 | Evaluated value | | | |
| 22 | Cd-115m | Ge | 44 | Pr-144m | Evaluated value | | | |

Ge: Ge semiconductor detector

LSC: Low background liquid scintillation counter

β-Spec: β-nuclide analyzer

ICP-MS: Inductively coupled plasma mass spectrometer

ZnS: α automatic measuring device (ZnS scintillation counter)

Evaluated value: The abundance is assessed through a calculation using the isotopic ratio and relative ratio of the measured nuclides.

TEPCO

## Analysis method and outline for each nuclide

| | Nuclide | Analysis method | Outline | Remarks |
|---|---|---|---|---|
| 1 | H-3 | LSC | After being isolated by distillation, the sample is mixed with a scintillator and measured. | In the measurement by Ge, the lower detection lower limit of nuclides of the low-energy side becomes higher due to the effect of Compton scattering. Still, the target* detection lower limit is secured by measuring for a long time.<br><br>*Target: Values set for individual nuclides to ensure that the sum of the ratios to regulatory concentrations limits is less than 1.<br><br>Ge: Ge semiconductor detector<br>LSC: Low background liquid scintillation counter<br>β-Spec: β-nuclide analyzer<br>ICP-MS: Inductively coupled plasma mass spectrometer<br>ZnS: α automatic measuring device |
| 2 | C-14 | LSC | After being isolated by capturing with absorbent, a sample is mixed with a scintillator and measured. | |
| 3 | Mn-54 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 4 | Fe-59 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 5 | Co-58 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 6 | Co-60 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 7 | Ni-63 | LSC | After being isolated with resin, a sample is mixed with a scintillator and measured. | |
| 8 | Zn-65 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 9 | Rb-86 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 10 | Sr-89 | β-Spec | After being isolated with resin, the precipitate is collected, mounted, and measured with β-Spec in a stainless steel plate. | |
| 11 | Sr-90 | β-Spec | After being isolated with resin, the precipitate is collected, mounted, and measured with β-Spec in a stainless steel plate. | |
| 12 | Y-90 | Evaluated value | The concentration is evaluated under radioactive equilibrium with Sr-90. | |
| 13 | Y-91 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 14 | Nb-95 | Ge | A homogenized sample is dispensed into Marinelli containers and measured. The half-life of the parent nuclide is used. | |
| 15 | Tc-99 | ICP-MS | The sample is diluted with HNO3 and measured. | |
| 16 | Ru-103 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 17 | Ru-106 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 18 | Rh-103m | Evaluated value | The concentration is evaluated under radioactive equilibrium with Ru-103. | |
| 19 | Rh-106 | Evaluated value | The concentration is evaluated under radioactive equilibrium with Ru-106. | |
| 20 | Ag-110m | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 21 | Cd-113m | LSC | After being isolated by ion exchange, a sample is mixed with a scintillator and measured. | |
| 22 | Cd-115m | Ge | Separate a homogenized sample into Marinelli Containers. | |

TEPCO

## Analysis method and outline for each nuclide

| | Nuclide | Analysis method | Outline | Remarks |
|---|---|---|---|---|
| 23 | Sn-119m | Evaluated value | The concentration is evaluated using the relative ratio to Sn-123. | In the measurement by Ge, the lower detection lower limit of nuclides of the low-energy side becomes higher due to the effect of Compton scattering. Still, the target* detection lower limit is secured by measuring for a long time.<br><br>*Target: Values set for individual nuclides to ensure that the sum of the ratios to regulatory concentrations limits is less than 1.<br><br>Ge: Ge semiconductor detector<br>LSC: Low background liquid scintillation counter<br>β-Spec: β-nuclide analyzer<br>ICP-MS: Inductively coupled plasma mass spectrometer<br>ZnS: α automatic measuring device |
| 24 | Sn-123 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 25 | Sn-126 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 26 | Sb-124 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 27 | Sb-125 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 28 | Te-123m | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 29 | Te-125m | Evaluated value | The concentration is evaluated under radioactive equilibrium with Sb-125. | |
| 30 | Te-127 | Ge | A homogenized sample is dispensed into Marinelli containers and measured. The half-life of the parent nuclide is used. | |
| 31 | Te-127m | Evaluated value | The concentration is evaluated using the relative ratio to Te-127. | |
| 32 | Te-129 | Ge | A homogenized sample is dispensed into Marinelli containers and measured. The half-life of the parent nuclide is used. | |
| 33 | Te-129m | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 34 | I-129 | ICP-MS | A reagent is added to the sample to adjust it to an iodate ion, and then the sample is measured. | |
| 35 | Cs-134 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 36 | Cs-135 | Evaluated value | The concentration is evaluated using the relative ratio to Cs-137. | |
| 37 | Cs-136 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 38 | Cs-137 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 39 | Ba-137m | Evaluated value | The concentration is evaluated under radioactive equilibrium with Cs-137. | |
| 40 | Ba-140 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 41 | Ce-141 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 42 | Ce-144 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 43 | Pr-144 | Evaluated value | The concentration is evaluated under radioactive equilibrium with Ce -144, and the half-life of the parent nuclide is used. | |
| 44 | Pr-144m | Evaluated value | The concentration is evaluated under radioactive equilibrium with Ce-144. | |

TEPCO

## Analysis method and outline for each nuclide

| | Nuclide | Analysis method | Outline | Remarks |
|---|---|---|---|---|
| 45 | Pm-146 | Ge | Separate a homogenized sample into Marinelli Containers. | In the measurement by Ge, the lower detection lower limit of nuclides of the low-energy side becomes higher due to the effect of Compton scattering. Still, the target* detection lower limit is secured by measuring for a long time.<br><br>*Target: Values set for individual nuclides to ensure that the sum of the ratios to regulatory concentrations limits is less than 1.<br><br>Ge: Ge semiconductor detector<br>LSC: Low background liquid scintillation counter<br>β-Spec: β-nuclide analyzer<br>ICP-MS: Inductively coupled plasma mass spectrometer<br>ZnS: α automatic measuring device |
| 46 | Pm-147 | Evaluated value | The concentration is evaluated using the relative ratio to Eu-154. | |
| 47 | Pm-148 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 48 | Pm-148m | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 49 | Sm-151 | Evaluated value | The concentration is evaluated using the relative ratio to Eu-154. | |
| 50 | Eu-152 | Ge | Separate a homogenized sample into Marinelli Containers | |
| 51 | Eu-154 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 52 | Eu-155 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 53 | Gd-153 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 54 | Tb-160 | Ge | Separate a homogenized sample into Marinelli Containers. | |
| 55 | Pu-238 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 56 | Pu-239 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 57 | Pu-240 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 58 | Pu-241 | Evaluated value | The concentration is evaluated using the relative ratio to Pu-238. | |
| 59 | Am-241 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 60 | Am-242m | Evaluated value | The concentration is evaluated using the relative ratio to Am-241. | |
| 61 | Am-243 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 62 | Cm-242 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 63 | Cm-243 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |
| 64 | Cm-244 | ZnS | After the iron is removed from the sample by ferric coprecipitation, the sample is evaporated to dryness in a stainless steel dish and measured. | |

TEPCO

## Verification of detection efficiency in daily inspections

- The performance of measuring instruments is verified with standard sources and standard solutions before measuring samples.

| Measuring instrument | Standard source | Verification method |
|---|---|---|
| Ge semiconductor detector | Co-57, Ba-133, Cs-137<br>Mn-54, Co-60 | Frequency: At the beginning of work each day<br>Method: Calculate a detection efficiency for each energy of standard sources, and check if it is within the judgment value (± 10%).<br>Measures to be taken in case of deviation: Re-evaluate the samples measured after the last judgment value. If necessary, remeasure the samples that were measured during the deviation period. |
| α automatic measuring device | Am-241 | |
| β nuclide analyzer | Sr-90<br>Cs-137 | |
| Low background liquid scintillation counter | H-3 | |

| Measuring instrument | Standard solution | Verification method |
|---|---|---|
| ICP-MS | Li, Co, Y, Tl | Frequency: Each use<br>Method: Measure the strength of each element to confirm that it is the judgment value or above. Then prepare a calibration curve before measurement.<br>Strength of the standard solution: Li: > 1000<br>Co • Y: > 200<br>Tl:>800 |

The Japanese version shall prevail.

## 6.3 ALPS treated water samples analysis method

TEPCO

| Nuclide | Analysis method | Target detection lower limit*1 | Applicable methods |
|---|---|---|---|
| γ ray emitting nuclides | Separate a sample into Marinelli containers and measure with a Ge semiconductor detector. | 0.07 Bq/L<br>Set using Cs-137*2 | Radioactivity Measuring Method Series No.7 (Gamma-ray Spectrometry using Germanium Detector) |
| Sr-90, Sr-89 | Sr is purified with Sr resin, and precipitated carbonate is collected and measured with a β nuclide analyzer. | 0.04 Bq/L<br>Set using Sr-90*3 | JAEA-Technology2009-051 (Simple and Rapid Determination Methods for Low-level Radioactive Wastes Generated from Nuclear Research Facilities (Guidelines for Determination of Radioactive Waste Samples)) |
| I-129 | Hypochlorous acid is added to the sample to adjust it to iodate ion, and then the sample is measured with an inductively coupled plasma mass spectrometer. | 0.2 Bq/L | Radioactivity Measuring Method Series No.32 (Rapid Analytical Method for Iodine 129 in Environmental Samples) |
| H-3 | A sample from which impurities have been removed by distillation is mixed with a scintillator. Then the sample is measured with a low background liquid scintillation counter. | 30 Bq/L | Radioactivity Measuring Method Series No.9 (Tritium Analysis) |
| C-14 | A sample is heated after adding concentrated nitric acid and potassium persulfate. Then, the generated $CO_2$ is collected in an absorbent, mixed with a scintillator, and measured by a low background liquid scintillation counter. | 10 Bq/L | Radioactivity Measuring Method Series No.25 (Radiocarbon Analysis)<br>JGC: Radiochemical Analysis of Radioactive Waste |
| Tc-99 | A sample is diluted with nitric acid and measured with an inductively coupled plasma mass spectrometer. | 2 Bq/L | RWMC: Research on the enhancement and rationalization of radiochemical analysis |
| Total α radioactivity | α nuclides are coprecipitated with iron hydroxide, and iron is removed by an extraction procedure. After evaporating to dryness and baked on a stainless steel plate, the residue is measured with an α automatic measuring device. | 0.04 Bq/L | PNC Tokai Plant: Standard Analytical Procedures |
| Cd-113m | Cd is refined, collected by ion exchange, mixed with a scintillator, and then measured with a low background liquid scintillation counter. | 0.2 Bq/L | BUNSEKI KAGAKU, vol.63, No.4 (Study on the Analysis of $^{113m}$Cd in Stagnant Water at Fukushima Daiichi NPS by β-ray Measuring Method Using Low Background Liquid Scintillation Counters) |
| Ni-63 | Ni is purified and collected with Ni resin and mixed with a scintillator, and then measured with a low background liquid scintillation counter. | 20 Bq/L | JAEA-Technology2009-051 (Simple and Rapid Determination Methods for Low-level Radioactive Wastes Generated from Nuclear Research Facilities (Guidelines for Determination of Radioactive Waste Samples)) |

*1: Values set for individual nuclides to ensure that the sum of the ratios to regulatory concentrations limits is less than 1.
*2: Values for other nuclides vary according to baseline, interfering nuclides, background, and γ-ray emission rate.
*3: The value for Sr-89 varies with Sr-90 concentration.

## 7.1 Preparation for sea area monitoring

TEPCO

- Samples with lower radioactive concentration(sea area monitoring samples) are analyzed and evaluated in the chemical analysis building.

| Target | Sampling points | | Measurement target | Current | (Proposed) change | Remarks |
|---|---|---|---|---|---|---|
| Seawater | Within the port | 10 points | Cesium 134, 137<br>Tritium | Cesium: Daily<br>Tritium: Once a week | Cesium: Daily<br>Tritium: Once a week | **Daily at the discharge vertical shaft (discharge end)** |
| | Within 2-km zone (and vicinity) | 7 points | | Cesium: Once a week<br>Tritium: Once a week | Cesium: Once a week<br>Tritium: Once a week | **3 sampling points are added (10 points in total)** |
| | Within 20-km zone | 6 points | | Cesium: Once a week<br>Tritium: Once every 2 weeks | Cesium: Once a week<br>**Tritium: Once a week** | **The analysis frequency of tritium is increased.** |
| | Outside 20-km zone (Off the coast of Fukushima Pref.) | 9 points | | Cesium: Once a month<br>Tritium: 0 times | Cesium: Once a month<br>**Tritium: Once a month** | **Tritium is added.** |
| Fishes | Within 20-km zone | | Cesium 134, 137<br>Strontium<br>Tritium | Cesium: Once a month (11 points)<br>Strontium: Quarterly<br>(Top 5 samples with higher cesium concentrations)<br>Tritium: Once a month (1 point) | Cesium: Once a month (11 points)<br>Strontium: Quarterly<br>(Top 5 samples with higher cesium concentrations)<br>**Tritium: Once a month (11 points)** | At present, fish are collected at 11 locations and analyzed for cesium, and one location is analyzed for tritium. After the change, **the remaining 10 samples are also analyzed for tritium.** |
| Seaweeds | Within the port | | Cesium 134, 137 | Cesium: Once a year (1 point) | **Cesium: 3 times a year (1 point)** | Three times a year in March, May, and July. |
| | Outside the port | | Cesium 134, 137<br>Iodine 129<br>Tritium | Cesium: 0 times<br>Iodine: 0 times<br>Tritium: 0 times | **Cesium: 3 times a year (2 points)**<br>**Iodine: 3 times a year (2 points)**<br>**Tritium: 3 times a year (2 points)** | **Two points outside the port is added.**<br>Three times a year in March, May, and July. (To be determined after a habitat survey) |

## 7.2 Sea area monitoring samples analysis method

TEPCO

- The nuclides measured on-site are shown in the table below. External organizations measure other nuclides.

| Nuclide | Analysis method | Target detection lower limit | Applicable methods |
|---|---|---|---|
| γ ray emitting nuclides | Separate a sample into Marinelli containers and measure with a Ge semiconductor detector. | 1 Bq/L<br>Set using Cs-137[*1] | Radioactivity Measuring Method Series No.7 (Gamma-ray Spectrometry using Germanium Detector) |
| H-3 | A sample from which impurities have been removed by distillation is mixed with a scintillator. Then the sample is measured with a low background liquid scintillation counter. | 0.4 to 3 Bq/L | Radioactivity Measuring Method Series No.9 (Tritium Analysis) |

*1: Values for other nuclides vary according to baseline, interfering nuclides, background, and γ-ray emission rate.

## 8.1 Preparation of analyzers

TEPCO

### Analysis functions of the chemical analysis building

- The following equipment is prepared to measure lower radioactive concentration samples.
- The building will be expanded further to enhance the analysis functions (next page).

As of February 2022

| Samples to be handled | Analyzer | Main applications | Number of units prepared |
|---|---|---|---|
| Monitoring samples: Seawater, etc.<br>Drainage water samples: Groundwater bypass, and sub-drain purification water<br><br>ALPS outlet water: Final stage<br>And others. | Ge semiconductor detector | γ ray emitting nuclides (Cs-134, Cs-137, etc.) | 12 |
| | α automatic measuring device | Total α | 2 |
| | Low background gas flow counter | Total β, Sr-90 | 5 |
| | β nuclide analyzer | Sr-90 | 2 |
| | Low background liquid scintillation counter | Tritium, C-14<br>Cd-113m, Ni-63 | 9 |
| | Inductively coupled plasma mass spectrometer (ICP-MS) | I-129, Tc-99 | 2 |

## 8.2. Expansion of the analysis facility and addition of equipment

TEPCO

- Expansion of the functions of the chemical analysis building
  - The following facilities are planned to be added as pretreatment facilities, and the enlarged capacity enable to process the increases amount (The construction work scheduled to be completed by the end of FY 2023).

[Pre-treatment area]

<table>
<tr><th>Target</th><th>Measurement target</th><th>Expansion scale<br>(Maximum number of samples per year)</th><th colspan="2">Pretreatment equipment<br>(planned number of units)</th></tr>
<tr><td rowspan="7">Seawater</td><td>H-3</td><td>156</td><td>Fume hood<br>Rotary evaporator<br>Electrolytic concentration device</td><td>4<br>5<br>4</td></tr>
<tr><td>I-129</td><td>8</td><td rowspan="2">Experimental table<br>Fume hood</td><td rowspan="2">2<br>7</td></tr>
<tr><td>C-14</td><td>20</td></tr>
<tr><td>γ ray nuclides<br>(including Sn-126)</td><td>12</td><td>Fume hood<br>Experimental table</td><td>4<br>2</td></tr>
<tr><td>α nuclides</td><td>12</td><td rowspan="3">Experimental table<br>Fume hood</td><td rowspan="3">1<br>4</td></tr>
<tr><td>Sr-90</td><td>12</td></tr>
<tr><td>Seabed sediment</td><td>Sn-126</td><td>20</td></tr>
<tr><td rowspan="2">Fishes</td><td>C-14</td><td>1</td><td rowspan="4">Fume hood<br>Experimental table<br>Lyophilizer<br>Electrolytic concentration device<br>H-3 → He conversion device</td><td rowspan="4">6<br>3<br>6<br>6<br>2</td></tr>
<tr><td>Sn-126</td><td>1</td></tr>
<tr><td rowspan="2">Seaweeds</td><td>C-14</td><td>2</td></tr>
<tr><td>Sn-126</td><td>2</td></tr>
</table>

[Measurement area]

<table>
<tr><th>Measurement target</th><th colspan="2">Measuring device<br>(planned number of units)</th></tr>
<tr><td>H-3<br>C-14</td><td>LSC<br>He-MS*1</td><td>3<br>2</td></tr>
<tr><td>γ ray nuclides<br>(including Sn-126)</td><td>Ge (LEPS*2)</td><td>2</td></tr>
</table>

*1: He-MS: Noble gas mass spectrometer for the measurement of H-3

*2: LEPS: High purity Ge semiconductor detector for low energy photons

- The facility is planned to be expanded by about 600 $m^2$.
- The number of analyzers may increase or decrease depending on monitoring plans and the detailed design of facilities to be determined.

## 9.1 Review of uncertainty assessment

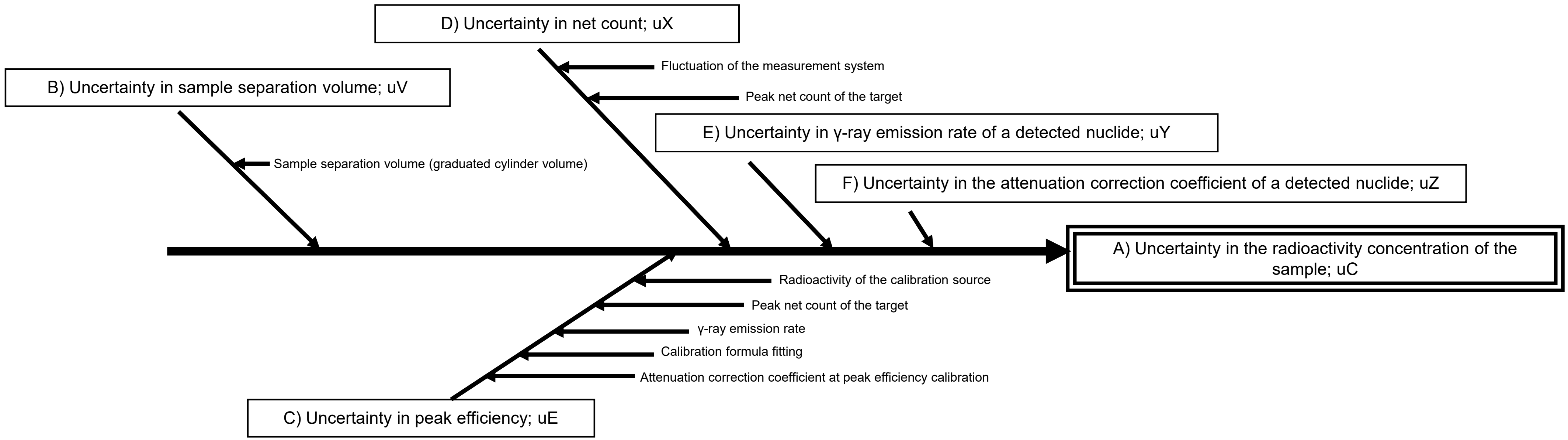
TEPCO

### Validation of analysis procedures by a third party

- In the analysis using a Ge semiconductor detector, changes in environmental doses due to the accident were not taken into account appropriately. Therefore, the analysis procedures were revised to suit Fukushima Daiichi, a unique analysis environment. The contents of the revised analysis procedures and the analysis site were reviewed by Japan Nuclear Fuel Limited (September 2013).
- The analysis procedures were developed based on the Radioactivity Measuring Method Series and publicly available papers and literature.

### Results of uncertainty assessment and future activities

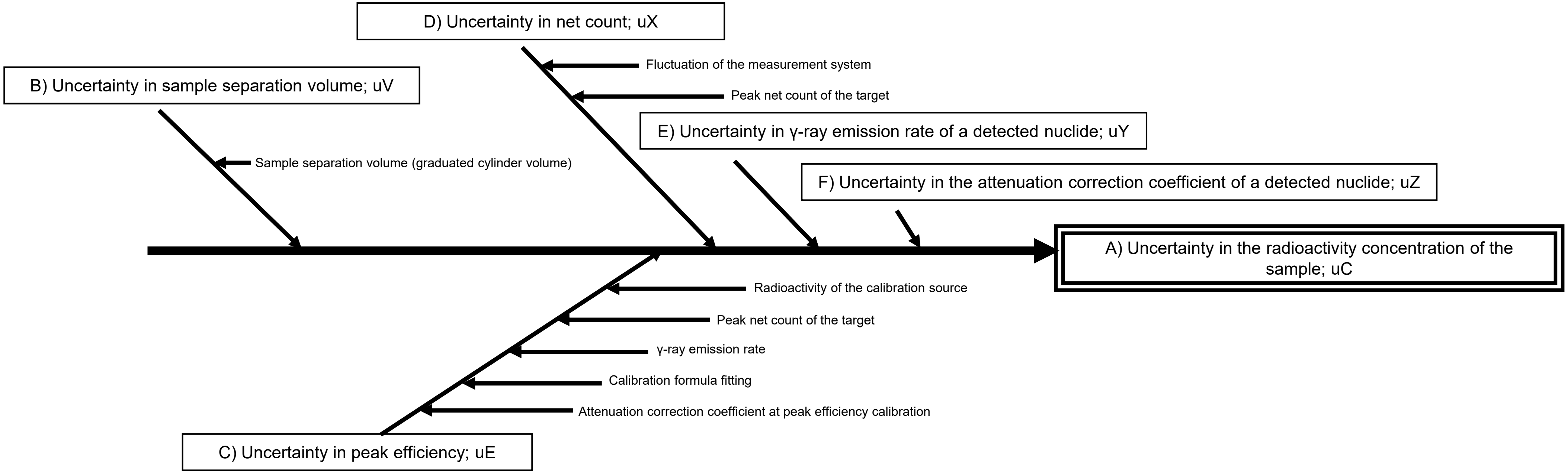
- When comparing uncertainty with a third party, if the results of both parties are within each other's uncertainty range, the analytically measured values of both parties are judged to be valid.
- Uncertainty is assessed from the result of reviewing characteristic factors on nuclides analyzed among the target nuclides to be discharged.
- A comparative assessment will emerge at a time of the ALPS secondary treatment test comparing a measurement result from an external analytical institution ( KAKEN Co., Ltd.) with TEPCO's measurement result of uncertainty.




Example) Uncertainty characteristic factors related to the analysis of radioactive concentration of γ-ray emitting nuclides

## 9.2.1 Review of uncertainty assessment

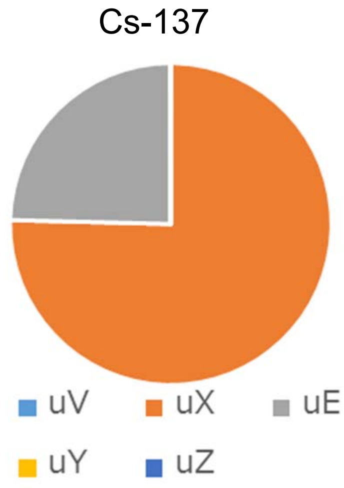
TEPCO

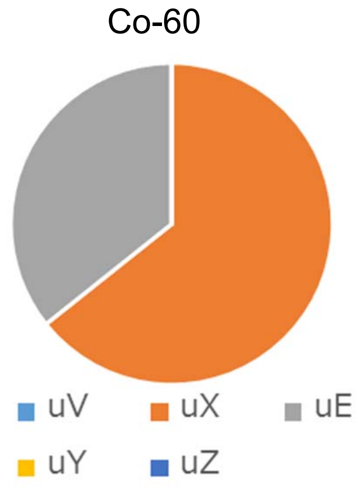



Example) Uncertainty characteristic factors related to the analysis of radioactive concentration of γ-ray emitting nuclides

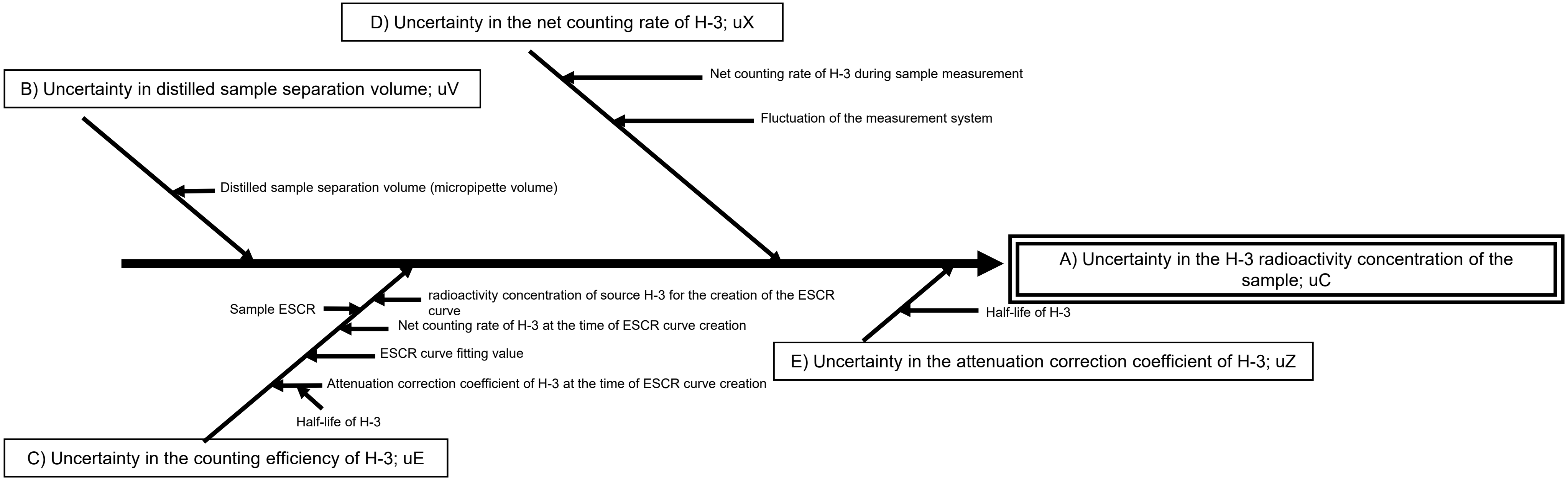
### Results of uncertainty assessment

- The uncertainty factor that has the most significant impact is the net count, followed in descending order by peak efficiency, the γ-ray emission rate of the detected nuclide, the sample separation volume, and attenuation correction coefficient of the detected nuclide.



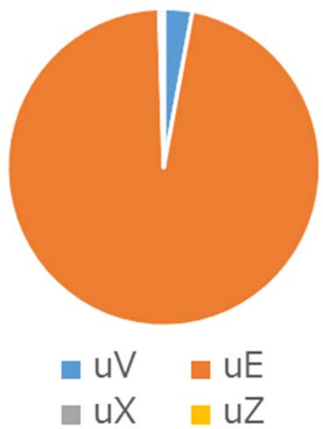
## 9.2.2 Review of uncertainty assessment



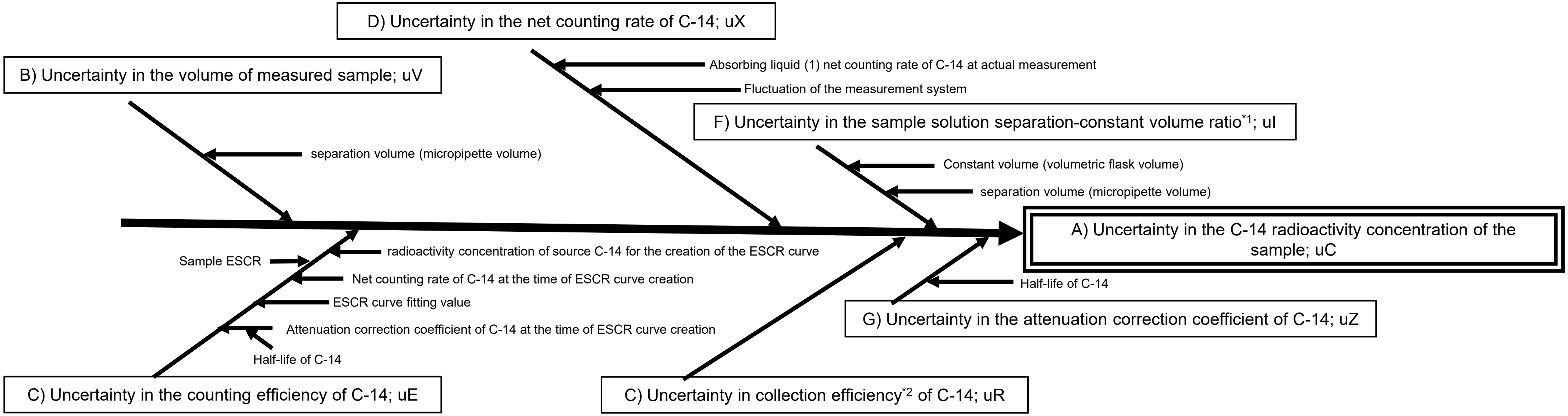

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of tritium

## ■ Results of uncertainty assessment

- The uncertainty factor that has the most significant impact is the counting efficiency of H-3, followed in descending order by distilled sample separation volume, net counting rate of H-3, and attenuation correction coefficient of H-3.
- Strictly speaking, the vapor pressure difference between HTO (or $T_2O$) water and $H_2O$ water is also assumed to impact the recovery rate of HTO (or $T_2O$) water. However, this is not taken into consideration because the distillation is performed under boiling conditions, and most of the sample water is distilled.
- ESCR is used for quench correction.



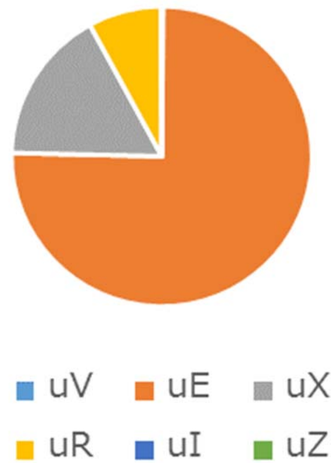
## 9.2.3 Review of uncertainty assessment




*1: Dilution ratio in the dispensing and quantification operations to prepare samples for measurement.
*2: Collection efficiency by absorption bulb

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of C-14

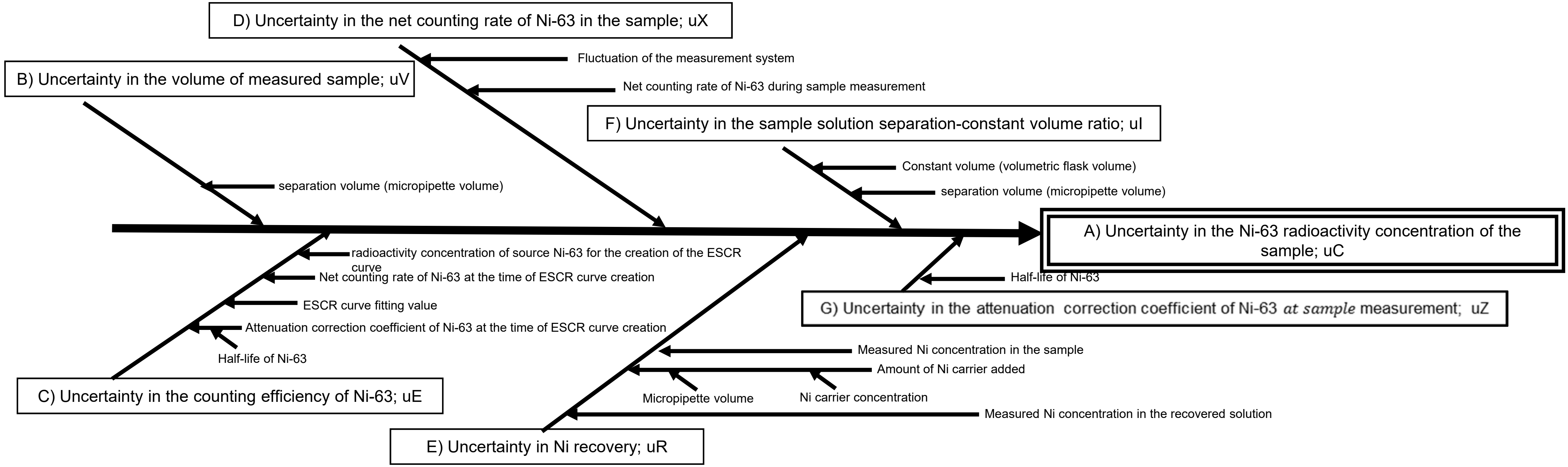
- Results of uncertainty assessment
  - The uncertainty factor that has the most significant impact is the counting efficiency of C-14, followed in descending order by net counting rate of C-14, the collection efficiency of C-14, volume of measured sample, sample solution separation-constant volume ratio, and attenuation correction coefficient of C-14.




The Japanese version shall prevail.

## 9.2.4 Review of uncertainty assessment

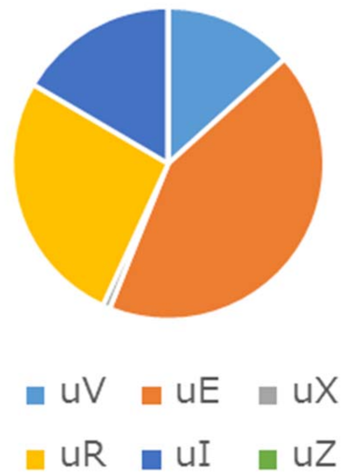
TEPCO



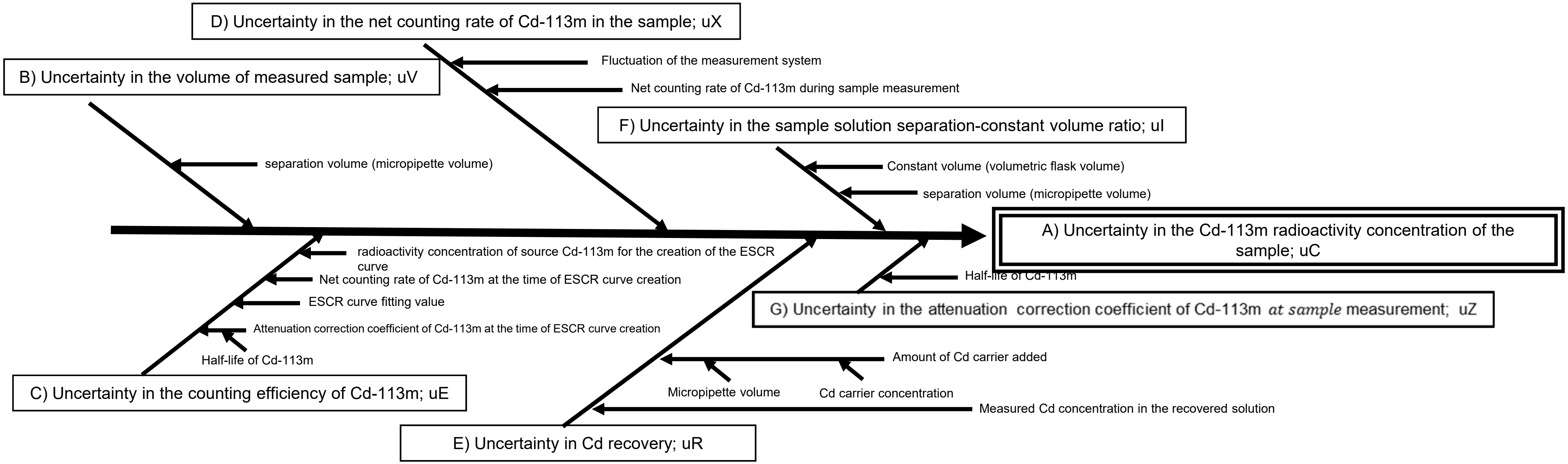

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of Ni-63

## Results of uncertainty assessment

- The uncertainty factor that has the most significant impact is the counting efficiency of Ni-63, followed in descending order by recovery of Ni, sample dispensing-constant volume ratio, the volume of measured sample, net counting rate of Ni-63 in the sample, and attenuation correction coefficient of Ni-63 during sample measurement.

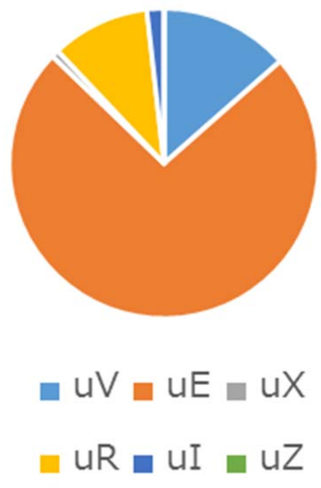


## 9.2.5 Review of uncertainty assessment



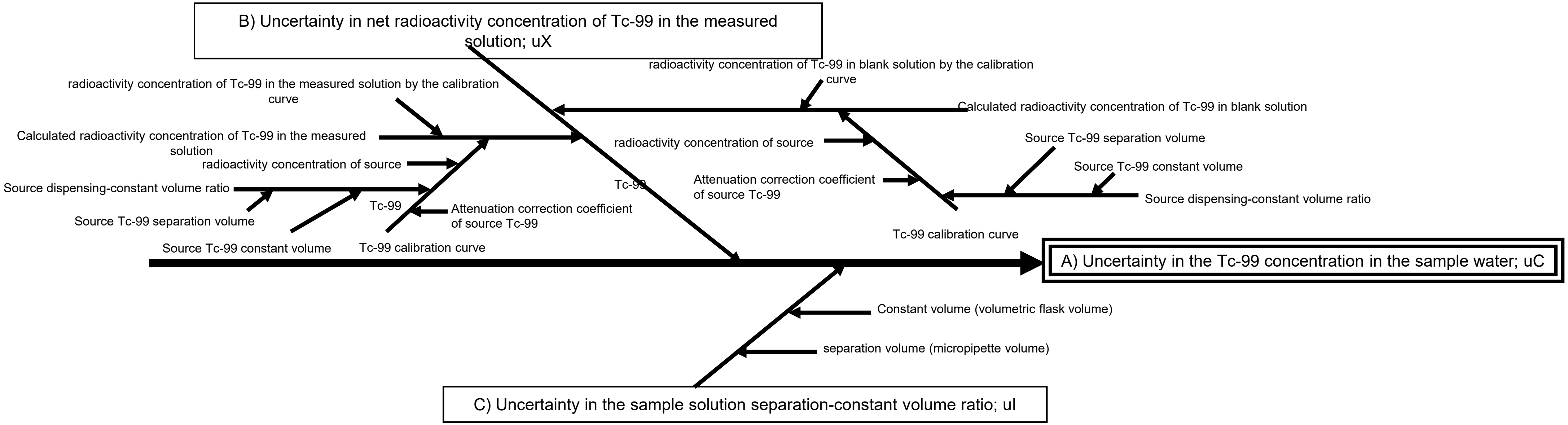

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of Cd-113m

- Results of uncertainty assessment
  - The uncertainty factor that has the most significant impact is the counting efficiency of Cd-113m, followed in descending order by volume of measured sample, Cd recovery, sample solution separation-constant volume ratio, and net counting rate of Cd-113m.
  - There is no impact of the uncertainty in the attenuation correction coefficient of Cd-113m during sample measurement.



## 9.2.6 Review of uncertainty assessment

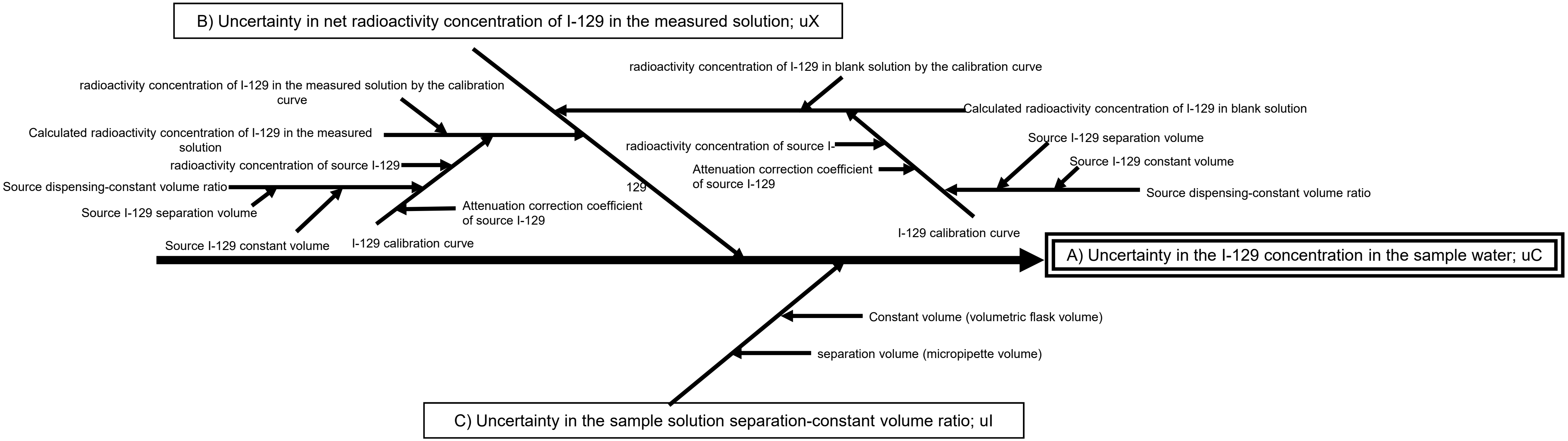
TEPCO




Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of Tc-99

- Results of uncertainty assessment
  - Since Tc-99 was not detected, only the uncertainty in the sample solution separation-constant volume ratio (There is no impact of the uncertainty in the net radioactivity concentration of Tc-99 in the measured solution).

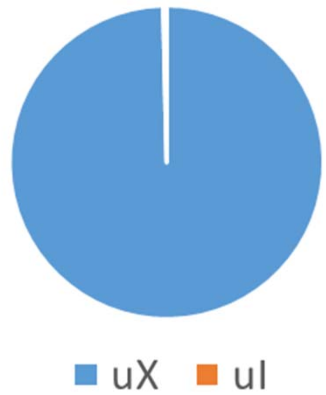

The Japanese version shall prevail.



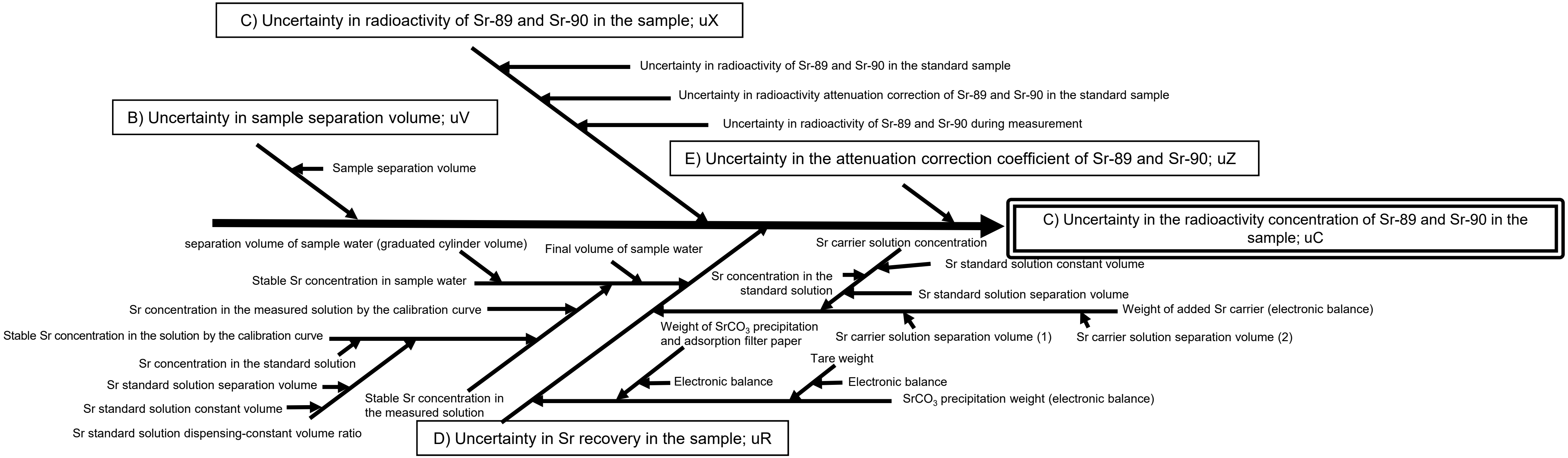

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of I-129

## Results of uncertainty assessment

- Since I-129 was detected, the uncertainty factor that has the more significant impact is the net radioactivity concentration of I-129 in the measured solution, followed by sample solution separation-constant volume ratio.

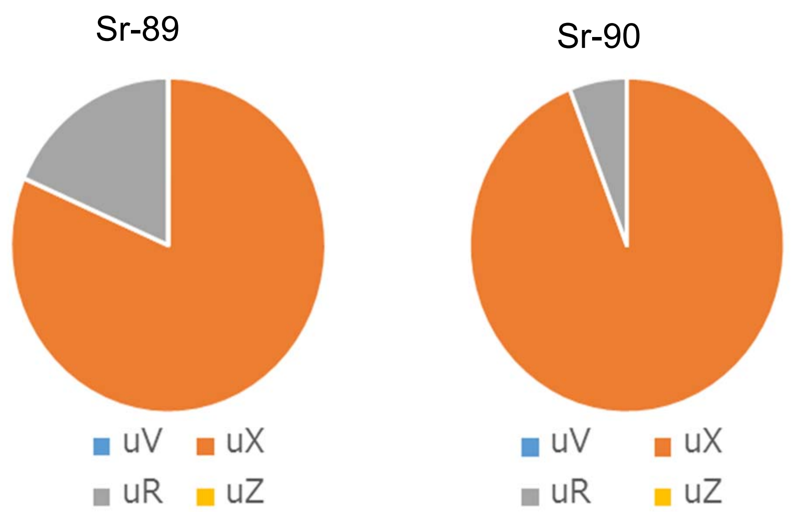


## 9.2.8 Review of uncertainty assessment



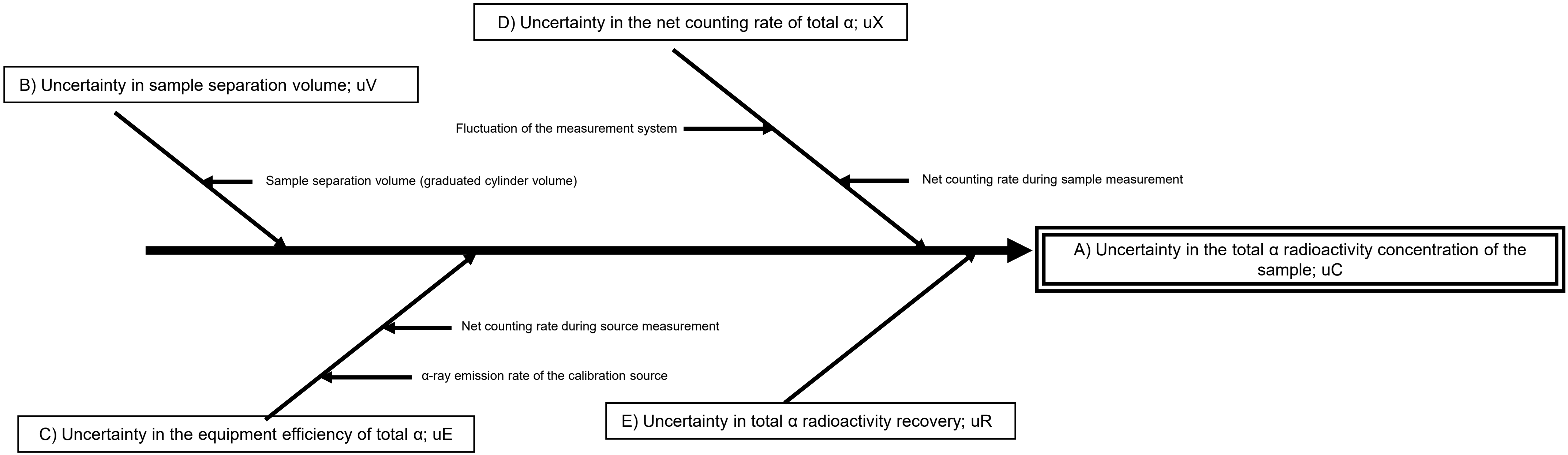

Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of Sr-89 and Sr-90

- **Results of uncertainty assessment**
  - The uncertainty factor that has the most significant impact is the radioactivity of Sr-89 and Sr-90 in the sample, followed ir descending order by Sr recovery in the sample, the sample separation volume, and attenuation correction coefficient of Sr-89 and Sr-90.




The Japanese version shall prevail.

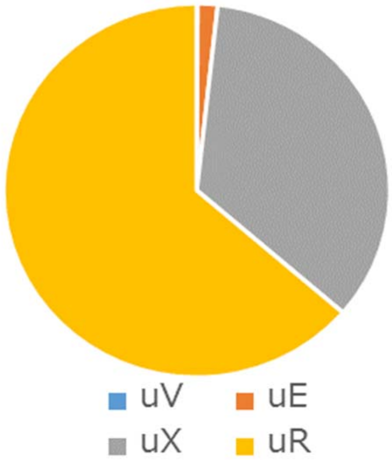
## 9.2.9 Review of uncertainty assessment




Example) Uncertainty characteristic factors related to the analysis of radioactivity concentration of total α

### Results of uncertainty assessment

- The uncertainty factor that has the most significant impact is the total α radioactivity recovery, followed in descending order by net counting rate of total α, total α equipment efficiency, and sample separation volume.



## 9.3.1 Verification and validation of analysis results

TEPCO

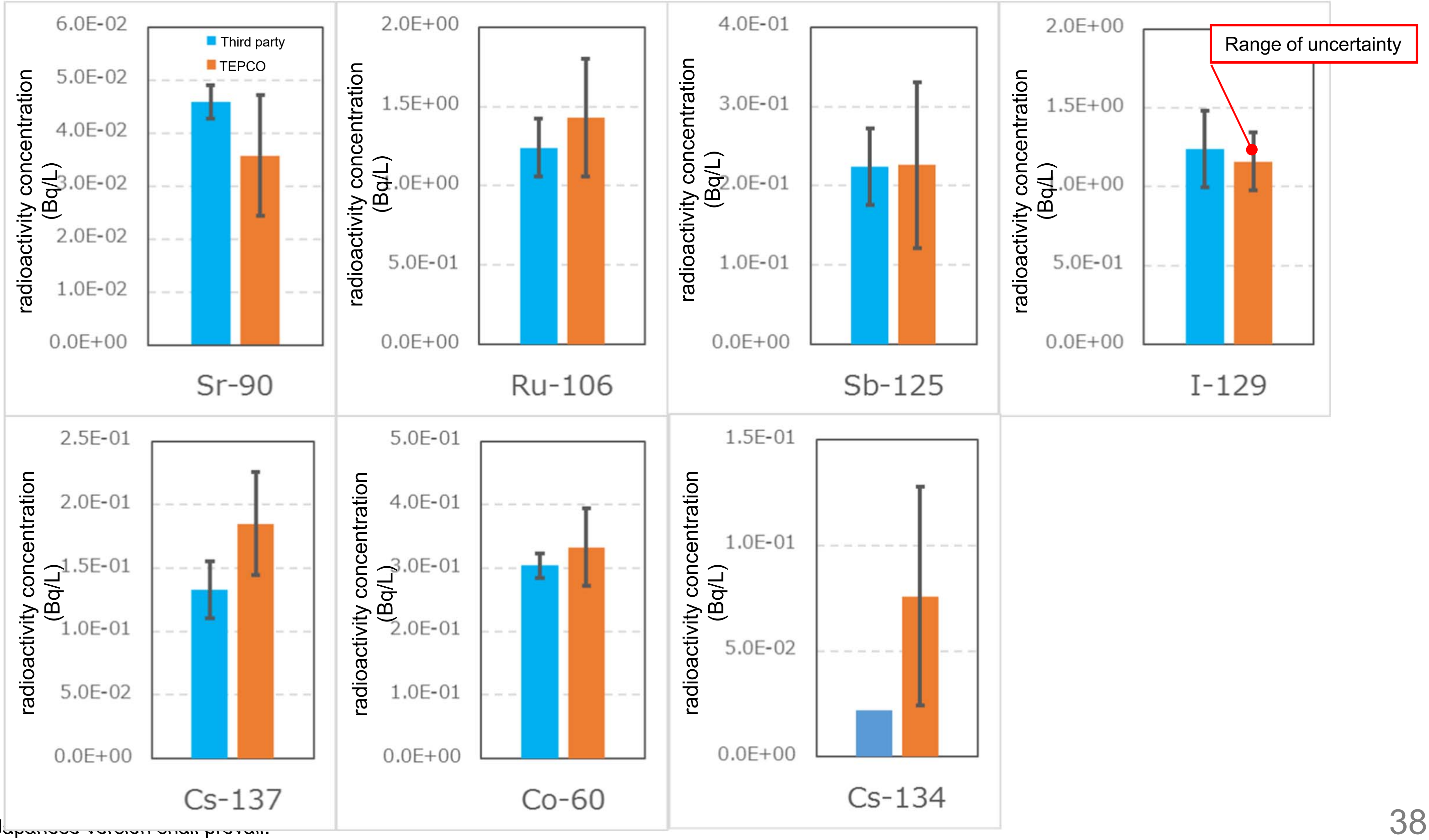
- ALPS secondary treatment performance verification test (Group J1-C)
  - The sum of the ratios to regulatory concentrations limits of Group J1-C is [0.35].
  - When uncertainty is taken into account, the ratio to regulatory concentration limit is [0.49].
  - As the ranges of uncertainty overlap, the results of measurements by both parties are consistent; that is, TEPCO's assessment that the sum of the ratios to regulatory concentrations limits is less than 1 is considered valid.

Example) Major 7 nuclides

| Nuclide | Third-party analysis institute | |
|---|---|---|
| | Analysis results (Bq/L) | Extended uncertainty (k = 2) (Bq/L) |
| Sr-90 | 4.59E-02 | 3.12E-03 |
| Ru-106 | 1.24E+00 | 1.81E-01 |
| Sb-125 | 2.24E-01 | 4.77E-02 |
| I-129 | 1.24E+00 | 2.41E-01 |
| Cs-137 | 1.33E-01 | 2.22E-02 |
| Co-60 | 3.04E-01 | 1.95E-02 |
| Cs-134 | <2.20E-02 | - |

| Nuclide | TEPCO's analysis facility | |
|---|---|---|
| | Analysis results (Bq/L) | Extended uncertainty (k = 2) (Bq/L) |
| Sr-90 | 3.57E-02 | 1.14E-02 |
| Ru-106 | 1.43E+00 | 3.72E-01 |
| Sb-125 | 2.26E-01 | 1.04E-01 |
| I-129 | 1.16E+00 | 1.83E-01 |
| Cs-137 | 1.85E-01 | 4.08E-02 |
| Co-60 | 3.33E-01 | 6.12E-02 |
| Cs-134 | <7.60E-02 | 5.17E-02 |

- If the uncertainty results of both parties are within each other's uncertainty range, the measured value is considered valid.



TEPCO

## Seawater

| Nuclide | Analysis method | Target detection lower limit | Applicable methods |
|---|---|---|---|
| γ ray emitting nuclides | Example: Kyushu Environmental Management Association<br>After a seawater sample is filtered and acidified, cesium chloride is added as a carrier, and then ammonium phosphomolybdate (AMP) is added.<br>The sample is allowed to stand overnight, the supernatant is removed, and AMP is filtered out and collected. After drying, the AMP is filled in a measuring container and measured by a Ge semiconductor detector. | 0.001 Bq/L<br>Set using Cs-137*1 | Radioactivity Measuring Method Series No.7 (Gamma-ray Spectrometry using Germanium Detector)<br>Radioactivity Measuring Method Series No.13 (Sample Pretreatment for Instrumental Analysis using Germanium Detector, etc.) |
| Sr-90 | Example: Japan Chemical Analysis Center<br>A sample for the radioactivity measurement is prepared through pre-concentration using ion exchange resin columns, the concentration of strontium by a carbonate precipitate formation, purification of strontium by an ion-exchange method, removal of Y-90 by a scavenging process, and milking operation. Then, the sample is measured with a low background gas flow counter. | 0.001 Bq/L | Radioactivity Measuring Method Series No.2 (Radiostrontium Analysis) |
| Pu-238, 239+240 | Example: Kyushu Environmental Management Association<br>A Pu-242 tracer and an iron (III) carrier are added to a sample that has been acidified in advance with nitric acid, plutonium is coprecipitated with iron (III) hydroxide, and then plutonium is separated and purified by anion exchange. Purified plutonium in the sample is electrodeposited on a stainless steel plate to prepare a sample for α-ray measurement, which is measured by a silicon semiconductor detector. | 0.01 mBq/L | Radioactivity Measuring Method Series No.12 (Plutonium Analysis) |

*1: Values for other nuclides vary according to baseline, interfering nuclides, background, and γ-ray emission rate.

TEPCO

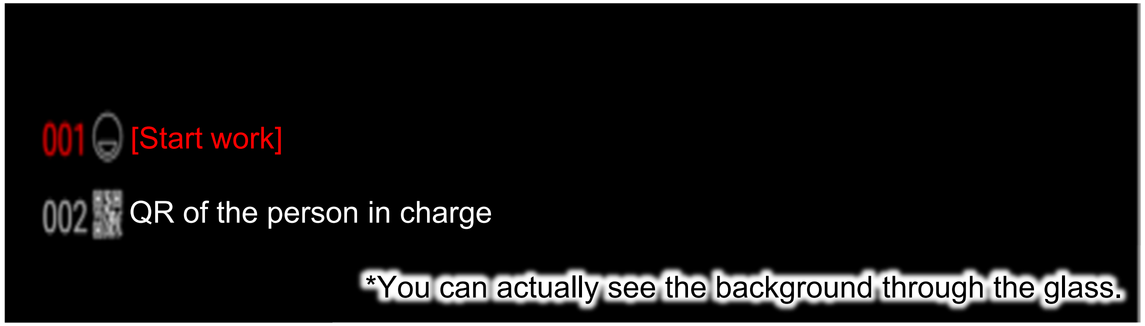
## Marine organisms

| Nuclide | Analysis method | Target detection lower limit | Applicable methods |
|---|---|---|---|
| γ ray emitting nuclides | Example: Environmental Division of Tokyo Power Technology Ltd.<br>The muscle part is separated from a seafood sample, minced, mixed, and filled in a measuring container (U-8 container).<br>The filled U-8 container is measured with a Ge semiconductor detector. | 10 Bq/kg raw<br>Set using Cs-137*1 | Radioactivity Measuring Method Series No.7 (Gamma-ray Spectrometry using Germanium Detector)<br>Radioactivity Measuring Method Series No.13<br>(Sample Pretreatment for Instrumental Analysis using Germanium Detector, etc.) |
| Sr-90 | Example: KANSO TECHNOS<br>A seafood sample is dried and incinerated, and Sr-90 is extracted from the incinerated ash with nitric acid. Sr-90 is purified from the extract by chemical separation such as ion exchange and barium chromate treatment. After that, it is allowed to stand for more than 2 weeks, and Y-90 in radiation equilibrium with Sr-90 is separated by milking and measured with a 2π gas-flow counter. | 0.01 Bq/kg raw | Radioactivity Measuring Method Series No.2 (Radiostrontium Analysis) |
| H-3 | Example: Kyushu Environmental Management Association<br><TFWT><br>A sample is frozen and treated by vacuum freeze-drying to obtain tissue-free water by cold trapping. The obtained water sample is decomposed in reflux, purified, and then to electrolytic concentration. The concentrated water is distilled and purified to be sample water for measurement.<br><OBT> Total organically bound tritium<br>A freeze-dried vacuum sample is treated by quartz tube combustion to obtain combustion water. Sodium peroxide is added to the combustion water to neutralize, potassium permanganate is added and purified by reflux decomposition and distillation to make sample water for measurement. | 0.1 Bq/L(TFWT)<br>0.3 Bq/L(OBT) | Radioactivity Measuring Method Series No.9 (Tritium Analysis) |

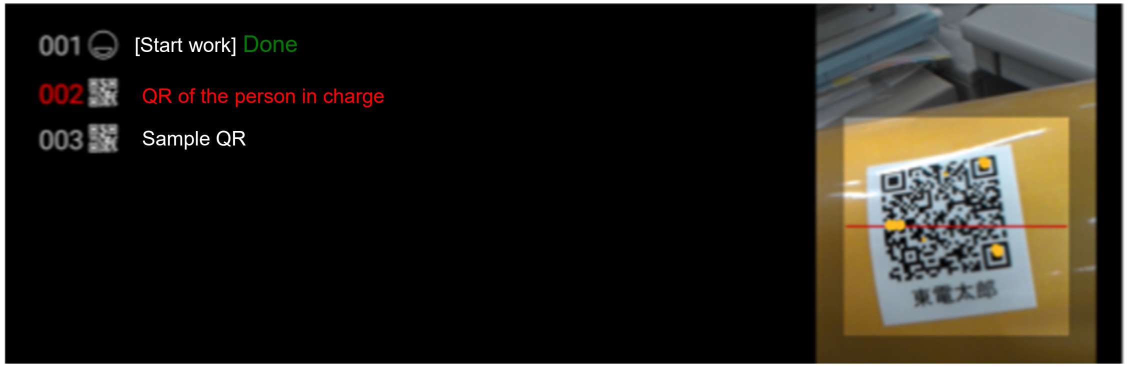
# [Reference] Quality control of the analysis process

TEPCO

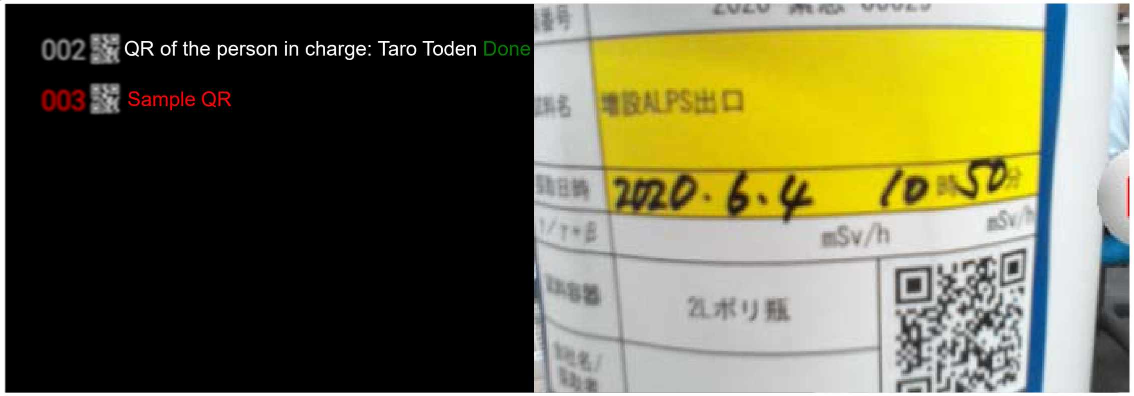
[1] Use the voice input saying “Start work”.




[2] Read the QR code issued for the person who receives the sample.




[3] Read the QR code issued for the sampling container.



[4] The sample name and the scheduled date and time of sampling appear based on the QR code information.

Say “Good” to move on to the next step.

Receiving

Analysis request number: 2020-Emergency-00103
Sample name: Seawater in the port/Point A

003 Sample QR Done
004 Scheduled date and time of sampling (14:00 07/26/2019) [Good]
005 Date and time of sampling; hh-mm/MM-DD-2020

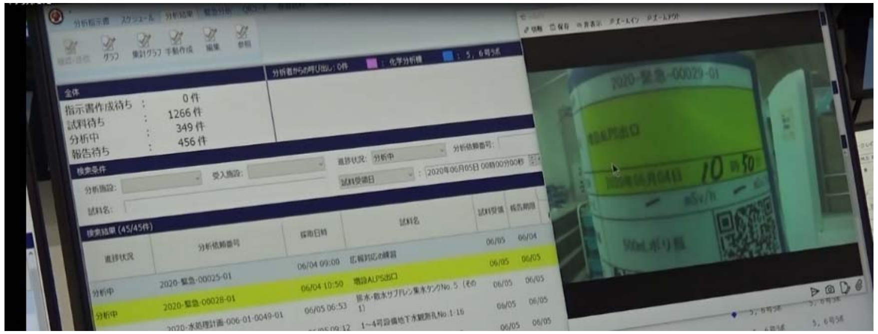
[5] Say the date and time of sampling.

Receiving

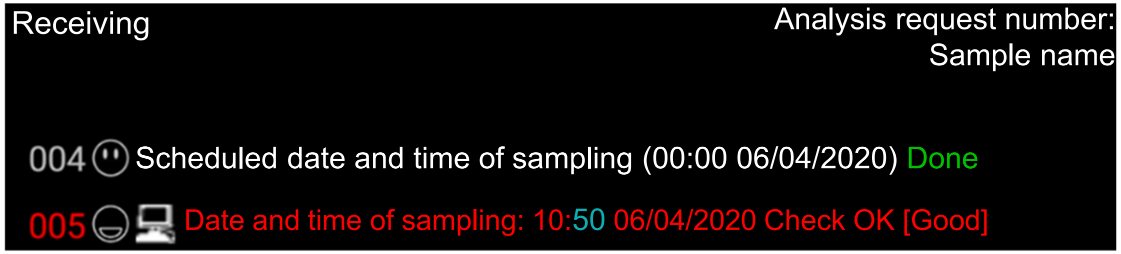
004 Scheduled date and time of sampling (00:00 06/04/2020) Done
005 Date and time of sampling: 10:50 06/04/2020 [Good]

[6] Transfer the sample label image to the data assessment room.

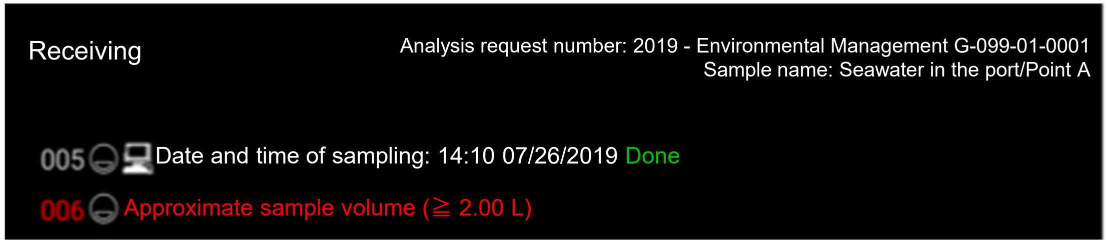

Input the date and time of sampling using a keyboard in the data assessment room.



[7] Data matching → “Check OK” → Register
Use the voice input and say “Good” to move on to the next step.

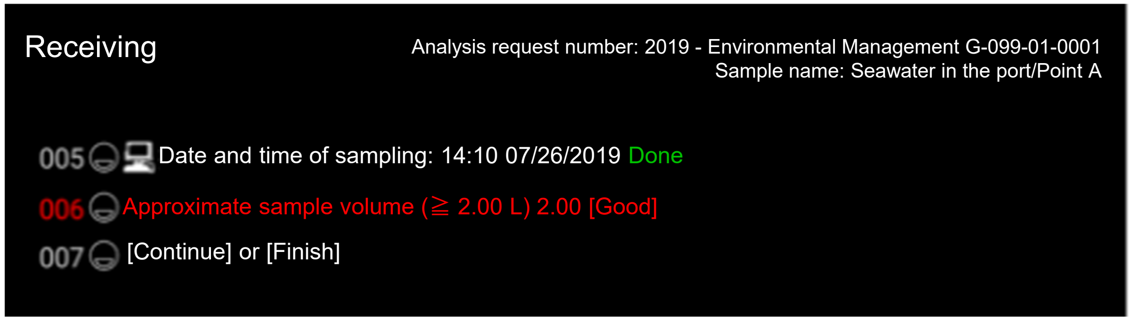



[8] Use the voice input to input the sample volume.
In this case, say “2” to input, then say “Good” to move on to the next step.




[9] Say “Finish” to move on to the next step.

Say “Continue” to continue the receiving of the following sample.



# 5-1 Diffusion simulation for the discharge into the sea (Repost of draft study)

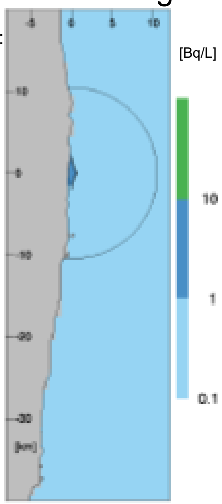
- Simulation conditions (the model verified with measured data of cesium-137)
  - Target sea area: A range about 500 km north to south and about 600 km offshore, mainly in Fukushima Prefecture
  - Resolution: 1 km mesh in a horizontal direction, 30 layers in a vertical direction along the water depth (up to 1 km deep).
  - Weather conditions, etc.: Wind velocity, atmospheric pressure, temperature, humidity, and precipitation from January to December 2014 are used.
    (Including flow conditions off the coast of Fukushima Prefecture (Kuroshio current and medium-scale eddies))

<Legend>
Black line: 1 Bq/L area (concentration level in tap water in Fukushima Prefecture before the 3.11 Earthquake)
Half-circle: Area within 10 km from the Fukushima Daiichi Nuclear Power Station
Background level: 0.1 to 1 Bq/L (concentration level off the coast of Fukushima Prefecture after the 3.11 Earthquake)

- Expanded images of the sea area off the coast of Fukushima Prefecture

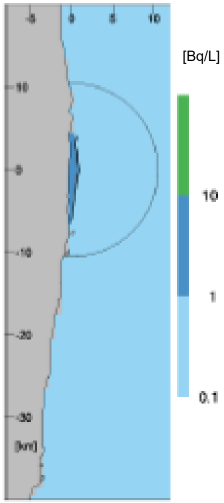
Volume of discharge: 22 trillion Bq/L

Target discharge management value for Fukushima Daiichi before the accident



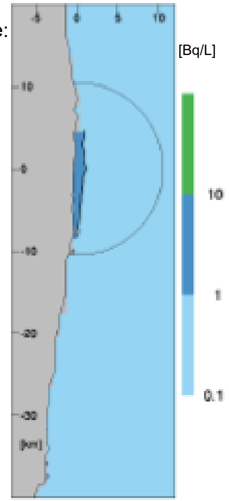

1 Bq/L area
- Approx. 1.5 km north (Northern edge of the area where common fishery rights are not set)
- Approx. 1.5 km south (Southern edge of the area where common fishery rights are not set)
- Approx. 0.7 km offshore

Volume of discharge: 40 trillion Bq/L



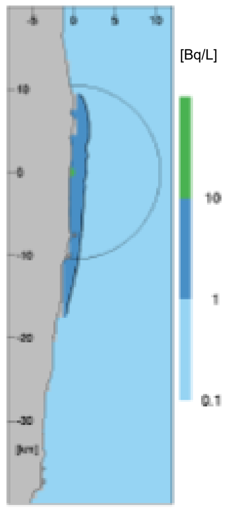

1 Bq/L area
- Approx. 6.5 km north Near Ukedo, Namie-machi
- Approx. 8 km south Near Oragahama, Tomioka-machi
- Approx. 1 km offshore

Volume of discharge: 50 trillion Bq/L




1 Bq/L area
- Approx. 7 km north (Near Ukedo, Namie-machi)
- Approx. 10 km south (Near Obama, Tomioka-machi)
- Approx. 1.5 km offshore

Volume of discharge: 100 trillion Bq/L




1 Bq/L area
- Approx. 10 km north (Near the boundary between Minamisoma City and Namie-machi)
- Approx. 20 km south (Near Iwasawa Beach, Naraha-machi)
- Approx. 2 km offshore

<TEPCO Draft Study Responding to the Subcommittee Report on Handling ALPS Treated Water>
Japanese: https://www.tepco.co.jp/decommission/progress/watertreatment/images/200324.pdf
English: https://www.tepco.co.jp/en/decommission/progress/watertreatment/images/200324.pdf

63

## 5-2 Sea area monitoring (plan) (seawater) (1/5)

- The simulation result (previous page) shows that the area where the radioradioactivity concentration is 1 Bq/L or more is limited. Even so, in order to understand the diffusion situation, monitoring will be strengthened further, such as by adding tritium measurement at points for the measurement of cesium.

  * Considering that the tritium concentration in tap water in Fukushima Prefecture is about 1 Bq/L, measurement frequency within the area where the concentration exceeds the level will be increased. Furthermore, it is well below the WHO drinking water standard of 10,000 Bq/L.

- The frequency of measurement varies according to the distance from Fukushima Daiichi NPS.
  - ✓ In principle, sampling outside the port is performed at a frequency equal to the current sampling frequency.
  - ✓ Within the port, sampling at the discharge vertical shaft (discharge end) is performed daily, whereas sampling at other points once a week.
  - ✓ Three sampling points will be added.

**Proposal on the measurement of tritium in seawater**

| Location | Number of points | Current | | (Proposed) change | Remarks |
|---|---|---|---|---|---|
| | | Cesium | Tritium | Tritium | |
| Within the port | 10 points | Daily | Once a week | • Once a week*1 | *1 Daily at the discharge vertical shaft (discharge end)<br>• No other changes |
| Within 2-km zone | 7 points | Once a week | Once a week | • Once a week*2 | *2 Three sampling points will be added. |
| Within 20-km zone | 6 points | Once a week | Once/2 weeks | • Once a week | |
| Outside 20-km zone (Off the coast of Fukushima Pref.) | 9 points | Once a month | 0 times | • Once a month | |

64

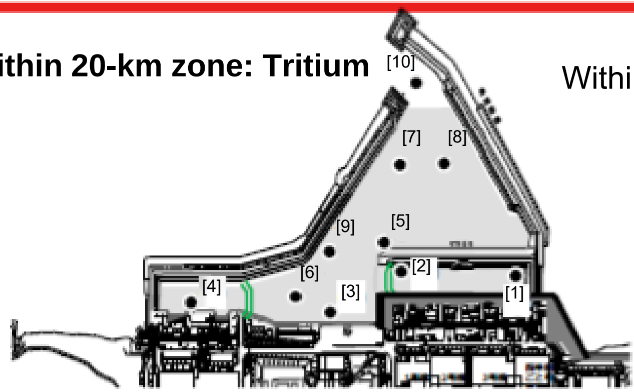
TEPCO

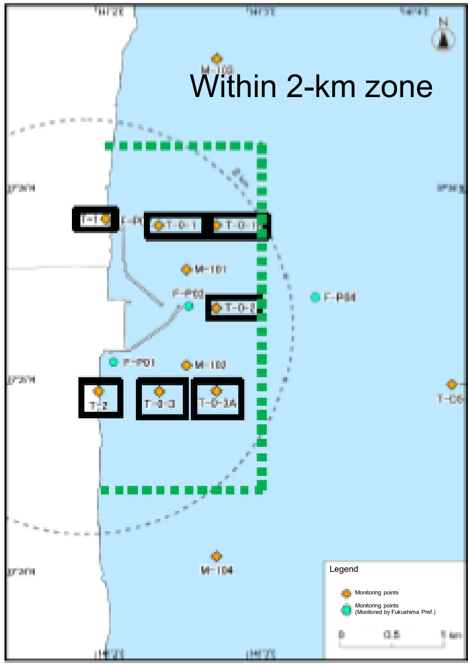
# 5-2 Sea area monitoring (plan) (seawater) (2/5)

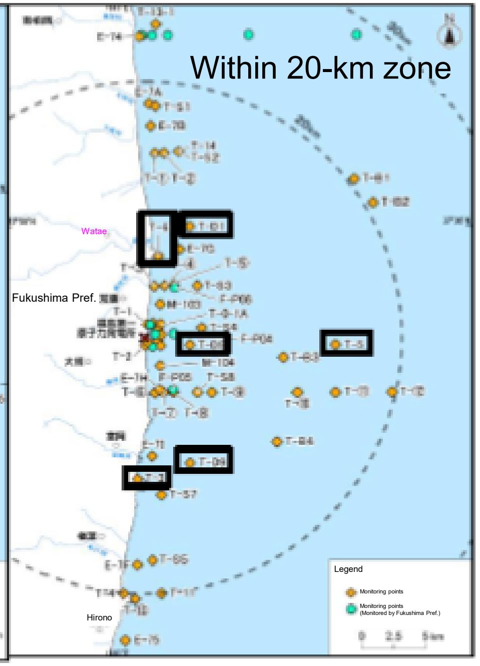
TEPCO

## (Current) Monitoring of seawater within the port and within 20-km zone: Tritium

| Location | Sample name | Frequency of analysis |
|---|---|---|
| Within the port | [2] Northside of the east inner breakwater | Once a week |
| | [1] In front of the south-side impermeable wall | Once a week |
| | [3] Seawater in front of the unloading wharf | Once a week |
| | [4] Seawater in front of the unit 6 intake channel | Once a week |
| | [10] Seawater at the mouth of the port | Once a week |
| | [7] Seawater in the eastside of the port | Once a week |
| | [9] Seawater in the westside of the port | Once a week |
| | [6] Seawater in the northside of the port | Once a week |
| | [8] Seawater in the southside of the port | Once a week |
| | [5] Center of the port | Once a week |
| Within 2-km zone | Near the south discharge port (T-2) | Once a week |
| | Northside of the units 5 & 6 discharge port (T-1) | Once a week |
| | Seawater to the eastside of the port mouth (T-0-2) | Once a week |
| | Seawater to the northside of the northern breakwater (T-0-1) | Once a week |
| | Seawater to the southside of the southern breakwater (T-0-3) | Once a week |
| | Seawater to the north-east side of the port mouth (T-0-1A) | Once a week |
| | Seawater to the south-east side of the port mouth (T-0-3A) | Once a week |
| Within 20-km zone | Discharge port to the north of 2F (T-3) | Twice a month |
| | The southside of Ukedo Port (T-6) | Twice a month |
| | 3 km offshore from Ukedo River (T-D1) | Twice a month |
| | 15 km off the coast of the 1F site (T-5) | Twice a month |
| | 3 km off the coast of the 1F site (T-D5) | Twice a month |
| | 3 km off the coast of the 2F site (T-D9) | Twice a month |




An area where no fishing is conducted on a daily basis*

1.5 km east to west, 3.5 km north to south

Tritium analysis points (Analyzed at all points within the port)

*: Area where common fishery rights are not set

65

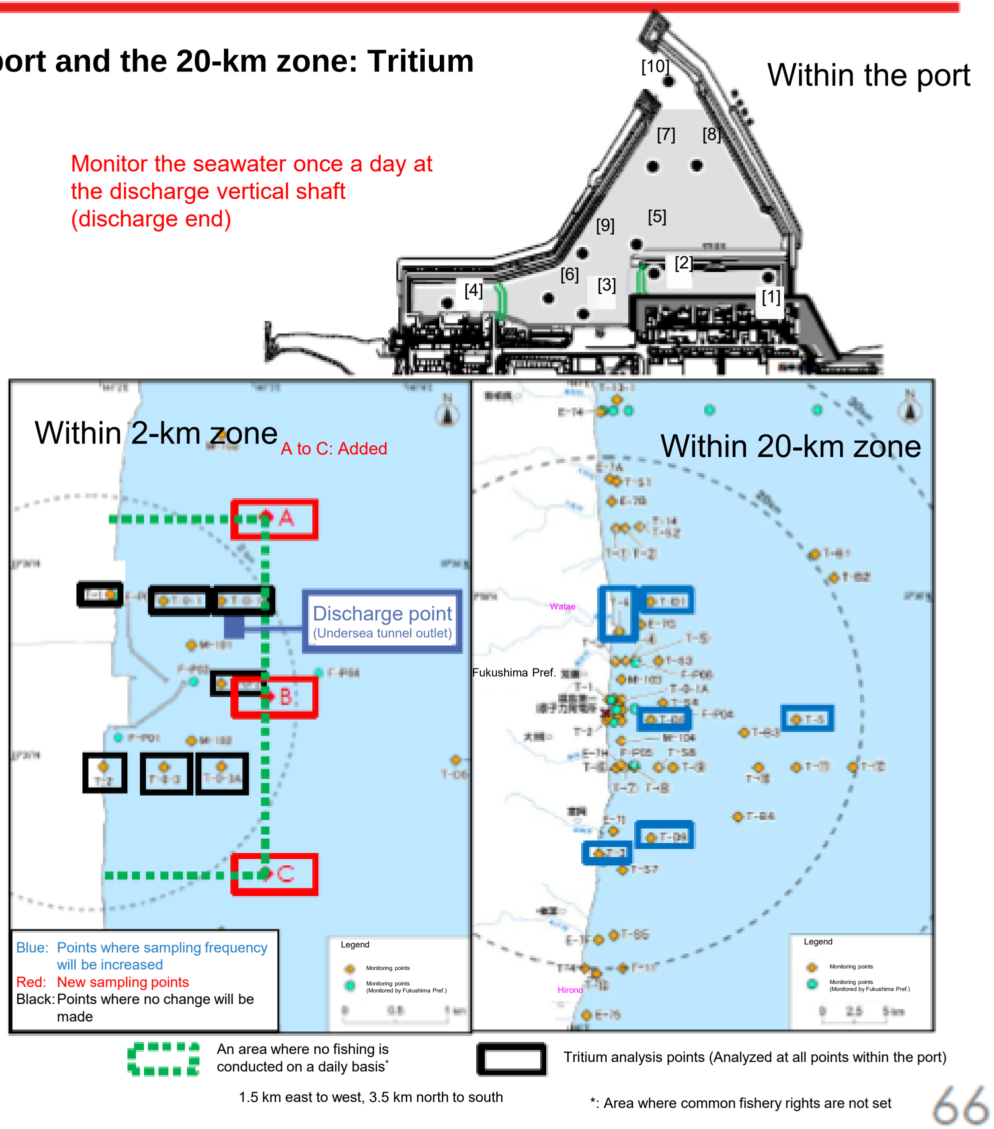
The Japanese version shall prevail.

https://www.tepco.co.jp/press/release/2021/1635125_8711.html

# 5-2 Sea area monitoring (plan) (seawater) (3/5)

## (Revised) Monitoring of seawater within the port and the 20-km zone: Tritium

| Location | Sample name | Frequency of analysis |
|---|---|---|
| Within the port | [2] Northside of the east inner breakwater | Once a week |
| | [1] In front of the south-side impermeable wall | Once a week |
| | [3] Seawater in front of the unloading wharf | Once a week |
| | [4] Seawater in front of the unit 6 intake channel | Once a week |
| | [10] Seawater at the mouth of the port | Once a week |
| | [7] Seawater in the eastside of the port | Once a week |
| | [9] Seawater in the westside of the port | Once a week |
| | [6] Seawater in the northside of the port | Once a week |
| | [8] Seawater in the southside of the port | Once a week |
| | [5] Center of the port | Once a week |
| Within 2-km zone and vicinity | Near the south discharge port (T-2) | Once a week |
| | Northside of the units 5 & 6 discharge port (T-1) | Once a week |
| | Seawater to the eastside of the port mouth (T-0-2) | Once a week |
| | Seawater to the northside of the northern breakwater (T-0-1) | Once a week |
| | Seawater to the southside of the southern breakwater (T-0-3) | Once a week |
| | Seawater to the north-east side of the port mouth (T-0-1A) | Once a week |
| | Seawater to the south-east side of the port mouth (T-0-3A) | Once a week |
| | North-east end of the area where no fishing is conducted on a daily basis* (New sampling point: A) | Once a week |
| | Midpoint on the east end of the area where no fishing is conducted on a daily basis* (New sampling point: B) | Once a week |
| | South-east end of the area where no fishing is conducted on a daily basis* (New sampling point: C) | Once a week |
| 20km Zone | Discharge port to the north of 2F (T-3) | Once a week |
| | The southside of Ukedo Port (T-6) | Once a week |
| | 3 km offshore from Ukedo River (T-D1) | Once a week |
| | 15 km off the coast of the 1F site (T-5) | Once a week |
| | 3 km off the coast of the 1F site (T-D5) | Once a week |
| | 3 km off the coast of the 2F site (T-D9) | Once a week |

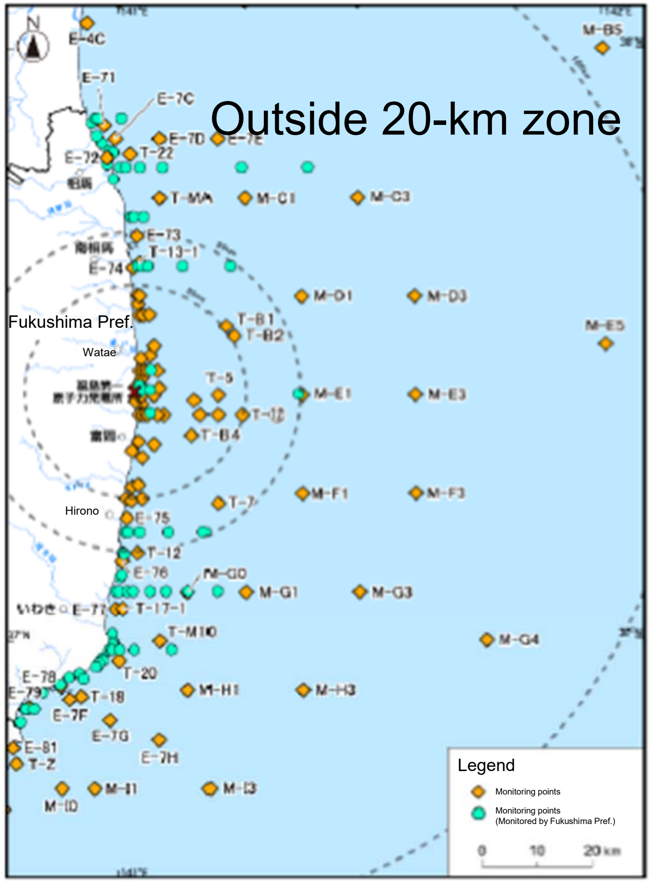



66

# 5-2 Sea area monitoring (plan) (seawater) (4/5)

## (Current) Monitoring of seawater within 20-km zone: Tritium

| Location | Sample name | Current |
|---|---|---|
| Outside 20-km zone (Fukushima) | 3 km off the coast of Soma (T-22) | 0 |
| | 5 km off the coast of Kasihma (T-MA) | 0 |
| | 1 km offshore from Niida River (T-13-1) | 0 |
| | 15 km off the coast of Iwasawa (T-7) | 0 |
| | 3 km off the northern coast of Iwaki City (T-12) | 0 |
| | 1 km offshore from Natsui River (T-17-1) | 0 |
| | 5 km off the coast of Numanouchi (T-M10) | 0 |
| | 3 km off the coast of Toyoma (T-20) | 0 |
| | 3 km off the coast of Onahama Port (T-18) | 0 |




Tritium analysis is not carried out at points outside the 20-km zone, but samples are collected once a month for cesium analysis.

67

TEPCO

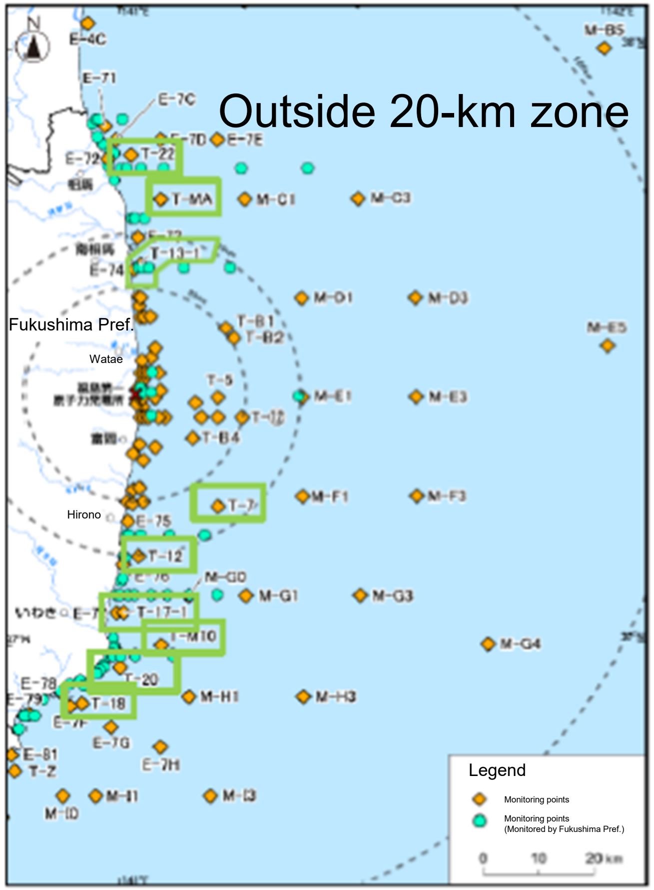
## 5-2 Sea area monitoring (plan) (seawater) (5/5)

TEPCO

### (After Review) Monitoring of seawater within 20-km zone: Tritium

**Green: Points where the analysis will be added**

| Location | Sample name | Current |
|---|---|---|
| Outside 20 km zone (Fukushima) | 3 km off the coast of Soma (T-22) | Once a month |
| | 5 km off the coast of Kasihma (T-MA) | Once a month |
| | 1 km offshore from Niida River (T-13-1) | Once a month |
| | 15 km off the coast of Iwasawa (T-7) | Once a month |
| | 3 km off the northern coast of Iwaki City (T-12) | Once a month |
| | 1 km offshore from Natsui River (T-17-1) | Once a month |
| | 5 km off the coast of Numanouchi (T-M10) | Once a month |
| | 3 km off the coast of Toyoma (T-20) | Once a month |
| | 3 km off the coast of Onahama Port (T-18) | Once a month |




68

The Japanese version shall prevail.

https://www.tepco.co.jp/press/release/2021/1635125_8711.html

TEPCO

## 5-3 Sea area monitoring (plan) (fish/seaweed) (1/5)

TEPCO

- Measurements are performed to monitor the transfer to fish and seaweeds of radioactive materials to be released.
- Analysis of fish for cesium is currently performed at 11 points within a 20-km zone off the coast of Fukushima Prefecture (Analysis for tritium is performed at one of them at the moment). In order to check impacts on tritium concentrations, analyses of fish for tritium will be performed at all of the 11 points and analyses of seawater for tritium at the same points.
- Analysis of seaweeds for gamma nuclides is currently performed at one point in the port. In order to check the concentrations of iodine and tritium, seaweed samples will be collected at two more points outside the port, and analyses for tritium and iodine 129 will be performed in addition to gamma nuclides.

**Proposal on the measurement of tritium and iodine 129 in fish/seaweeds**

| | | Current | (Proposed) change | Remarks | |
|---|---|---|---|---|---|
| Fishes | Within 20-km zone | Once a month (1 location) | Once a month (11 locations) | [Current]<br>[After change] | Fish are collected at 11 locations, and tritium of flounder is analyzed at one of the locations.<br>At 10 locations used for collecting fish for cesium analysis, tritium analysis will also be performed. |
| Seaweeds | Within the port | 3 times a year (1 location) | 3 times a year (1 location) | [Current]<br>[After change] | It is conducted three times a year in March, May, and July at 1 location within the port (considering the summer growth depression and no growing in winter).<br>Two locations outside the port will be added, and gamma nuclides, iodine 129, and tritium will be analyzed (reviewed by habitat survey). |
| | Outside the port | 0 times | 3 times a year (2 locations) | | |

69

# [Reference] Sea Area Monitoring Plan, excerpt from the plan published on August 25, 2021

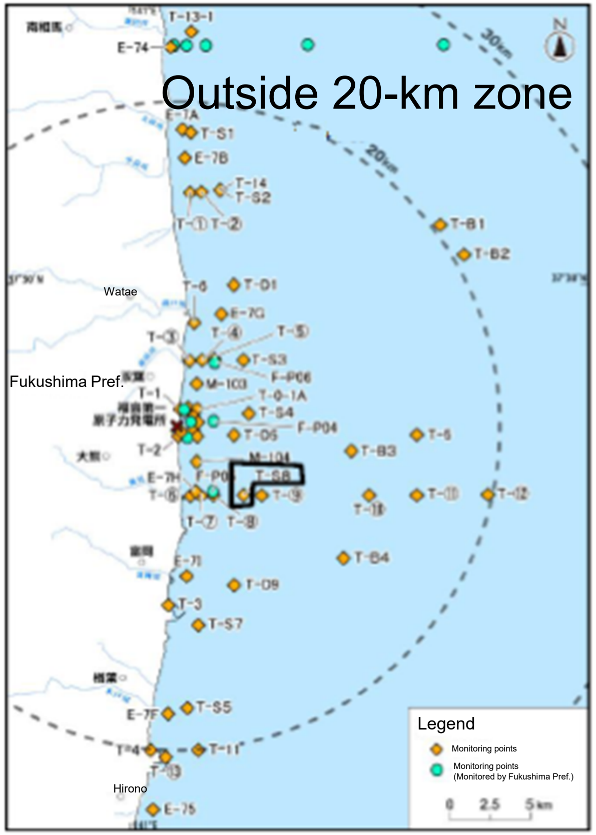
TEPCO

## 5-3 Sea area monitoring (plan) (fish/seaweed) (2/5)

TEPCO

### (Current) Monitoring of marine organisms (fish): Tritium

| Sample name | Fish | Seawater |
|---|---|---|
| | Frequency of analysis | Frequency of analysis |
| Approx. 1 km offshore from Ohta River (T-S1) | - | - |
| Approx. 3 km offshore from Odaka-ku (T-S2) | - | - |
| Approx. 3 km offshore from Ukedo River (T-S3) | - | - |
| Approx. 3 km offshore from the 1F site (T-S4) | - | - |
| Approx. 2km offshore from Kidokawa (T-S5) | - | - |
| Approx. 2km offshore from the 2F site (T-S7) | - | - |
| Approx. 4km offshore from Kuma River (T-S8) | Once a month (Detailed analysis) | Once a month (Detailed analysis) |
| Approx. 15 km offshore from Odaka-ku (T-B1) | - | - |
| Approx. 18 km offshore from Ukedo River (T-B2) | - | - |
| Approx. 10km offshore from the 1F site (T-B3) | - | - |
| Approx. 10 km offshore from the 2F site (T-B4) | - | - |




Fish (tritium) analysis points

| | Detailed analysis |
|---|---|
| Lower limit of detection | Approx. 0.1 becquerel/liter |

70

The Japanese version shall prevail.

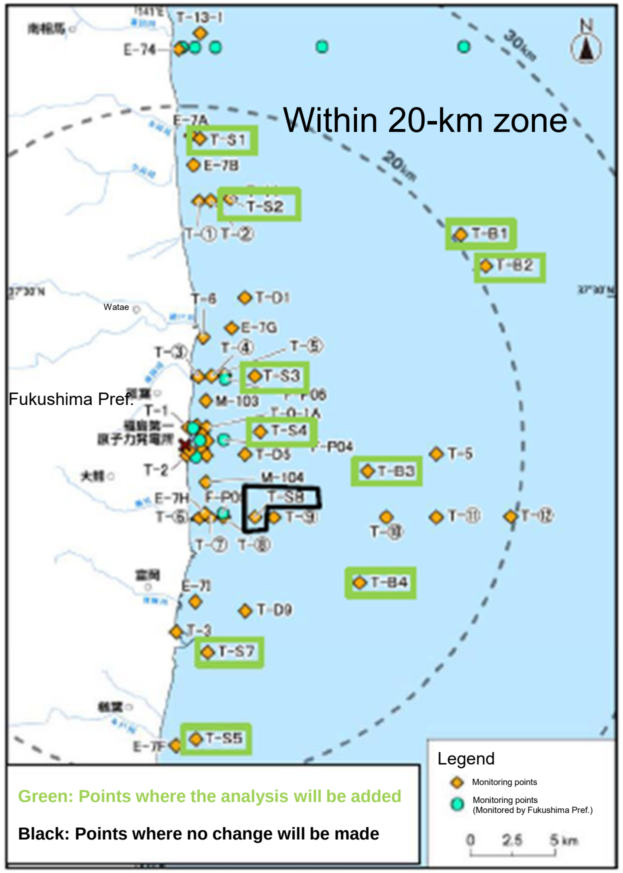
https://www.tepco.co.jp/press/release/2021/1635125_8711.html

# 5-3 Sea area monitoring (plan) (fish) (3/5)

TEPCO

## (After review) Monitoring of fishery products (fish): Tritium

| Sample name | Fish | Seawater |
|---|---|---|
| | Frequency of analysis | Frequency of analysis |
| Approx. 1 km offshore from Ohta River (T-S1) | Once a month | Once a month |
| Approx. 3 km offshore from Odaka-ku (T-S2) | Once a month | Once a month |
| Approx. 3 km offshore from Ukedo River (T-S3) | Once a month | Once a month |
| Approx. 3 km offshore from the 1F site (T-S4) | Once a month | Once a month |
| Approx. 2km offshore from Kidokawa (T-S5) | Once a month | Once a month |
| Approx. 2km offshore from the 2F site (T-S7) | Once a month | Once a month |
| Approx. 4km offshore from Kuma River (T-S8) | Once a month (Detailed analysis) | Once a month (Detailed analysis) |
| Approx. 15 km offshore from Odaka-ku (T-B1) | Once a month | Once a month |
| Approx. 18 km offshore from Ukedo River (T-B2) | Once a month | Once a month |
| Approx. 10km offshore from the 1F site (T-B3) | Once a month | Once a month |
| Approx. 10 km offshore from the 2F site (T-B4) | Once a month | Once a month |

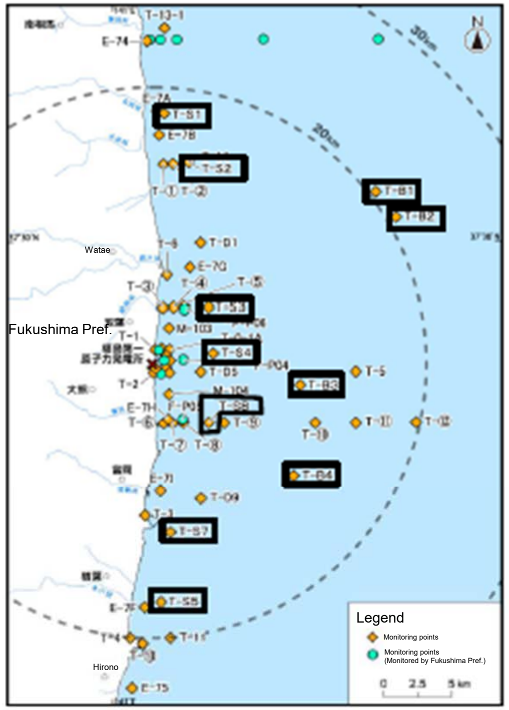



71

# 5-3 Sea area monitoring (plan) (fish) (4/5)

## (No change) Monitoring of fishery products (fish): cesium, strontium

| Sample name | Cesium | Strontium |
|---|---|---|
| | Frequency of analysis | Frequency of analysis |
| Approx. 1 km offshore from Ohta River (T-S1) | Once a month | 20 times a year<br>Sample measurement of the top five samples of cesium concentrations every quarter |
| Approx. 3 km offshore from Odaka-ku (T-S2) | Once a month | |
| Approx. 3 km offshore from Ukedo River (T-S3) | Once a month | |
| Approx. 3 km offshore from the 1F site (T-S4) | Once a month | |
| Approx. 2km offshore from Kidokawa (T-S5) | Once a month | |
| Approx. 2km offshore from the 2F site (T-S7) | Once a month | |
| Approx. 4km offshore from Kuma River (T-S8) | Once a month | |
| Approx. 15 km offshore from Odaka-ku (T-B1) | Once a month | |
| Approx. 18 km offshore from Ukedo River (T-B2) | Once a month | |
| Approx. 10km offshore from the 1F site (T-B3) | Once a month | |
| Approx. 10 km offshore from the 2F site (T-B4) | Once a month | |




Fish (cesium, strontium) analysis points

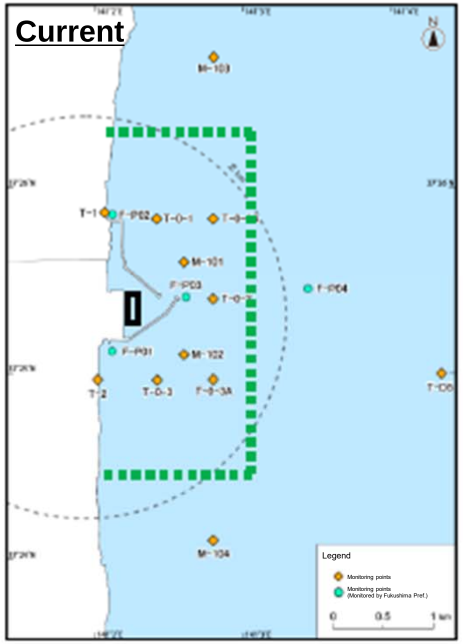
72

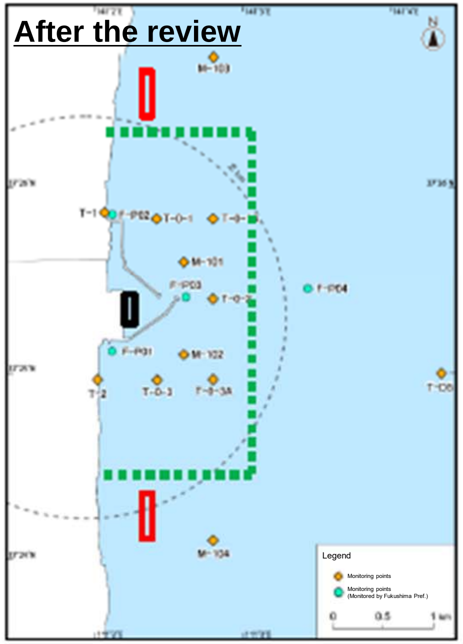
## 5-3 Sea area monitoring (plan) (seaweed) (5/5)

TEPCO

**(Current and after review) Monitoring of seaweed: cesium, iodine 129, tritium** (times/year)

| Sampling points | Analytical items | Current | After the review |
|---|---|---|---|
| Within the port (Inside of the southern breakwater) | Cesium 134, 137 | 3 | 3 |
| | Iodine 129 | 0 | 0 |
| | Tritium | 0 | 0 |
| Outside the port | Cesium 134, 137 | 0 | **3 x 2 points** |
| | Iodine 129 | 0 | **3 x 2 points** |
| | Tritium | 0 | **3 x 2 points** |




**Red: New sampling points**
(studied by habitat survey)
**Black: Points exsisting**

The sampling points outside the port are set outside an area where no fishing is conducted on a daily basis*

An area where no fishing is conducted on a daily basis*
1.5 km east to west, 3.5 km north to south

*: Area where common fishery rights are not set

## 5-4 Matters to be considered in the sea area monitoring

- Sea area monitoring will start around spring of 2022, about 1 year before the start of the scheduled discharge.
- On the implementing sea area monitoring (sampling, radioactivity measurement, etc.), we will ask participation and inspection visits from agriculture, forestry, fisheries companies, and local government officials.
- As mentioned above, measures to enhance the sea area monitoring are being studied in accordance with the distance from the Fukushima Daiichi NPS. Further necessity and method for improvement and expansion the sea area monitoring, TEPCO will review based on the government's monitoring coordination meeting.
- The improvement of the simulation of discharge and dispersion will pursue and the radiation impact assessment on human and the environment will be maid. To improve the accuracy of the simulation of discharge and diffusion into the sea, we will continue the investigation and evaluate the impact of radiation on humans and the environment.

74

**Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS treated water into the sea**

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

**(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)**

**(1) Discharge Facilities of ALPS Treated Water into the Sea**

**[3] Methods of seawater intake and discharging ALPS treated water after dilution**

**[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.**

**(Dilution facility and related facility(discharge facilities))**

- The following points must be summarized and explained for each structure, system, and component consisting of the facilities for the discharge into the sea: Safety functions, impacts in the event of the loss of safety functions, basic specifications, and the grounds for their establishment, the main structure, applicable standards, etc.

**Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS treated water into the sea**

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

**(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)**

**(1) Discharge Facilities of ALPS Treated Water into the Sea**

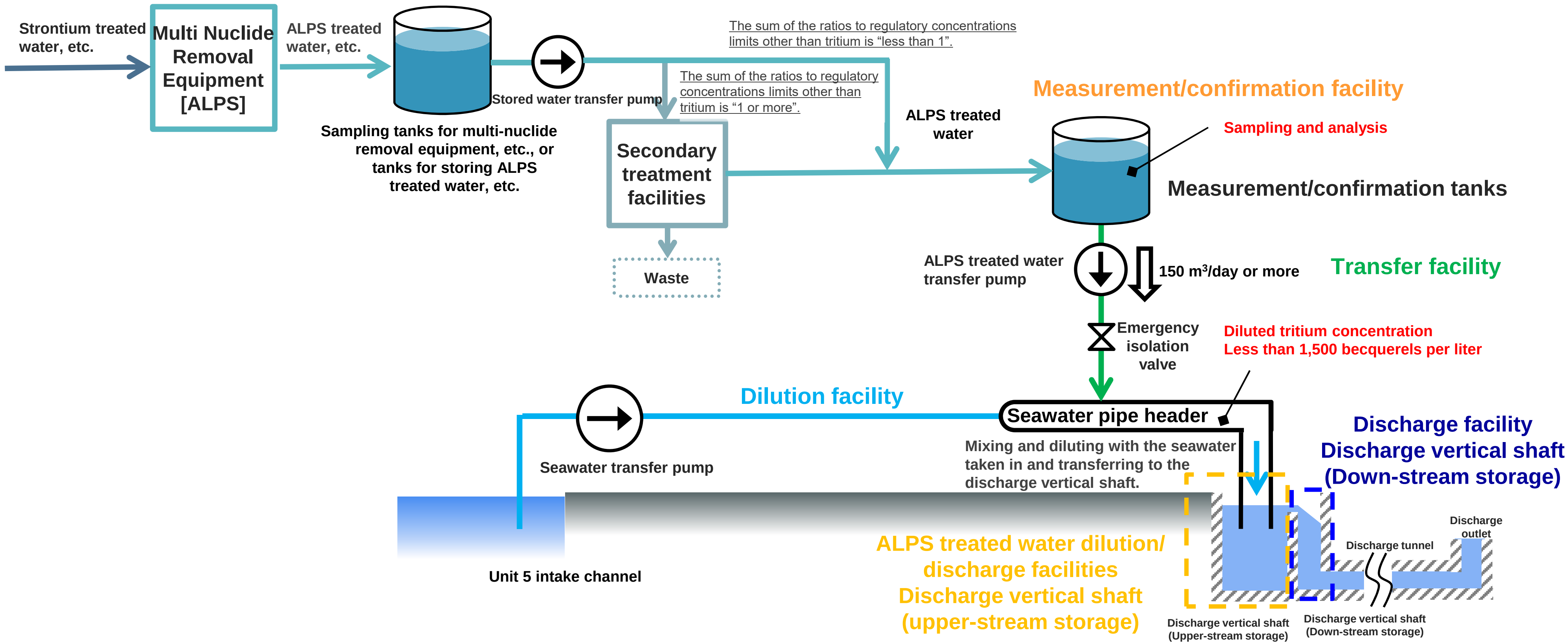
**[3] Methods of seawater intake and discharging ALPS treated water after dilution**

**(Design related to Dilution facility/related facility(discharge facility))**

## 1. Overview of the ALPS treated water Dilution/Discharge Facilities

TEPCO

- The figure below summarizes the structure and strength of the discharge vertical shaft (upper-stream storage and down-stream storage), protection against natural phenomena, and their reliability in the ALPS treated water Dilution/Discharge Facilities and the Related Facility.



# 2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
## 2. Facility overview for ensuring safety

Source: This map was created by Tokyo Electric Power Company Holdings, Inc. based on a map published by the Geographical Survey Institute (Electronic Map Web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1

**Secondary treatment facility (new reverse osmosis membrane equipment)**

Secondarily treats treated water to be purified in which the sum of ratios to regulatory concentration limits other than tritium is “1 to 10”.

**Secondary treatment facility (ALPS)**

Secondarily treats treated water to be purified in which the sum of ratios to regulatory concentration limits other than tritium is “not less than 1”.

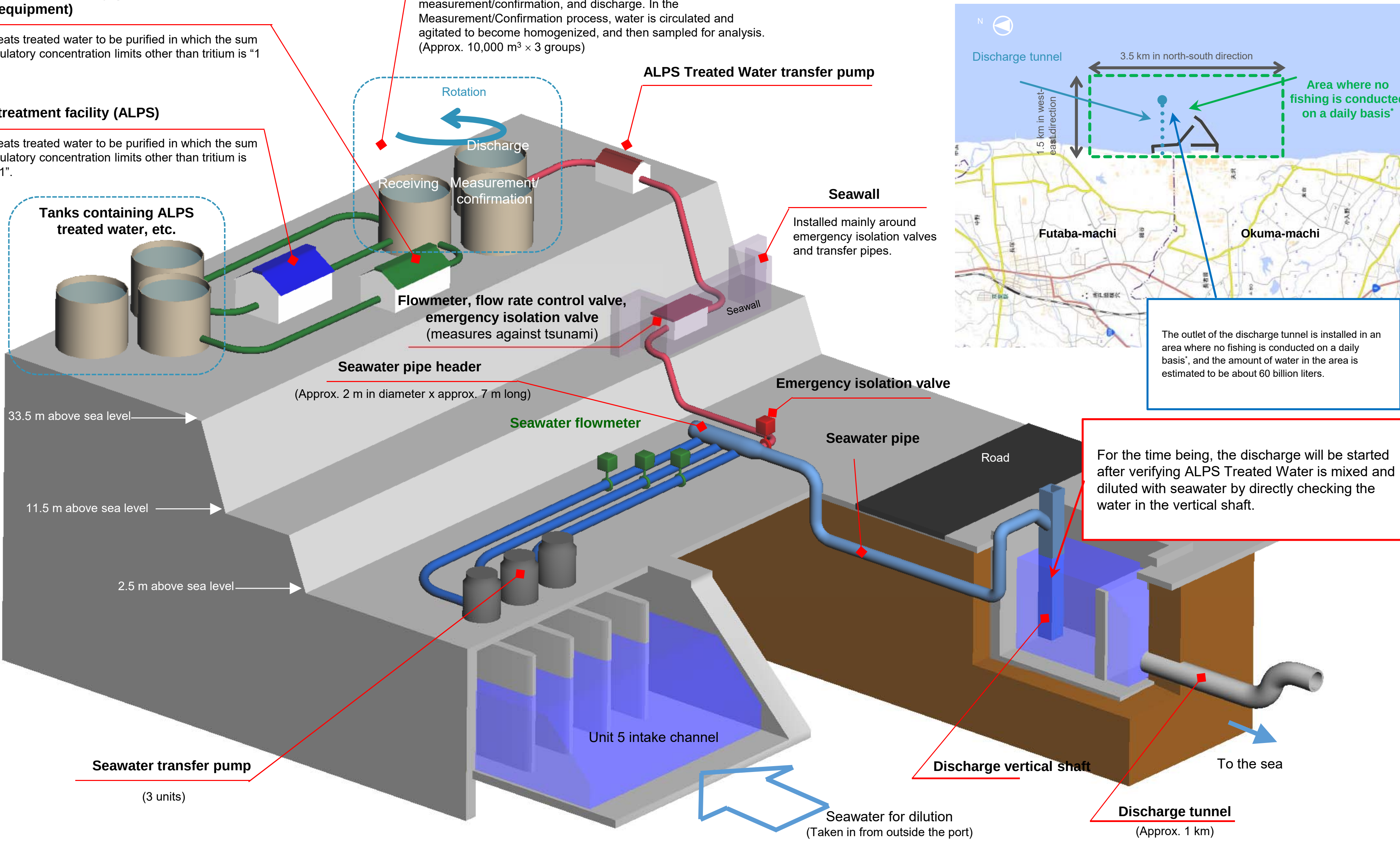
**Measurement/Confirmation facility** (K4 tank groups)

Consists of 3 groups, each of which is responsible for receiving, measurement/confirmation, and discharge. In the Measurement/Confirmation process, water is circulated and agitated to become homogenized, and then sampled for analysis. (Approx. 10,000 m³ × 3 groups)

**ALPS Treated Water transfer pump**

**Seawall**

Installed mainly around emergency isolation valves and transfer pipes.




The outlet of the discharge tunnel is installed in an area where no fishing is conducted on a daily basis*, and the amount of water in the area is estimated to be about 60 billion liters.

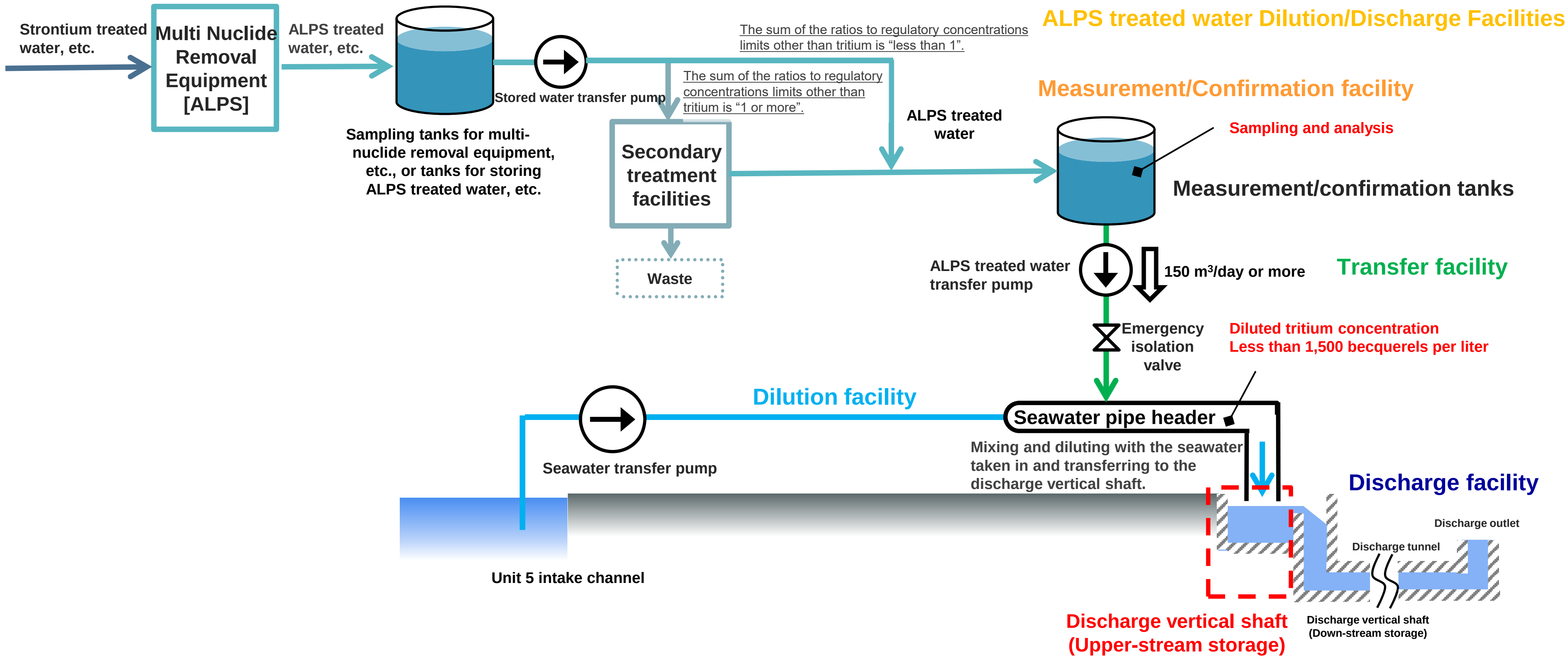
For the time being, the discharge will be started after verifying ALPS Treated Water is mixed and diluted with seawater by directly checking the water in the vertical shaft.

*Area where common fishery rights are not set.

## 3. Determination of the structure of discharge vertical shaft (upper-stream storage, down-stream storage)

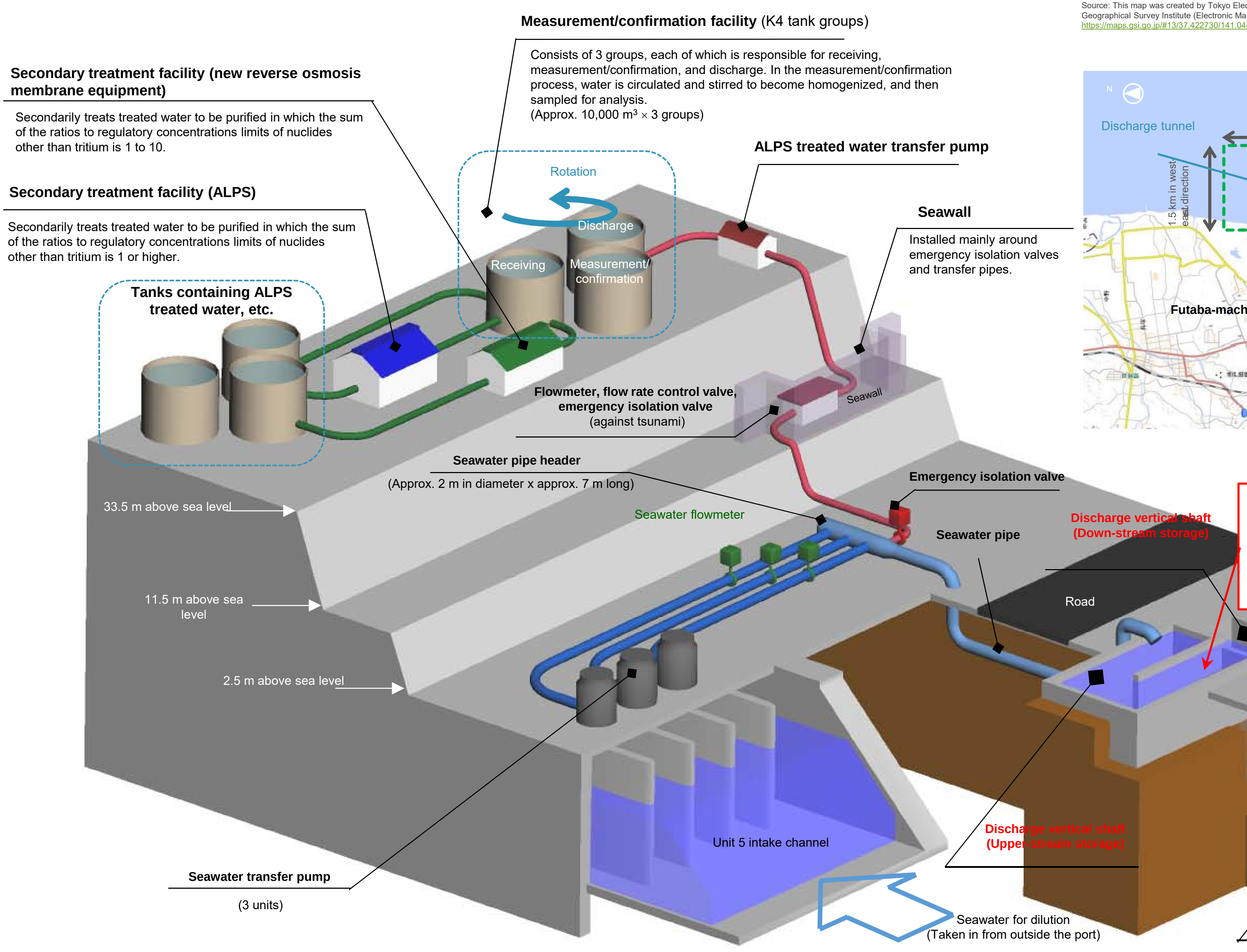
TEPCO

- Regarding a discharge vertical shaft (upper-stream storage and down-stream storage), in organizing the structure and strength, protection against natural phenomena, and reliability, the structure of the discharge vertical shaft (upper-stream storage and down-stream storage) was determined.

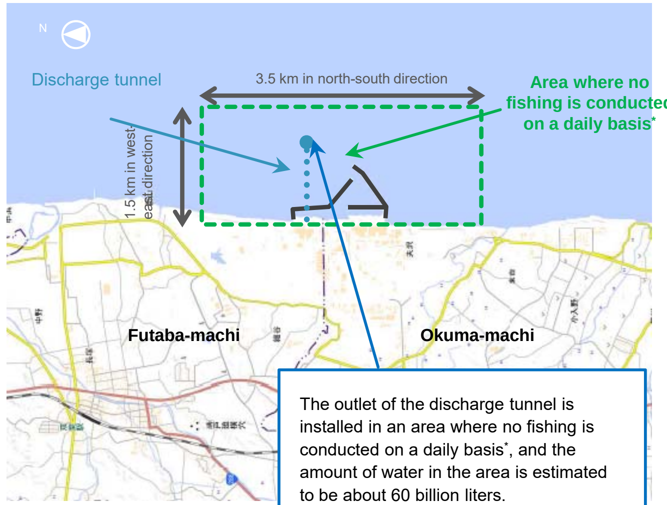


# 2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution

## 4. Overview after determining the structure of the discharge vertical shaft (upper-stream storage, down-stream storage)




Source: This map was created by Tokyo Electric Power Company Holdings, Inc. based on a map published by the Geographical Survey Institute (Electronic Map Web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1



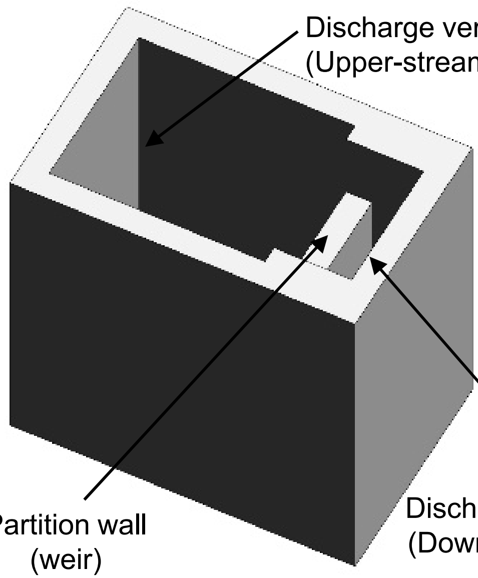
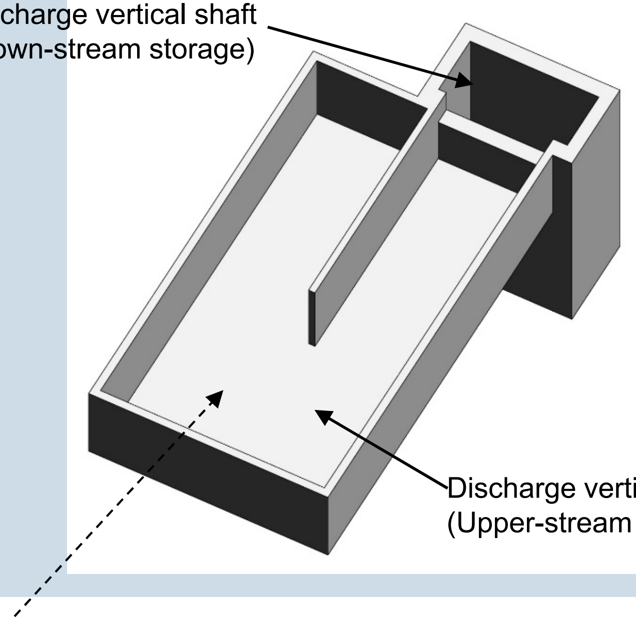

The outlet of the discharge tunnel is installed in an area where no fishing is conducted on a daily basis*, and the amount of water in the area is estimated to be about 60 billion liters.

*Area where common fishery rights are not set.

For the time being, the discharge will be started after verifying ALPS treated water is mixed and diluted with seawater by directly checking the water in the vertical shaft.

## 2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution [Supplement] Overview of the structure of the discharge vertical shaft (upper-stream storage, down-stream storage)

- Details of determining the structure of the discharge vertical shaft (upper-stream storage, down-stream storage)
  - Referring to the offshore discharge system of other power plants in the fundamental design phase, in our original plan for the discharge vertical shaft (upper-stream storage, down-stream storage) structure was planned: to install a partition wall (weir) inside the shaft for directly measuring the tritium concentration to secure a capacity (about 2,000 m$^3$) in the upper-stream.
  - Regarding the discharge vertical shaft (upper-stream storage), we reassessed the structure to be a broader, shallower tank by considering safety in construction and maintainability after being placed in service.

| | Original plan | After determining the structure |
|---|---|---|
| Structure |  |  |

*: No change was made in the original plan as for securing a capacity of about 2,000 m$^3$ for the upper-stream storage.
*: Dimensions may change within the range where there will be no impact on the structural strength.

# 2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution [Supplement] Advantages of determining the structure of discharge vertical shaft (upper-stream storage, down-stream storage)

TEPCO

- We aimed that improving the efficiency during construction/after service by determining the structure of a discharge vertical shaft (upper-stream storage, down-stream storage).

The structure of the 2,000 $m^3$ discharge vertical shaft (upper-stream storage) was determined from the following viewpoints:

1) To improve facility quality and labor-saving and enhance the safety during construction work using of precast products.
2) In considering operational aspects such as maintainability and emergency response, it is easier to maintain shallow water storage than deeper water storage as initially planned.
3) From the perspective of natural disaster countermeasures, placing water storage in front of the seawater transfer pipe (orifice flow measurement range) can reduce the risk of damage at times of storm surge and frequent tsunamis (about 2 m (about once every 10 years)). (it may be flooded but can mitigate the direct wave forces)

## Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS treated water into the sea

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

**(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)**

**(1) Discharge Facilities of ALPS Treated Water into the Sea**

**[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.**

# Design of discharge vertical shaft*

## Design of discharge vertical shaft (upper-stream storage)

## Design of discharge vertical shaft (down-stream storage)

*: This report describes the results of an examination that the design complies with the standards and criteria for general civil engineering structures and has sufficient safety, durability, earthquake resistance, etc.

## 1.1 Facility overview of discharge vertical shaft (upper-stream storage)

TEPCO

- For the vertical discharge shaft (upper-stream storage), precast products will be used to improve facility quality, labor-saving, and safety during construction work.

**Specifications of discharge vertical shaft (upper-stream storage)***

| | |
|---|---|
| Framework dimensions | Width approx. 18 m x Length approx. 37 m x Height approx. 7 m |

*: Dimensions may change within the range where there will be no impact on the structural strength.

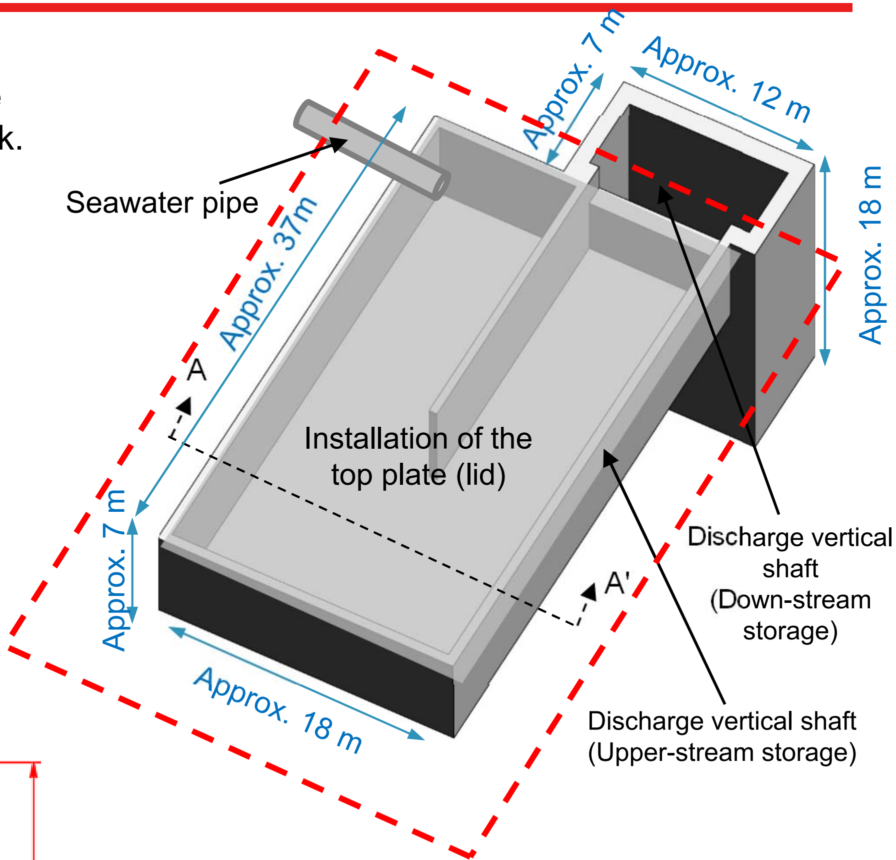
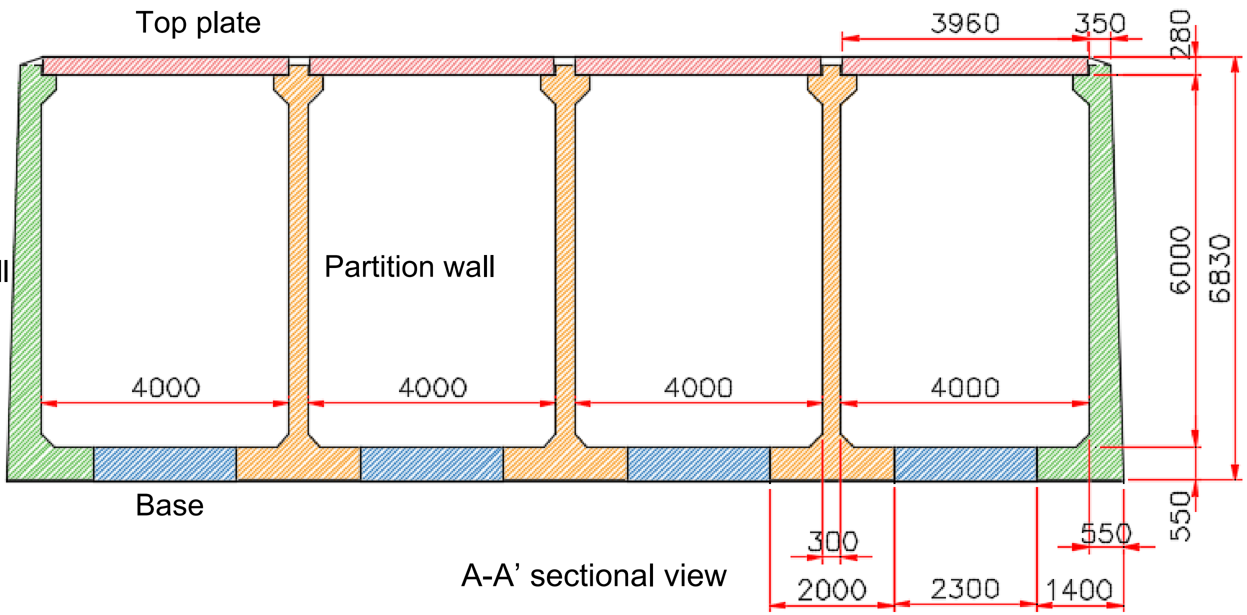



Image drawing of upper-stream and down-stream storage




A-A' sectional view

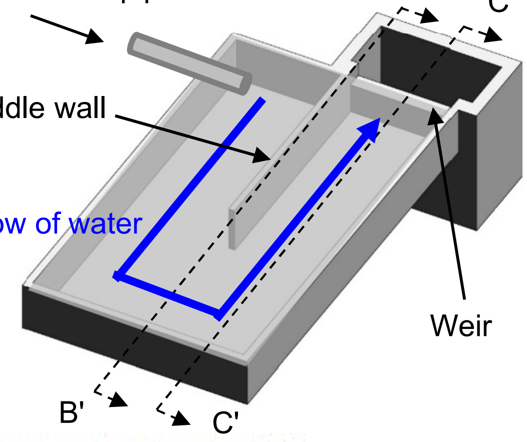
Units: mm

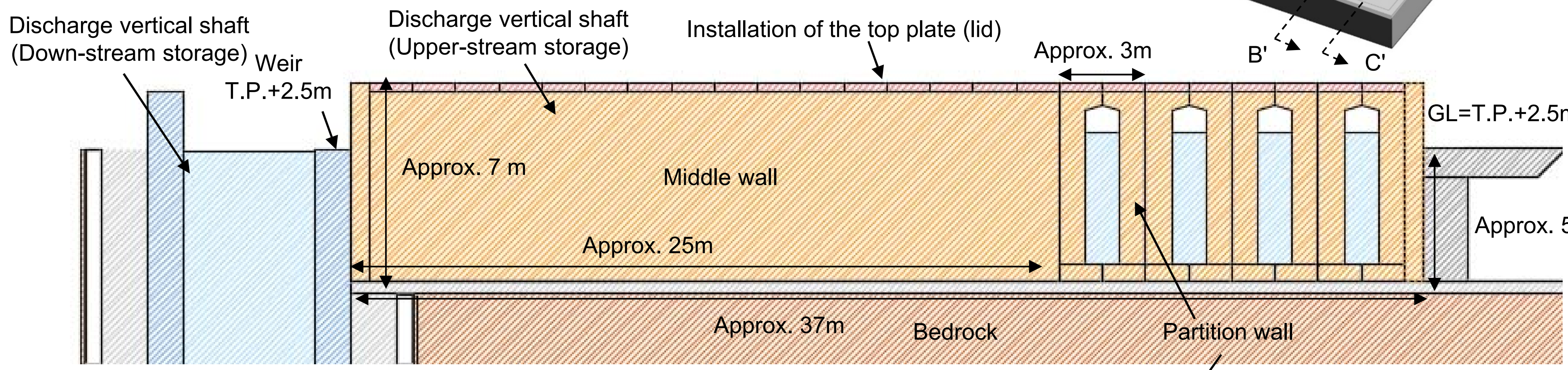
The Japanese version shall prevail.

**[Supplement] Section view of discharge vertical shaft (upper-stream storage)**

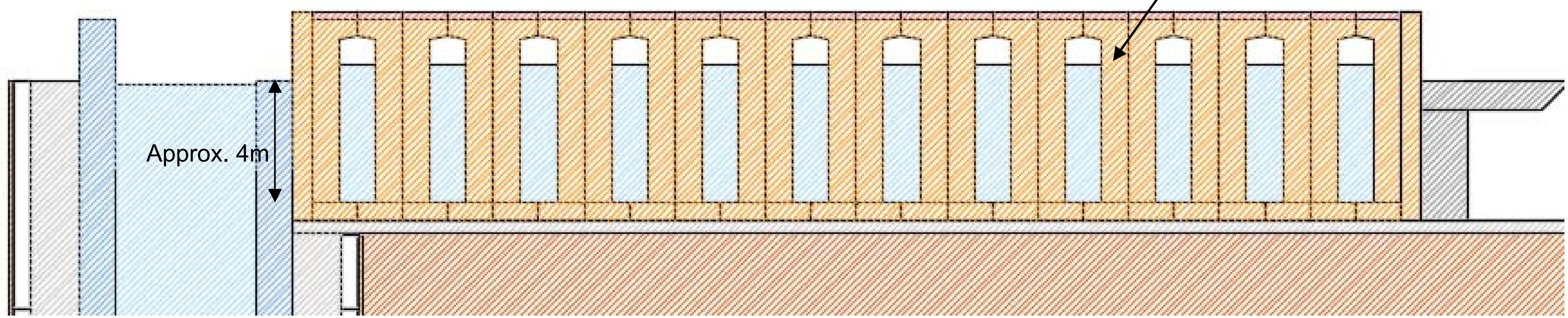
TEPCO

- A middle wall is provided in a part of the north side inside the upper-stream storage to guide the diluted water flowing from the seawater pipe to the down-stream storage.
- The water flows into the down-stream storage by overflowing the weir between the upper-stream storage and the down-stream storage.




B-B' sectional view




C-C' sectional view

**"14. Design considerations [1] Applicable standards and criteria"**

- The designing, selection of materials, manufacturing and inspections of structures, systems and components having safety functions shall comply with standards deemed appropriate to the importance of the safety functions they should perform.

- Design, selection of materials, and manufacturing are evaluated in accordance with the following:
  - Technical Manual for Precast Rainwater Underground Storage Facilities (Revised); 2020) Japan Sewerage New Technology Organization
  - Concrete Standard Specifications (Design Edition); Established in 2017), Japan Society of Civil Engineers
  - Concrete Standard Specifications (Structural Performance Examination Edition); established in 2002), Japan Society of Civil Engineers
  - Seismic Countermeasures Guideline and Explanation for Sewerage Facilities, 2014 Edition, Japan Sewerage Works Association
  - Specifications for Highway Bridges and Explanation I, Common Edition, 2012, Japan Road Association
  - Specifications for Highway Bridges and Explanation, IV, Lower Structural Edition, 2012, Japan Road Association
  - Specifications for Highway Bridges and Explanation V, Seismic Design Edition, 2012, Japan Road Association
  - Guidelines for Design and Construction of Reinforced Concrete Using Epoxy Resin-Coated Rebar (Revised edition); 2013), Japan Society of Civil Engineers
  - Common Ditch Design Guideline 1986, Japan Road Association

**“14. Design considerations [2] Design considerations for natural phenomena” (earthquakes)**

- Structures, systems, and components having safety functions shall be classified in terms of seismic design in consideration of the importance of their safety functions and the impacts on the safety the loss of their function might have in the event of an earthquake, and shall be designed to sufficiently withstand the design seismic load that is considered to be appropriate.

- The discharge vertical shaft (upper-stream storage) of the ALPS treated water Dilution/Discharge Facilities handles water that has been diluted with seawater, with the sum of the ratios to regulatory concentrations limits of all nuclides including tritium is less than 1. *Based on this, the amount of leakage at the time of loss of function of the facilities (equivalent to about 3 $m^3$ as ALPS treated water) is sufficiently smaller than that of the measurement/confirmation tanks. Accordingly, it is assumed that the impact of radiation on the public at the time of loss of function of the ALPS treated water dilution and discharge facilities can be represented by evaluating the measurement/confirmation tanks.

*When 2 or more seawater transfer pumps are operated, it is diluted 680 times or more.

- At the 6th Review Meeting, the explanation was given regarding the grounds for the appropriate seismic category classification of the ALPS treated water Dilution/Discharge Facilities as “Class C” based on the effects of the loss of the function of the measurement/confirmation tank.

*A top plate (lid) is installed to prevent overflow due to sloshing in an earthquake.

**[Evaluation method]**

✓ It should be Seismic Class “C,” and the examination should be carried out using horizontal design seismic coefficient of kh=0.2.

**"14. Design considerations [2] Design considerations for natural phenomena" (natural phenomena other than earthquakes)**

- Structures, systems, and components having safety functions shall be designed so that the safety of facilities is not impaired by postulated natural phenomena other than earthquakes (such as tsunamis, heavy rains, typhoons, tornados). Structures, systems, and components having safety functions of particularly high importance shall be designed while taking into consideration the conditions of a postulated natural phenomenon that is considered to be the severest or a case where accident loads are added to natural forces.

- Tsunami
  - Since inundation against tsunami is inevitable, specifications should be provided with wave pressure resistance according to the recoverability.
- Typhoon (storm surges)
  - The design should also take into account the effects of sea-level rise due to typhoons (storm surges).
- Snow accumulation
  - In order to protect facilities from damage caused by accumulated snow, buildings should be designed to withstand the snow load designated by the Regulations for Enforcement of Building Standard Law and Detailed Rules for Enforcement of Fukushima Prefectural Building Standard Law.

**"14. Design considerations [4] Design considerations for fire"**

- The design should be such that fire does not impair the safety of facilities by appropriately combining measures for fire prevention, fire detection, extinguishing, and reduction of the effects of fire.

- Fire (Implementation Plan: II-2-50-5)
  - In order to prevent fire occurrence, ALPS treated water Dilution/Discharge Facilities use non-flammable or flame-retardant materials as much as it is practically possible.

**[Evaluation method]**

✓ There is no concern about fire due to its RC structure.

**"14. Design considerations (8) Design considerations for reliability"**

- Structures, systems, and components with safety and monitoring functions should be designed to ensure and maintain sufficiently high reliability.

- Structure
  - The discharge vertical shaft (upper-stream storage) is grounded to bedrock so that the structure will not be easily affected by an earthquake.

- Soundness
  - The structure is established by verifying that it is within the allowable stress intensity for stationary and earthquake loads. It has also been confirmed that there is no structure uplift. In addition, the crack width and salt damage to be generated in the reinforced concrete framework are examined, and it has been confirmed that the durability during the service period is ensured by setting proper rebar cover. The reinforced concrete framework shall be designed in a conservative manner such that it does not require maintenance during the service period. (Periodic inspection is carried out based on the long-term inspection plan.)

- The discharge vertical shaft (upper-stream storage) of the ALPS treated water dilution and discharge facilities is examined as shown in the table below. It has been confirmed that its durability during its service life is ensured.

Items to be examined for the discharge vertical shaft (upper-stream storage)*

| Examination items | | Discharge vertical shaft (Upper-stream storage) | Contents of examination |
|---|---|---|---|
| At all times | Structure | ○ | It should be within allowable stress intensity.*1 |
| | Crack | ○ | The crack width should be equal to or less than the allowable crack width.*2 |
| | salt damage | ○ | Chloride ion concentration at the position of steel materials should not reach the corrosion limit of steel materials.*2 |
| | Uplift | ○ | There should be no uplift. |
| At the time of the earthquake | | ○ | It should be within allowable stress intensity against earthquakes.*3 |

*1. Safety: The stress intensity of the material caused by the action of the load should be within the allowable stress intensity.
*2. Durability: During the design service period, the performance of the structure should not deteriorate due to corrosion of steel materials caused by cracks or intrusion of chloride ions.
*3. Seismic resistance: It should be Seismic Class “C,” and the examination should be carried out using horizontal design seismic coefficient of kh=0.2.

## Stress intensity examination

- Of the materials used for the discharge vertical shaft (upper-stream storage), concrete should be ordinary concrete (Ordinary Portland Cement), and the design-basis strength should be $40N/mm^2$. The rebar should be SD345.
- Verify whether the stress intensity of the material caused by the action of the load is within the allowable stress intensity.

Allowable stress intensity of concrete

| Design basis strength of concrete | Long-term | | Short-term | |
|---|---|---|---|---|
| | Compression ($N/mm^2$) | Shear ($N/mm^2$) | Compression ($N/mm^2$) | Shear* ($N/mm^2$) |
| $40N/mm^2$ | 14.0 | 0.55 | 21.0 | 0.825 |

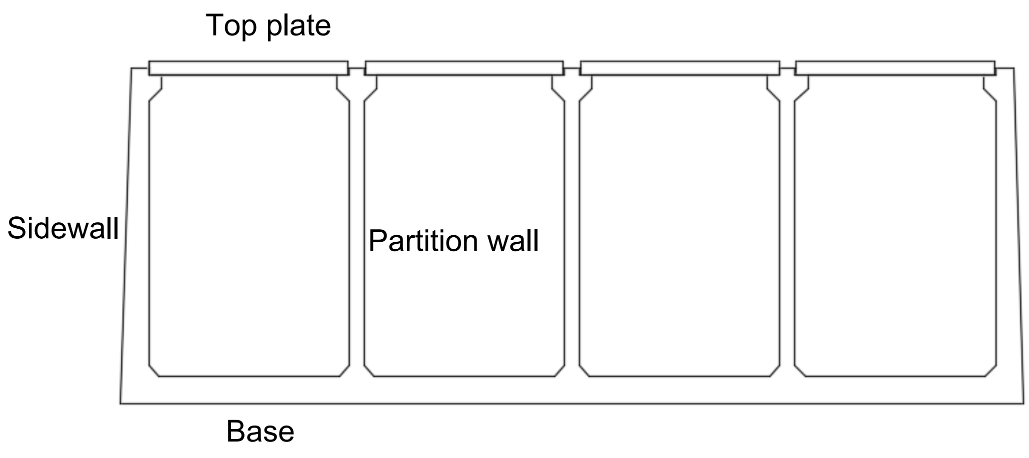
Allowable stress intensity of rebar

| Material used | Long-term | Short-term |
|---|---|---|
| | Tension ($N/mm^2$) | Tension ($N/mm^2$) |
| SD345 | 200 | 300 |

- As a result of stress intensity examination, it has been confirmed that the proof stress is ensured.

Load combination

| Load for study | At all times (long term) | At the time of the earthquake (short term) |
|---|---|---|
| Self-weight | ○ | ○ |
| Loading load | ○ | ○ |
| Earth pressure | ○ | ○ |
| Internal water pressure | ○ | ○ |
| Buoyancy | ○ | ○ |
| Seismic inertial force | | ○ |
| Dynamic water pressure | | ○ |



Areas for study

- The operating stress is compared with the allowable stress. The results of examining the part where the ratio of the operating stress to the allowable stress is maximum and the load case are shown in the table below.
- It has been confirmed that it is within the allowable stress intensity (operating stress/allowable stress intensity < 1.00) for stationary and seismic loads.

Results of stress intensity examination

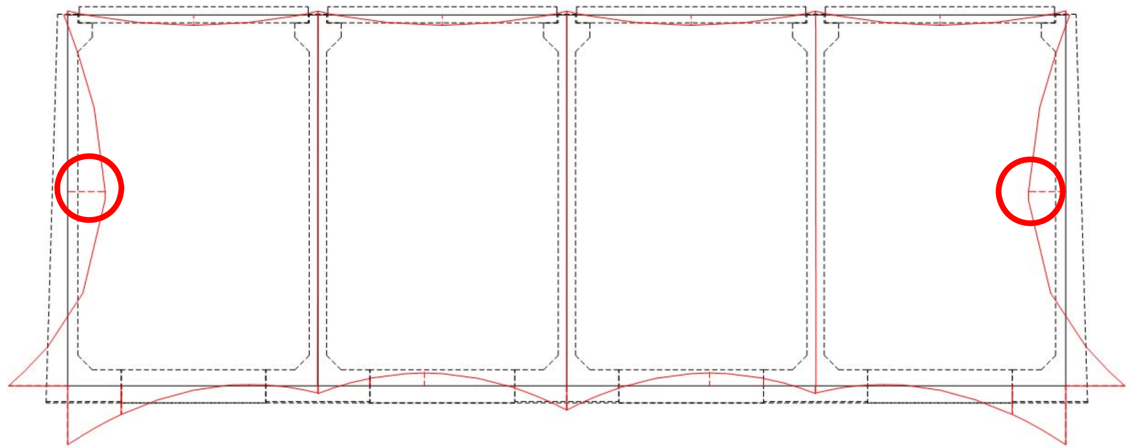
| Areas for study | Load case | Target material | Stress | Operating stress ($N/mm^2$) | Allowable stress ($N/mm^2$) | Operating stress/ Allowable stress |
|---|---|---|---|---|---|---|
| Base | At all times | Rebar | Bending moment | 75 | 200 | 0.38 |
| Sidewall | At all times | Concrete | Shear force | 0.31 | 0.55 | 0.56 |
| Partition wall | At the time of the earthquake | Rebar | Bending moment | 94 | 300 | 0.31 |
| Top plate | At all times | Concrete | Shear force | 0.15 | 0.55 | 0.27 |

## Results of examining the stress intensity at areas for study

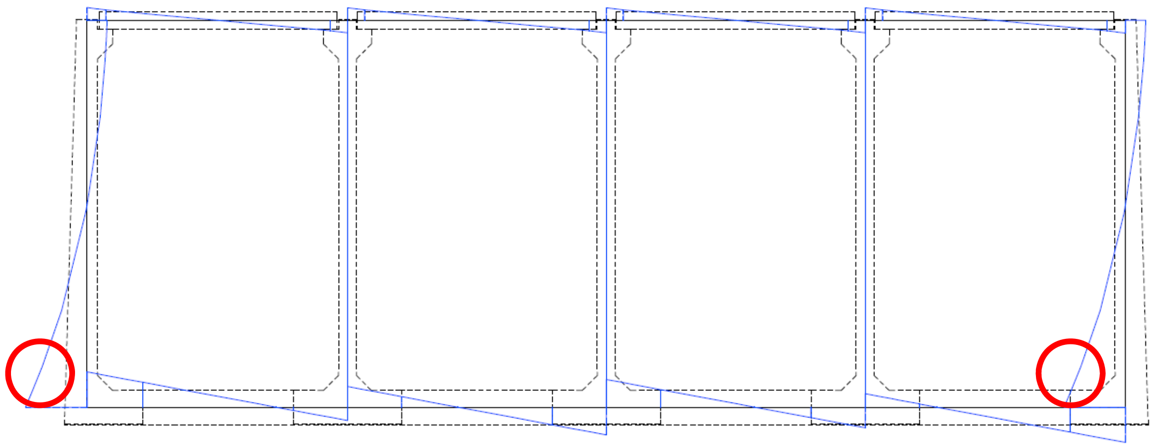
Results of stress intensity examination

| Areas for study | Examining stress intensity (Operating/Allowance) | |
|---|---|---|
| | Bending moment | Shear force |
| Base | 0.38 | 0.33 |
| Sidewall | **0.45** | **0.56** |
| Partition wall | 0.31 | 0.22 |
| Top plate | 0.22 | 0.27 |

*Red: maximum value for stress intensity examination



Section force diagram (bending moment)



Section force diagram (shear force)

○ : Examination of stress intensity, maximum position

## Examination of crack width

- The crack width is examined by the following formula to confirm that the crack width "w" of the concrete surface is equal to or less than the limit value $w_a$ of the crack width against corrosion of steel materials.

  $w / w_a \leq 1.0$

Crack Width w

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

Where:

$k_1$: Coefficient representing the effect of crack width on the surface shape of steel materials. 1.1 <u>due to the adoption of epoxy resin coated rebars</u>

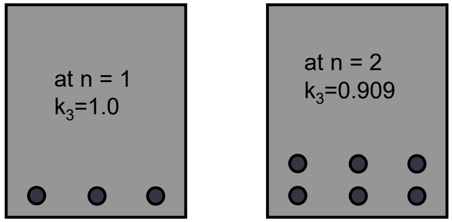
$k_2$: Coefficient by which the quality of the concrete affects the crack width based on the following formula:

$$k_2 = \frac{15}{f'_c + 20} + 0.7$$

$f'_c$: Compressive strength of concrete ($N/mm^2$), generally using design compressive strength $f'_{cd}$

$k_3$: Coefficient representing the effect of the number of stages n of tensile steel materials based on the following formula:

$$k_3 = \frac{5(n+2)}{7n+8}$$




Schematic diagram of the relationship between the number of tensile steel material stages n and $k_3$

c: Covering (mm), $c_s$: Center spacing of steel material (mm), φ: Steel material diameter (mm),
$\sigma_{se}$: Increase in stress intensity in the rebar ($N/mm^2$);
$\varepsilon'_{csd}$: Strain to take account of increase in crack width due to shrinkage and creep of concrete

(When examining the corrosion of steel materials, the value of $\varepsilon'_{csd}$ is about $150 \times 10^{-6}$.)

## salt damage examination

- Confirm that the chloride ion concentration at the position of steel materials does not reach the corrosion limiting concentration of steel materials during the design service life.
- The limit value of crack width against corrosion of steel materials is determined according to environmental conditions, covering, and type of steel materials.
- In the upper-stream storage, epoxy resin-coated rebars are used to ensure durability.
- The environmental conditions should be a particularly severe corrosive environment, and the crack width limit should be 0.0035c*1.1 (mm).

  (c: Pure covering)

| | Examination formula |
|---|---|
| Calculation formula of the design diffusion coefficient | $D_d = \gamma_c \cdot D_k + \left[\frac{w}{l}\right] \cdot \left[\frac{w}{w_a}\right]^2 \cdot D_0$ |
| Calculation formula of the chloride ion concentration design value at the position of steel materials | $C_d = \gamma_{cl} \cdot \left\{1 - erf\left(0.1 / 2\sqrt{t} \left( c / \sqrt{D_d} + c_{ep} / \sqrt{D_{epd}} \right)\right)\right\}$ |
| Examination formula of the chloride ion concentration at the position of steel materials | The design value of chloride ion concentration at the position of steel materials is equal to or less than the corrosion limiting concentration of steel materials. $\gamma_i \cdot \frac{C_d}{C_{lim}} \leq 1.0$ |

$D_d$: Design diffusion coefficient
$D_k$: Characteristic value of diffusion coefficient for chloride ion of concrete ($cm^2$/year)
$D_0$: Coefficient representing the effect of cracks on the transfer of chloride ion in concrete ($cm^2$/year). In general, it should be 200 $cm^2$/year.
w: Crack width (mm)
$w_a$: Limit value of crack width (mm) for corrosion of steel materials), $\gamma_i$: structure coefficient. In general, it is 1.0.
w/l: Ratio of crack width to crack spacing
$C_d$: Design value of the chloride ion concentration at the position of steel materials
$C_{ep}$: Expected thickness of epoxy resin coating film (mm)
$D_{epd}$: A design value ($cm^2$/year) of the apparent diffusion coefficient for chloride ions when the intrusion of chloride ions into the epoxy resin coating film is regarded as a diffusion phenomenon. In general, it is $2.0 \times 10^{-6} cm^2$/year

- As a result of examining crack width and salt damage of a discharge vertical shaft (upper-stream storage), it has been confirmed that durability during the service period is ensured.

**[Examination of crack width]**

The bending crack width generated in a discharge vertical shaft (upper-stream storage) is compared with the allowable bending crack width. The examination result of the portion where the ratio of the generated bending crack width to the allowable bending crack width is at its maximum is shown in the table below.

Examination results of crack width

| Areas for study | Generated bending crack width (mm) | Allowable bending crack width (mm) | Generated bending crack width/Allowable bending crack width |
|---|---|---|---|
| Base | 0.22 | 0.27 | 0.81 |
| Sidewall | 0.25 | 0.27 | 0.93 |
| Partition wall | 0.06 | 0.27 | 0.22 |
| Top plate | 0.15 | 0.27 | 0.56 |

**[salt damage examination]**

Chloride ion concentration in a discharge vertical shaft (upper-stream storage) is compared with the corrosion limiting concentration of rebars. The results of examining the portion where the ratio of chloride ion concentration at the position of rebars to the corrosion limiting concentration of rebars is the maximum are shown in the table below.

Results of salt damage examination

| Areas for study | Chloride ion concentration at the position of rebars ($kg/m^3$) | Corrosion limiting concentration of rebars ($kg/m^3$) | Concentration of chloride ion at the position of rebars/Corrosion limiting concentration of rebars |
|---|---|---|---|
| Base | 0.06 | 1.20 | 0.05 |
| Sidewall | 0.07 | 1.20 | 0.06 |
| Partition wall | 0.04 | 1.20 | 0.03 |
| Top plate | 0.05 | 1.20 | 0.04 |

## Examination of uplift

Uplift is examined by the following formula.

$Fs = W/U$
$U = Vw \cdot \gamma w$

U: Buoyancy (kN/m)
W: Vertical load (kN/m)
Vw: Capacity equal to or less than the underground water level ($m^3$/m)
γw: Unit weight of water (seawater) (kN/$m^3$)

Safety factor for uplift

| Applicable conditions | At all times |
|---|---|
| Uplift safety factor | 1.20 |

- As a result of checking the uplift of a discharge vertical shaft (upper-stream storage), it has been confirmed that durability during the service period is ensured.

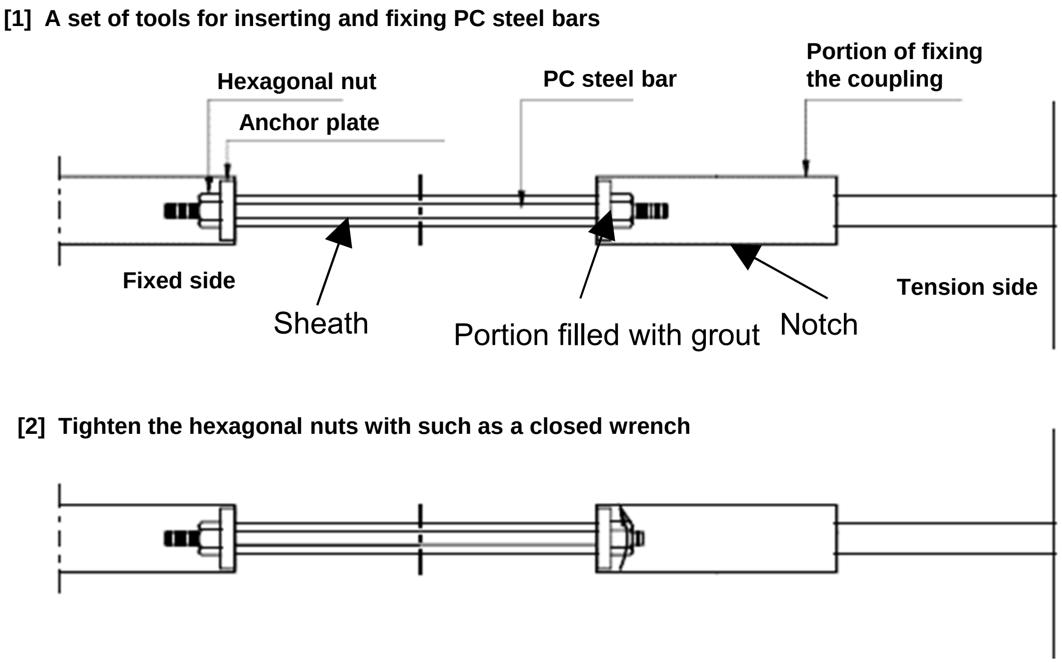
The following table shows the results of examining the uplift of a discharge vertical shaft (upper-stream storage).

Examination results for uplift

| | At all times |
|---|---|
| Calculated value | 1.48 |
| Uplift safety factor | 1.20 |

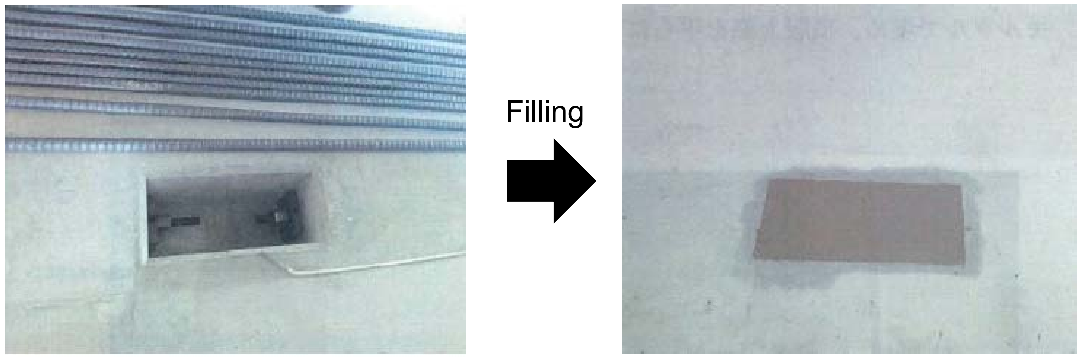
## [Supplement] Connection method between precast members

- The precast concrete (PC) members are connected by a torque coupling method. Torque coupling is common connecting PC members.
- In the notch, torque is controlled with a torque wrench, and grout is filled in a gap in the sheath to protect the steel material from rust.
- After finishing the tightening, the notch for fixing the coupling is filled with non-shrinkage mortar for protection.
- Detailed connection methods are under consideration.



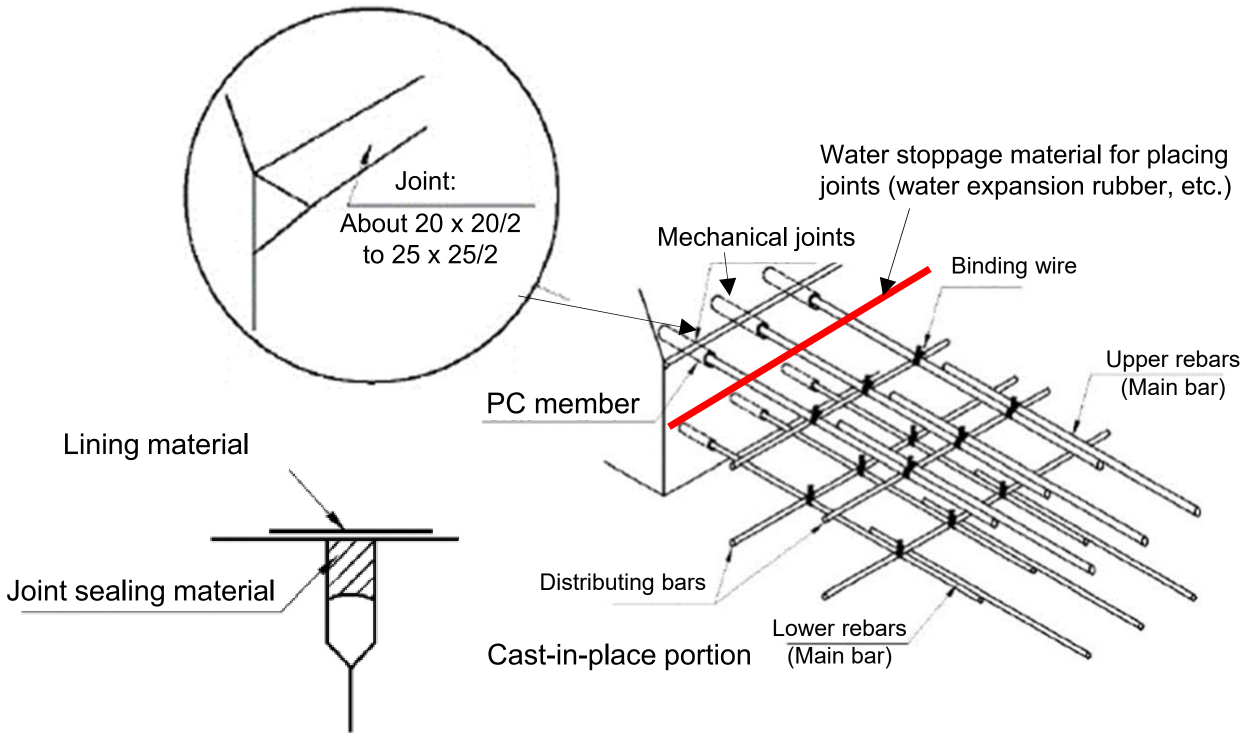

Example of torque coupling method


Example of precast product assembly




Notch filled with mortar

- The bar arrangement of the base cast-in-place portion is constituted of the main bar, a distributing bar, and a rebar joint of the body block, and it is tightly bound.
- For the rebar joint of the body block, common-use mechanical joints are adopted. The surface texturing of the PC member is carried out at the manufacturing plant in advance for the integration into the cast-in-place concrete.
- As a water cut-off measure, water stoppage materials for placing joints and joint sealants are commonly used. Detailed water cut-off methods are under investigation.




Example of mechanical joints and water stoppage measures at the base cast-in-place portion

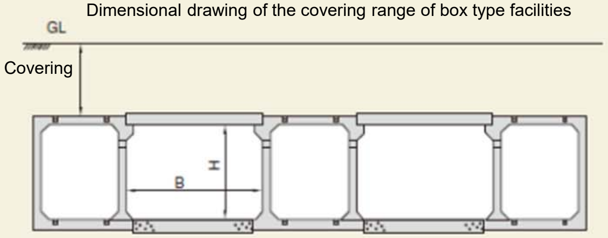
Example of construction for water cut-off measures
(Joint sealing material)

# [Supplement] Actual results of precast water tanks

- The technology of precast underground rainwater storage facilities is used.
- As a characteristic of precast products, they are superior in earthquake resistance and, as factory products, they can improve quality, shorten the construction period, and save construction labor.

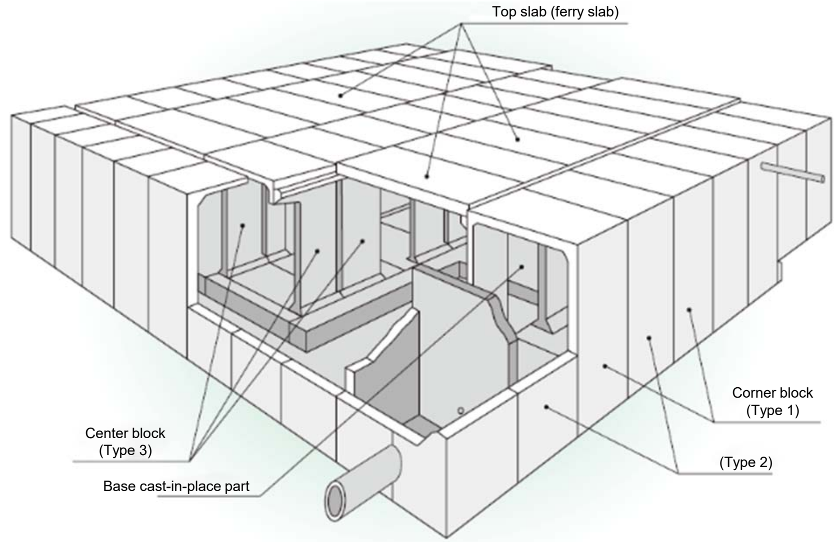
· Cover range

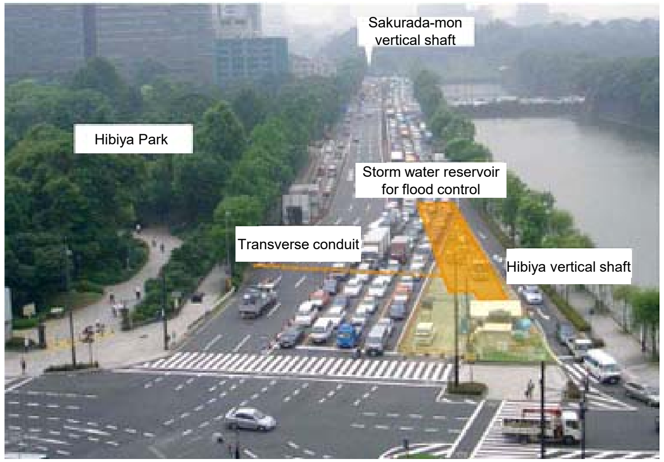
Dimensional drawing of the covering range of box type facilities




In principle, the standard installation conditions should be as follows.

(1) Load on top: q=10 kN/m$^2$.　(2) Covering range




Example of an underground water storage tank in Hibiya Park

With the cooperation between the Ministry of Land, Infrastructure, Transport and Tourism and the Tokyo Metropolitan Government Bureau of Sewerage, a precast water tank was adopted, which can shorten the construction period under the limited construction period and construction conditions of a narrow work zone.

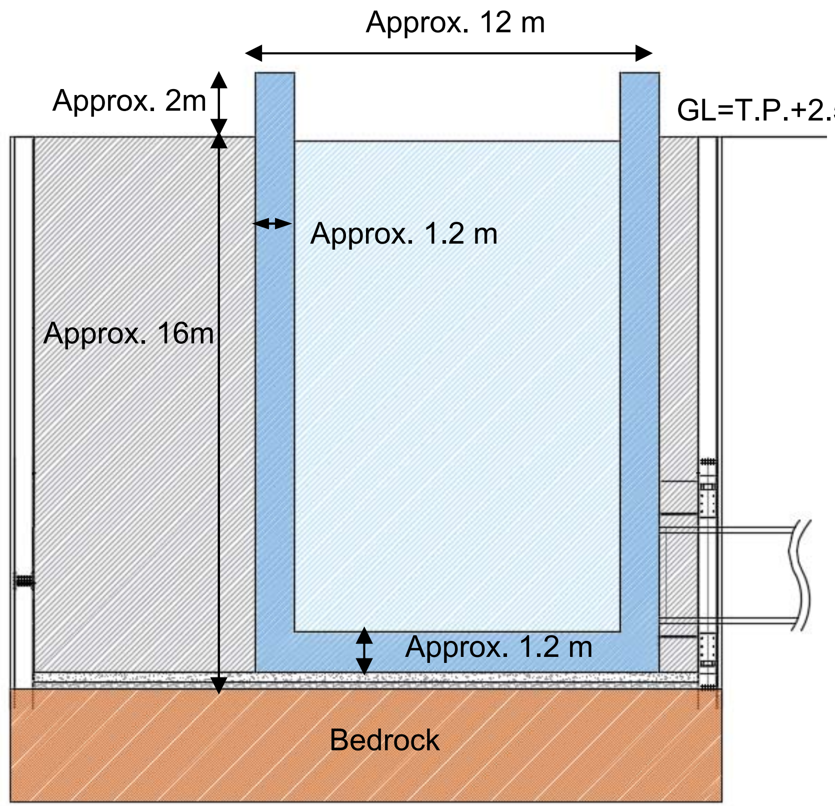
# Design of discharge vertical shaft*

## Design of discharge vertical shaft (upper-stream storage)
## Design of discharge vertical shaft (down-stream storage)

*: This report describes the results of an examination that the design complies with the standards and criteria for general civil engineering structures and has sufficient safety, durability, earthquake resistance, etc.

### Specifications of discharge vertical shaft (down-stream storage)

| | |
|---|---|
| Framework dimensions | Width approx. 7 m x Length approx. 12 m x Height approx. 18 m |




D-D' sectional view

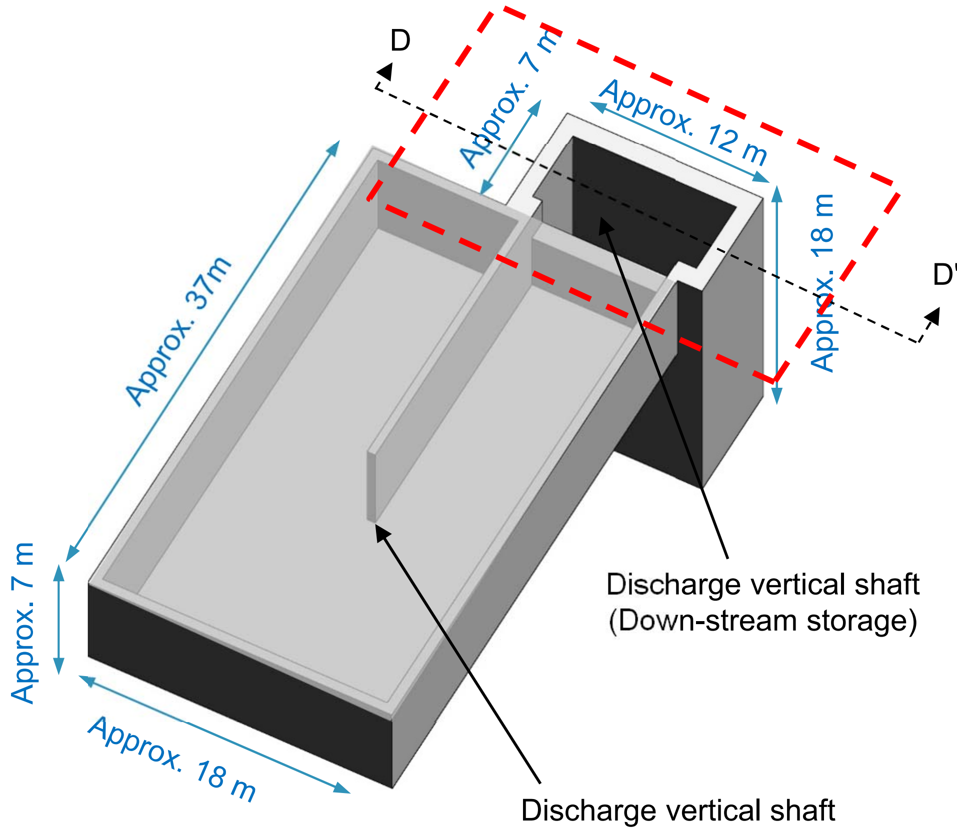



Image drawing of upper-stream and down-stream storage

# 2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.

## 2.2 Compliance assurance to the matters for which measures should be taken

**"14. Design considerations [1] Compliance and criteria"**

- The designing, selection of materials, manufacturing and inspections of structures, systems and components having safety functions shall comply with standards deemed appropriate to the importance of the safety functions they should perform.

- Design, selection of materials, and manufacturing are evaluated in accordance with the following:
  - Design of Civil Engineering Structures of Thermal and Nuclear Power Plants (enlarged and revised edition), Electric Power Civil Engineering Association
  - Concrete Standard Specifications (Design Edition); Established in 2017), Japan Society of Civil Engineers
  - Concrete Standard Specifications (Structural Performance Examination Edition); established in 2002), Japan Society of Civil Engineers*
  - Tunnel Standard Specifications [Common Edition] and Explanation/[Shield Method Edition], Explanation (established in 2016), Japan Society of Civil Engineers
  - Tunnel Standard Specification for Excavating Methods and Explanation (established in 2016)
  - Technical Standards and Explanations of Port Facilities 2018: The Ports and Harbors Association of Japan
  - Specifications for Highway Bridges and Explanation I, Common Edition, 2017, Japan Road Association
  - Specifications for Highway Bridges and Explanation IV, lower structure edition, 2017, Japan Road Association
  - Common Ditch Design Guideline 1986, Japan Road Association

*Red: Applied to design discharge vertical shaft (down-stream storage).

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

The Japanese version shall prevail.

Page 55 revised of document 1-1, the 3rd Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

**"14. Design considerations [2] Design considerations for natural phenomena" (earthquakes)**

- Structures, systems, and components having safety functions shall be classified in terms of seismic design in consideration of the importance of their safety functions and the impacts on the safety the loss of their function might have in the event of an earthquake, and shall be designed to sufficiently withstand the design seismic load that is considered to be appropriate.

➢ Based on the fact that discharge facilities will treat the drainage water from ALPS treated water Dilution/Discharge Facilities (water diluted with seawater and in which the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1), the facilities are classified as Seismic Class "C" due to the impact of radiation on the public due to loss of functions of facilities.

(Implementation Plan: II-2-50-Attachment 5-1)

➢ The validity of the classification as the Seismic Class "C" has been explained at the 6th review meeting.

**[Evaluation method]**

✓ It should be Seismic Class "C," and the examination should be carried out using horizontal design seismic coefficient of kh=0.2.

## 2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.

### 2.2 Compliance assurance to the matters for which measures should be taken

**"14. Design considerations [2] Design considerations for natural phenomena" (natural phenomena other than earthquakes)**

- Structures, systems, and components having safety functions shall be designed so that the safety of facilities is not impaired by postulated natural phenomena other than earthquakes (tsunami, heavy rain, typhoon, tornado, etc.). Structures, systems, and components having safety functions of particularly high importance shall be designed while taking into consideration the conditions of a postulated natural phenomenon that is considered to be the severest or a case where accident loads are added to natural forces.

- Tsunami (Implementation Plan: II-2-50-8)
  - Since inundation against tsunami is inevitable, specifications should be provided with wave pressure resistance according to the recoverability.
- Typhoon (storm surges) (Implementation Plan: II-2-50-8)
  - The design should also take into account the effects of sea-level rise due to typhoons (storm surges).

**"14. Design considerations [4] Design considerations for fire"**

- The design should be such that fire does not impair the safety of facilities by appropriately combining measures for fire prevention, fire detection, extinguishing, and reduction of the effects of fire.

■ Fire (Implementation Plan: II-2-50-8)

- ➢ To avoid fire occurrence, non-flammable or flame-retardant material should be used as much as it is practically possible. The fire risk is extremely low because the inside of the facilities is filled with seawater.

**[Evaluation method]**

✓ There is no concern about fire due to its RC structure.

**"14. Design considerations (8) Design considerations for reliability"**

- Structures, systems, and components with safety and monitoring functions should be designed to ensure and maintain sufficiently high reliability.

- Fire (Implementation Plan: II-2-50-7)
  - Discharge facility are grounded to bedrock so that the structure will not be easily affected by an earthquake. The discharge tunnel is to be installed inside the bedrock. The shield method is adopted in consideration of the risk of advancing the seabed and its durability during the service period. Water cut-off performance is secured by providing a sealing material on a lining plate made of reinforced concrete constituting a discharge tunnel.

- Considerations for integrity (Implementation Plan: II 2-50-7)
  - The structure is established by confirming that it is within the allowable stress intensity for stationary, wave, and earthquake loads. It has also been confirmed that there is no structure uplift. In addition, the crack width and salt damage to be generated in the reinforced concrete framework are examined, and it has been confirmed that the durability during the service period is ensured by setting proper rebar cover. The reinforced concrete framework shall be designed in a conservative manner such that it does not require maintenance during the service period. (Periodic inspection is carried out based on the long-term inspection plan.)

*Red: Applied to design discharge vertical shaft (down-stream storage).

## 2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.
## 2.2 Compliance assurance to the matters for which measures should be taken

"14. Design Considerations (8) Design considerations for reliability" (continued)

- By examining discharge facilities as per the below table, it has been confirmed that durability during the service period will be ensured.

Examination items for discharge facilities

| Examination items | | Discharge vertical shaft (Down-stream storage) | Discharge tunnel | Discharge outlet | Contents of examination |
|---|---|---|---|---|---|
| At all times | Structure | ○ | ○ | ○ | It should be within allowable stress intensity.*1 |
| | Structure (High wave) | | | ○ | It should be within allowable stress intensity.*1 |
| | Crack | ○ | ○ | ○ | The crack width should be equal to or less than the allowable crack width.*2 |
| | salt damage | ○ | ○ | ○ | Chloride ion concentration at the position of steel materials should not reach the corrosion limit of steel materials.*2 |
| | Uplift | ○ | | ○ | There should be no uplift. |
| At the time of the earthquake | | ○ | ○ | ○ | It should be within allowable stress intensity against earthquakes.*3 |

*1. Safety: The stress intensity of the material caused by the action of the load should be within the allowable stress intensity.
*2. Durability: During the design service period, the performance of the structure should not deteriorate due to corrosion of steel materials caused by cracks or intrusion of chloride ions.
*3. Seismic resistance: It should be Seismic Class "C," and the examination should be carried out using horizontal design seismic coefficient of kh=0.2.

TEPCO

# 2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.
## 2.2 Compliance assurance to the matters for which measures should be taken (allowable stress intensity of primary materials)

■ Stress intensity examination

- Of the materials used for the discharge facilities, concrete should be ordinary concrete (Ordinary Portland Cement, blast furnace cement B type), and the design-basis strength should be 24N/mm², 30N/mm², and 42N/mm². The rebar should be SD345.
- Verify whether the stress intensity of the material caused by the action of the load is within the allowable stress intensity.

*Red: Applied to design discharge vertical shaft (down-stream storage).

Allowable stress intensity of concrete

| Design basis strength of concrete | Long-term | | Short-term | | Remarks |
|---|---|---|---|---|---|
| | Compression (N/mm²) | Shear (N/mm²) | Compression (N/mm²) | Shear* (N/mm²) | |
| 24N/mm² | 9.0 | 0.45 | 13.5 | 0.675 | Discharge vertical shaft (Down-stream storage) |
| 30N/mm² | 11.0 | 0.50 | 16.5 | 0.75 | Discharge outlet |
| 42N/mm² | 16.0 | 0.73 | 24.0 | 1.095 | Discharge tunnel |

Allowable stress intensity of rebar

| Material used | Long-term | Short-term |
|---|---|---|
| | Tension (N/mm²) | Tension (N/mm²) |
| SD345 | 200 | 300 |

The Japanese version shall prevail.

## 2.2 Compliance assurance to the matters for which measures should be taken (results of stress intensity examination (1))

TEPCO

- As a result of stress intensity examination, it has been confirmed that the proof stress is ensured.

Load combination

| Load for study | At all times | At the time of the earthquake |
|---|---|---|
| Self-weight | ○ | ○ |
| Ground surface load | ○ | |
| Lateral pressure | ○ | ○ |
| Uplift pressure | ○ | ○ |
| Internal water pressure | ○ | ○ |
| Inertial force | | ○ |
| Dynamic water pressure | | ○ |

- The operating stress is compared with the allowable stress. The results of examining the part where the ratio of the operating stress to the allowable stress is maximum and the load case are shown in the table below.
- It has been confirmed that it is within the allowable stress intensity (operating stress/allowable stress intensity < 1.00) for stationary and seismic loads.

Results of stress intensity examination

| Areas for study | Load case | Target material | Stress | Operating stress ($N/mm^2$) | Allowable stress ($N/mm^2$) | Operating stress/Allowable stress |
|---|---|---|---|---|---|---|
| Base | At all times | Rebar | Bending moment | 98.0 | 200 | 0.49 |
| Sidewall | At all times | Rebar | Bending moment | 148.3 | 200 | 0.74 |

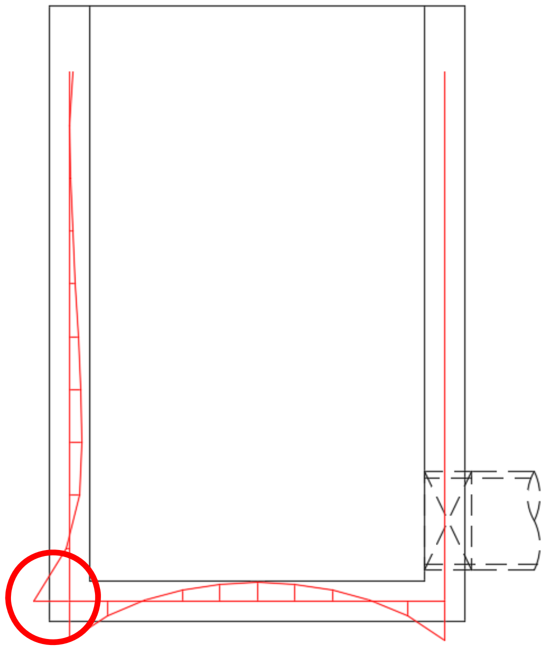
## Results of examining the stress intensity at areas for study

Results of stress intensity examination

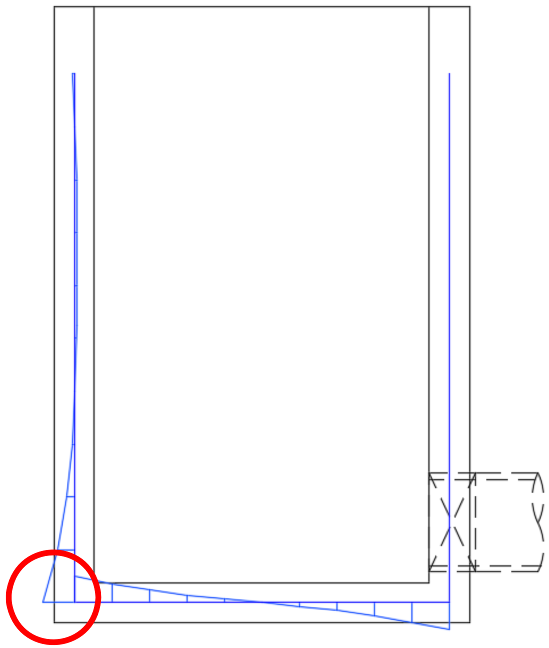
| Areas for study | Examining stress intensity (Operating/Allowance) | |
|---|---|---|
| | Bending moment | Shear force |
| **Base** | 0.49 | -* |
| **Sidewall** | **0.74** | -* |

*Red: maximum value for stress intensity examination

*Regarding the evaluation of shear force, the operating stress exceeds the allowable stress; however, the proof stress is secured by arranging shear reinforcing bars. (Compliance to the Concrete Standard Specifications (Structural Performance Examination Edition); Established in 2002) by Japan Society of Civil Engineers)



Section force diagram (bending moment)



Section force diagram (shear force)

○ : Examination of stress intensity, maximum position

## Examination of crack width

- The crack width is examined by the following formula to confirm that the crack width "w" of the concrete surface is equal to or less than the limit value $w_a$ of the crack width against corrosion of steel materials.

  $w / w_a \leq 1.0$

Crack Width w

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

Where:

$k_1$: Coefficient representing the effect of crack width on the surface shape of steel materials. In general, it is 1.0 for deformed bars.

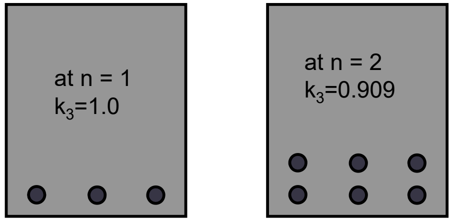
$k_2$: Coefficient by which the quality of the concrete affects the crack width based on the following formula:

$$k_2 = \frac{15}{f'_c + 20} + 0.7$$

$f'_c$: Compressive strength of concrete ($N/mm^2$), generally using design compressive strength $f'_{cd}$

$k_3$: Coefficient representing the effect of the number of stages n of tensile steel materials based on the following formula:

$$k_3 = \frac{5(n+2)}{7n+8}$$




Schematic diagram of the relationship between the number of tensile steel material stages n and $k_3$

c: Covering (mm), $c_s$: Center spacing of steel material (mm), φ: Steel material diameter (mm),

$\sigma_{se}$ : Increase in stress intensity in the rebar ($N/mm^2$);

$\varepsilon'_{csd}$: Strain to take account of increase in crack width due to shrinkage and creep of concrete

(When examining the corrosion of steel materials, the value of $\varepsilon'_{csd}$ is about $150 \times 10^{-6}$.)

**2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.**

**2.2 Compliance assurance to the matters for which measures should be taken (durability evaluation (salt damage))**

TEPCO

## salt damage examination

- Confirm that the chloride ion concentration at the position of steel materials does not reach the corrosion limiting concentration of steel materials during the design service life.
- The limit value of crack width against corrosion of steel materials is determined according to environmental conditions, covering, and type of steel materials.
- The crack width limit should be 0.005 c* (mm). (c: Pure covering)

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

| | Examination formula |
|---|---|
| Calculation formula of the design diffusion coefficient | $D_d = \gamma_c \cdot D_k + \lambda \cdot \left(\frac{w}{l}\right) \cdot D_0$ |
| Calculation formula of the chloride ion concentration design value at the position of steel materials | $C_d = \gamma_{cl} \cdot C_0 \cdot \left\{1 - erf\left(\frac{0.1 \cdot C_d}{2 \cdot \sqrt{D_d \cdot t}}\right)\right\} + C_i$ |
| Examination formula of the chloride ion concentration at the position of steel materials | The design value of chloride ion concentration at the position of steel materials is equal to or less than the corrosion limiting concentration of steel materials. $\gamma_i \cdot \frac{C_d}{C_{lim}} \leq 1.0$ |

$D_d$: Design diffusion coefficient
$D_k$: Characteristic value of diffusion coefficient for chloride ion of concrete ($cm^2$/year)
$D_0$: Coefficient representing the effect of cracks on the transfer of chloride ion in concrete ($cm^2$/year). ~~In general, it is 200 $cm^2$/year.~~
w: Crack width (mm)
$w_a$: Limit value of crack width for corrosion of steel materials (mm)
w/l: Ratio of crack width to crack spacing
$C_d$: Design value of the chloride ion concentration at the position of steel materials
γi: Structure coefficient In general, it is 1.0.

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan
400 $cm^2$/year

The Japanese version shall prevail.

- Results of examining crack width and salt damage of a discharge vertical shaft (down-stream storage) revealed that the durability during the service period is ensured.

**[Examination of crack width]**
The bending crack width generated in a discharge vertical shaft (down-stream storage) is compared with the allowable bending crack width. The examination result of the portion where the ratio of the generated bending crack width to the allowable bending crack width is maximum is shown in the table below.

Examination results of crack width

| Areas for study | Generated bending crack width (mm) | Allowable bending crack width (mm) | Generated bending crack width/Allowable bending crack width |
|---|---|---|---|
| Base | 0.34 | 0.50 | 0.68 |
| Sidewall | 0.39 | 0.50 | 0.78 |

**[salt damage examination]**
Comparing chloride ion concentration in a discharge vertical shaft (down-stream storage) with the corrosion limiting concentration of rebars, the examined results on the maximum position of rebars where the ratio of chloride ion concentration at the position of rebars to the corrosion limiting concentration of rebars are shown in the table below.

Results of salt damage examination

| Areas for study | Chloride ion concentration at the position of rebars ($kg/m^3$) | Corrosion limiting concentration of rebars ($kg/m^3$) | Concentration of chloride ion at the position of rebars/Corrosion limiting concentration of rebars |
|---|---|---|---|
| Base | 0.94 | 1.84 | 0.51 |
| Sidewall | 1.66 | 1.84 | 0.90 |

## Examination of uplift

Uplift is examined by the following formula.

Fs = W/U
U = Vw • γw

U: Buoyancy (kN)
W: Vertical load (kN/m)
Vw: Capacity equal to or less than the underground water level ($m^3$)
γw: Unit weight of water (seawater) ($kN/m^3$)

Safety factor for uplift

| Applicable conditions | At all times |
|---|---|
| Uplift safety factor | 1.20 |

- As a result of examining the uplift of a discharge vertical shaft (down-stream storage), it has been confirmed that durability during the service period is ensured.

The following table shows the results of examining the uplift of a discharge vertical shaft (down-stream storage).

Examining results against uplift

| | At all times |
|---|---|
| **Calculated value** | 1.68 |
| **Uplift safety factor** | 1.20 |

The following slides are for reference.

# [Reference] Required function of the ALPS treated water Dilution/Discharge Facilities

[1] The discharge capacity into the sea must be larger than the amount of contaminated water generated (increase due to inflow of groundwater and rainwater).

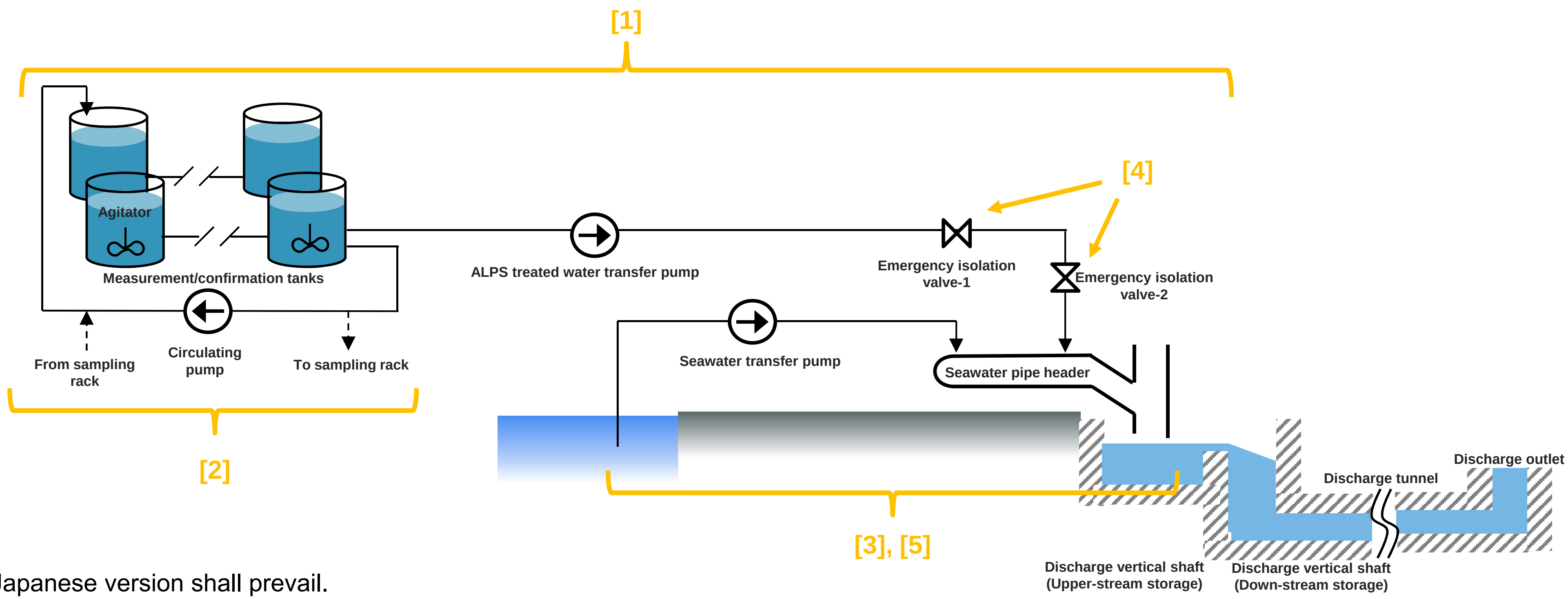
[2] To ensure that the undiluted water before discharge is ALPS treated water, the facilities must be able to homogenize the concentration of radioactive materials in a tank and a tank group and collect samples.

[3] The facilities must dilute ALPS treated water with seawater and discharge it into the sea.

[4] The facilities must be equipped with functions to immediately stop the discharge of ALPS treated water into the sea in the event of an abnormality.

[5] The facilities must be capable of diluting ALPS treated water 100 times or more with seawater so that the tritium concentration in the diluted water becomes sufficiently below the regulatory concentration limit (60,000 Bq/L).

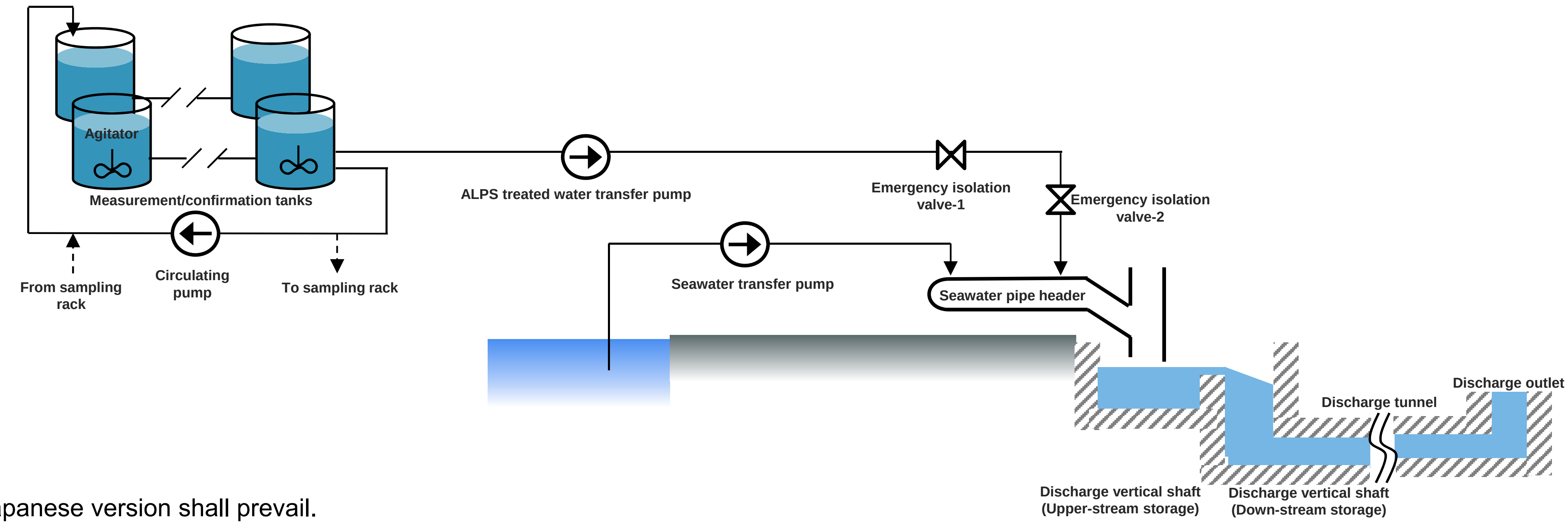
(Implementation Plan: II-2-50-1)



# [Reference] Required functions of the discharge facilities (1/2)

[1] The facilities must be able to discharge the water from the ALPS treated water Dilution/Discharge Facilities (water diluted with seawater so that the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1) into the sea from a location approx. 1 km away from the coast.

(Implementation Plan: II-2-50-7)



# [Reference] Overview of the ALPS treated water Dilution/Discharge Facilities

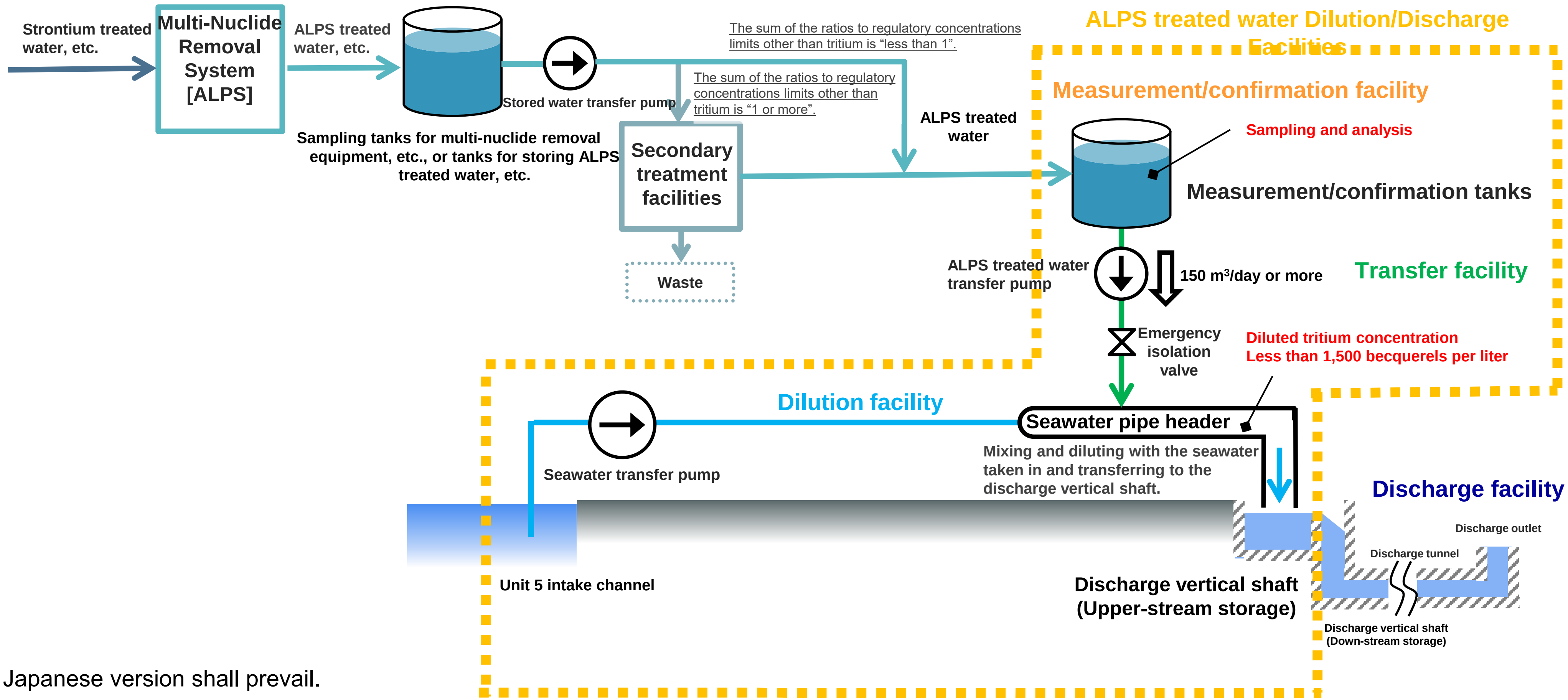


## Objective

The facilities ensure that the water treated by multi-nuclide removal equipment until the radionuclide concentration becomes sufficiently low is the ALPS treated water (water in which the sum of the ratios to regulatory concentrations limits of nuclides other than tritium is less than 1), dilute the treated water with seawater, and then discharge it into the sea.

## Facilities Overview

The Measurement/Confirmation Facility homogenizes the concentration of radionuclides all tanks of the tank group in the status of measurement/ confirmation, and then collects and analyzes samples to ensure that the water is ALPS treated water. Thereafter, the Transfer Facility sends the ALPS Treated Water to the seawater pipe header, and then the Dilution Facility dilutes the water with seawater taken in by the seawater transfer pump at the unit 5 intake channel until tritium concentration in it becomes less than 1,500 Bq/L, and discharge the water to the Discharge Facility.




The Japanese version shall prevail.

TEPCO

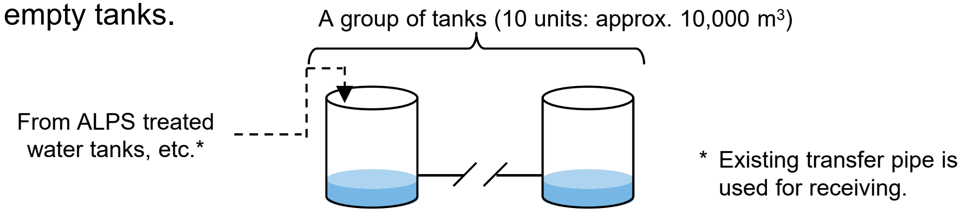
# [Reference] Overview of the ALPS treated water Dilution/Discharge Facilities (Measurement/confirmation facility)

## Measurement/confirmation facility

- K4 area tanks (approx. 30,000 $m^3$ in total) are reused for the measurement/confirmation tanks, and each group from A to C consists of 10 tanks (approximately 1,000 m3 per unit).
- Each tank group takes the following steps (1) to (3) in rotation, and in the (2) measurement/confirmation process, water is circulated and stirred to become homogenized, and then sampled for analysis.

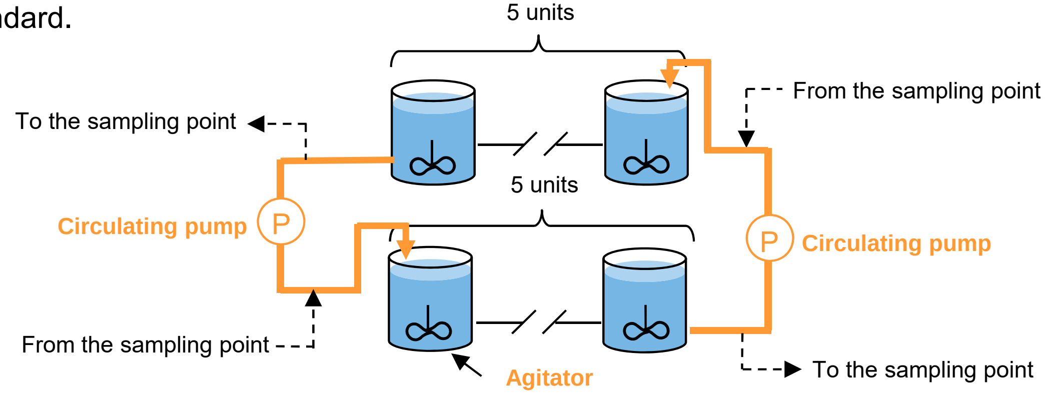
(1) Receiving process

ALPS treated water from ALPS treated water storage tanks, etc., is transferred into a group of empty tanks.



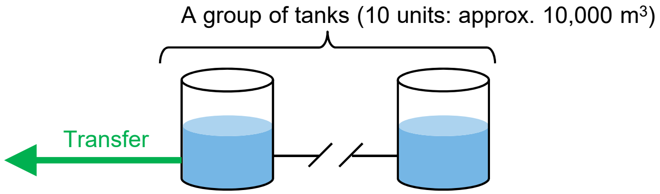

(2) Measurement/Confirmation process

After the quality of water in the tank group is homogenized by the agitation equipment and circulation pumps, the water is sampled to check if it meets the discharge standard.

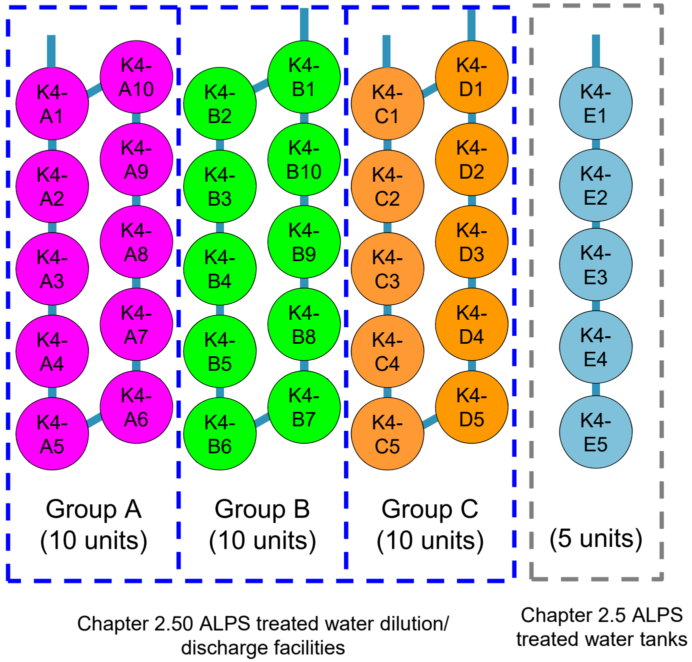



(3) Discharge process

After confirming that the ALPS treated water satisfies the discharge standard, the water is transferred to the Dilution facility by the Transfer facility.




K4 area tank groups: 35 tanks



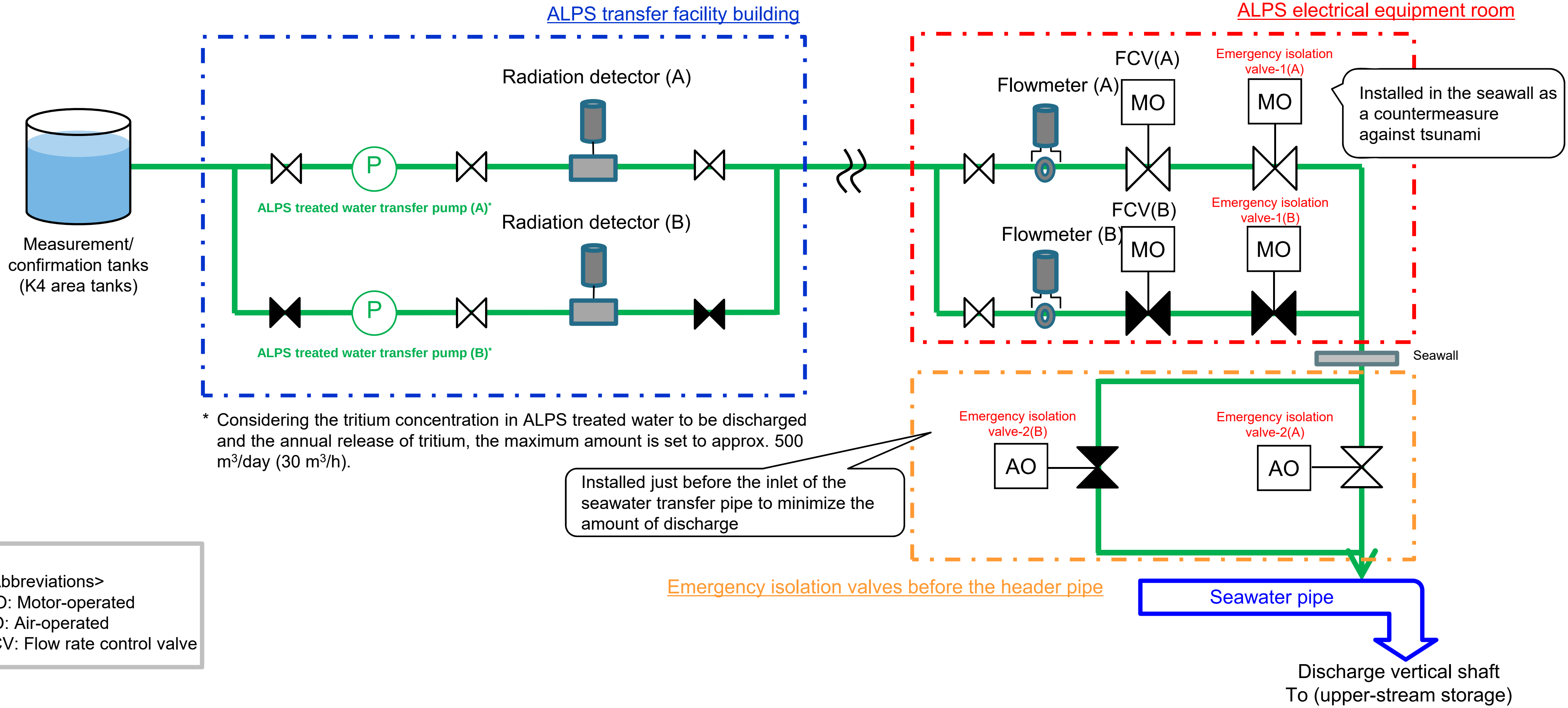

| | Group A | Group B | Group C |
|---|---|---|---|
| 1st cycle | Receiving | - | - |
| 2nd cycle | Measurement/ confirmation | Receiving | - |
| 3rd cycle | Discharge | Measurement/ confirmation | Receiving |
| 4th cycle | Receiving | Discharge | Measurement/ confirmation |
| … | Measurement/ confirmation | Receiving | Discharge |

# [Reference] Overview of the ALPS treated water Dilution/Discharge Facilities (Transfer facility)

TEPCO

## Transfer facility

- The Transfer facility consist of ALPS treated water transfer pumps and transfer pipes.
- Two ALPS treated water transfer pumps are prepared, a unit in operation and a backup unit, to transfer ALPS treated water from measurement/confirmation tanks to the Dilution facility.
- Emergency isolation valves are provided both before the seawater pipe header and in the seawall as a countermeasure against tsunami so that the transfer can be stopped immediately when an abnormality occurs.



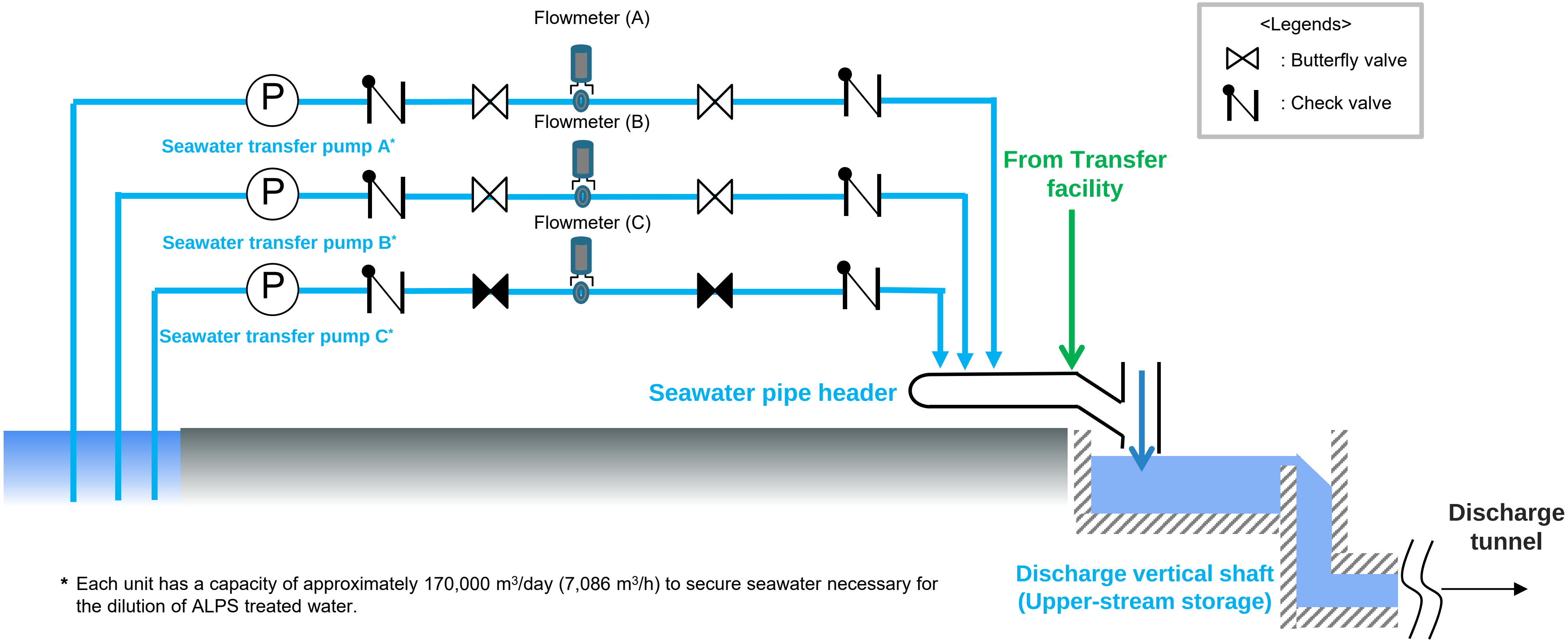

* Considering the tritium concentration in ALPS treated water to be discharged and the annual release of tritium, the maximum amount is set to approx. 500 $m^3$/day (30 $m^3$/h).

<Abbreviations>
MO: Motor-operated
AO: Air-operated
FCV: Flow rate control valve

# [Reference] Overview of the ALPS treated water dilution/discharge facilities (Dilution facility)

## Dilution facility

- Consisting of seawater transfer pumps, seawater pipes (including a header pipe), a discharge guide, and a discharge vertical shaft (upper-stream storage), the Dilution facility dilute ALPS treated water with seawater, transfer it to the discharge vertical shaft (upper-stream storage), and discharge it to the discharge facilities.
- The seawater transfer pumps have a capacity that can dilute ALPS treated water transferred by the Transfer facility 100 times or more.




* Each unit has a capacity of approximately 170,000 $m^3$/day (7,086 $m^3$/h) to secure seawater necessary for the dilution of ALPS treated water.

The Japanese version shall prevail.

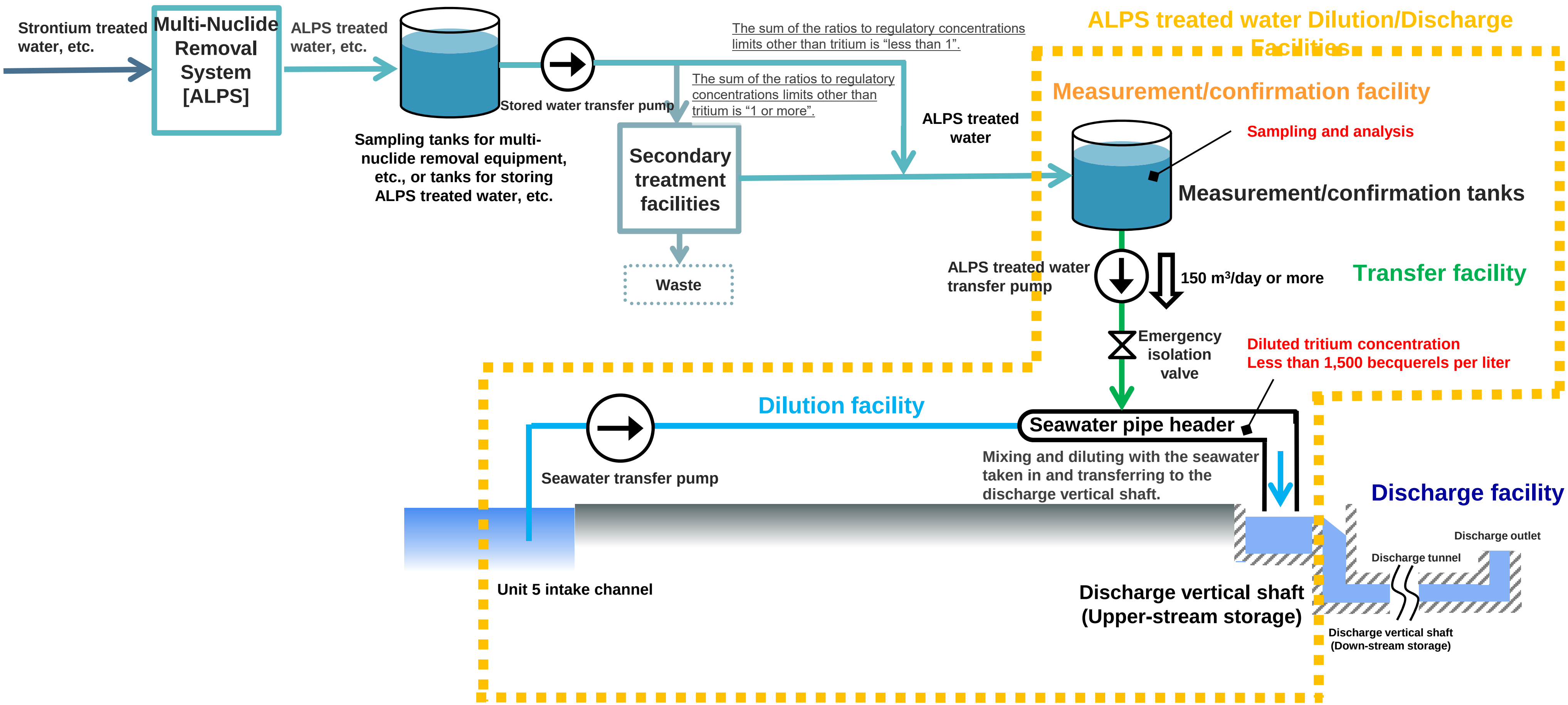
# [Reference] Overview of the related facility(discharge facilities)

## Objective

Drainage water is discharged from the ALPS treated water Dilution/Discharge Facilities (water diluted with seawater so that the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1) into the sea from a location approximately 1 km away from the coast.

## Facilities Overview

The discharge facilities consist of a discharge vertical shaft (down-stream storage), a discharge tunnel, and a discharge outlet to achieve the above objective.

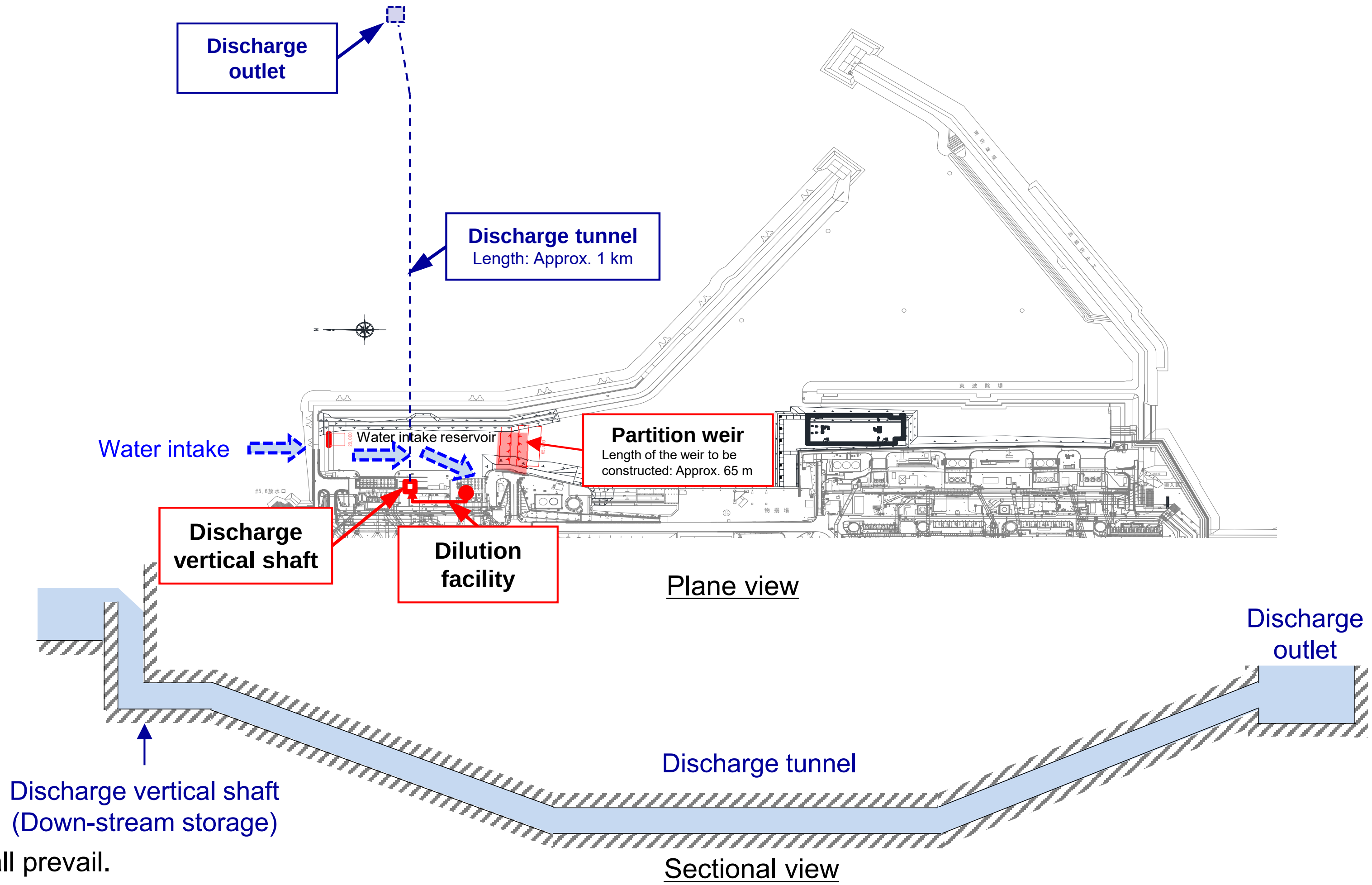



The Japanese version shall prevail.

# [Reference] Overview of related facility(discharge facilities) (1/2)

## Discharge Facility

- Discharge Facility has a design so that they can transfer water flowing out over the partition wall in the discharge vertical shaft to the outlet, which is approximately 1 km away from the shore, by using the water head difference between water in the discharge vertical shaft (down-stream storage) and the sea surface. In addition, the design concept includes friction losses in the Discharge Facility and elevation of water surface.



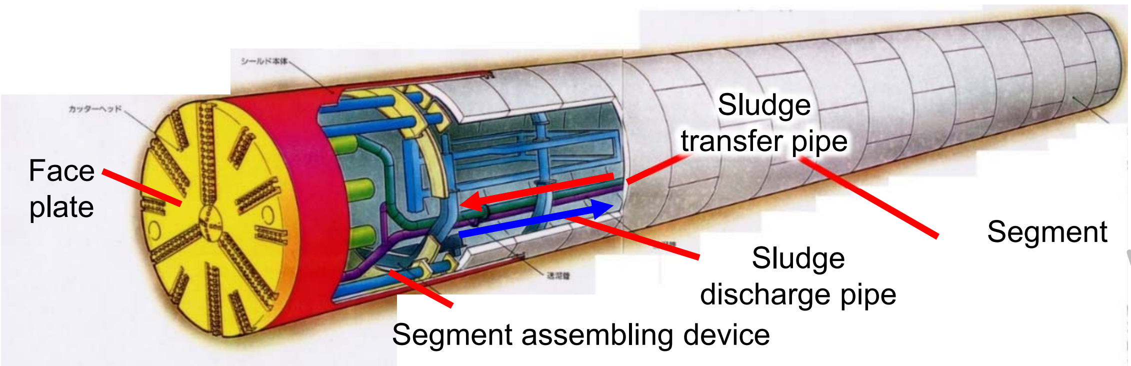
# [Reference] Overview of related facility(discharge facilities) (2/2)

## Overview of the structural design

- Water flows through the bedrock layer to minimize the leakage risk and to ensure a highly earthquake-resistant structure.
- A shield method is adopted and double-layer seals are installed in the reinforced concrete segment to ensure water cut-off performance.
- The tunnel body (segment) is designed considering the impacts of typhoons (high waves) and storm surges (sea level rise).

## Construction of tunnel (shield method)

- As there are many discharge tunnels constructed by the shield method, this secure construction will minimize the possibility of trouble.




*Slurry shield method was adopted this time.

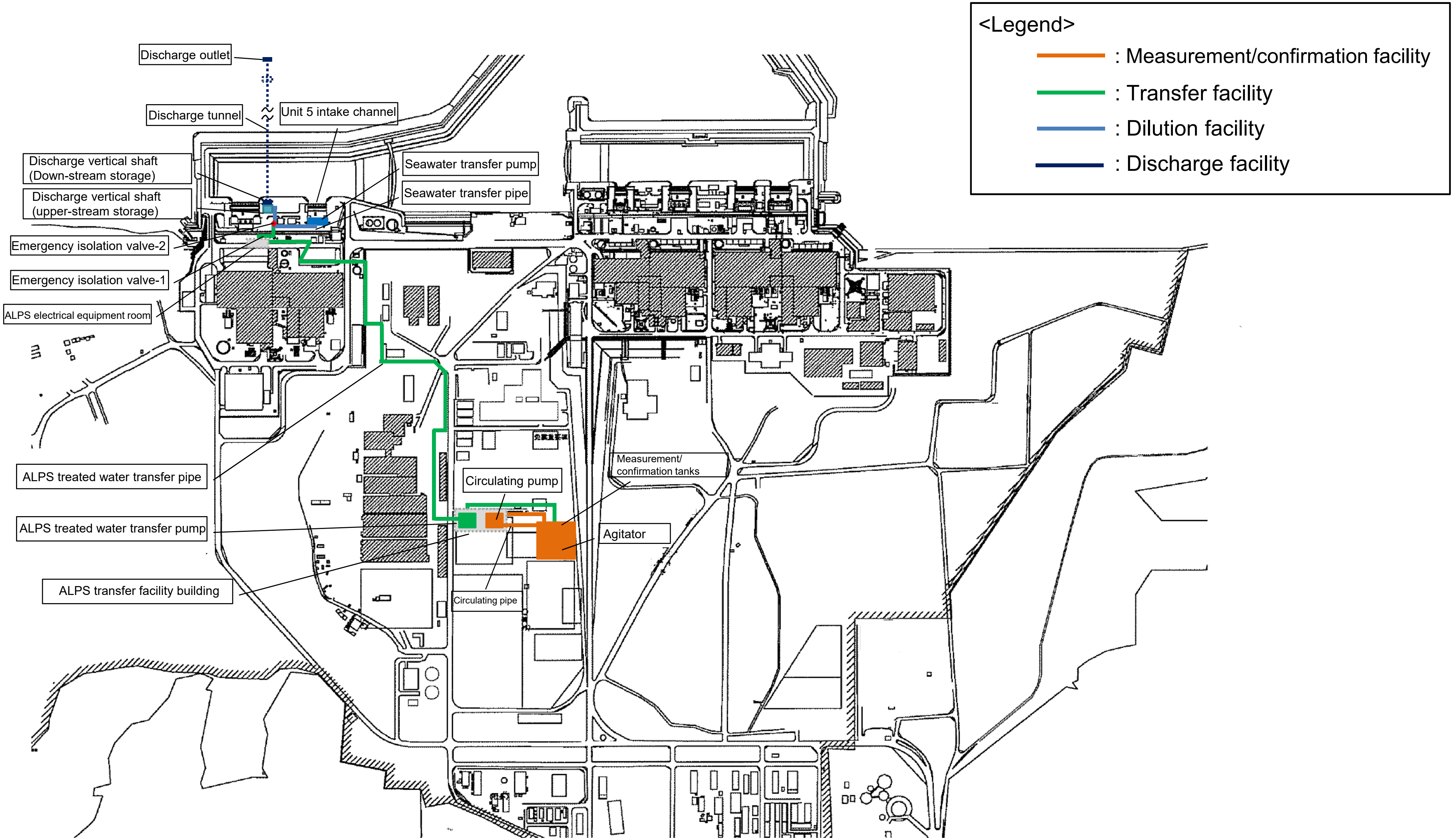
Schematic diagram of a shield machine


Segment

Excerpt from the document 1-1, the 3rd Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

# [Reference] Layout plan of ALPS treated water Dilution/Discharge Facilities and Related Facility

- The layout of the ALPS treated water Dilution/Discharge Facilities and the related facility is as follows. (Implementation Plan: II-2-50-Attachment 1-2)



# [Reference] Installation schedule for ALPS treated water Dilution/Discharge Facilities and Related Facility



- Once the approval is granted after review by the Nuclear Regulatory Authority, the on-site installation and assembly of the facilities will commence, and completion is scheduled for around mid-April 2023. (Implementation Plan: II-2-50-Attachment 6-1)